AVMA Guidelines for the Humane Slaughter of Animals: 2024 Edition

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ISBN 979-8-9877127-6-4

Version 2024.0.1

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Introduction

In 1963, the AVMA convened the first Panel on Euthanasia (POE) to provide guidance for veterinarians who perform or oversee the euthanasia of animals. In 2011, the AVMA POE responded to the need to address and evaluate the methods and agents veterinarians may encounter when animals are killed under conditions that fall outside the scope of the POE definition of euthanasia. The guidance contained within this document relates to the humane slaughter of animals intended for consumption, primarily as food.

The first edition of the AVMA Guidelines for the Humane Slaughter of Animals was published in 2016. It is constitutive of the AVMA's series of Humane Endings guiding documents for veterinary practitioners, which also include the AVMA Guidelines for the Euthanasia of Animals[1] and the AVMA Guidelines for the Depopulation of Animals.[2] Jointly, these Guidelines reflect the AVMA's ongoing commitment to science-informed techniques and core principles of animal welfare[3] and veterinary ethics[4] to ensure that the termination of an animal's life under various circumstances is as good as it can be.

While much remains to be learned about animal pain and consciousness and new evidence and technological innovation may lead to the adoption of more humane techniques, this edition of the Guidelines relies on the scientific evidence currently available. The techniques may differ from euthanasia methods outlined in the AVMA's Guidelines for Euthanasia.[1]

The Humane Slaughter Guidelines stress the AVMA's ethical and professional commitments, as much as is practicable, that no unnecessary pain, injury, or distress is inflicted on conscious animals prior to and during termination. "A painful or stressful death may eclipse or negatively color all that came before."[5] Careful attention to empirical observation is essential when assessing farming practices and slaughter methods from an ethical perspective. The AVMA encourages its members and practitioners to utilize their scientific knowledge, practical expertise, and well-reasoned ethical judgment to protect and promote the health and welfare of all animals. Thus, the welfare of animals slated for consumption can be improved by greater engagement with the veterinary profession and professionals; ongoing development of science-based humane slaughter methods and animal welfare methods; clear industry policies regarding the treatment of injured, sick, or displaced animals across multiple taxa; training and accountability of personnel handling and slaughtering animals; increasing public engagement and education to enhance transparency about animal care and welfare practices and slaughter methods; and harmonization of local, state, and national regulatory policies and oversight mechanisms with ethically informed standards of care. Ongoing collaborations between stakeholders across the food and fiber sectors will help to strengthen best practices and improve both the welfare of and slaughter outcomes for animals.

Physical methods, which include mechanical and electrical techniques, and controlled atmosphere and gas methods are used to bring about unconsciousness through physical disruption, hypoxia, neuronal depression, or epileptiform brain activity in food animals at slaughter. A range of factors, including expanded knowledge about the cognitive capabilities of animals, technological and economic conditions, and social and ethical considerations affecting the sustainability of animal agriculture, the care and management of animals, and food security, will influence the recommendations in this and future editions of this document. Additionally, the scientific community and the public share an interest in the possibility of substantial cognitive, emotional, psychological, and social abilities in nonhuman species.[6]

The primary focus of these Guidelines is to emphasize good animal welfare and care-oriented practices during the slaughter process. The humane slaughter methods and agents described in these Guidelines are designed to bring about rapid loss of consciousness and, ultimately, a complete loss of brain function in animals destined for use as food. This means preventing and minimizing (and, where possible, eliminating) negative outcomes (such as injury, disability, fear, anxiety, pain, and distress) associated with terminating the lives of the following species of animals: bovids (cattle, American bison, water buffalo), swine, small ruminants (goats, sheep, camelids, cervids), equids (horses, donkeys), poultry (chickens, turkeys, quail, pheasants, ratites), aquatics (fish, cephalopods, decapods), furbearers (rabbits, mink, fox), and reptiles and amphibians (including crocodilians). The POHS is monitoring and recommends long-term studies on the welfare science for animals such as insects.[7,8] These animals are gaining in popularity as farmed food, feed, or skin sources.[9,10] When animals are designated for slaughter, they should be treated with respect and handled appropriately and the slaughter process should limit any harms experienced by these animals.[9,10] These Guidelines acknowledge that the slaughter of animals for consumption purposes is a process involving more than just what happens at the time of death. Veterinary responsibilities associated with slaughter also include applying good preslaughter animal care and handling practices. Information about confirmation of death for species not previously covered in the 2016 edition has also been included in this edition.

The process of termination, as defined here, encompasses the preslaughter period (eg, which for terrestrial food animals includes the arrival and lairage at a slaughter facility), restraint period (including [pre]stunning and bleeding techniques [depending on species] until animals are verified to be unconscious), and ultimately verification of death and readiness for entry into the consumption chain. Handling food animals well is still a central feature of the Guidelines.

The POHS supports scientific research that improves the quality of life of food animals, including welfare-improvement research (eg, advancing harm assessments and development of refinements on and new techniques and technologies in preventing/minimizing harm) during the slaughter process. While the POHS is motivated primarily by the science and ethics of animals' welfare, members of the Panel are also sensitive to adjacent concerns related to the farming and slaughter of animals. These include, nonexhaustively, public health and safety, food safety and quality, environmental and economic sustainability, climate change, production adequacy and sustainability, occupational health and the impact on the labor force, international animal welfare and trade standards, broader ethical values and religious and cultural expectations, and evolving dietary preferences. These issues, however, are not the focus of this document. The veterinarian's primary responsibility of doing what is in the animal's best interest under the circumstances (ie, using the most appropriate and painless slaughter method possible and considering the context of the animals' welfare in the US) should not be displaced by quality, quantity, or economic arguments. The veterinarian's primary ethical responsibility in humane slaughter is to minimize negative welfare outcomes in food animals by using the most appropriate and painless slaughter method possible.

The AVMA Guidelines for the Euthanasia of Animals: 2020 Edition[1] should be consulted if individual animals are deemed inappropriate for the food chain. The 2019 AVMA Guidelines for the Depopulation of Animals[2] should be consulted in emergency events such as zoonotic disease, foreign animal disease, natural disasters, or other urgent circumstances.

While these Guidelines are meant for US-based industries and legal, cultural, and practical circumstances, the AVMA recognizes that they may be impactful globally in some cases. Hence, there may be differences in both acceptable stunning methods to render the animal unconscious and actual killing methods. Since religious slaughter is protected under US law, the Guidelines also include restraints and techniques that reflect kosher and halal practices and provisions, in which animal welfare outcomes are intertwined with larger religious perspectives on the sacred and human-nature relationships. The AVMA also recognizes that animals of the same species can be slaughtered with pluralistic goals in mind (eg, protein, medicine, and/or skin/hide), which can influence how the different industries are audited.

A. Membership of the Panel and Notes on the Current Edition

These Guidelines are the result of the efforts of the POHS, a collective entity with broad-based expertise in the affected species and environments in which humane slaughter is performed. These Guidelines represent more than 2 years' worth of deliberation by more than 30 individuals, including veterinarians, animal scientists, and an animal ethicist. The POHS emphasizes a strong ethical commitment to transparency, open inquiry, and fair deliberation processes when applying science and social norms to assess current slaughter methods and ethical duties to animals destined for slaughter. In reviewing the literature and formulating their recommendations, members of the Panel tapped the expertise of colleagues in pertinent fields and received invaluable input from AVMA members and others during a designated comment period. The scientific integrity and practical utility of these Guidelines are a direct result of AVMA members' input, as well as suggestions from others concerned about the welfare of animals used for food and, specifically, techniques used for slaughter.

In these Guidelines, methods, techniques, and agents used to slaughter animals humanely are discussed. Illustrations, diagrams, and tables have been included (and updated) to assist veterinarians in applying their professional judgment. Species-specific information is provided for terrestrial and aquatic species that are commonly farmed and slaughtered for consumption.

The wider scope of species covered in this edition is another pertinent update. In addition to new species designated for food (crustaceans and cephalopods), fur-bearing animals (mink, rabbits, fox) and donkeys are now covered in these Guidelines. The POHS recommends that all slaughter facilities have a dedicated written plan for animal welfare, referred to by the Food Safety and Inspection Service (of the USDA) as a systemic approach for the humane handling of animals. The plan should contain standard operating procedures for each step of animal handling to ensure that animal welfare is properly implemented on the basis of relevant indicators. These plans should also include specific corrective actions in case of specific risks, like power failures or other circumstances that could negatively affect the welfare of animals. Finally, the format of the document itself has been updated to increase accessibility by separating the chapters by species groupings (bovids, swine, aquatics, equids, furbearers, reptiles and amphibians, poultry, and small ruminants) in contrast to the 2016 version, which separated the sections by technique.

B. Statement of Use

These Guidelines were developed by the POHS to provide guidance primarily for members of the veterinary profession and food and fiber system stakeholders with an interest in the humane slaughter of animals. The POHS's objective in creating the Guidelines is to provide guidance for veterinarians about how to prevent pain and distress in animals that have been designated for slaughter. These Guidelines discuss methods, techniques, and agents used to prevent or minimize negative outcomes for animals designated for consumption. While we believe the Guidelines contain valuable information that can help assure and improve animals' welfare during slaughter, it is important to understand that the

Humane Slaughter Act (HMSA)[11] and its regulations provide final federal authority regarding slaughter practices in the US. Veterinary professionals involved in the slaughter of animals should ensure that they act in accordance with all applicable federal, state, and local laws and regulations.

These Guidelines do not address methods and techniques involved in the termination of animals hunted for food (subsistence or otherwise). While the Guidelines now include guidance on the slaughter of certain animals raised for their fur or fiber and skin, as well as crustacean decapods, they do not include guidance on the termination of insects in commercial farms.

Veterinarians experienced in the species of interest should be consulted when choosing a method of slaughter, especially for those species not covered by the HMSA (eg, poultry, fish).[11] To minimize distress to animals and prevent human injury during slaughter, methods and agents should be selected that maintain calm animals. Attention to species-specific anatomy, physiology, natural history, husbandry, and behavior will assist in understanding how various methods and agents may impact animals and personnel during slaughter.

Veterinarians performing or overseeing humane slaughter should assess the potential for species-specific distress secondary to physical discomfort, abnormal social settings, novel physical surroundings, pheromones or odors from previously slaughtered animals, the presence of humans, and other factors. In evaluating slaughter methods, veterinarians should also consider human safety, availability of trained personnel, potential infectious disease concerns, conservation or other animal population objectives, regulatory oversight, availability of proper equipment and facilities, options for carcass disposal, and the potential for secondary toxicity and other public health risks. Ensuring human safety is of utmost importance, and appropriate safety equipment, protocols, and expertise must be available before animals are handled.

Preparing personnel to perform humane slaughter techniques should include training them in the appropriate slaughter method and assuring they have an understanding of and sensitivity toward animals' welfare, standards of care, and local, state, and federal regulatory policies and standards.

Psychological, emotional, and physical fatigue can result from routine slaughter of animals and impact animals' welfare. The wellness of veterinarians and slaughter facility staff should be considered to ensure their effectiveness in bringing about a safe, timely, and humane end for animals raised for food or fiber.

Special attention should be paid to unique species attributes that may affect how animals are handled, stunned, and rendered unconscious. Once an animal has been slaughtered, death must be carefully verified by appropriate personnel. Also, collaborations between stakeholders in the food and fiber sectors and veterinary professional and government oversight entities are integral to the implementation of humane slaughter best practices, for identifying gaps in knowledge and resources, and for supporting humane decision-making and animal welfare outcomes.

C. Evaluating Slaughter Methods

Some methods of slaughter require physical handling of the animal. The amount of control and kind of restraint required will be determined not only by the species, breed, and size of the animal involved but also by the level of excitement and prior handling experience of the animal and competence of the personnel performing slaughter. Proper handling is vital to minimizing injury, pain, and distress in animals and ensuring the safety of the person performing slaughter, any bystanders, and other animals that are nearby.

The nature of humans' relationships with food animals in the commercial setting can have either positive or negative implications for animal productivity and welfare.[12] Providing high-quality care for food animals begins from the top down, including a commitment from managers and supervisors to ensure a supportive work environment and culture and constant improvement. Each facility where slaughter is performed is responsible for appropriately training its personnel and maintaining a strong culture of animal care. Training programs should help slaughterhouse staff develop and internalize good techniques and best animal care and welfare practices. Personnel who slaughter animals for food should be selected on the basis of their positive attitudes toward animals and their colleagues and must demonstrate proficiency in the use of the technique in a closely supervised environment. Training should include sensitivity to cultural differences in attitudes toward animal welfare and normal species and animal care knowledge, familiarity with the normal behavior of the species, an appreciation of how handling and restraint can influence animals' behavior and vice versa, and an understanding of the mechanism by which the selected technique induces loss of consciousness and death. Further, selection of the most appropriate method of humane slaughter in any situation will depend on the species and number of animals involved, age, available means of animal restraint, skill of personnel, and other practical considerations. Experience in the humane restraint of the species of animal is critical.

Veterinarians play an important role in training and supporting slaughterhouse personnel and others tasked with humanely killing animals for entry into the food system. Their knowledge and expertise is invaluable, and their participation is integral to optimizing animal welfare outcomes in slaughterhouses. Death must be verified before invasive dressing begins or before disposal of the animal for meat-quality reasons. Personnel must be sufficiently trained to recognize the cessation of vital signs of different animal species.

The appropriateness of slaughter methods are contingent on the following: (1) ability to induce loss

of consciousness followed by death with minimal pain or distress; (2) time required to induce loss of consciousness and the behavior of the animal during that time, especially for religious slaughter; (3) reliability and irreversibility of the methods resulting in death of the animal; (4) safety of personnel; (5) compatibility with intended animal use and purpose (ie, meat consumption); (6) potential psychological or emotional impacts on personnel; (7) ability to maintain equipment and technologies in proper working order; and (8) legal and religious requirements.

These Guidelines do not address every contingency. In circumstances that are not clearly covered by these Guidelines, a veterinarian experienced with the species in question should apply professional judgment and knowledge of clinically acceptable techniques in selecting a humane method of slaughter or euthanasia (if required) to end an animal's life. When appropriate, the veterinarian should consider whether (1) the procedure results in the best outcome for the animal; (2) their actions conform to acceptable standards of veterinary practice and are consistent with applicable federal, state, and local regulations; and (3) the choice of slaughter (or euthanasia) technique is consistent with the veterinarian's professional obligations and ethical commitment to society.

D. Stress and Distress, Unconsciousness, and Pain

These Guidelines acknowledge that a humane approach to the slaughter of any animal is warranted, justifiable, and expected by society. The overall goal should be to minimize or eliminate anxiety, pain, and distress prior to loss of consciousness. The manner in which an animal under the charge of humans, like food animals, dies has been described as a significant welfare concern.[13–15] Animals destined for consumption, especially as part of a commercial enterprise, are expected to be humanely slaughtered. While all negative experiences may not realistically be eliminated from the slaughter process,[16] the overall goal of humane slaughter should be to observe the best possible standards, practices, and techniques of animal welfare, including to minimize, as much as possible, injury, anxiety, pain, and distress prior to loss of consciousness, resulting in a swift end.[17,18] Therefore, both the induction of unconsciousness and handling prior to slaughter must be considered. Criteria for determining the humaneness and effectiveness of a particular slaughter method can be established only after the mechanisms of pain, distress, and consciousness are understood. For a more extensive review of these issues, the reader is directed to the AVMA Guidelines for the Euthanasia of Animals: 2020 Edition.[1]

Humane slaughter methods produce unconsciousness through 4 basic mechanisms: (1) physical disruption of brain activity (eg, blunt cranial trauma, penetrating captive bolt, gunshot), (2) hypoxia (eg, controlled low atmospheric pressure for poultry, N_2, Ar, exsanguination), (3) direct depression of neurons necessary for life function (eg, CO_2), or (4) epileptiform brain activity (eg, electric stunning). Because loss of consciousness resulting from these mechanisms can occur at different rates, the suitability of a particular agent or method will depend on the species and whether an animal experiences pain or distress prior to loss of consciousness.

Distress during slaughter may be created by the method itself or by the conditions under which the method is applied and may manifest behaviorally (eg, overt escape behaviors, approach-avoidance preferences [aversion]) or physiologically (eg, changes in heart rate, sympathetic nervous system activity, hypothalamic-pituitary axis activity). Stress and the resulting responses have been divided into 3 phases.[19] Eustress results when harmless stimuli initiate adaptive responses that are beneficial to the animal. Neutral stress results when the animal's response to stimuli causes neither harmful nor beneficial effects to the animal. Distress results when an animal's response to stimuli interferes with its well-being and comfort.[20] Although sympathetic nervous system and hypothalamic-pituitary axis activation are well accepted as stress response markers, these systems are activated in response to both physical and psychological stressors and not necessarily associated with higher-order CNS processing and conscious experience by the animal. Furthermore, use of sympathetic nervous system and hypothalamic-pituitary axis activation to assess distress during application of controlled atmosphere stunning (CAS) methods is complicated by continued exposure during the period between loss of consciousness and death.[1]

Ideally, humane stunning and slaughter methods result in rapid loss of consciousness and the associated loss of brain function. The perception of pain is defined as a conscious experience[21] and requires nerve impulses from peripheral nociceptors to reach a functioning conscious cerebral cortex and the associated subcortical brain structures. The International Association for the Study of Pain describes pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage. Activity induced in the nociceptor and nociceptive pathways by a noxious stimulus is not pain, which is always a psychological state, even though we may well appreciate that pain most often has a proximate physical cause."[22]

Distress during administration of CO, CO_2, and the inert gases N_2 and Ar has been evaluated by use of behavioral assessment and aversion testing and reviewed in the context of euthanasia.[1] It is important to understand that aversion is a measure of preference, and while aversion does not necessarily imply that an experience is painful, forcing animals into aversive situations creates distress. The conditions of exposure used for aversion studies, however, may differ from those used for stunning or slaughter. One of the characteristics of anesthesia in humans is the feeling that one is having an out-of-body experience, suggesting a disconnect between one's sense of self and one's awareness of time and space.[23] Al-

though we cannot know for certain the subjective experiences of animals, one can speculate that similar feelings of disorientation may contribute to the observed signs of distress with inhaled methods. In addition, agents identified as being less aversive (eg, Ar or N_2 gas mixtures) can still produce overt signs of behavioral distress (eg, open-mouth breathing) for extended periods of time prior to loss of consciousness under certain conditions of administration (eg, gradual displacement).[24]

Unconsciousness, defined as loss of individual awareness, occurs when the brain's ability to integrate information is blocked or disrupted. In animals, loss of consciousness is functionally defined by loss of righting reflex (LORR), also called loss of position (LOP).[21,25,26] This definition is quite useful because it is an easily observable, integrated whole-animal response. Although any physical movement occurring during anesthesia, euthanasia, slaughter, or depopulation is often interpreted as evidence of consciousness, cross-species data from the anesthesia literature suggest that both memory formation and awareness are abolished early in the overall process relative to loss of reflex muscle activity.[21] Thus, vocalization and nonpurposeful movement observed after LORR or LOP with properly applied CAS methods are not necessarily signs of conscious perception by the animal. While generalized seizures may be observed following effective CAS methods, these generally follow loss of consciousness; indeed, anesthesia, coma, and generalized seizures all represent a loss of consciousness in which both arousal and awareness in humans are low or absent.[27] Loss of consciousness should always precede loss of muscle movement.

Although measurements of brain electrical function have been used to quantify the unconscious state, electroencephalogram (EEG) data cannot provide definitive answers as to onset of unconsciousness even when state-of-the-art equipment is used. At some level between behavioral unresponsiveness and the induction of a flat EEG (indicating the cessation of the brain's electric activity and brain death), consciousness vanishes. However, current EEG-based brain function monitors are limited in their ability to directly indicate unconsciousness, especially around the transition point.[28,29] Also, it is not always clear which EEG patterns are indicators of activation by stress or pain.[30] Reduction in alpha-to-delta brain wave ratios coincides with LOP in chickens,[31,32] reinforcing the usefulness of LOP or LORR as an easily observable proxy for loss of animal consciousness.

According to 1 study,[33] terrestrial animals are conscious when they exhibit any of the following 6 indicators: standing posture, head or body righting reflex, voluntary vocalization, spontaneous blinking (no touching), eye pursuit, and response to threat or menace test (no touching). Some modification of these indicators may be required on the basis of factors such as species and developmental stage. A terrestrial animal that is unconscious and brain-dead will not have corneal reflex, eyelash reflex (in response to touch), or rhythmic breathing.[33] Determining similar indicators for other species of animals is desired, and research into them is highly encouraged to help practitioners distinguish between animals that are brain-dead, unconscious (by anesthesia), immobilized, or sedated. Following are the 6 indicators of definite consciousness, in list form:

- Standing posture
- Head or body righting reflex
- Voluntary vocalization
- Spontaneous blinking (no touching)
- Eye pursuit
- Response to threat or menace test (no touching)

Before carcass disposal or invasive dressing procedures occur at a slaughter plant, it should be confirmed that an animal is unconscious or brain-dead. Ensuring that an animal is unconscious or brain-dead requires all 3 of the following indicators:

- Absence of corneal reflex
- Absence of eyelash reflex (response to touch)
- Absence of rhythmic breathing[33]

Physical methods that destroy or render nonfunctional the brain regions responsible for cortical integration (eg, gunshot, captive bolt, cerebral induction of epileptiform activity in the brain [eg, electric stunning], blunt force cranial trauma, maceration) produce instantaneous unconsciousness. When physical methods directly destroy the brain, signs of unconsciousness include immediate collapse (LORR or LOP) and a several-second period of tetanic spasm, followed by slow hind limb movements of increasing frequency.[34,35] In cattle, however, there is species variability in this response. The corneal reflex will also be absent.[36] Signs of effective electric stunning that induces both epileptiform activity in the brain and cardiac arrest are LORR, loss of menace reflex and tracking of moving objects, extension of the limbs, opisthotonos, downward rotation of the eyeballs, and tonic spasm changing to clonic spasm, with eventual muscle flaccidity.[35,37] Physical methods are inexpensive, are humane, minimize pain if performed properly, and leave no drug residues in the carcass. Furthermore, animals presumably experience less fear and anxiety with methods that require little preparatory handling. However, physical methods usually require a more direct association of the operator with the animals, which can be offensive to and upsetting for the operator. Physical methods must be skillfully executed to ensure a quick and humane death because failure to do so can cause significant stress, distress, and pain. Physical disruption methods are usually followed by exsanguination to ensure death and improve meat quality. Exsanguination is also a method of inducing hypoxia, albeit indirectly.

Controlled atmosphere stunning methods also depress the cerebral cortical neural system, producing loss of consciousness accompanied by LORR or LOP. Purposeful escape behaviors should not be observed during the transition to unconsciousness. Depending on the speed of onset of unconscious-

ness, signs associated with release of conscious inhibition of motor activity (such as vocalization or uncoordinated muscle contraction) may be observed at LORR or LOP. Signs of an effective stun when the animal is in deep levels of anesthesia include LORR or LOP, loss of eye blink (menace reflex) and corneal reflex, and muscle flaccidity.[38] As with physical disruption methods, CAS methods are usually followed by exsanguination to ensure death and improve meat quality.

Decapitation and cervical dislocation are physical methods of slaughter that require separate comment. The interpretation of brain electric activity, which can persist for up to 30 seconds following these methods,[39–41] has been controversial.[42] As indicated previously, EEG cannot provide definitive answers as to the exact onset of unconsciousness. Other studies[40,41,43–45] indicate that such activity does not imply the ability to perceive pain and conclude that loss of consciousness develops rapidly.

In summary, the cerebral cortex or equivalent structures and associated subcortical structures must be functional for pain to be perceived. If the cerebral cortex is nonfunctional because of physical disruption, hypoxia, generalized epileptic seizure, or neuronal depression, pain cannot be experienced. Motor activities occurring following LORR or LOP, although potentially distressing to observers, are not perceived by an unconscious animal as pain or distress. Reflexive kicking in unconscious animals may be mistaken for conscious activity and can occur even after decapitation, as neurologic circuits involved with walking are located in the spinal cord.[46] Given that we are limited to applying slaughter methods based on these 4 basic mechanisms, efforts should be directed toward educating individuals involved in the slaughter process, achieving technical proficiency, and refining the application of existing methods, including handling conditions prior to slaughter.

E. Animal Behavioral Considerations

These Guidelines are concerned with minimizing animal distress, including negative affective or experientially based states such as fear, aversion, anxiety, and apprehension, during the slaughter process. They are also meant to support human well-being and safety as regards the repeated termination of animals' lives. Veterinarians and other personnel conducting slaughter should familiarize themselves with preslaughter protocols, be attentive to species and individual variability, and ensure proper functioning of all equipment and technologies related to the slaughter (or if needed, euthanasia) process to mitigate distress in both food animals and human handlers. The method for inducing unconsciousness and the handling and restraint methods associated with it must be evaluated as an entire system.[47] Physical methods require more handling and restraint of individual animals, compared with CAS, but they induce instantaneous unconsciousness. Controlled atmosphere stunning does not induce instantaneous unconsciousness, but possible distress during handling may be reduced. There may be a tradeoff between possible distress during a longer time to induce unconsciousness and the benefits of reduced handling of individual animals.

Intentional violations of the HMSA must not be tolerated. Unintentional pain and/or distress at slaughter caused by mistakes by personnel, failure to properly store and maintain equipment, or poorly designed facilities must be addressed promptly. At all stages of the process of termination, animals should be treated with respect and compromises to animal welfare should be treated as unacceptable if not unlawful. Veterinary practitioners and stockpersons should ensure the following:

- No conscious animal is dragged, shackled, hoisted, or cut inappropriately. Before invasive dressing (eg, skinning, leg removal, scalding) begins, all signs of brain stem function, such as the corneal reflex, must be abolished.
- Excessive force or frequent use of electric prods to move animals off trucks, up and down ramps, or into slaughter facilities or restraint devices is avoided. Animals should not be forced to move faster than a normal walking speed. Handlers should move animals quietly, without use of driving devices that would cause unnecessary pain and/or distress.
- Nonambulatory or disabled animals are isolated and moved with suitable equipment (eg, bucket of a loader, sled) and provided appropriate veterinary attention. Conscious nonambulatory animals must never be dragged.
- Livestock are provided with access to water in the lairage pens. All animals should have sufficient room to move in accordance with state, federal, and local statutes, and pens should have room for all animals to lie down.
- Slaughter facilities and equipment are well maintained to minimize negative impacts, like injury, to the animals and employees.
- The induction of unconsciousness (eg, stunning) causes minimal distress to the animal.
- All personnel involved in the application of stunning methods and animal handling should be properly trained.

F. Human Behavioral Considerations

Veterinarians may be asked to bridge the physical and psychological divide between current practices used in the care and management of food animals and consumers by communicating the realities of conventional food production. They may also be asked to provide an ethical accounting and monitoring of animals' welfare on the farm, in feedlots, and at slaughterhouses to the public in a transparent fashion. Veterinarians are encouraged to increase their awareness of slaughter methods and enhance understanding of the science behind the methods currently used with a view toward the day-to-day complexities of managing food animals and the range

of challenges facing our contemporary food animal sector. Likewise, industry agents, nonfood veterinarians, animal caretakers, and others engaged with the slaughter of animals for food should be encouraged to understand the diversity and intensity of public concerns about commercial animal production, animal welfare and ethics, and trending societal values and expectations related to how animals are farmed and slaughtered for food.

The humane slaughter of animals is a learned skill that requires training, respect for animals, and awareness of species-specific welfare issues and self-awareness of one's professional capacities. Personnel performing animal slaughter should be ethically cognizant of their roles and responsibilities and must be technically proficient. Periodic professional continuing education on the latest methods, technologies, and equipment available for slaughter is highly encouraged. Personnel must also possess a temperament that does not bolster brutality. Self-awareness of one's professional capacities will help to identify professional limitations (especially during unexpected events), mitigate compassion fatigue and callousness, and advance a culture of animal welfare–focused outcomes when it comes to processing animals for food.

The slaughter of individual livestock or poultry by farm workers who are also responsible for providing husbandry can substantially impact emotions.[48] Therefore, appropriate oversight of the psychological well-being of slaughter employees is paramount to mitigate guilt, distress, sadness, fatigue, alienation, anxiety, and behaviors that lack consideration of others or may lead to harming themselves, animals, or other people. Veterinarians, farmers, animal caretakers, and food processors may have individual differences in how they psychologically react to the job of killing animals.[49]

Veterinarians and staff who are regularly exposed to the slaughter process should also be monitored for emotional burnout, psychological distress, or compassion fatigue and be encouraged to seek appropriate psychological counseling.[50,51] While integrating good animal welfare in the food chain, some food animal practitioners may be torn among serving the best interest of the farmed animal, the human client (individual), personal professional interests, and societal concerns about improving quality of life for animals and ensuring the availability of safe and affordable animal protein. More studies on both the impact of animal slaughter on the personnel performing it, including the "caring-killing paradox,"[52] and attitudes toward the consumption of animals for food among the public will go a long way toward promoting healthier and more respectful human–food animal relationships.

G. References

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Rules and Regulations on Slaughter in the US

A. History of Regulations, Industry Guidance, and Employee Training in the US

The Federal Meat Inspection Act of 1906 (as amended) requires the USDA to inspect all cattle, sheep, swine, goats, and horses brought into any plant to be slaughtered and processed for human consumption[1]; it does not cover poultry. Inspection of poultry products for human consumption did not become mandatory until passage of the 1957 Poultry Products Inspection Act.[1] The 1978 Humane Methods of Slaughter Act (HMSA) made mandatory the humane slaughter and handling of livestock in connection with slaughter of food animals in USDA-inspected plants. Animals included under the 1978 Act are cattle, calves, horses, mules, sheep, goats, swine, and other livestock.[2] Two methods of slaughter were determined to be humane under the 1978 Act. The first requires that livestock be rendered insensible to pain by a single blow or gunshot or electrical, chemical, or other means that is rapid and effective before being shack-led, hoisted, cast, or cut. The second method is in accordance with the ritual requirements of any religious faith that prescribes a method of slaughter whereby the animal suffers loss of consciousness due to ischemia caused by the simultaneous and instantaneous severance of the carotid arteries with a sharp instrument.[2] Additionally, Section 1906 exempts the handling or other preparation of livestock for slaughter under the second method from the terms of the Act.[2] Therefore, the statutory requirement that livestock are rendered insensible to pain prior to shackling, hoisting, casting, or cutting does not apply to the handling or restraint that is immediately associated with the cut when the second method of slaughter is being used. Examples of this type of slaughter include Jewish (kosher) slaughter and Islamic (halal) slaughter.[3]

Currently, the HMSA of 1978 does not cover poultry.[2] However, some practices that promote good welfare for poultry are covered by regulatory requirements for good commercial practices. These regulations can be found in 9 CFR Part 381.65(b) (Poultry Products Inspection Act Regulations). Under the Poultry Products Inspection Act, a poultry product is adulterated if, among other circumstances, it is in whole, or in part, the product of any poultry that has died by a method other than slaughter.[4] For example, poultry that are still breathing on entering the scalder and die from drowning and not from slaughter are considered adulterated and unfit for human food and are condemned.[3] Furthermore, in 2005, the USDA published a Federal Register Notice (Docket No. 04-037N) on the treatment of live poultry before slaughter. The USDA defined a "systematic approach" as one in which establishments focus on treating poultry in such a manner as to minimize excitement, discomfort, and accidental injury during the time that live poultry are held in connection with slaughter.[5] Currently, this approach is voluntary on the part of industry. A provision in the USDA Appropriations Act for fiscal year 2001 (PL 106-387) amended the Poultry Products Inspection Act to include mandatory Food Safety and Inspection Service (FSIS) inspection for meat from ratites and quail.[1]

Regulations for the inspection of exotic animals can be found under 9 CFR 352.10. The authority for the inspection of exotic animals comes from the Agriculture Marketing Act of 1946, found in 7 USC 1621 et seq, which promotes distribution and marketing of agricultural products (including exotic species not under the Federal Meat Inspection Act).[6] Exotic animals that are defined by these regulations are reindeer, elk, deer, antelope, water buffalo, and bison.[7] This section includes regulations that address humane handling during antemortem inspection and stunning practices to render the animals unconscious that are consistent with the regulations pertaining to the 1978 HMSA (9 CFR 313.15 or 313.16).[2]

Many countries have set standards for welfare practices with regard to humane slaughter, and the World Organisation for Animal Health also includes standards for the humane conduct of slaughter in Chapter 7 of its Terrestrial Animal Health Code.[8] The impact of such standards has just recently begun to be felt in global trade. As an example, the European Union's Strategy for the Protection and Welfare of Animals not only lays a foundation for improving welfare standards in the European Union and making sure those standards are applied and enforced in all European Union countries but also expresses intent to apply equivalent welfare standards to imports from other countries in the future.[9]

B. Enforcement of Humane Slaughter in the US

The FSIS of the USDA is tasked with the enforcement of humane slaughter regulations. In the 1980s and 1990s, enforcement of humane handling was not a priority as the FSIS focused on improving food safety though the implementation of hazard-based inspection systems. This was highlighted in 1997, when a survey was conducted for the USDA.[10,11] Only 3 out of 10 beef plants were capable of rendering cattle unconscious with a single shot from a captive bolt. The main cause of poor captive bolt stunning was lack of maintenance.[11] There were numerous other problems observed in the 22 beef, pork, lamb, and veal plants that were surveyed.[10,11] The FSIS recognized a need for improvement and produced a video that served as a training tool for supervisory public health veterinarians.

In 2001, Congress provided the USDA with additional funding to assist in enforcing the HMSA. This funding enabled the FSIS to hire 17 district veterinary medical specialists.[12] The district veterinary medical specialist is the primary contact for humane

handling and slaughter issues in each district and serves as the liaison between the district office and headquarters on all humane handling matters. In addition, in February 2004, the FSIS began tracking the amount of time spent by inspection program personnel to ensure that humane handling and slaughter requirements are met.[12]

In February 2010, the Government Accountability Office published a report[13] that expressed concern about uneven enforcement of humane handling and slaughter. Enforcement discrepancies were found to be greater in small plants than in larger plants.

Following the release of that report, in April 2010, the FSIS established a Humane Handling Enforcement Coordinator position[14] to increase the frequency with which enforcement and inspection activities are reviewed. The Humane Handling Enforcement Coordinator coordinates the agency's implementation and daily enforcement of humane handling requirements and provides professional expertise to support inspectors in the field.[14] Additionally, in 2011, the FSIS revised and combined older directives and notices that defined egregious animal abuse, providing field inspectors with clearer guidance that supports more consistent enforcement.[15]

In October 2013, the FSIS published a guidance on the systematic approach to the humane handling of livestock.[16] Proper implementation of this guidance by industry should ensure the humane treatment of livestock presented for slaughter because the guidance provides establishments with a set of practices that will assist in minimizing excitement, discomfort, and accidental injury. The agency will continue to improve its guidance to ensure the best practices are implemented in establishments.

On September 24, 2020, the FSIS provided practices[17] that would result in a slaughter establishment being suspended and prevented from operating. Some of the most important ones are making cuts on or skinning a conscious animal or cutting off ears or feet of a conscious animal. It is also considered egregious if more than 2 stunning attempts are required to render an animal unconscious. Excessive beating or prodding is also an egregious act.[17]

On April 25, 2022, the FSIS published a revision of its Custom Exempt Review Process directive.[18] Custom exempt animals are slaughtered for the owner's personal use, and meat from the animal may not be resold. While custom exempt establishments are not subject to routine inspection, periodic reviews are to be conducted generally at a frequency of once per year.[18] A review of FSIS records suggests these reviews are not being conducted. The FSIS has stated that compliance with the HMSA regulations is required at custom exempt establishments; however, by directive, all HMSA regulations other than those that address stunning and the handling of nonambulatory animals are considered "voluntary welfare practices."[18] Reviews at these establishments should occur annually, and all HMSA regulations should apply to animals slaughtered under custom exempt inspection.

The Food Safety and Inspection Service inspection program personnel perform humane handling activities on an ongoing basis. The FSIS can, and does, take enforcement actions against slaughter plants that do not comply with the HMSA or regulations. The goal is to prevent the suffering of animals while protecting the food supply.

C. Auditing by Private Industry

A scoring system that was developed for use as part of a 1997 review became the basis of the voluntary industry guidelines published by the American Meat Institute (now the North American Meat Institute).[10,11] The first version was published in 1997, and the most recent complete version is by Temple Grandin.[19] The guideline considers 5 outcome measures. The use of outcome-based measurements to assess animal welfare is recommended.[20–22] Following is a summary of the 5 major measurements[23]:

1. Percentage of animals rendered unconscious with a single shot from a captive bolt or percentage of animals in which the electric stunner is placed on the head in the correct position. The minimum acceptable scores are 96% first-shot efficacy for captive bolt and 99% correct positioning for electric stunning.
2. Percentage of animals rendered unconscious before hoisting to the bleed rail. To pass an audit, 100% unconsciousness is required on a sample of 100 animals. There is zero tolerance for starting invasive procedures, such as skinning or leg removal, on an animal showing any signs of return to consciousness.
3. Percentage of cattle and pigs that remain silent and do not vocalize (bellow, moo, or squeal) in the stunning area. To pass an audit, 97% of cattle or 95% of pigs must remain silent in the stun box or conveyor restrainer or during restraint for religious slaughter. Refer to Grandin[19] for more detailed information on scoring vocalization. Vocalization scoring should not be used for sheep or goats.
4. Percentage of animals moved without an electric prod. The minimum acceptable score is 75% of the animals moved without use of an electric prod. An excellent score is 95%.
5. Percentage of animals that remain standing and do not fall during handling. A score of a fall is given if the body touches the ground. Restrainer devices that are designed to trip animals and make them fall are not acceptable. The minimum acceptable score is 99% handled with no falling. Falling is scored in all parts of the facility.

Acts of abuse that should never be tolerated include but are not limited to the following: (1) dragging nonambulatory animals; (2) beating animals; (3) poking sensitive areas such as the animal's eyes, nose, udder, or anus; (4) deliberately driving animals over the top of other animals; and (5) deliberately slamming gates on animals.

In 1999, the use of this scoring system by major meat-buying customers resulted in great improvements. A year after McDonald's Corporation

and Wendy's International started using the objective scoring system, more than 90% of beef plants were able to render 95% of cattle unconsciousness with a single shot.[24,25] The use of electric prods and percentage of animals vocalizing were also greatly reduced.[25]

The AVMA Panel on Humane Slaughter believes that important elements for best practice with regard to humane slaughter are the following: (1) maintenance logs on stunners, (2) training programs for employees, and (3) auditing by use of accepted industry auditing methodologies, such as video auditing.[17] Individual plants can vary on the structure and elements of their approach, so each plant will need to develop its own program. Developing best practices for humane slaughter and handling is similar to writing a hazard analysis and critical control points plan for food safety. Industry assessors and auditors should conduct direct observations to ensure that the plant employees are following their plant's written program. Best practices for humane slaughter include procedures that are done in the plant. There should be records to show that reviews have been conducted and procedures are being followed. Additional critical areas for best practice include nonslip floors on unloading ramps and in stun boxes, electric prod use, and handling of down, nonambulatory animals. Many assessors/auditors use the North American Meat Institute objective scoring system to determine when a plant has a problem.

D. Clear Comments

When a problem is identified, it is essential that both FSIS inspectors and private auditing companies write clear comments describing exactly what they saw. When assessing return to sensibility, it is important to understand the difference between corneal reflex, nystagmus, and natural blinking (menace reflex). An animal that has a weak corneal reflex or nystagmus after electric stunning is usually unconscious, but after captive bolt or gunshot, the corneal reflex must be absent. An animal that has menace reflex like a live animal in the lairage is definitely sensible. This applies to all types of stunning methods.

An example of a poor description in an inspection report would be "rough handling." An example of a clear description of an abusive handling incident would be "intentional electric prod use on sensitive mucosal areas." Clear comments are essential so that supervisors may appropriately manage problem behavior. The FSIS has 2 excellent examples of clear descriptions of an egregious situation of inhumane handling in attachments 4 and 5 of Directive 6900.2, revision 3.[26]

E. Video Auditing by Industry

Many major meat companies have installed video cameras that are monitored by a private third-party auditing company. The use of video auditing helps prevent the problem of employees following correct procedures when they are being watched and then reverting to inappropriate methods after the inspector or auditor is gone. Video auditing is most effective when it is done by a third-party auditor over the Internet. Experience has shown that internal video auditing programs are less effective.

F. Auditing Religious Slaughter to Improve Animal Welfare for Both Kosher and Halal Slaughter of Cattle, Sheep, or Goats

The following audit methods are recommended to maintain an acceptable level of animal welfare when religious slaughter is performed by cutting of the neck.

1. Calm animals will lose sensibility quicker. Follow all procedures for handling that are in other parts of this document.[27,28]
2. Conduct collapse-time scoring. Researchers in Europe reported a result of around 95% of cattle collapsing and losing the ability to stand quickly when a well-designed upright restraint device was used.[29] In a rotating box, collapse-time scoring is impossible because the animal is on its back. Alternative measures for determining onset of unconsciousness are time until eye rotation and the amount of time to abolish the presence of natural blinking such as seen with a live animal in the yards (lairage). Natural blinking and menace reflex must not be confused with the corneal reflex. To evaluate menace reflex, a hand is waved within 10 cm (4 inches) of the eye without touching it. A natural blink occurs if the eye does a full cycle of closing and then reopening without stimulus. Omit scoring of time to insensibility if pre- or postcut stunning is used.
3. The vocalization score should be 5% or less for cattle.[23,30] Score on a per-animal basis as a silent animal or vocalizer (mooing or bellowing). All cattle that vocalize inside the restraint device are scored. A bovine is also scored as a vocalizer if it vocalizes in direct response to being moved by a person, electric prod, or mechanical device into the restraint device, which represents a handling problem and not a slaughter problem. Do not use vocalization scoring for sheep. Standards for vocalization scoring of goats will need to be developed.
4. In all species, score restraint methods for the percentage of animals that actively struggle before loss of position.
5. The percentage of animals (all species) that fall down in the chute (race) leading up to the restraint device or fall before the throat cut in the restraint device should be less than 1%, with a goal of zero. This is the same as conventional slaughter. Restraint devices that are designed to make an animal fall are unacceptable and result in an automatic audit failure. Rotating boxes must fully support the body, and the animal's body should not shift position or fall when the box is rotated.

6. Electric prods should be used judiciously and only in extreme circumstances when all other techniques have failed.[31] Score prod use with the same criteria as conventional slaughter.
7. Perform the cut quickly, preferably within 10 seconds after the head is fully restrained. Omit this measure if preslaughter stunning is used (but need to remain stunned if preslaughter stunned).
8. Reduce the pressure applied by the head holders (but do not remove it), rear pusher gates, and other devices immediately after the cut to promote rapid bleed out.
9. Corneal reflexes, rhythmic breathing, and all other signs of return to sensibility must be absent before invasive dressing procedures such as skinning, leg removal, or dehorning are started. This is a requirement for all methods of slaughter, both conventional and religious, to be absolutely sure that the animal is completely insensible.
10. Do not use stressful methods of restraint for mammals, such as shackling and hoisting by suspension by 1 or more limbs; shackling and dragging by 1 or more limbs; shackling, hoisting, moving, and casting; or trip floor boxes that are designed to make animals fall, leg-clamping boxes, or other similar devices.
11. If either pre- or postcut stunning is used, score the same as conventional slaughter.

G. The Importance of Measurement With Religious Slaughter

By routinely measuring the performance of religious slaughter procedures, the standards for such slaughter are kept high. Measuring collapse times for unconsciousness or other indicators such as time to eye rollback or the absence of natural blinking will enable both plant personnel and religious slaughter personnel to improve their procedures.

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Chapter I: Aquatics

A. Fish

1. General considerations

In the US, fish are not covered by the Humane Methods of Livestock Slaughter Act.[1] In addition, these Guidelines are not intended to address the humane killing of fish or aquatic animals that are caught for recreational purposes, although some of these methods may be applicable. Euthanasia and depopulation of fish can be found in separate AVMA documents[2,3] devoted to those topics. Slaughter is used primarily to describe the humane killing (ie, killing without the animal experiencing unnecessary fear, pain, or anxiety) of animals intended for human consumption for food or other uses (eg, agricultural harvest [catfish, salmon, and tilapia] and commercial fishing [wild-caught salmon, grouper, and snapper]).

It was historically thought that fish, amphibians, reptiles, and invertebrates lacked the anatomic structures necessary to perceive pain as we understand it in birds and mammals. However, recent scientific evidence indicates that fish possess components of nociceptive processing systems similar to those found in terrestrial vertebrates,[4–18] but debate continues on questions of the impact of quantitative differences in numbers of specific components such as unmyelinated C fibers in major nerve bundles. Studies indicating that fish responses to pain represent simple reflexes[19] have been refuted by studies demonstrating forebrain and midbrain electric activity in response to stimulation that differs with the type of nociceptor stimulation.[20,21] Slaughter methods should be employed that minimize the potential for distress or pain in all animal taxa, and these methods should be modified as new taxa-specific knowledge of their anatomy and physiology is acquired.

2. Animal behavioral considerations

Due to the large diversity of fish species that are consumed within the US, it is vital that individuals handling and performing slaughter of these species recognize this immense diversity of behavior and physiology to ensure the highest level of good welfare.

3. Human behavioral considerations and training

The Panel on Humane Slaughter (POHS) sees the importance of having highly trained, competent personnel as a necessity for the humane killing of fish. Training should include appropriate handling and care for living fish to reduce stress, recognition of the signs of insensibility, application and competence of appropriate method of slaughter, and the operation and maintenance of any equipment involved in the killing process.

4. Facility design and slaughter process

This section will consider fish welfare implications during harvesting when fish are removed from their growth or production habitat and are transported to slaughter. Food is usually withheld from farmed fish prior to handling, transportation, and slaughter to reduce regurgitation, defecation, nitrogenous waste production, and CO_2 buildup. The length of fasting necessary to empty the gut is dependent on the species and water temperature (1 to 5 days), but withholding food should be limited to the minimum time for gut emptying and not based on tradition or operational convenience.[22]

Crowding to concentrate the fish for grading or movement should be for as short a time as possible to minimize stress in the fish and should take into consideration the species' natural history, behavior, and propensity for stress. In ponds, raceways, and tanks, seine nets are commonly used or partitions or grids are moved to reduce habitat space. This is achieved in sea nets (net pens) by means of slowly lifting part of the net or by inserting a second net. Although there might be several different physiologic changes as a result of crowding, shortage of oxygen is the most common problem.[22] The environment should be as quiet and nonstimulatory as possible, and light intensity should be reduced, if possible, but with adequate lighting for personnel. Nets should be moved slowly to reduce panic in fish like tuna and bass and raised slowly for fish raised at depth like cod to prevent swim bladder issues. Depth of water may need to be maintained to prevent excessive sunlight exposure for salmon and char or a cover placed over the habitat to reduce sunlight and encourage fish to use the full water column for benthic species like halibut. Fish should be monitored for abnormal behaviors (eg, signs of asphyxia, increased excitement, and morbidity).

During crowding, moving, and transportation, water quality should be similar to that of the growth or production environment from which the fish originated for the duration of the killing process. If of acceptable quality for fish health, water in which they have been housed or captured should be used. Water quality should be monitored periodically for parameters such as oxygen, pH, CO_2, salinity, ammonia, and temperature and optimized for the species and stocking density of the fish species in question. Any necessary changes should be made gradually to allow the fish time to adjust. Supplemental aeration and temperature control should be used when necessary. Although not specifically approved, the addition of salt (2 to 8 g/L) to the water can also reduce stress in freshwater fish during holding periods.[23] Handling and crowding, as well as time out of water during movement, should be minimized as much as possible to control and minimize physiologic stress in fish. Equipment used to grade and/or transfer fish (eg, nets, brailing devices, pumps, and transfer pipes) should be constructed of materials and operated (eg, appropriate pumping height, pressure, and speed) to minimize physical injuries.[24] In addition, nets and tanks should be designed to

minimize physical injuries by using smooth materials and surfaces appropriately designed for use with fish and by checking on a regular basis for holes, tears, biofouling, or other changes that would compromise the integrity of the materials.

The slaughter facility should have equipment and facilities appropriate for unloading and holding fish of the species being slaughtered. Transfer of fish should be accomplished within water, if possible, to minimize injury and stress to the fish, and holding times should be as short as possible to reduce stress. Dewatering (eg, killing by asphyxiation by removal from water) is not recommended prior to slaughter as this induces aversive behavior and is highly stressful for fish.[25,26] This method also provides no stunning, and suffering before death is prolonged and likely to last longer than it appears based on activity of the fish.[27–30] Water quality and signs of stress should be monitored while the fish are in the holding facility prior to being stunned and processed for slaughter. Fish that are not correctly or completely stunned should be killed before consciousness is recovered.[24]

5. Techniques

Tissue residues from the use of drugs and other chemicals make many slaughter methods unacceptable unless they have been approved by the FDA for this purpose and appropriate withdrawal periods are followed. Use of any unapproved chemicals for slaughter prohibits entry of the fish into the food chain, either by rendering, as fish meal or oil, or by distribution for directly consumed product.[31] Carbon dioxide is a drug of low regulatory priority for enforcement[32] that avoids unacceptable residues, but it is not an FDA-approved method for killing aquatic animals used for food.[12] Physical methods for killing fish include manually applied blunt force trauma to the head, decapitation, and pithing.

The following methods, or a combination of the following methods, can be applied for slaughter of food fish, providing they are performed with proper equipment that is properly maintained and by trained personnel who are regularly monitored for proficiency.

i. Physical methods

Percussive stunning—Percussive stunning can result in both rapid and prolonged insensibility but is dependent on correct, accurate placement of the blow with sufficient strength to the cranium. This method is commonly used in the salmon and trout industry[30] for medium- to large-sized fish.[24] Blunt trauma can be applied manually by use of a club that is often referred to as a "priest" or by a hand-held captive bolt device.[30,33] The relatively small size of the fish brain compared to mammals makes accurate placement imperative to cause sufficient trauma.[34] The location of the blow should be targeted at the area where the brain is closest to the surface of the head and where the skull is its thinnest **(Figure 1)**. This blunt force trauma can cause immediate unconsciousness and potentially death but should be followed by a secondary kill step such as exsanguination (the cutting of the gill arches to bleed the fish) or pithing (destruction of brain tissue). The fish species, anatomy and size, and characteristics of the blow (including its accuracy, speed, and club mass) will determine the efficacy of manually applied blunt force trauma. Operators of the manual percussive stunning method should be trained in the proper location of the blow to the head and should be given frequent breaks and rotated often to avoid operator fatigue. A nonpenetrating captive bolt gun with either a wide mushroom-shaped head or flat head that does not penetrate the cranium is also commonly used and can partially alleviate the issue of operator fatigue. In general, nonpenetrating captive bolt guns only stun animals and fish should be killed by a second-step method before consciousness is recovered.[24]

Automated or semiautomated stunning equipment is commonly used commercially and can eliminate several of the issues seen with manual stunning but comes with its own set of issues. Fish need to be graded prior to use of this method, as percussive stunning equipment is unlikely to be suitable for a wide range of fish sizes[22,35] (ie, need to remove extreme of sizes—small and large—as well as deformed or sexually mature fish). Additional challenges to automated percussive stunning are posed by flat fish (both sinistral and dextral individuals) or by some farmed fish species such as catfish, pangasius, carp, and tilapia, which are resilient to percussive stunning because of conformation of their cranium and the protection it affords.[36,37] Due to the difficulty of designing equipment that operates fast enough to make this approach economically viable, automated percussion is also generally not used for small fish.[22] Automated systems require training for operators on a regular basis and a preventative maintenance program to ensure the proper functioning of the equipment.

Care should be taken to minimize the time fish are out of water prior to percussive stunning. Fish should be monitored poststunning for controlled and coordinated movement including but not limited to rhythmic motion of the opercula, vestibulo-ocular reflex (eye roll), and struggling that indicate that the fish is not adequately stunned. Although the lack of a vestibulo-ocular reflex may not be a definitive indicator that the fish are insensible, it is still considered as the best indicator available in a commercial setting.[38] Note that fish that are properly stunned may exhibit occasional spasmodic convulsions.[35] Manual percussive stunning may be used as a backup method for ineffectively stunned individual fish from the automated or semiautomated stunning equipment

Gunshot—This technique is primarily used with large fish such as tuna and was developed to dispatch these high-value fish quickly to prevent damage and stress during capture attempts. However, the noise when discharging the gun may illicit vigorous escape attempts from the other fish in the nets.[25] When aimed correctly, the bullet enters the brain to cause immediate damage and brain death, resulting in it being both a stun and kill method. Operators

using this method should be trained in the proper aiming required to ensure the correct location of the bullet to the brain of the fish and to ensure human safety. Tuna can be gaffed and shot while in the water, which is preferable with regard to fish welfare, rather than gaffed, hoisted out of the water, and then shot.[22,25,39] (Refer to the section Techniques—Physical Methods—Concussive—Gunshot for further safety information.)

Pithing—The pithing method is similar to spiking, coring, or ikejime. This is suitable for medium- to large-sized fish that can be adequately restrained to allow for the procedure.[24] A spike is quickly inserted into the brain of the fish to cause immediate brain death, resulting in it being both a stun and kill method. Pithing can be used either as a 1-step stun and kill method or as a secondary kill method. The technique of ikejime originated in Japan, with the insertion of the spike directly into the hind portion of the brain of the fish. Spiking, or ikejime, will kill the fish instantly and prevent stress to the fish. There are 2 main ikejime methods: from the top of the head **(Figures 2 and 3)** or through the gill cover **(Figure 4)**. The first method is used for most medium-sized fish, in which a sharp spike is driven into the brain from 1 side of the head. Depending on the species, the position of spiking is diagonal and about 2 cm behind the eye. Smaller fish can be spiked through the opercular (gill) opening with a sharp knife. This will both kill and exsanguinate the fish. The aim of both methods is to destroy the hindbrain of the fish, which is the part of the brain controlling movement. Operators using this method should be trained in the proper location for the species being slaughtered[40] and timing of the pithing process to ensure minimal stress and rapid brain death for the fish.

Decapitation followed by secondary kill step—Rapid severance of the head and brain from the spinal cord, followed by pithing of the brain, will cause rapid death and unconsciousness. Decapitation alone is not considered a humane approach, especially for species that may be particularly tolerant of low oxygen concentrations. Pithing helps ensure rapid loss of brain function and death for those species.[34]

Decapitation without prior stunning is not considered to be an ideal killing method for any species because the brain continues to function for an appreciable amount of time and it is uncertain whether animals are sensible during that period. Decapitation has been used as a means to kill eels that are notoriously difficult to kill. Eels are restrained on a board and the head completely severed. The heart is usually severed at the same time because of the proximity of the heart and brain.[25] However, electroencephalogram measurements have shown that some eel brain function continues for up to 13 minutes following decapitation.[41] Decapitation is unsuitable as a killing method for other species of fish, as their body shape prevents its easy application.[25] Cervical transection using a knife or other sharp instrument inserted caudal to the skull is used to sever the spinal cord and cervical vertebrae, which is then followed by a secondary kill step.

The rationale for this approach is similar to that for decapitation (destruction of connections between the brain and spinal cord) and pithing (destruction of brain tissue), except that the head is still physically attached to musculature of the body.

Electrical stunning (suitable for small- to medium-sized fish)—With this method, an electric current is passed through the water containing the fish for slaughter. The voltage and amperage conditions of the electric current should be sufficient not only to stun the fish, creating immediate unconsciousness, but also to kill the fish (electrocution). It is imperative that the electrical parameters (eg, voltage and exposure time) be optimized for the fish, as vertebral fractures and blood spots (ie, hematomas) in fillets, both of which can negatively affect fillet quality, may occur when this technique is improperly applied. Operators using this method should be sufficiently trained in the level of electric current appropriate to be used for the species and size of fish in question as well as in safety measures for themselves and other personnel.[24]

Exsanguination as a secondary kill step—With this method, the gill arches are cut to cause bleeding of the fish and ultimately death. Exsanguination without prior stunning should be avoided, as fish may struggle intensely[28] with vigorous head shakes and tail flaps.[42]

Rapid chilling (1-step or 2-step hypothermic shock)—This method of killing is not appropriate for temperate-, cool-, or cold-water–tolerant fish, nor is it currently acceptable for medium- to large-bodied fish because of surface-to-volume considerations. Fish display vigorous movement upon chilling. Thus, this method is most commonly used for fry and fingerling of warmwater species of fish such as tilapia; live-chilling decreases plasma glucose when compared with no chilling before slaughter. This decreased plasma glucose was once thought to be due to decreased stress[43]; however, more recent literature shows that this is likely due to rapid depletion of energy stores as a result of struggling during capture.

ii. Atmospheric methods

Carbon dioxide—Immersion in CO_2-saturated water causes narcosis and loss of consciousness after several minutes.[44,45] This method is most often used as the first step of a 2-step process with another method such as exsanguination. Many species may exhibit hyperactivity prior to loss of consciousness.[46,47] Other species might display other signs of distress such as excess mucus production.[25,48] Purity and concentration of CO_2 are important for effectiveness. The use of lower concentrations of CO_2 to prevent these aversive reactions has been researched in salmon but did not provide the stunning/anesthetic effect needed. Therefore, it is not recommended for the slaughter of Atlantic salmon[49] and is prohibited in several countries.[35,49] It should not be used if there are other more humane methods available. Only CO_2 from a source that allows for careful regulation of concentration, such as from cylinders, is acceptable.

Other gases—Other gases such as nitrogen, carbon monoxide, and nitric oxide have been exam-

ined as possible alternatives. Nitrogen caused more aversive effects in salmon and was considered unsuitable.[49] It was also found to be unacceptable for use in channel catfish.[50] Carbon monoxide has been investigated in several species of fish. It is an efficient fish sedative that does not cause the aversive reactions seen with CO_2, but also stabilizes the color of red fish muscle and inhibits microbial growth and lipid peroxidation, making it a promising candidate for use in humane fish slaughter.[51] Nitric oxide provides some of the similar positive qualities as CO, but further research is needed due to health concerns about formation of N-nitrosamines.[52,53] Care must be taken when using gases to prevent exposure to personnel (ie, slaughter must be conducted in well-ventilated areas).

iii. Immersion methods

Clove oil—Clove oil has been investigated as an agent to reduce stress of fish stunning prior to slaughter and was shown to result in relatively rapid induction of anesthesia and to extend the shelf life of fresh fish.[49,54] Clove oil is composed of several essential oils, including eugenol, isoeugenol, and methyleugenol.[55] Eugenol is classified as a "generally regarded as safe" food additive by the FDA[55] and as an exempted least-toxic pesticide active ingredient by the US Environmental Protection Agency.[56] Isoeugenol (liver, thyroid, mammary, and histiocytic tumors) and methyleugenol (liver tumors) are established carcinogens on the basis of studies of rodents.[57,58] The anesthetic mechanism of clove oil and its derivatives has been poorly studied, but they appear to act similarly to other local anesthetics by inhibition of voltage-sensitive sodium channels within the nervous system.

However, the US FDA has issued industry guidance raising concerns regarding the potential of clove oil and/or its derivatives to adversely affect human or animal food safety when used for anesthesia in fish harvested for consumption or in fish that are released and may enter the food chain of other aquatic species that might eventually enter the food chain.[59] The current FDA stance is that neither clove oil nor its derivatives are acceptable for use in fish intended for human consumption.[59]

6. Special considerations

None to mention currently in this version of the guidance document.

B. Decapod Crustaceans (Shrimp, Lobsters, Crabs, and Crayfish)

1. General considerations

In recent years, more attention has been garnered for the welfare of decapod crustaceans (shrimp, lobsters, crayfish, crabs) that are killed and consumed by people in the US and abroad. Decapod crustaceans are covered by animal welfare legislations of various governments, including (at the time of drafting this document) New Zealand, Norway, Switzerland, Australia, and Italy.[60] Likewise, there has been an increase in attention to the welfare of decapods in the US (particularly lobsters). Altogether, this growing attention to this taxon of animals has led to inclusion of decapod crustaceans in the POHS revised guidelines.

In the US, decapods are not covered by the Humane Methods of Livestock Slaughter Act.[1] In addition, these Guidelines are not intended to address the humane killing of these decapods that are caught for recreational purposes, although some of these methods may be applicable. Slaughter is used primarily to describe the humane killing (ie, killing without the animal experiencing unnecessary fear, pain, or anxiety) of animals intended for human consumption for food or other uses (eg, agricultural harvest [shrimp] and commercial fishing [wild-caught crab, lobster, etc]).

It was historically thought that invertebrates lacked the anatomic structures necessary to perceive pain as we understand it in birds and mammals. However, recent research suggests that the responses of decapod species to stimuli are beyond simple reflexes and create the possibility that these invertebrates do in fact feel pain.[61–63]

While there is ongoing debate about the ability of invertebrate animals to feel pain or otherwise experience compromised welfare, the AVMA's Panel on Euthanasia assumes that a conservative and humane approach to the care of any creature is warranted, justifiable, and expected by society,[2] and the POHS supports that approach. Slaughter methods should be employed that minimize the potential for distress or pain in all animal taxa, and these methods should be modified as new taxa-specific knowledge of their anatomy and physiology is acquired.

2. Animal behavioral considerations

Due to the large diversity of decapods that are consumed within the US, it is vital that individuals handling and performing slaughter of these species recognize this immense diversity of behavior displayed.[63]

3. Human behavioral considerations and training

Individuals who are harvesting decapod species from the wild or aquaculture should be knowledgeable of the behavior and general physiology of decapod species. It is essential to ensure good welfare of decapod species by ensuring individuals are competent at handling these animals. Thus, the importance of careful handling of decapods at risk of physical damage is essential. Such physical damage can result in hemolymph leaking rapidly from cracks in the exoskeleton and killing the animal,[11] and similarly to fish, shock from exposure to incorrect water parameters and death by desiccation or asphyxiation can occur if not properly stored or shipped in a moist environment prior to slaughter.[60]

Overall, the POHS sees the importance of highly trained, competent personnel as necessary for the humane killing of decapod crustaceans. Training should include appropriate handling and care for liv-

ing crustaceans to reduce stress, recognition of the signs of insensibility, application and competence of appropriate method of slaughter, and the operation and maintenance of any equipment involved in the killing process.

4. Facility design and slaughter process

Not applicable to this species group.

5. Techniques

Tissue residues from the use of drugs and other chemicals make many slaughter methods unacceptable unless they have been approved by the FDA for this purpose and appropriate withdrawal periods are followed. Use of any unapproved chemicals for euthanasia prohibits entry of the invertebrate into the food chain, either by rendering, as meat meal, or by distribution for directly consumed product.[64] Carbon dioxide is a drug of low regulatory priority[32] that avoids unacceptable residues, but it is not an FDA-approved method for killing aquatic animals used for food.[12]

Crustacean slaughter techniques are diverse because different species vary greatly in their physiologic and anatomical characteristics. When considering the welfare of invertebrates intended for slaughter, loss of consciousness and loss of normal behavior with irreversible death prior to processing is of utmost importance. Determining loss of consciousness varies with the species and the method used but generally includes resistance to handling, no limb movement, lack of eye response and mouth when palpated, and no signs of autotomy (dropping limbs) during the slaughter method.[60]

However, in terms of slaughter, there are killing methods likely to be painful and distressful on the basis of the current literature on decapods. These unacceptable methods include the following: any form of dismemberment, removal of the shell in live nonstunned decapods, placing crustaceans in inappropriate water parameters (temperature, pH, salinity), and placement of nonstunned crustaceans in boiling water.[60,63] These methods are listed above for informational purposes only.

The following methods, or a combination of the following methods, can be applied for humane slaughter of decapods, providing they are performed with proper equipment that is properly maintained, and performed by trained personnel who are regularly monitored for proficiency.

i. Physical methods

Electrical stunning—On the basis of the limited information in the current literature, electrical stunning appears to be the most humane and reliable humane method to stun/kill decapod crustaceans for slaughter.[13] Successful electrical stunning is highly likely to depend on the electrical parameters used. Those parameters will need to be adjusted according to species, size, developmental stage, and stage of molt of the animals. One such electrical stunning device has been developed and evaluated[15] for the commonly consumed decapods brown crab (*Cancer pagurus*) and lobster (*Homarus gammarus*). Studies[14] have shown that L-lactate levels did not differ between sham and electrically stunned individuals, which is suggestive of no significant stress from the electrical current. Further, when placed back into a saltwater (saline) solution, no recovery was appreciated among electrically stunned/killed individuals. For this proposed method,[14] the animals are placed in a saline solution with a 110 V, 2- to 5-amp electrical charge. Findings show that the device disrupts the CNS within a second and sensibility is lost within 10 seconds[14] and the device should be considered a possible method of slaughter.

Another study[15] has shown promise for application of a large-scale dry electrical stunning system for crustaceans. This method utilizes a stainless-steel plate on which a crab is placed, with another electrode placed directly on the animal. The device generates 220 V, 50 Hz AC, which appears to result in loss of sensibility and death within 10 seconds. This study also showed that neither prechilling nor keeping in air or ice water after stunning resulted in crab recovery. Signs of visible stress (autotomy) were minimal (3% to 6%) and appeared not to be correlated with voltage or exposure time.[15]

Splitting—Splitting, as a slaughter technique for lobsters, destroys the nervous system by cutting quickly along the longitudinal midline of the crustacean's head and thorax with a large sharp knife, where the main chain of nerve centers (ganglia) is localized **(Figure 5)**.[13] A skilled operator is required to ensure destruction of the nervous tissue to ensure a quick and irreversible death.

Spiking—Spiking is similar to splitting but involves destruction of a more centralized nervous system found in crabs that consists of 2 anterior ganglia.[9] With the use of an awl, both ganglia should be pierced and rapidly destroyed to ensure humane slaughter **(Figure 6)**. This method, like splitting, requires adequately trained personnel to ensure minimal stress and irreversible death.[13]

Dismemberment—This method involves the removal of all or some of the limbs without prior stunning. Sometimes this involves the removal of claws (such as in crabs), with the live animals returned to the sea. The argument for this practice is that decapod crustaceans can regenerate limbs and contribute to sustainable fishery practices.[65] However, evidence suggests that this method is not humane as the animal is still sensible during the removal of limbs, it often results in direct mortality of animals that are meant to be released following removal of just the claw(s),[17] and the animals have increased stress with regard to feeding, gaining resources, and defending against predation.[18]

Boiling—Boiling is a method of slaughter that is commonly employed. Recent research over the past several years has demonstrated that such a method results in behavior signs of shock (eg, lobsters struggle violently for about 2 minutes after being placed in boiling water[19,62] and lobsters and crabs thrash and try to escape and display autotomy, another indicator of stress).[20] Another issue with this method is that the time to death is prolonged and behavioral

indicators suggest that the animals are sensible during the process. One study[21] measured the internal temperature of edible crabs and suggested that they can sense the heat for at least 2.5 minutes and prechilling could extend that time. Similarly, another study[23] demonstrated how chilled crabs regained their senses when placed in hot water.

It is likely that smaller species of decapod crustaceans commonly consumed (such as shrimp and crayfish) have a shorter time to insensibility and death versus larger lobster and crab species.[60] Albeit this fact, these animals are potentially sensible for a significant amount of time. Therefore, the POHS recommends that, on the basis of the current literature, boiling is not an acceptable slaughter method for decapods regardless of size.

ii. Atmospheric methods

High-pressure killing—This method of slaughter utilizes hydrostatic pressure processors to generate pressure levels around 3,000 to 4,200 bar (44.1 to 60.3 kpsi), in which animals are held for 45 to 90 seconds.[60] This method is likely to become more common for commercial reasons, as it allows the muscles to detach from the exoskeleton, making extraction of the meat less labor intensive, and has the commercial advantage of killing microorganisms.[13,17,18] This method requires further investigation on the ease of application, loss of sensibility prior to death, and other signs of stress in the animals.

iii. Immersion methods

Carbon dioxide—This method is not FDA approved for aquatic animals intended for the human food chain. Furthermore, 1 study[3] suggested that crustaceans have negative reactions and show behavioral signs of sensibility when exposed to CO_2 as a method of killing.

Ice slurry/chilled air—This method requires more research, as the current literature is not rigorous enough to support ice slurry or chilled air as a method of slaughter. Many decapods are temperate or cold adapted and thus it is difficult to achieve loss of sensibility quickly and to evaluate physiologic signs of stress, and/or these animals demonstrate autotomy, recovery, or other escape behaviors when ice slurry or chilled air is utilized.[19,45,46] Furthermore, even when animals appear insensible, it is difficult to determine whether this is due to loss of consciousness or simply neuromuscular paralysis.[13] On the other hand, this method could potentially be usable in tropical species.[13,46,47]

Freshwater or saltwater exposure—This method should never be utilized, as immersing saltwater species in freshwater (and freshwater species in saltwater) leads to death due to osmotic shock[19] and likely induces pain and distress in these animals.[46]

6. Special considerations

None to mention currently in this version of the guidance document.

C. Cephalopods (Squid, Octopus, and Cuttlefish)

1. General considerations

The current literature is limited on the humane slaughter of this unique group of animals that are consumed by humans, and presently there are no established standards. This clade of animals is considered and have been demonstrated through various observational and experimental studies to be highly intelligent with signs of language, emotions, and even tool use.[63] This high level of intelligence and unique behavior has recently led to more attention and concern for these animals' welfare in both research[66] and slaughter.[63] At the time of writing this document, the POHS are not aware of any commercial farms raising cephalopods within the US, with these animals being harvested wild caught and sold to different food markets.

In summary, the POHS sees it necessary to provide a synopsis on the current state of slaughter on these animals, albeit brief, to pave the way for further research on techniques to ensure the highest level of welfare for these unique species.

2. Animal behavioral considerations

Cephalopods are typically solitary animals that are often aggressive toward each other in confined spaces, and there is no reliable humane slaughter method that could be performed commercially on a large scale. Likewise, there is tremendous diversity within these animals and the ecological niches they occupy, making it challenging to establish good welfare when attempting to meet their physiologic, behavioral, and environmental needs.[63]

3. Human behavioral considerations and training

The POHS sees the importance of having highly trained, competent personnel as a necessity for the humane killing of cephalopods. Training should include appropriate handling and care for living cephalopods to reduce stress, recognition of the signs of insensibility, application and competence of appropriate method of slaughter, and the operation and maintenance of any equipment involved in the killing process.

4. Facility design and slaughter process

This is not applicable, as all cephalopods are currently wild caught prior to slaughter within the US.

5. Techniques

Similar to other aquatic animals, including both fish and other invertebrate species, tissue residues from the use of drugs and other chemicals make many slaughter methods unacceptable unless they have been approved by the FDA for this purpose and appropriate withdrawal periods are followed. Use of any unapproved chemicals for euthanasia prohibits entry of the invertebrate into the food chain, either by rendering, as fish meal, or by distribution for di-

rectly consumed product.[64] Carbon dioxide is a drug of low regulatory priority[55] that avoids unacceptable residues, but it is not an FDA-approved method for killing aquatic animals used for food.[12]

Wild-caught cephalopods usually die soon after being taken from the water, with significant welfare issues due to physical trauma and asphyxiation. If the animals are still alive when harvested, they soon die from asphyxiation. There are reports of physical methods (clubbing, brain slice, and reversing the mantle) used for killing cephalopods, but there is a lack of evidence to support their use as humane methods of slaughter.[67]

Overall, the welfare issues are similar to those arising for wild-caught fish as mentioned previously in this chapter of the slaughter guidelines. This will require further research and the development of best practices to ensure good welfare for the slaughter of wild-caught cephalopods. The POHS recognizes that the current literature is limited on suggestions for improved welfare and recommends further research on this topic to minimize pain and distress and to optimize humane slaughter methods.

6. Special considerations

None to mention currently in this version of the guidance document.

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E. Figures

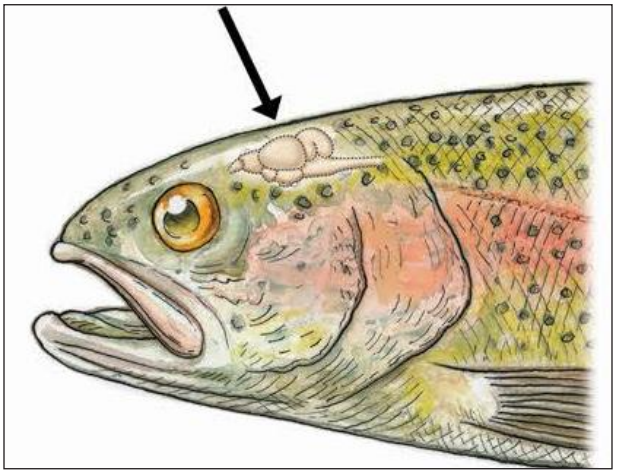

Figure 1

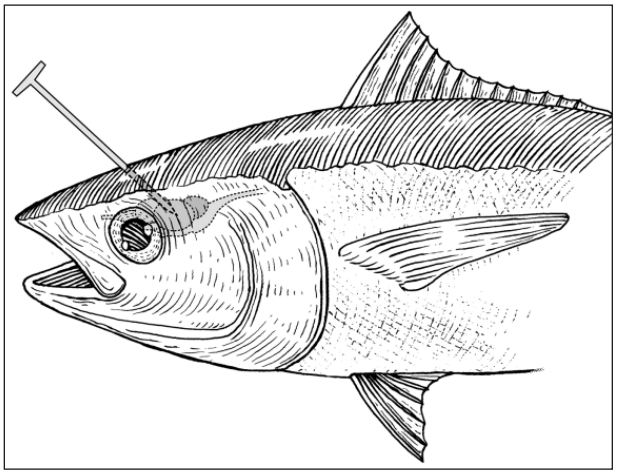

Figure 2

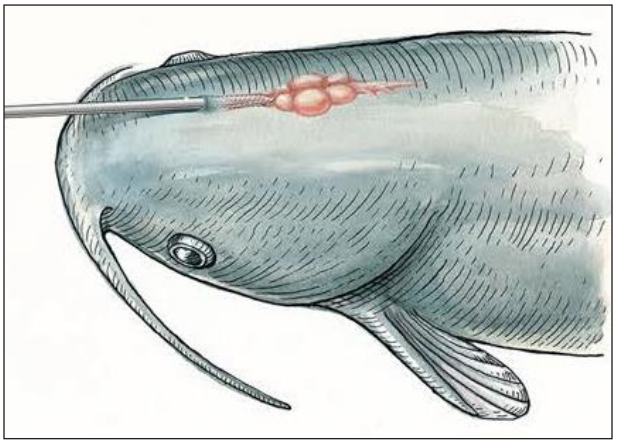

Figure 3

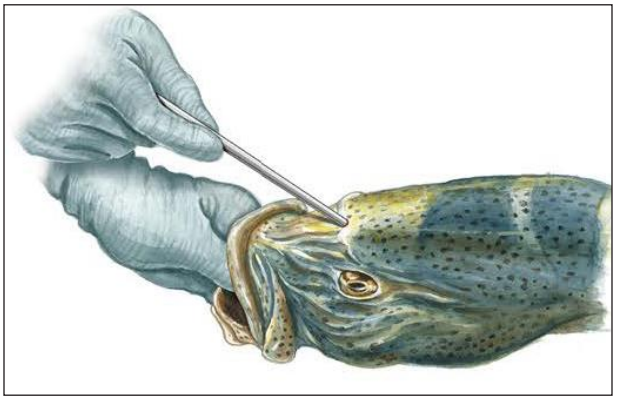

Figure 4

Figure 5

Figure 6

Chapter II: Poultry

A. Chickens

1. General considerations

Slaughter of chickens for human consumption primarily involves broiler chickens, which have been specifically bred and reared for meat production. Specialty markets are associated with end-of-lay "spent light fowl" (3.5 lb live weight/bird) from table egg–laying flocks and "spent heavy fowl" (7 lb live weight/bird) from breeder flocks that produce broiler hatching eggs.

2. Animal behavioral considerations

Chickens display escape and wing-flapping behaviors in response to handling, posing the risk of traumatic injury during catch and processing procedures. End-of-lay "spent light fowl" are particularly at risk of skeletal injuries from handling,[1] with 2.8% and 8.1% antemortem injury rates associated with enriched cages[2] and aviary housing,[3] respectively.

In broilers, catching in subdued lighting will keep the birds calmer during the process of loading into cages or modules. Injury may occur with both manual and mechanical catching methods, ranging from 0.4% to 3.2%.[4] Crates or modules should be designed to accommodate the weight and size of the bird to minimize injuries when birds are introduced. Crate designs with narrow openings are associated with greater injury risk.[5] Wing tips are prone to bruising,[6–8] likely due to wing flapping and impact with crate or module openings during loading. Birds caught individually and carried upright are less likely to display agitation and less likely to strike the crate during handling.[9,10] Transport imposes multiple stressors on birds, including extreme microclimates, motion, vibration, acceleration, and noise (broilers[11]; layer hens[12]). Lengthy lairage durations (> 6 hours) and resultant prolonged periods of feed and water withdrawal are associated with greater stress in broilers.[13] During unloading, casualty animals (individual birds with severe injuries) should be euthanized. Employees who are working in unloading areas must be trained to unload birds as smoothly as possible to prevent unnecessary damage or injuries. In 1 study, significant increases in prevalence of wing fractures occurred between lairage and shackling,[14] as broilers extend their wings for stabilization when they are put in an unbalanced situation, thus exposing the wings to potential damage. There is some evidence that provision of blue light in lairage and shackling results in improved animal welfare outcomes[15,16] by reducing fear and stress.[17,18]

Shackling involves hanging birds upside down, which is an unnatural posture for poultry. In chickens, inverted restraint produces greater corticosterone response than restraint in an upright posture, and physiologic stress outcomes increase with the duration of being hung on a shackle line.[19]

Species and/or strain differences may exist, since shackled turkeys remained quiet for extended periods with no signs of struggle or distress if undisturbed.[20] Wing flapping, an escape behavior, is performed by 90% of chickens immediately after being shackled and can also be influenced by wing flapping of adjacent chickens on the processing line.[21] Shackle lines can be constructed and maintained to reduce wing flapping by provision of breast rubs to keep inverted birds calm, controlling line speed to minimize jolting, and provision of appropriate shackle size for the weight of the bird being processed.[22] To reduce discomfort of the shanks while shackled, it is important that shackle size be appropriate for the size of the bird. Multisized shackles are available for small facilities that may process birds of different sizes.[23,24]

3. Human behavioral considerations and training

Several studies report differences between catching teams in terms of broiler injuries.[10,25] Greater wing injuries are associated with faster loading speeds.[25] Training for personnel involved with catching and shackling broilers improved several welfare outcomes.[26,27] Manual catching and shackling are physically taxing, and opportunities to reduce fatigue include slowing down the processing speed and rotating staff between different tasks.[28] Providing incentive pay and an auditing process has also been shown to reduce wing fractures after catching.[29] It is difficult to determine the proportion of injuries associated with catch versus handling at the processing plant.[30] Utilization of standardized animal welfare audit tools, particularly animal-based outcomes at slaughter, provides opportunities to identify risk factors and "best in class" metrics for handling crews to inform management decisions. As an example, birds can be sampled manually for catching injuries before being unloaded at the plant. The difference between these sample numbers and numbers collected in the plant can provide indicators of where injuries are occurring.

4. Facility design and slaughter process

i. Arrival at plant/receiving/lairage

Broilers arrive at the plant and are weighed on a truck scale while they are still within transport crates or modules on the vehicle.

ii. Lairage

After weighing, the poultry truck is parked in the lairage shed with the birds still within transport crates or modules. Covered sheds may be equipped with fans and misters to keep the birds cool during hot weather, depending upon geographical area. Holding time at the plant should be minimized and on average should not be more than 4 hours.[31]

iii. Staging

The truck is then moved from the lairage to the covered unloading area. This area may be equipped with fans and misters to keep birds comfortable. Modules or crates are removed from the truck for unloading.

iv. Unloading/handling system

If a modular drawer system or individual crates are being used, the drawers or crates are removed from the palletized rack either manually or with use of automated equipment and are conveyed into the shackle room. If a module system is used, it should be operated in such a manner that birds can gently slide out of the transport system onto the conveyor.

Care must be taken to not unload birds on top of others while unloading. It is important to wait until the belt is clear before unloading additional birds.

v. Restraint

Handlers pick up live birds and place them on the shackle line by inserting their shanks into the processing line shackle. The birds are then conveyed to the water-bath stunner or to the individual responsible for the neck cut in the case of nonstun slaughter.

vi. Detection of problems

The most common problems encountered in poultry transport, handling, and slaughter are overloaded containers, heat stress, frostbite, and death due to exposure. Poorly maintained, broken containers may injure birds. Bird pileups or birds falling out of general flow may occur if birds are unloaded too quickly. Broken wings are more likely to occur in heavy birds unloaded from modular hauling systems, compared with lighter birds. In drawer and crate systems, a common problem is head entrapment. This is caused by rough or hurried loading on the farm or poor design of the transport container. Rough handling by employees attempting to work too fast may cause bruising or injury with any system used.

vii. Corrective actions

Stocking densities for travel containers have been established through research and practical experience. A maximum stocking density gives sufficient space for all birds to lie down without being on top of one another. To prevent head entrapment in drawer-and-crate systems, when closing the drawer or crate lid on the farm, there should be a 1.5-inch gap between the top of the plastic drawer and the metal rack or the crate lid and crate frame. Processing plants should have an emergency plan to care for birds in case of power failure at the plant or natural disasters that make roads impassable. Arrangements should be made so that catching and loading of birds at the farm can be quickly cancelled before loading is started. Loaded shipments that are already in route should be diverted to nearby plants for processing. Training of employees who unload modules is essential. Employees must learn to wait until the receiving conveyor belt has open space before unloading more birds. It is also important to never shake the module to unload birds. It is recommended that slides be used to unload birds so they are more evenly spread over the receiving belt. The height and speed of transition from one conveying belt to another should be monitored to ensure that excessive wing flapping does not occur. Once the birds are unloaded, a darkened room illuminated with blue lighting will help keep birds calm.[32] The live bird shackling area requires constant supervision to prevent rough handling and bird abuse.[33]

5. Techniques

i. Physical methods

Electrical stunning—Electric stunning is the most universally used method for stunning prior to slaughter for poultry.[34] The most widely used method for electro-stunning poultry is the electric water-bath stunning method **(Figure 1)**, which involves the direct contact of the bird's head in an electrified salt-water bath. The birds, which can be chickens, turkeys, or other poultry, are moved to the water-bath stunner while they are inverted and suspended by their shanks in individual shackles on the moving shackle line. The bird's head has direct contact with the water bath, and an electric current is passed from the water through the bird to the leg shackle and ground bar. The water bath and grounding equipment must be maintained to convey a sufficient electric current through the bird's body to provide an adequate stun until exsanguinated.[35]

Efficacy of the water-bath system is influenced by the species, number, gender, body composition, feather condition, weight of the birds, adequate salinity of the water bath, proper grounding of the equipment, and number of empty shackles passing through the water bath. Variable resistance can result in insufficient current to produce immediate unconsciousness. Constant-current stunners may alleviate this problem.[36]

Smaller commercial facilities may use a handheld electrical stunner. When this method is used, birds must be properly restrained. Electrodes must be properly constructed to ensure contact with skin through the bird's feathering. Placing water on the head of the bird reduces resistance and enhances the stunning process.

US model—Contrary to the European model, electrical stunning in the US involves pulsed direct current with low current (25 to 45 mA/ bird),[34] low voltage (10 to 25 V),[34,37,38] and high frequency (approx 500 Hz).[34,37,38] This type of system became possible with advances in electrical circuitry and changes to the length of the water bath cabinet that increase dwell time of the birds and decrease the total resistance in the water bath.[34] In a survey of 329 US poultry plants, 92.1% reported using electrical stunning, and 77.4% of those plants used low-voltage (10 to 25 V), high-frequency (500 Hz) systems.[39]

Behavioral reactions—Efficacy of the stunning in US slaughter plants has been determined by assessing corneal and comb reflexes.[39] Typically, a bird is considered stunned by plant personnel when it becomes unresponsive to stimulation of the cornea or comb with its eyes wide open, an arched neck, and tucked wings.[39] One study[40] evaluated a 2-phase step-up stunner, with a first phase consisting of low-voltage (12 and 15 V), high-frequency (550 Hz) pulsed direct current for 10 seconds and a second phase consisting of sinusoidal wave alternating current (50 Hz at 40, 50, and 60 V for 5 seconds).[40] The best results for this combination occurred in male birds at the highest voltage settings (phase one, 15 V; phase two, 60 V).[39] Under these conditions, only 22% of the birds had corneal

reflexes, 18% had spontaneous blinking, and < 10% had wing flapping.[40]

Physiologic reactions—One study[40] that evaluated a 2-phase step-up stunner, with a first phase consisting of low-voltage (12 and 15 V), high-frequency (550 Hz) pulsed direct current for 10 seconds and a second phase consisting of sinusoidal wave alternating current (50 Hz at 40, 50, and 60 V for 5 seconds), found that 45% of the birds did not achieve an isoelectric electroencephalogram (EEG). Contradicting this, another research group evaluating a similar 2-phase step-up stunner (phase one, 23 V [550 Hz direct current for 10 seconds]; phase two, 15 V [60 Hz alternating current for 5 seconds]) found that the poststunning EEG had a brief period of high-amplitude spikes that progressively decreased in amplitude over time.[41] These investigators found the EEG recording of the brain activity to be very similar to that seen with the European model of electrical stunning.[41]

Detection of problems during electric water-bath stunning of poultry—If wing flapping occurs immediately prior to the entrance of the water-bath stunner, the wings of the birds may receive prestun shocks before the bird's head comes in direct contact with the water bath.[42] These shocks do not produce unconsciousness because they occur before the bird's head enters the water bath and may cause the bird to rise up in the shackle, missing a sufficient stun to deliver unconsciousness. Mis-stunned birds may also occur in flocks with poor uniformity in which smaller birds miss direct contact with the water bath.

Poorly stunned birds may also be caused by setting the stunner amperage too low, inappropriate water bath height, or insufficient water in the water bath. Improperly stunned birds may miss both the machine designed to cut the blood vessels in the neck and the manual backup, and doing so will result in insufficient blood loss to cause death and the potential for the birds to return to consciousness. Birds should have the vessels of their neck cut within 10 seconds of the stun. To ensure appropriate bleeding, a ventral cut of the neck (cutting both carotid arteries) is recommended. The neck cut can be performed by a single or twin-blade automate neck-cutting machine or manually with a sharp knife. Blood loss should be completed within 45 seconds of the vessels being cut. Uncut birds can be easily detected after feather removal because there will be no throat cut and the skin will be bright red. The red skin is caused by lack of bleed-out. Plant management should strive to have 0% uncut red birds.

Correction of problems with electric water-bath stunning—The height of the water-bath stunner must be adjusted so that the birds cannot pull themselves up and avoid the stunner. It is also essential to avoid distractions such as people walking under the birds or doors opening and closing near the stunner entrance. These distractions can cause birds to pull up in the shackle and miss the water bath. The processing line should run smoothly because a start-and-stop ride may cause birds to flap their wings and avoid the stunner. Breast rubs, low lighting, and a smooth transition into the stunner can reduce the frequency of wing flapping and help with the birds entering the stunner in proper position to receive a good-quality stun. Proper stunner design, including a nonconductive entrance, will also help eliminate prestun shocks. Shackles must be of the appropriate size for the species and specific birds. Because of the variable resistance between species, flocks, and even individual birds, recommendations for optimal electric parameters for effective stunning in poultry are difficult to make.[43]

Summary—Results of studies of birds stunned with the low-voltage US model indicate that the birds are unresponsive to stimuli. However, the physiologic data are contradictory, and it is unclear whether birds truly reach a state of unconsciousness. As noted by others,[40,44,45] further research is needed to evaluate the effectiveness and humaneness of electrical stunning with low voltage settings in 1- and 2-phase stunning systems. In the EU, only certain current and frequency combinations are allowable, based on a large body of research determining the likelihood of an effective stun with various electrical parameters.[28] Meat quality assessments show that an inherent conflict exists between reliable electrical stunning and economically relevant carcass quality outcomes, leading the European industry to widely adopt controlled atmosphere stunning (CAS).

Conclusions—While electrical stunning offers the possibility of immediate induction of unconsciousness, in practice the biological variability of birds may make it difficult to consistently apply optimal parameters. Inadequate electrical variables can result in a return to consciousness before birds enter the neck slitter, and even constant-current systems do not avoid harms associated with shackling or the risk that some birds may miss the stunner completely. Use of certain electrical frequencies is associated with blood spotting and carcass waste. Risks to welfare can be reduced by applying appropriate current and ensuring appropriate contingencies for inadequate or mis-stunned birds.

ii. Other physical methods

Decapitation—Decapitation is not commonly employed in the commercial slaughter of food animals but is often used for on-the-farm slaughter, primarily of poultry.[38] When properly employed, this technique can be a quick and humane method of slaughter, but if done incorrectly, it has the potential to induce pain and distress in the animals. This method may be found to be aesthetically displeasing to those performing or observing the technique.

In poultry killed by decapitation, convulsions frequently occur immediately to several seconds following application of the technique. Postmortem convulsions were minimized when chickens were electrically stunned prior to decapitation.[46]

Decapitation without prior stunning is rarely used in poultry slaughter plants.[39] Decapitation is also a method that is sometimes used for home slaughter of poultry.[38] Early studies[47,48] on the effects of decapitation on brain electric activity in chickens, sheep, and rats showed persistence of activity for up to 13 to 14 seconds following decapitation,

resulting in the conclusion that the animals' heads remained conscious during this time and may have experienced pain. However, many recent studies[49–52] have shown that this activity does not imply the ability to perceive pain, and they conclude that loss of consciousness occurs rapidly following decapitation. The concern that the blow from the decapitating device might induce pain is mitigated by the fact that afferent sensory nerves for the head and neck enter the spinal cord at the level of the second cervical vertebra in most species; therefore, the severing of the spinal cord at or above that level would prevent sensory input from the tissue injury from reaching the brain.[51]

Operator competence is required to perform decapitation in a humane fashion. The operator must be familiar with the technique and able to accurately place the blade high on the neck, ideally at the level of the first vertebra. Blades used for decapitation must be maintained to be kept sharp and able to sever the entire head without need for more than 1 blow. Birds must be restrained to prevent them from moving away from the blade. For poultry, restraint in a bleeding cone will not only facilitate accurate aim but will also minimize tissue trauma from postmortem convulsions. Electrically stunning a bird prior to decapitation reduces the occurrence of postmortem convulsions.[46]

Cervical dislocation—Cervical dislocation is not commonly employed in the commercial slaughter of food animals but is often used for on-the-farm slaughter, primarily of poultry and rabbits[53]; therefore, the Panel has opted to provide guidance. Manual cervical dislocation must be performed by individuals with a demonstrated high degree of technical proficiency. Those responsible for the use of this method must ensure that personnel performing cervical dislocation are properly trained and physically able to consistently apply it humanely and effectively.

Cervical dislocation is a method that may induce rapid loss of consciousness,[49,54] does not chemically contaminate tissue, and can be rapidly accomplished. However, cervical dislocation may be aesthetically displeasing to personnel performing or observing the method, and it requires mastering technical skills to ensure that loss of consciousness is rapidly induced. If cervical dislocation is improperly performed and there is incomplete separation of the spinal cord from the brain, pain and prolonged death may occur. For some classes of poultry, however, there is evidence that cervical dislocation may not cause immediate unconsciousness.[48,55–57] In these cases, other physical methods such as captive or noncaptive bolt, decapitation, or blunt force trauma may be employed when available or practicable.[58]

When performed on poultry, cervical dislocation must result in complete luxation (or separation) of the cervical vertebrae from the spinal cord without primary crushing of the vertebrae and spinal cord. For poultry, both legs of the bird should be grasped with the nondominant hand (or wings if grasped at the base). The neck is then encircled with the thumb and index finger of the dominant hand at the base of the skull. Using the legs to support the bird's body, if necessary, the performing personnel should stretch the neck by pulling the head while applying a ventrodorsal rotational force to the skull until the luxation of the cervical vertebrae is felt. Reflexive wing flapping and leg movement at this point are normal occurrences. Crushing of cervical vertebrae and spinal cord is not acceptable unless the bird is first rendered unconscious. It is recommended that personnel should be trained using anesthetized or dead animals to demonstrate proficiency.

iii. Atmospheric methods

Controlled atmosphere stunning—Compared with electric stunning methods, CAS for poultry presents some animal welfare advantages because stressful manual handling and shackling of live birds is eliminated and there is a greatly reduced risk of an ineffective stun. In addition, CAS can also eliminate welfare issues associated with unloading live birds from their transport cages or modules prior to stunning; however, this depends on the design and implementation of CAS at the processing plant. CAS and killing methods, also called modified atmosphere stunning or killing, produce unconsciousness, and can eventually lead to death, by 1 of 2 basic methods: (1) by displacing air and the oxygen it contains to produce O^2 levels < 2% (eg, hypoxia or anoxia using inert gases such as N_2 or Ar, or low-atmospheric-pressure stunning [LAPS]), or (2) by progressively inducing decreased intracellular pH and cellular function through acute hypercapnia (eg, CO_2 used either alone or together with inert gases and supplemental oxygen to produce hypercapnic anoxia, hypercapnic hypoxia, or hypercapnic hyperoxygenation).[59] Sequential combinations of the 2 methods, also called 2-step or multiphase processes, may use 1 gas or a mixture of gases to induce unconsciousness prior to exposure to a different gas mixture or higher gas concentration. These approaches are used for turkeys as well as chickens, where broadly the same welfare considerations apply.

Whether a CAS method is classified as stunning or killing depends on the amount of time the animal remains in the modified atmosphere. Killing methods eliminate the concern that animals may regain consciousness prior to exsanguination. In practice, CAS is usually nonrecovery because although it is possible to induce a temporary loss of consciousness with gas exposure, birds tend to rapidly regain consciousness on reexposure to air, leading to an elevated risk of recovery on the slaughter line. Use of CAS eliminates the pain, stress, and fear associated with shackling. As with all inhaled or atmospheric methods, unconsciousness is not immediate, and any perceived distress and discomfort by animals will vary depending on the species, process, and gases used.

There is controversy in the scientific community as to the optimum CAS gas mixture and conditions of application for humane slaughter. Distress during administration of CO_2 and the inert gases N_2 and Ar has been evaluated by means of both behavioral assessment and aversion testing and has been re-

viewed in the context of euthanasia.[60] It is important to realize that aversion is a measure of preference and that while aversion does not necessarily imply that the experience is painful, forcing animals into aversive situations creates stress. The conditions of exposure used for aversion studies, however, may differ from those used for stunning or killing. In addition, agents identified as being less aversive (eg, Ar or N_2 gas mixtures) can still produce overt signs of behavioral distress (eg, open-mouth breathing) for extended time periods prior to loss of consciousness under certain conditions of administration (eg, gradual displacement).[61]

A distinction must be made between immersion, where animals are placed directly into a high concentration of a gas or vapor within a container, and commercial CAS processes as employed for the stunning of poultry and pigs. The transport or introduction rate may be slow or relatively quick, depending on the process, gases used, and specific species. Further, denser-than-air CAS gases including CO_2 layer into gradients within an enclosed space.[62] Thus, animals are not immediately exposed to stunning conditions known to be aversive or painful, and several CAS systems are designed to achieve this, avoiding nociceptive concentrations of CO_2 (approx 45% and over), until birds are unconscious.[63]

In studies of turkeys[64] and chickens,[65] hypoxia produced by inert gases such as N_2 and Ar appeared to cause little or no aversion, where birds freely entered a chamber containing < 2% O_2 and > 90% Ar. When Ar was used to euthanize chickens, exposure to a chamber prefilled with Ar, with an O_2 concentration of < 2%, led to EEG changes and collapse in 9 to 12 seconds. Birds removed from the chamber at 15 to 17 seconds failed to respond to comb pinching. Continued exposure led to convulsions at 20 to 24 seconds. Somatosensory-evoked potentials (SEPs) were lost at 24 to 34 seconds, and the EEG became isoelectric at 57 to 66 seconds.[66] With turkeys, immersion in 90% Ar with 2% residual O_2 led to EEG suppression in 41 seconds, loss of SEP in 44 seconds, and isoelectric EEG in 101 seconds, leading the authors to conclude that exposure times > 3 minutes were necessary to kill all birds.[67] It was also reported that chickens did not avoid chambers containing < 2% O_2, and birds gradually became unconscious without showing signs of distress.[68] However, the design of such studies can be problematic in that once in the modified atmosphere, birds rapidly become cognitively impaired and may be unable to express behavioral preferences or escape reactions.

Chickens[68–71] and turkeys[64] killed by hypoxia show less head shaking and open-beak breathing than birds exposed to CO_2. Respiratory disruption, defined as open-beak breathing with prolonged inspiration or prolonged open-beak gaping with apparent apnea or dyspnea, is less in anoxia-stunned birds compared with methods combining anoxia with CO_2.[68,72] This is probably because CO_2 is a potent respiratory stimulant and may be associated with a sensation of "air hunger," though this has never been specifically investigated in birds.[73] Mandibulation, the rapid opening and closing of the beak, may occur with anoxic systems, but may occur less than in other systems.[74] However, broilers are noted to have more episodes of wing flapping when stunned with N_2, either alone or combined with 30% CO_2, than with a 2-step process using 40% CO_2, 30% O_2, and 30% N_2 followed by 80% CO_2 in air.[72] However, since these episodes happen after loss of posture (LOP), they reflect convulsive activity, which has no welfare consequences. Failure to maintain < 2% O_2 when using hypoxic or anoxic inert gas methods prolongs survival.[75,76]

A sizable proportion of chickens and turkeys will enter a chamber containing moderate concentrations of CO_2 (60%) to gain access to food or social contact.[64,65,68] Following incapacitation and prior to loss of consciousness, birds show behaviors such as open beak breathing and head shaking. Since these behaviors are seen at subnociceptive concentrations without withdrawal, they do not automatically signal distress.[69] Unlike N_2 and Ar, which must be held within a very tight range of concentration to produce O_2 levels (< 2%), CO_2 can render animals unconscious over a wide range of concentrations, even when O_2 is > 2% because it has anesthetic properties.[77]

Death via exposure to CO_2 has been described for individual and small groups of birds.[61] CO_2 and its application to the slaughter of chickens, turkeys, and ducks have been studied extensively, resulting in information about times to collapse, unconsciousness and death, loss of SEPs, and changes in EEG. Leghorn chicks 7 days of age collapsed in 12 seconds after exposure to 97% CO_2.[78] Broilers 5 weeks of age collapsed an average of 17 seconds after entering a tunnel filled with 60% CO_2.[68] In a CAS system designed for small flock depopulation, LOP was observed in approximately 20 seconds for various ages of layers and broilers in a 50% CO_2 atmosphere and approximately 30 seconds for turkeys in a 40% atmosphere.[61] In tests where it took 8 seconds to achieve the target gas concentration, broilers and mature hens collapsed in 19 to 21 seconds at 65% CO_2 and 25 to 28 seconds at 35% CO_2.[75] In a gradual-fill study, 30 ducks and turkeys lost consciousness before 25% CO_2 was reached and died after the concentration reached 45%. At 49% CO_2, EEG suppression, loss of SEP, and EEG silence occurred in 11, 26, and 76 seconds in chickens.[79] In turkeys, EEG suppression took place in an average 81 of 21 seconds at 49% CO_2 but was reduced to 13 seconds at 86% CO_2. In the same report, time to loss of SEPs was not affected by gas concentration, averaging 20, 15, and 21 seconds, but time to EEG silence was concentration dependent (ie, 88, 67, and 42 seconds for 49%, 65%, and 86% CO_2, respectively).[80]

Exposure to CO_2 concentrations producing a gradual induction of unconsciousness reduces convulsions, compared with anoxia with N_2 and Ar.[70,81] Practical experience in commercial slaughter facilities indicates that a smooth, gradual increase in CO_2 from 0% to more than 50% to 55% reduces bird reactions (eg, head shaking, open-beak breathing) prior to LOP; chickens require a more gradual increase in

CO_2 concentration over time than turkeys.[82] CO_2 may invoke involuntary (unconscious) motor activity in birds, such as flapping of the wings or other terminal movements, which can damage tissues and be disconcerting for observers.[78] However, wing flapping is less with CO_2 than with N_2 or Ar.[72,81] A 2-step or multiphase process combining inert gases and CO_2 is used commercially for slaughter of poultry, where birds are exposed initially to 40% CO_2, 30% O_2, and 30% N_2, followed by 80% CO_2—low concentrations of CO_2 that build in a series of steps. The early phases are sometimes hyperoxygenated, which has both welfare and carcass-quality advantages.[72,83,84] Thus, vocalization and nonpurposeful movement observed after loss of the righting reflex or LOP with properly applied controlled atmospheric methods are not necessarily signs of conscious perception by the animal. While generalized seizures may be observed following effective CAS methods, these generally follow loss of consciousness; indeed, anesthesia, coma, and generalized seizures all represent a loss of consciousness where both arousal and awareness in humans is low or absent.[85] Loss of consciousness should always precede loss of muscle movement.

CAS design—The mechanical design of commercial CAS systems has been reviewed.[82] In open CAS systems **(Figure 2)**, the entry point is open to the atmosphere with negligible concentrations of stunning gas present. Animals are moved on continuous conveyors through a tunnel or into a pit containing a heavier-than-air gas, such as CO_2 or Ar. In a closed CAS system, batches of animals are placed inside a chamber, and stunning gases are introduced to the specified concentration through a recirculating ventilation system that displaces oxygen by the stunning gases. As with other inhaled methods, changes in gas concentration within any enclosed space involve 2 physical processes: (1) wash-in of new gas (or washout of existing gas) and (2) the time constant required for that change to occur within the container for a known flow rate.[86,87] Although closed systems can potentially operate using any stunning gas, inert gases such as N_2 work best in such systems because O_2 levels < 2% can be achieved. This level of hypoxia is difficult to achieve in open CAS systems because N_2 is less dense than air and, therefore, difficult to contain. Also, closed CAS systems use a greater volume of stunning gas than open systems because the stunning area must be evacuated prior to loading the next group of animals.

Low-atmospheric-pressure stunning—LAPS **(Figure 3)** is a relatively novel method for stunning birds. Entire modules or crates are rolled into a pressure vessel where the air is slowly removed during a 280-second cycle. Unconsciousness due to hypoxia occurs following a controlled and gradual reduction of barometric pressure.[88–90] Following extensive welfare assessment research,[91,92] LAPS was added to EU Regulation 1099/2009 in 2018 for broilers up to 4 kg and has been granted "no objection" status by the USDA.

LAPS is not rapid decompression, as currently deemed unacceptable by the AVMA Guidelines for the Euthanasia of Animals: 2020 Edition, but rather it is negative atmospheric pressure applied gradually over time, typically in just over 1 minute in broilers, which results in an acute hypoxic state not unlike being in an unpressurized airplane at higher altitudes. Maximum observed negative pressure during commercial broiler LAPS is 24 in Hg (605 mm Hg); this corresponds to an atmospheric pressure of 156 mm Hg and an inspired P_{O_2} of 33 mm Hg (assuming barometric pressure of 760 – 605 mm Hg = 155 mm Hg X 0.21 = 33 mm Hg oxygen). Thus, LAPS P_{O_2} at maximum negative pressure is equivalent to a 4% oxygen atmosphere at sea level (33 mm Hg/760 mm Hg). For comparison, the atmospheric pressure on top of Mount Everest (elevation, approx 30,000 feet) is 225 mm Hg, and the P_{O_2} is 47 mm Hg; at 40,000 feet, atmospheric pressure is 141 mm Hg, and P_{O_2} is 30 mm Hg.

Welfare concerns relevant to LAPS are potential gas expansion in body cavities leading to potential barotrauma (and associated pain) and air hunger responses to hypoxia. Rapid decompression can cause both pain and distress, but in the case of birds, gases are unlikely to be trapped in the lungs or abdomen during LAPS owing to the unique anatomic structure of the avian respiratory system and are thus unlikely to become a source of abdominal distention.[92] Avian lungs are open at both ends, rigid, and attached to the ribs and do not change size during ventilation. Attached to the lungs are 9 air sacs that fill all spaces within the thoracic and abdominal cavities. Because birds lack a diaphragm, they move air in and out during sternal movement using the intercostal and abdominal muscles; air movement is simultaneous and continuous with no passive or relaxed period. Thus, it is unlikely that significant amounts of gas can be trapped within the avian lungs or abdomen unless the trachea is blocked for some reason.[93] In contrast to reports of hemorrhagic lesions in the lungs, brain, and heart of animals undergoing rapid decompression,[94] no such lesions were observed in birds undergoing LAPS.[89] No pathological evidence of ear damage has been noted in LAPS birds,[91] and a study employing analgesic intervention[95] did not find evidence of pain during induction.

The LAPS target pressure for broilers is achieved within 67 seconds from the start of the LAPS cycle and is followed by a second phase in which the rate of decompression is reduced (68 to 180 seconds) before a "hold" phase in the final 100 seconds of the cycle, which ensures that recovery does not occur prior to exsanguination. The decompression curve is automatically adjusted within tight limits to compensate for ambient temperature and humidity, which affect gas density. A consistent series of behavioral responses are seen in response to LAPS, and these closely resemble those seen in normobaric hypoxic environments. The time to loss of consciousness during LAPS (as determined by behavioral and EEG indicators) is approximately 60 seconds,[96] which is within the range of other CAS systems. A significant advantage of LAPS over electric stunning and live- dump CAS is elimination of welfare issues associated with unloading live birds onto the conveyor line and elimination

of manual handling and shackling of live birds prior to electric stunning. Other advantages of LAPS are that it will work with all existing chicken transport systems, it is easy to maintain, there is no expensive gas to purchase, and there are no supply logistics to consider. LAPS must have a full electric stunner backup. During commercial operation, birds undergoing LAPS are contained within palletized shipping cages on transport trucks in a holding area adjacent to the LAPS cylinders. Pallets are directly loaded into the LAPS cylinders with a forklift. A computer in the control booth controls and displays the status of the individual LAPS units. LAPS operations are fully automated, such that once a cycle is initiated, the load operator cannot override or manually change the LAPS cycle. Each LAPS cylinder has a video camera mounted inside that can be viewed in real time on a monitor in the control booth. Following the LAPS cycle, the palletized cages containing stunned birds are moved to the unloading station. After unloading, the birds are moved by conveyor belt to the shackling area prior to entry to the processing line. As previously noted, LAPS corticosterone levels are lower than with electric stunning, likely owing to elimination of live bird shackling. Welfare risks associated with the operation of LAPS include a too rapid decompression rate or insufficient dwell time—in practice both risks are eliminated by the design of the system.

Detection of problems with CAS and LAPS—Some of the most common problems associated with CAS are CO_2 concentrations that are too low or insufficient dwell time in the chamber. Maintaining the correct gas mixtures is essential for birds to have a smooth induction with a minimum amount of open-beak breathing or head shaking. If the birds flap wildly and attempt to escape from the chamber, it is not acceptable[70] and may indicate a problem with the gas mixture. These problems can result in either a return to sensibility on the slaughter line or stressful anesthetic induction. All chamber-type systems for either CAS or LAPS must have either windows or video cameras so that problems with induction can be observed. Some discomfort during induction, such as head shaking or gasping, may be a reasonable trade-off to eliminate live shackling, as live shackling is highly stressful. It is also essential to maintain the correct dwell times in the chamber to ensure nonrecovery.

Corrective action for CAS and LAPS problems—Adjust gas mixtures or LAPS system to provide a smoother induction before LOP. Plant management should have a monitoring procedure to visually monitor induction and record atmospheric parameters. The chamber should have a documented maintenance protocol for daily, weekly, and monthly maintenance. It is strongly recommended that all chamber-type systems have a full electric stunner backup. This will enable a plant to keep running if one of their chambers break. In systems where there is more than 1 chamber, this will prevent the temptation to run a single chamber faster to temporarily replace a broken chamber. In LAPS, speeding up the cycle would likely cause severe stress to the animals. When plants install LAPS or CAS, they should purchase sufficient capacity so that the chambers can be operated with the correct dwell time. If a power failure or other malfunction occurs during the stunning process, live birds should be immediately removed from the chamber.

Conclusions—With CAS systems, initial exposure to lower CO_2 concentrations and a gradual increase of CO_2 concentrations apparently produce a smoother induction of unconsciousness and reduce convulsions, compared with anoxia with N_2 and Ar. CO_2 may invoke involuntary (unconscious) motor activity in birds, such as flapping of the wings or other terminal movements, which can damage tissues and be disconcerting for observers; however, wing flapping is less with CO_2 gas mixtures than with N_2 or Ar.

LAPS produces a gradual transition to unconsciousness via hypobaric hypoxia without escape behaviors and with minimal physical activity and wing flapping. Although wing flapping may be observed, it occurs following LOP and, therefore, consciousness. Compared with live-unload CAS methods and electric stunning methods, LAPS may be better from an animal welfare standpoint because of elimination of welfare issues associated with unloading live birds onto the conveyor line, elimination of manual handling and shackling of live birds prior to electric stunning, and reliable stunning. LAPS may have cost-saving and environmental advantages over CAS in shipping cages due to elimination of the need for gases and associated greenhouse gas emissions.

iv. Religious slaughter

In order to improve animal welfare for both kosher and halal slaughter of chickens, turkeys, and other poultry, the following considerations should be kept in mind regarding the performance of religious slaughter:

- If stunning is used, audit and monitor the percentage of birds that are effectively stunned using the same criteria as for conventional slaughter.
- Score the performance of shacklers for faults such as 1-legged shacking using the same criteria as conventional slaughter.
- There should be 0% uncut red-skinned birds that emerge from the defeathering machine. This is an indicator that a bird entered the scalder alive. This measure is the same as used for conventional slaughter.
- Score the percentage of birds that wing flap after restraint. In a well-designed shackle line with a breast rub in place, the percentage of flapping birds should be very low. This measure is the same as used for conventional slaughter.

B. Turkeys

1. General considerations

Please refer to General considerations in the Chickens section of this chapter.

2. Animal behavioral considerations

Casualty animals should be separated and immediately slaughtered or euthanized or receive veterinary care.

3. Human behavioral considerations and training

Please refer to Human behavioral considerations and training under the Chickens section of this chapter.

4. Facility design and slaughter process

i. Receiving

Commercial turkeys arrive at the plant and are weighed on a truck scale while they are still on the vehicle.

ii. Lairage

After weighing, the poultry truck is parked in the lairage shed with the birds still in the travel containers. The sheds are equipped with fans and misters to keep the birds cool during hot weather or maintained to protect birds from the elements in cold weather. Holding time at the plant should be minimized and not exceed 24 hours.[97]

iii. Handling system

Controlled atmosphere stunning—There are 2 general methods in which turkeys are stunned using a CAS system.

Individual container stunning—If birds are being stunned in individual containers, the containers are removed from the palletized rack with the use of automated equipment. They are placed on a conveyor that runs into the CAS system.

Trailer stunning—If birds are stunned on the travel trailer, the truck and trailer pull into the stunning area. The stunning equipment is placed around a single vertical stack of travel containers still on the trailer, and the birds are stunned. The truck then moves forward so the next vertical stack can be stunned. This process is repeated until the entire trailer is stunned.

Low-atmospheric-pressure stunning—The use of LAPS is not currently recommended for turkeys.

iv. Restraint (including religious slaughter)

Handlers pick up CAS-stunned birds and hang them on the shackle line. The birds are then moved by the shackle conveyor to the water-bath stunner or individual responsible for the neck cut in the case of nonstun slaughter.

v. Detection of problems

The most common problems encountered in poultry slaughter are overloaded containers, heat stress, and death due to exposure. During periods of hot humid weather, stocking densities in travel containers should be reduced to help minimize heat stress on the birds, particularly in birds coming from controlled environment housing. Poorly maintained, broken containers may allow birds to escape. One problem that can occur with live bird shackling is worker fatigue, particularly in heavy toms. The shackling line should be adequately staffed with workers frequently rotated to help minimize fatigue. Broken wings are more likely to occur in electric water bath stun systems, compared with CAS systems.

vi. Corrective actions

Stocking densities for travel containers have been established through research and practical experience. A maximum stocking density gives sufficient space for all birds to lie down without being on top of each other. Processing plants should have an emergency plan to care for birds in case of power failure at the plant or natural disasters that make roads impassable.

Arrangements should be made so that loading of birds at the farm can be quickly cancelled before loading is started, if possible. Loaded shipments that are already in route should be diverted to nearby plants for processing or be returned to the farm and unloaded. The use of breast support and dim lighting can help to further minimize stress on live turkeys during shackling.

5. Techniques

i. Religious slaughter

Please refer to the Chickens section.

C. Ratites (Emu and Ostrich)

1. General considerations

Ratites are flightless birds that include the ostrich, emu, and rhea. Currently, ostriches and emus are raised in several countries for slaughter purposes. Slaughter facilities for ratites include commercial plants specifically designed for these birds, custom slaughter plants that process a broad range of species, and plants previously utilized for a different species that have been adapted for ratites (eg, a beef slaughter plant adapted for ostrich). Ostriches should always be treated with the utmost care and respect, as they can be unpredictable and are capable of inflicting considerable damage to humans, other ostriches, and infrastructure.

2. Animal behavioral considerations

Ostrich behavior is complex and variable, comparable to animals belonging to the most developed and complex social orders, which complicates the identification of normal behavior patterns and abnormal behaviors. Typically, ratites are aggressive and dangerous when sexually active. Such aggression can cause injuries to handlers and animals. Females may also initiate egg laying in addition to sexual behaviors. Behaviors like cuing and displays further increase the sexual activity and aggravation of the males in lairage. This may cause issues not only in breeding birds, but also in younger birds who may be sexually stimulated and exhibit agonistic sexual behaviors. It is important to consider that avian communication does not require animals to be in the same pen to stimulate these behaviors. Casualty animals should be separated and immediately slaughtered, be euthanized, or receive veterinary care.

3. Human behavioral considerations and training

Regardless of the slaughter facility used, care should be taken to avoid standing in front of ratites during handling or catching. Ostriches kick forward, and thus handling, loading/arrival, and movement of ostriches require the correct facility design, specific handling techniques, and an appropriate level of training of stockpeople. A kick from a slaughter-weight bird can cause severe injury from the last phalanx of the third toe, which is pointed and carries a claw. It is advised to stay at the side or toward the

rear of the bird for handling purposes. Toe trimming/amputation of the birds is a husbandry option, but the third toe plays a primary role as a lever for balance, exertion of traction forces, and directional impetus during locomotion,[98] and trimming can negatively affect their balance, making the birds prone to slipping in wet conditions.[99]

When slaughter-stage ratites (live body weight of ± 100 kg/220 lb) are worked with, highly stressed and aggressive birds should be caught first to prevent agitation within the rest of the group. A minimum of 3 handlers is needed to restrain an adult bird to avoid injuries to both the ostrich and handlers. Handlers can capture by catching the beak in 1 hand and pulling the bird's head down and in the direction the handler wishes the bird to move. A handler must be positioned at each side of the ostrich holding the wings. One of these handlers must be positioned between the wing and tail, taking hold firmly of both the wing and the tail. One handler should be employed at the head, where he holds the neck-head junction while immediately putting a blindfold or hood over the head of the ostrich. The handler at the head must prevent injury to the soft beak as well as interference with respiration. After hooding, ostriches will be calm, and the handler can move to the wing while the handler at the wing moves backward to the tail, from which the ostrich can be steered. Care must also be taken not to exert excessive force on the wings of the bird and to hold them close to the shoulder joint to avoid their fracture or dislocation.[100] Lifting the tail up and/or holding the head down makes it more difficult for ratites to kick forward and injure personnel. A shepherd's crook is typically not required for emus, and they do not respond well to hooding unless they have been restrained prior to placement of the hood.[101]

i. Loading facilities

The loading facilities should be designed to allow the transport truck access to the area where the birds will exit the holding pens. The level of this passage is to be on the same height as the floor of the truck to allow birds to walk into the truck compartments. Loading facilities were designed in the past to incorporate a ramp, but this is not advisable as birds do not like to walk uphill, especially when they are hooded and cannot see where they are going.

When using a loading facility where a ramp forms part of the design, the ramp incline should not be too steep, for ostriches do not like walking up an incline. The walkway should also be wide enough to allow for the bird and a handler on either side to fit comfortably on the walkway. When a ramp is designed, it should be kept in mind that a bird may struggle when it is led onto the ramp, and therefore the width of the walkway should accommodate this.

When loading ramps are made of metal, a covering such as a thin layer of conveyor belting should be used to cover the surface of the ramp. This will absorb the noise that is created when a bird steps onto the ramp, which will help to minimize the noise stress that is experienced during handling. The conveyor belting will also prevent the metal from heating when loading activities are performed during a hot day. The latter scenario is the exception to the rule, for normally loading and arrival should be limited to the cooler hours of the day to ensure the least amount of heat stress to the birds.

Typically, the loading facility would be situated in a corner of the pen and consist of a crowd/forcing pen, a raceway, and then the loading ramp. All the sides should be solid from leg height upwards to ensure ventilation, as this will keep the birds calmer and facilitate movement. The sides should be high enough (1.7 to 2.0 m) to prevent the birds from seeing distractions. A walkway on 1 side or both sides will allow a stockperson access to the birds. The crowd gate that closes behind the birds should also be solid. There should be no sharp corners or intrusions, as these will cause injury and bruises. The floor of the crowding pen and raceway should be coarse and slip-proof to minimize injuries should a bird fall. These areas usually contain sand and are free of stones and so forth that may cause damage to the feet of the birds. Care should be taken, however, to ensure that the sand that is trodden out is replaced, as birds, especially birds that are not used to humans and being handled, have been noted to lie down to allow the crowding gate to pass over them.[102]

ii. Transport

Design of the transport truck—When a contractor is used to transport slaughter birds, it is critical to ensure that the contractor and his personnel have experience transporting ostriches. The design of trucks and trailers that are used to transport ostriches must adhere to certain requirements to ensure the safe transport of ostriches. The sides of the truck should be solid (ie, with no gaps at the bottom), and an opening should exist between the roof and the side to ensure adequate ventilation. Most trucks that are used in the South African industry to transport ostriches are, however, not fitted with roofs, so ventilation is generally not a problem. However, extensive bruising has been noted on the necks of ostriches when transported.[103,104]

The floor of the vehicle must be solid, nonabsorbent, and slip-free. Typically, metal gridding or rubber matting is used. This will prevent birds from slipping, and the latter will also provide protection against the cold metal surfaces, especially if long distances are going to be covered. Although rubber matting is less durable, observations and discussions with transporters indicate that this material is more suitable, as the metal mesh can hurt the toes of the birds.

The corners of trucks need to be protected with a form of cushioning material to prevent the birds from being injured by any sharp edges in the corners. The loading space should not have sharp angles, protrusions, or holes that may injure the birds. No loose objects should be stored in the truck compartments.

Partitions must be installed at every 3 m of loading space if the truck is longer than 4 m. The minimum required floor space is 0.5 m^2/bird. Using the optimal stocking density when transporting birds is important to ensure as stress-free a journey as possible. It is also important to remember that stocking

densities should be adjusted when transporting ostriches during summer, when birds need more space and sufficient ventilation is important for ostriches to be able to thermoregulate properly.

It is important to use enough handlers per compartment to monitor the status of the birds during transport (ie, whether they are sitting down or trampling each other). Birds that tend to sit down during transport are frequently hung in a sling harness in one of the corners of the compartment. When driving, it is important to maintain a speed that will not endanger the birds and handlers when the truck needs to stop quickly. Acceleration and braking should be smooth, and sharp turns or tight corners should be avoided when transporting birds.

4. Facility design and slaughter process

i. Arrival at the plant

ii. Unloading

The arrival of ostriches into lairage at the abattoir is similar to their loading. First, the facility should allow for easy access from the transportation truck. Unloading pens should consist of a crowd/forcing pen (solid sides with no sharp corners or protrusions, which cause injuries and/or bruising), followed by a raceway and a loading ramp, ideally placed at the corner of the holding pen. The raceway (for loading and arrival) should be at the same height as the truck floor and 3 m wide (few birds will allow themselves to be herded individually). Ostriches do not like to walk uphill, particularly if hooded, and thus any ramp inclines should not be too steep. All sides of the truck from leg height upward should be made from solid material, 1.7 to 2.0 m high. This facilitates ventilation while preventing the birds from seeing outside the truck, keeping them calmer, and enabling movement in and out of the compartments and truck. A walkway along the sides of the truck allows stockpeople to access the birds without direct contact. Flooring in the raceway should be made of antislip material (coarse but without stones that can cause injuries) that minimizes injuries if birds do fall. The flooring should be clean, and if sand is used, it should be replaced regularly, as ostriches, especially those that are not used to humans and being handled, have been noted to lie down, which allows the crowding gate to pass over them.[102]

iii. Lairage

Lairage helps ostriches become familiar with their new surroundings and recover somewhat before slaughter, thereby improving meat quality.[102] Time in lairage should be minimized. If wait time exceeds 12 hours, feed should be available to animals on arrival and at intervals appropriate to the species.

Under extraordinary circumstances (eg, weekends and holidays), lairage can be extended for up to 4 days. Slaughter ostriches weigh approximately 90 to 100 kg live weight, and if kept in lairage without food, they will lose approximately 1 kg over 24 hours. This is due to emptying of gut contents[105] and weight loss in the muscles, which is also affected by transportation distance. For example, under identical lairage conditions, birds that were transported for 600 km lost 3% more carcass weight than birds transported for only 60 km.[106]

Social anxiety is the main stressor in lairage, together with the unknown environment and lack of nutrition. To ease this, ostriches from different farms, and ideally even from different groups from the same farm, should not be mixed.[102] It is also important that water be supplied ad libitum.[103] Drinking troughs should be placed outside the pens at a height of at least 1 m from the ground.

During movement from different pens toward the killing point, ostriches may show strong herd instinct, which may increase tripping, falling, and trampling incidences. Stress responses often include birds running blindly into structures with wings extended. In addition to causing injury and stress, these behaviors cause damage to the carcass and skin, decreasing value. Thus, flooring should be made from a nonslip surface (without stones), and animals should be moved carefully. Loud noises from motorized mechanisms and people should be avoided as much as possible.[102]

The recommended space per bird in the lairage is 1.2 m^2. The pen should be in an octagonal design to avoid flocking and prevent injury from sharp corners. Floors should be made from cement with grooves and metal grids (1- to 1.5-cm sided square holes) raised above a concrete floor to prevent slipping, or sand. Lairage should be under a roof to provide protection against sun and rain.[107] Pen sides should be 1.7 to 2 m high and strong enough to withstand animals running into and pushing against them and structured to allow adequate ventilation.[102]

iv. Handling system

The design of the abattoir facilities is crucial in ensuring that birds can be easily moved without excessive use of tools or intervention from personnel. Distances between arrival, lairage, and slaughter should be minimized as much as possible. This is also important for maintaining muscle glycogen levels and thereby ensuring a normal pH decline postmortem and avoiding associated meat quality issues. Low light levels and minimal noise in the lairage may help birds remain quiet and calm.

v. Restraint (including religious slaughter if applicable [ie, halal but not kosher permits slaughter of these species])

Restraint and stunning of ostriches require specialized facilities and procedures because of their long neck, head anatomy, and physiology. The restraining area is often a V-shaped structure, high enough (1.2 m) that the stunner operator is not kicked. After (and sometimes during) stunning, the birds are rocked backward, and a rubberized leg clamp is placed over the legs at the tarsometatarsal bone, which immobilizes them, and allows ring/chain shackling via the big toes. Birds are then hoisted onto a 3.4-m overhead rail and manually conveyed to another area for exsanguination. This conventional stunning procedure has been replaced in many abattoirs with a new restraining and stunning mechanism (stunning box) that completely encompasses the ostrich in a padded clamp holder and allows for the whole bird to be

restrained without affecting the quality of the feathers and the skin.

vi. Detection of problems

Please refer to earlier sections of this chapter for guidance.

vii. Corrective actions

Please refer to earlier sections of this chapter for guidance.

5. Techniques

i. Physical methods

A large number of ostriches are slaughtered annually in South Africa. The most common method used is electric head-only stunning of restrained birds performed with handheld tongs **(Figure 4)**. An electrical current in excess of 400 mA at 50 Hz AC applied only to the head has been reported to prevent recovery in more than 90% of ostriches when bled within 60 seconds of stunning.[103,104] The South African legislation requires a stunning current of 400 to 600 mA, 90 to 110 V for a duration of 4 to 6 seconds.[103,104] Other recommendations for stunning include a current of 1.5 to 2 A, 90 V for a duration of 10 to 15 seconds.[107] Glatz[101] recommended stunning emus using 120 V at 1.2 A for 10 seconds and ostriches using 120 V at 1.2 A for 15 seconds. The Canadian Food Inspection Authority (CFIA) manual of procedures[108] also includes recommendations for electric stunning.

The poststunning first stages of recovery in the birds are accompanied by rhythmic breathing movements, whose identification, however, may be difficult, as they can be confused with rhythmic body movements in response to spinal reflexes and limb muscle contractions.[102,109]

During traditional stunning with handheld tongs, birds are held in a restraining area by gentle pressure applied from behind on the tail feathers. The restraining area is often a V-shaped structure high enough that the stunning operator is not kicked. After (or during) stunning, the bird is rocked backward and a leg clamp is placed over the legs, immobilizing the birds and allowing them to be shackled. The birds are then hoisted onto a 3.4-m rail and conveyed to an exsanguination area.

The new Ostrich Stunning box (Divac) is built from a combination of galvanized mild steel and stainless steel, which encapsulates the ostrich in a padded clamp-type holder, ensuring no physical damage occurs to the bird. The bird is gently pushed into the box, which is then closed manually around the bird. The double-padded sides restrain the bird by holding the upper thighs. A rubberized pneumatic foot clamp restrains the bird's feet, while the bird's head is placed manually into the stunning clamp. As the bird is stunned, the whole stunning box rotates through 180°, thereby positioning the bird for the toe clamps respecting the safety measures for the operator. After the stunning is completed, the box is opened and the bird hoisted for exsanguination. The time from stunning to exsanguination has also been reduced to < 20 seconds. Once released from the clamp, the unit rotates to its initial position, ready for the next ostrich.

An air-powered captive needle pistol can also produce an effective stun in birds.[110,111] When a captive needle pistol is used, the needles should be applied at the intersection of 2 imaginary lines drawn from the ear on one side of the head to the inner corner of the eye on the other side.[110,111] The CFIA manual of procedures[108] pertaining to ratites recommends a captive bolt device with a short bolt and the smallest charge appropriate for poultry or rabbits applied to the top of the head at the midpoint of an imaginary line between the outer openings **(Figure 5)**.[108]

Birds should be bled within 60 seconds of stunning.[99] The ostrich head is normally held between 2 horizontal metal bars to minimize blood spillage on the feathers and skin. The CFIA recommends that the birds be bled out using a complete ventral cut of the neck (both carotid arteries) or a thoracic stick within 15 seconds of stunning so that consciousness is not regained.[109] In a pilot investigation,[112] where the efficiency of the 2 bleeding methods was compared, a lower bleed-out percentage (defined as a weight of blood expressed as percentage of body weight) was observed when the ventral throat cut alone was performed compared with the combined ventral cut and thoracic sticking (2.8 ± 1.03% vs 3.3 ± 0.34%). Furthermore, the additional thoracic stick had no effect on meat quality, in terms of drip and cooking loss, color, or pH and temperature readings, of the fillet (M. iliofibularis), big drum (M. gastrocnemius, pars interna) and inside loin (M. iliotibialis cranialis). Nonetheless, the use of the thoracic stick would be recommended for ostrich slaughter, as it may result in a faster death.

D. Miscellaneous (Ducks and Geese)

1. General considerations

For ducks (including the foie gras industry) and geese, the industries are small and specialized relative to the rest of the poultry industry, and most plants are optimized for their specific breeds/lines of ducks and geese, including special means of transportation, lairage systems, handling systems, restraint, and stunning. Most commercial facilities have universally accepted methods of confirmation of stunning and correct bleeding modeled after the greater poultry industries. Ducks and, more frequently, geese can lift and remove their heads from many commercially produced immersion bath stunning operations, resulting in some commercial operations developing alternative means of stunning or no stunning techniques at all. The Panel on Humane Slaughter recommends that all animals, including ducks and geese, be stunned prior to slaughter, unless religious slaughter requirements preclude even reversible stunning.

2. Animal behavioral considerations

Ducks and, more frequently, geese can lift and remove their heads from many commercially produced immersion bath stunning operations, resulting

in some commercial operations developing alternative means of stunning or no stunning techniques at all. For geese and Pekin ducks, walking on and walking from trailers is the preferred method of transportation and handling for these larger birds relative to cages, crates, and modules. Casualty animals should be separated and immediately slaughtered or euthanized or receive veterinary care.

3. Human behavioral considerations and training

A basic understanding of the behavioral indicators of stress and pain in ducks and geese is recommended for all employees involved in live bird handling prior to and up through the stunning and bleeding phase of slaughter operations. Periodic refresher training should be considered for commercial operations.

4. Facility design and slaughter process

i. Arrival at the plant

Ducks and geese should arrive at the plant on well-designed and not overloaded trailers or by walking when lairage systems are close to grower houses in vertically integrated systems. Some facilities use crates or module systems whereby mechanized systems can transport birds to holding areas prior to unloading from transport vehicles.

ii. Unloading

Birds are removed by hand from crates or modules in most operations when employed. When trailers are used, careful walking or carrying of obtunded birds is necessary. Some weak or obtunded birds will recover in lairage systems and should be set in segregated regions or pens to facilitate this process. If birds die or require euthanasia, these carcasses should be removed from further slaughter processing.

iii. Receiving

Received birds should be visually inspected for antemortem inspection prior to lairage with separation of injured, sick, or obtunded birds. Birds with significant injuries or illness should be euthanized immediately.

iv. Lairage

If ducks are held for greater than an hour in the lairage, they should be provided with a water source prior to processing. During lairage, geese may be provided with water and cooling via sprinkler systems or misting systems prior to stunning, and they should be provided with a water source if held in lairage for > 1 hour. Time in lairage should be minimized. If wait time exceeds 12 hours, feed should be available to animals on arrival and at intervals appropriate to the species. Lairage locations should be shielded from wind on at least 1 or 2 sides depending on prevailing wind patterns.

v. Handling system

Most commercial operations use a manual movement system beyond the lairage stage. The foie gras industry often employs specially designed carts where emphasis is placed on gentle handling and smooth flooring inside the carts, as hybrid Muscovy and Pekin ducks have large digital claws that can grip into rough flooring resulting in toe injuries and thrashing resulting in liver hemorrhage.

vi. Restraint (including religious slaughter)

Shackling is either by 1 or 2 legs depending on the bird and system employed. Most employ a 2-leg shackling system prior to stunning. When single-leg shackling is used, critical evaluation by inspectors of birds must be employed to ensure birds are calm prior to entry to the stunning and bleeding area. Efforts should be made to minimize time shackled prior to stunning and bleeding.

The goose industry often uses single-bird-per-employee hand restraint during stunning prior to shackling and bleeding. The size and strength of these birds and tendency to wing flap and thrash on shackles have anecdotally shown this to be a preferred method of restraint, with fewer downgraded carcasses discovered at the time of slaughter.

vii. Detection of problems

If stunning is used, audit and monitor the percentage of birds that are effectively stunned using the same criteria as for conventional slaughter of other poultry. There should be 0% uncut, red-skinned birds that emerge from the defeathering machine. This is an indicator that a bird entered the scalder alive. This measure is the same as used for conventional slaughter. Score the percentage of birds that wing flap after restraint. In a well-designed shackle line, the percentage of flapping birds should be very minimal.

viii. Corrective actions

Actions to correct faults are tailored to the fault at hand and should be discussed with the USDA inspectors and veterinarians prior to implementation.

5. Techniques

i. Physical methods

Physical methods are rarely used in the commercial duck and goose industries other than cervical dislocation to euthanize birds not able to be slaughtered.

ii. Atmospheric methods

Few to no commercial operations in North America utilize these methods, and most, if not all, currently rely on immersion water bath stunning techniques.

iii. Immersion methods

Suggested optimal settings for goose and duck stunning are 130 mA, < 200 Hz, and an exposure time to water bath of > 4 seconds.[113]

iv. Religious slaughter without stunning

Some commercial duck operations operate with no stunning. In these cases, USDA inspector and veterinarian evaluations deem this to be an acceptable means of slaughter.

6. Special considerations

Ducks and geese may not have the same degree of size and shape uniformity often found in other commercial poultry species used for food. This has resulted in specific modification of mechanized stunning systems designed to deliver appropriate stunning prior to bleeding. Some facilities have eliminated

stunning activities prior to bleeding due to animal welfare issues resulting from unsatisfactory stunning, carcass downgrading, and altered meat quality. It is critical to note that there is not the same body of empirical evidence available with these species when compared with broilers, layers, and turkeys. Research and best practice development are needed for these species to fill the gaps in knowledge that exist today. Specific knowledge gaps include stunning parameters and behavioral evaluation of stunning methods, shackling techniques, and evaluation of stunned versus nonstunned birds prior to bleeding.

E. Miscellaneous (Pheasants and Quail)

1. General considerations

For pheasants and quail, the industries are very small and highly specialized. Most processing plants are optimized for other species and process these species on the side. Most commercial facilities have universally accepted methods of confirmation of stunning and correct bleeding modeled after the greater poultry industries. An exception common in these industries is that most facilities do not weigh trucks at time of delivery.

2. Animal behavioral considerations

Limited, and often only anecdotal, information is available for these species, and heavy extrapolation from other species is employed.

3. Human behavioral considerations and training

A basic understanding of the behavioral indicators of stress and pain in pheasants and quail is recommended for all employees involved in live bird handling prior to and up through the stunning (if used) and bleeding phase of slaughter operations. Periodic refresher training should be considered for commercial operations.

4. Facility design and slaughter process

i. Arrival at the plant

Pheasants and quail should arrive at the plant on well-designed and not overloaded trailers. Most facilities use crates or module systems whereby mechanized or manual systems can transport birds to holding areas prior to unloading from transport vessels.

ii. Unloading

Birds are removed by hand from crates or modules in most operations, when employed. If birds die or require euthanasia prior to slaughter, they should be removed from the process.

iii. Receiving

Received birds should be visually inspected for antemortem inspection prior to lairage with separation of injured, sick, or obtunded birds.

iv. Lairage

If birds are held for greater than an hour in lairage, they should be provided with a water source prior to further processing. Lairage locations should be shielded from wind on at least 1 or 2 sides depending on prevailing wind patterns.

v. Handling system

Most commercial operations employ manual movement systems beyond the lairage stage.

vi. Restraint (include religious slaughter without stunning)

As these are both flighted birds, manual restraint of birds at time of stunning or bleeding is critical. Efforts must be made using proper restraint to limit the extent of wing flapping and thrashing prior to stunning or bleeding.

vii. Detection of problems

Problems that might arise during stunning and/or bleeding include ineffective handling due to small size of the bird and neck movement that can lead to ineffective stunning and therefore bleeding. Employees must be properly trained on methods such as cervical dislocation, and efficacy must be monitored. If stunning is used, audit and monitor the percentage of birds that are effectively stunned using the same criteria as for conventional slaughter of other poultry. There should be 0% uncut red-skinned birds that emerge from the defeathering machine. This is an indicator that a bird entered the scalder alive. This measure is the same as used for conventional slaughter. Score the percentage of birds that wing flap after restraint. In a well-designed shackle line, the percentage of flapping birds should be very low.

viii. Corrective actions

Actions to correct faults are tailored to the fault at hand and should be discussed with the USDA inspectors and veterinarians prior to implementation.

5. Techniques

i. Physical methods

Cervical dislocation may be employed for these species by trained staff.

ii. Atmospheric methods

Commercial operations in North America may use these techniques, and care should be taken to ensure appropriate stun is achieved prior to bleeding.

iii. Immersion methods

Electrical stunning through immersion methods can be employed for these species; however, care should be taken to ensure birds enter immersion systems calmly without wing flapping and thrashing. Adjustments to water baths are critical to ensure birds enter the system calmly. Smaller, nonconforming birds may require alternative means of stunning prior to bleeding.

iv. Religious slaughter without stunning

Some facilities may be doing a religious slaughter without stunning and, with proper restraint, achieve anecdotally calm birds with limited carcass downgrading.

6. Special considerations

Pheasants and quail may not have the same degree of size and shape uniformity often found in other commercial poultry species used for food. This has resulted in specific modification of mechanized stun-

ning systems designed to deliver appropriate stunning prior to bleeding. Some facilities have eliminated stunning activities prior to bleeding due to animal welfare issues resulting from unsatisfactory stunning, carcass downgrading, and altered meat quality.

It is critical to note that there is not the same body of empirical evidence available with these species when compared with broilers, layers, and turkeys. Research and best practice development are needed for these species to fill the gaps in knowledge that exist today. Specific knowledge gaps include stunning parameters with immersion water bath techniques, physiologic and behavioral evaluation of stunning methods, shackling techniques, and evaluation of stunned versus religious slaughter without stunning of birds prior to bleeding.

For small production systems related to upland game birds that are shot prior to slaughter as a hunted game bird species, the specifics related to gunshot as a means of slaughter are covered in other areas.

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G. Figures

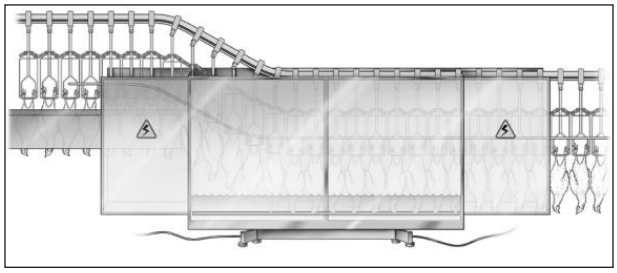

Figure 1

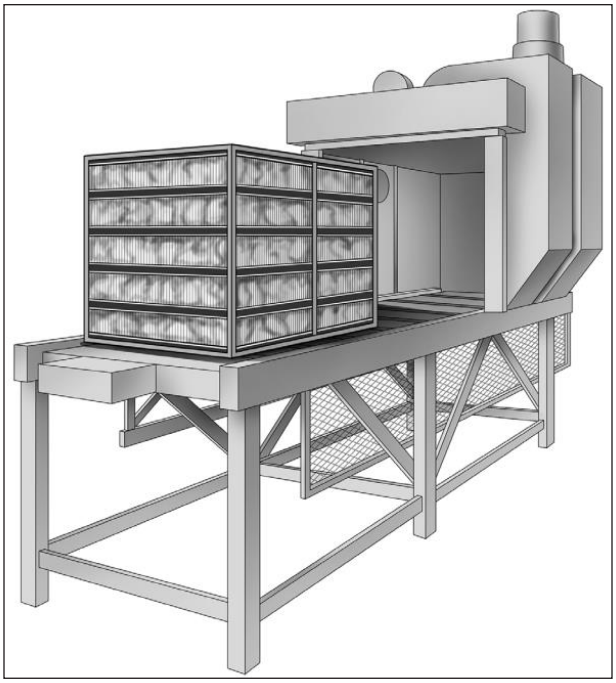

Figure 2

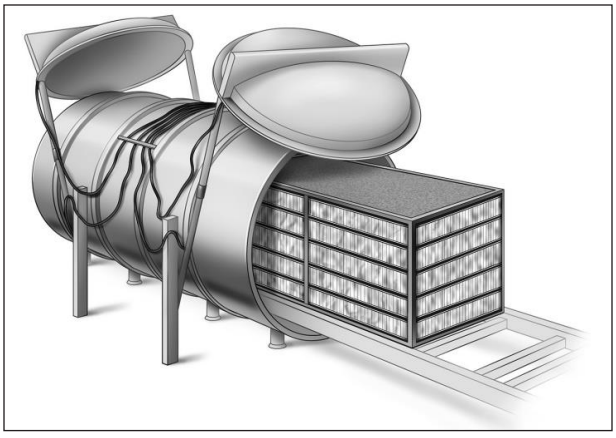

Figure 3

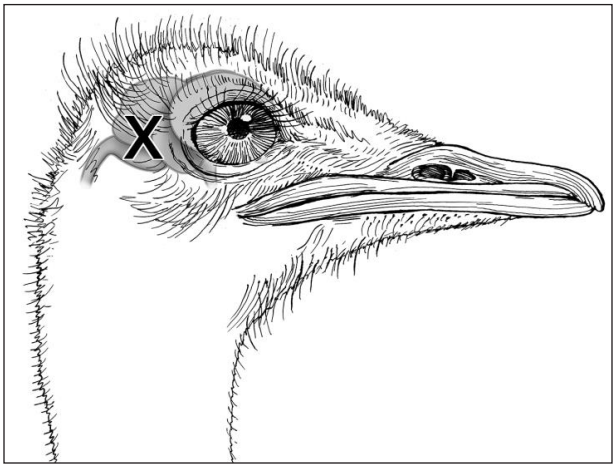

Figure 4

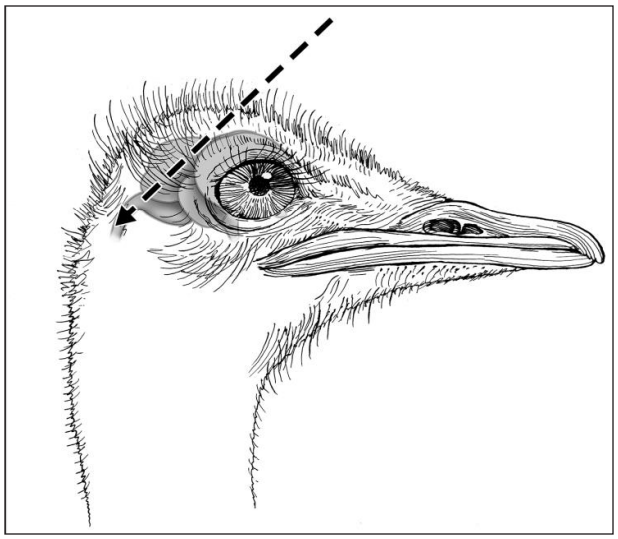

Figure 5

Chapter III: Bovids

A. General Considerations

These Guidelines are part of a triad of documents on humane killing—the other two being the AVMA Guidelines for the Euthanasia of Animals: 2020 Edition[1] and the AVMA Guidelines for the Depopulation of Animals.[2] Less than 10% of veterinarians are involved in promoting the health and welfare of animals that will eventually become food.[3] The Panel on Humane Slaughter has worked diligently to identify and apply the best research and empirical information available to promote the humane slaughter of the species of animals addressed in this document. Animals designated for slaughter should be treated with respect and handled appropriately. The slaughter process should limit the harms experienced by these animals through the use of slaughter methods and agents designed to bring about a rapid loss of consciousness and, ultimately, a complete loss of brain function (insensibility) in animals destined for use as food.

Humane slaughter methods produce insensibility through 4 basic mechanisms: (1) physical disruption of brain activity (eg, blunt cranial trauma, penetrating captive bolt, gunshot), (2) hypoxia (eg, controlled low atmospheric pressure for poultry, N_2, Ar, exsanguination), (3) direct depression of neurons necessary for life function (eg, CO_2), or (4) epileptiform brain activity (eg, electric stunning). Given that slaughter is limited to applying 1 of these 4 basic mechanisms, efforts should be directed toward educating individuals involved in the slaughter process, achieving technical proficiency, and refining the application of existing methods, including handling conditions prior to slaughter.[4]

B. Animal Behavioral Considerations

These Guidelines are concerned with minimizing animal distress, including negative affective or experientially based states such as fear, aversion, anxiety, and apprehension, during the slaughter process. They are also meant to promote human well-being and safety as regards the repeated termination of animals' lives. Veterinarians and other employees conducting slaughter should familiarize themselves with preslaughter protocols and be attentive to species and individual variability to mitigate distress in both food animals and human handlers. The method for inducing unconsciousness and insensibility, and the handling and restraint methods associated with it, must be evaluated as an entire system.[5]

Physical methods require more handling and restraint of individual animals, compared with controlled atmosphere stunning, but they induce instantaneous insensibility. Controlled atmosphere stunning does not induce instantaneous unconsciousness, but possible distress during handling may be reduced. There may be a trade-off between possible distress during a longer time to induce unconsciousness and the benefits of reduced handling of individual animals.

Intentional violations of the Humane Methods of Livestock Slaughter Act (HMSA)[6] must not be tolerated. Unintentional pain and/or distress at slaughter caused by mistakes by personnel or poorly designed facilities must be promptly addressed. At all stages of the process of termination, animals should be treated with respect, and compromises to animal welfare should be treated as unacceptable if not unlawful. Practitioners and stockpeople should ensure the following:

No conscious animal is dragged, shackled, hoisted, or cut inappropriately. Before invasive dressing (eg, skinning or leg removal) begins, all signs of brainstem function, such as the corneal reflex, must be abolished.

- Excessive force or frequent use of electric prods to move animals off trucks, up and down ramps, or into slaughter facilities or restraint devices is avoided. Animals should not be forced to move faster than a normal walking speed. Handlers should move animals quietly, without using driving devices that would cause unnecessary pain and/or distress.
- Nonambulatory or disabled animals are isolated and moved with suitable equipment (eg, bucket of a loader, sled) and provided appropriate veterinary attention. Conscious nonambulatory animals must never be dragged.
- Terrestrial animals are provided with access to water in the lairage pens. Animals should have sufficient room to move in accordance with state, federal, and local statutes, and pens should have room for all the animals to lie down and should be designed to allow as many animals as possible to stand or lie down against a wall.
- Slaughter facilities and equipment are well maintained to minimize injury or pain to the animals and employees.
- The induction of unconsciousness (eg, stunning) causes minimal distress to the animal.
- All personnel are trained in both the application of stunning methods and behavioral principles of animal handling.

C. Human Behavioral Considerations and Training

Food animal veterinarians may be asked to bridge the physical and psychological divide between current practices used in the care and management of food animals and consumers by communicating the realities of conventional food production. They may also be asked to provide an ethical accounting and monitoring of the animals' welfare on the farm, in feedlots, and at slaughterhouses to the public in a transparent fashion. Food animal veterinarians are encouraged to increase their awareness of slaughter

methods and to enhance their understanding of the science behind the methods currently used with a view toward understanding the day-to-day complexities of managing food animals and the range of challenges facing the contemporary food animal sector. Likewise, industry agents, veterinarians, caretakers, and others engaged with the slaughter of animals for food should be encouraged to understand the diversity of public concerns and trending societal values and expectations related to how animals are farmed and slaughtered for food.

The humane slaughter of animals is a learned skill that requires training, respect, and self-awareness. Personnel performing humane slaughter must be technically proficient. Periodic professional continuing education on the latest methods, techniques, and equipment available for slaughter is highly encouraged. Personnel must also possess a temperament that does not bolster brutality. Self-awareness when it comes to processing animals for food will help to mitigate compassion fatigue and callousness.

The slaughter of individual livestock by farm workers who are also responsible for providing husbandry can substantially impact their emotions.[7] Therefore, appropriate oversight of the psychological well-being of slaughter employees is paramount to mitigate guilt, distress, sadness, fatigue, alienation, anxiety, and behaviors that lack consideration of others or may lead to harming themselves, animals, or other people. People may have individual differences in how they psychologically react to the job of killing animals.[8] It is difficult to care about animals when they have to be killed. This is called the "caring-killing paradox."[9]

Veterinarians and staff who are regularly exposed to the slaughter process should also be monitored for emotional burnout, psychological distress, or compassion fatigue and be encouraged to seek appropriate psychological counseling.[10,11] While integrating good animal welfare in the food chain, some food animal practitioners may be torn among serving the best interest of the farmed animal, the human client (individual), personal professional interests, and societal concerns about improving the quality of life for animals and ensuring the availability of safe and affordable animal protein. More studies on both the impact of animal slaughter on the personnel performing it and on attitudes toward the consumption of animals for food among the general public will go a long way toward promoting healthier and more respectful human–food animal relationships.

D. Facility Design and the Slaughter Process

1. Arrival at the plant

The normal process is for the animals to be unloaded promptly after a vehicle arrives at the plant. In the best operations, the vehicles are unloaded within 15 to 60 minutes after arrival, and industry guidelines recommend a maximum wait time of 60 minutes.[12] This requires the scheduling of an appointment between the plant and transporter. Scheduling vehicle arrival times prevents the problem of too many vehicles arriving at the same time, which results in long lines and delays at unloading. During hot weather, delayed unloading can result in severe animal welfare problems due to heat stress. **Figure 1** shows the step-by-step flow of animals through the plant.

2. Unloading

When unloading is done correctly, animals will move off the vehicle in a quiet, orderly manner. Handlers should be quiet and refrain from yelling, whistling, or repeatedly hitting the sides of the vehicle. The sound of people yelling has been shown to be very stressful for livestock.[13,14] Electric prods can be completely eliminated during unloading of most cattle.

3. Receiving

For cattle, unloading areas for large trucks should be designed with at least a 10-foot (3-m) level unloading dock before the ramp starts.[15] After unloading, the normal practice in most plants is to verify that the number of animals on the vehicle matches the paperwork. In some plants, there is an extra handling step of weighing individual animals after unloading. However, many plants have eliminated this by weighing the entire truck before unloading. Weighing the entire truck has the advantage of reducing cattle bruising.

Animal identification is maintained by placing the animals from each trailer in their own pen and placing their identification paperwork in a holder on the fence.

4. Lairage

Lairage pens may also be called stockyards or antemortem pens. In most plants, animals are held in the same groups that they traveled with on the trucks, which is ideal. In large plants, a typical lairage pen holds either 1 or 2 entire truckloads; it is important to design the pens to hold a whole number of truckloads, as a pen designed to hold 1.5 truckloads will invariably end up having 2 loads forced into it. When new stockyards are being built, they should be laid out so that there is 1-way livestock movement through the yards. Ideally, the unloading ramps are at one end of the yards and the chutes to the stunner are at the other end. One good plant design is to have all the animals enter the pens from one alley and move to the stunner through the opposite end of the pens. Designs for lairage pens are described in various reports.[16,17]

In smaller plants, there may be single animals or small groups of animals arriving from many different owners. Animals from each owner must either be held in their own small pen or have physical identification (such as ear tags for electronic identification or tattoos) to prevent their identification information from becoming mixed up with that of other animals.

The HMSA 9 CFR 313.2 (e) requires that all lairage pens be equipped with water troughs or other

suitable devices so that the animals have access to water.[18] Well-designed and maintained lairage pens will be free of sharp edges that can injure animals. Industry recommendations for lairage pen space are 20 sq ft (1.87 m^2) for cattle. For really large cattle (over 635 kg [1,400 lb]), 22 sq ft (2.04 m^2) will be required.[19] The animals should be provided sufficient space that they can all lie down at the same time. Before animals can be moved to the slaughter area, they undergo antemortem inspection. After inspection, the lairage pen is tagged as ready for processing. The exception to this rule is custom-exempt plants, which process animals for personal use by the owner or producer.

5. Handling systems

A wide variety of systems are available to move cattle from lairage pens to the place where they are stunned or ritually slaughtered.[15–17,20] When animals are handled correctly, they move in an orderly fashion with no falling or pileups and minimal vocalizing and seldom require the use of electric prods. During the last few minutes before slaughter, excessive use of electric prods can negatively affect meat quality. In 1 study,[21] multiple shocks on beef cattle produced tougher meat. Animals should never be backed into the stun box.

6. Restraint

A list of design principles to reduce stress during restraint follows. These principles are applicable to conventional slaughter, which uses stunning before bleeding, and religious slaughter. Upright restraint is always preferred. Suspending or hosting conscious cattle by their feet or legs is unacceptable.

1. Ensure pressure applied is optimal. The device must apply enough pressure to make an animal feel restrained but avoid excessive pressure that will cause struggling or vocalization. A common mistake is to apply additional pressure when an animal struggles.[22]
2. Do not trigger fear of falling. This is why nonslip flooring is so important. When devices are used that hold an animal with its feet off the floor, the animal must be held in a balanced, comfortable upright position. When a device is used that rotates an animal from an upright position, the body must be securely held and supported to prevent struggling and slipping within the device. Restrainer conveyors should be equipped with a false floor to prevent animals from seeing a visual cliff under the restrainer,[23,24] as animals have depth perception.[25] For conventional stun boxes where the animal stands upright, nonslip flooring is critical. Stun boxes should never have a steep sloped or stepped floor. Instead, a flat floor is recommended.
3. Ensure smooth, steady motion of parts of the restraint device that contact animals. Sudden jerky motion will cause animals to become agitated.[22]
4. Block animal's vision of people, moving equipment, and activity on the floor. To prevent balking and improve ease of entry into the restraint device, animals entering the device should not be able to see people, moving equipment, or activity on the processing floor.[17]
5. Ensure stun boxes are of the appropriate size. Stun boxes must be the appropriate size for the animals being processed. Animals must not be able to turn around in the box.

7. Detection of problems

i. Arrival at the plant

There have been unfortunate cases where many cattle have died while waiting an entire day to unload. This serious problem is most likely to occur when there is an emergency such as a power failure or storm, which either shuts down the plant or makes roads impassable.

ii. Unloading

Industry guidelines advise that if more than 1% of cattle fall during unloading or more than 5% of animals are unloaded using an electric prod, there is a welfare problem in the unloading area.[26–28] Most plants can achieve this standard, as the majority of larger plants have banned the use of the electric prod at unloading. There is a problem if animals in the unloading area run into fences or pile up. Quiet handling also provides the advantage of greatly reducing bruises,[23] which is an economic incentive for the facility. At the time of unloading, plant employees should note whether the vehicle is overloaded. Vehicles should be loaded per industry and international guidelines.[12,29]

Overloading of trucks can cause severe economic losses. Bruised meat cannot be used for human consumption. In cattle, overloading of trucks will increase bruises, lameness, and the likelihood of nonambulatory cattle.[30–33] Bruising may be underestimated when the surface of the carcass is viewed.[34] In cull cows, there may be deep bruising underneath (for US transport regulations refer to 49 USC Section 80502).[35] A large survey[36] in both the US and Canada showed that 49% of the cattle trucks arriving at processing plants were overloaded. Cattle that are heat stressed will have increased respiratory rates and breathe with their mouths open.[37] Most US slaughter plants employ heat reduction methods. Misters, sprinklers, or shade is used in most plants.[38] Animals should also be observed for transport-induced welfare problems such as frostbite, lacerations, and heat stress.

Another problem that can seriously compromise animal welfare at the slaughter plant is when the animal is in poor condition prior to leaving the farm. Weak, emaciated animals or severe lameness can make human handling difficult. A survey[39] of 10 cattle auction markets found that 13.3% of cull dairy cows and 3.9% of cull beef cows were severely emaciated. Most of the cows sold at these auctions go to slaughter. A more recent survey[40] indicated that many cull dairy cows are arriving at the plant in poor condition. A survey[41] at auctions indicated that 10% of cull dairy cows were thin, 7% were severely lame, and 13% had engorged or inflamed udders. In fed cattle, a recent survey[42] showed that lameness had increased from

2016 to 2020. In both cull cows and fed steers lameness can make it more difficult to handle animals in a low-stress manner.[43] Another problem that may cause an increase in nonambulatory feedlot cattle is congestive heart failure. The incidence of congestive heart failure in heavy fed steers and heifers has increased.[44] There are many on-farm animal welfare problems that can be easily monitored at the slaughter plant. The USDA does not permit the slaughter of nonambulatory downed or emaciated cattle. Packers should clearly communicate back to producers that the shipment of unfit animals is unacceptable and implement a financial penalty for the practice. The Panel on Humane Slaughter strongly recommends adoption of international fitness-to-travel standards promulgated by the World Organisation for Animal Health (WOAH [formerly known as OIE]).[45]

Another type of animal that is extremely difficult to handle in a humane manner is the neonatal "bob veal" dairy calf that is less than a week old. Seventy percent of neonatal dairy calves are sold at auctions.[46] Many of these bob calves are dehydrated.[47] To make humane handling possible, these calves should be properly cared for and remain on the farm until they are old enough to walk easily without assistance from a person.

iii. Receiving

For cattle and other bovids, falling, piling up, or hitting fences would be an indicator that handling needs to be improved.

iv. Lairage

The 3 main problems that can occur in the lairage pens are overstocking of the pens, fighting between animals causing injuries, and animals that become nonambulatory. Bulls are more likely to fight than steers or cows. Bison can get into severe fights that result in death. Another problem is animals mounting each other, which may result in weak animals falling down.

v. Handling

Both industry guidelines—the AVMA 2016 guidelines[4] and USDA Food Safety and Inspection Service (FSIS) regulations[48]—prohibit abusive practices such as dragging downed nonambulatory animals; poking sensitive areas such as the eyes, anus, or udder; slamming gates deliberately on animals; deliberately driving animals over the top of a down animal; and beating animals.[12,48] Handling problems that compromise welfare can result from a facility problem or an employee training issue. Before modifications are made to a facility, employees should be trained to use behavioral principles of livestock handling.[16,17,49,50] When people handle livestock in a calm, quiet manner, design problems in the facility can be easily located and corrected. For all species, if more than 1% of the animals fall at any point in the facility, there is a problem that needs to be corrected.[12,26,51] An automated powered gate that causes an animal to either fall or be dragged along the floor is a serious problem.

In cattle, vocalization during restraint, handling, or painful procedures (eg, bellowing or mooing) are associated with physiologic measures of stress.[52] In 2 studies,[53,54] vocalization during cattle handling and restraint at slaughter plants was associated with obvious aversive events such as excessive use of electric prods, excessive pressure from a restraint device, and sharp edges. In another study,[55] beef plants with good handling had < 3% of the cattle vocalizing in the stun box, restrainer, and handling in the lead-up chute. Plants with serious problems during handling and restraint have 25% to 32% of the cattle vocalizing in this area.[53,54,56] In a beef plant where the stun box had a slippery floor and an electric prod was the main driving tool, the vocalization score was 39.9% of the cattle.[57] Vocalization is a good indicator of poor welfare in the stun box area.[57,58] More recent research in slaughter plants shows that vocalizations in cattle are associated with electric prod use. In well-managed beef plants in 1 report,[55] the average percentages of cattle moved with an electric prod with well-trained handlers were 10% entering stun boxes and 16% entering a center track conveyor restrainer. In plants where there is no supervision, electric prod use can be excessive and problematic.

vi. Restraint

Vocalization can be easily measured in plants to detect problems with restrainers that are used for cattle. Animals will vocalize if excessive pressure is applied or another aversive event occurs.[53,54] Devices that have serious problems, such as excessive pressure, will have high percentages (25% to 32%) of the cattle vocalizing.[53,54,56,59] Well-designed and skillfully operated cattle restraint devices that have a head holder will have 5% or less of cattle vocalizing.[26,55]

When a restraint system is overloaded beyond its design capacity, the use of electric prods may increase as handlers attempt to move animals through the plant. The following measures can be used to assess the performance of restraint devices:

1. Percentage of cattle that vocalize while entering the restraint device and while they are held in the restraint device.[56,58,60] The North American Meat Institute voluntary industry standard for vocalization is 5% or less of the animals.[12]
2. Percentage of animals (all species) that fall down to the extent that the body touches the ground.[45,56,58,60,61] The voluntary industry standard is 1%.[12] However, the goal should be zero. Restraint devices that trip animals or that are designed to make animals fall are not permitted in the voluntary industry standard.[12]
3. Percentage of animals moved with an electric prod into the restraint device.[56,62,63] The voluntary industry standard for cattle is < 5% for an excellent score and < 25% for an acceptable score. The WOAH[45] recommends that electric prods not be used on young calves. AVMA policy states that "(electrical devices (e.g., stock prods) should be used judiciously and only in extreme circumstances when all other techniques have failed."[64]

All scores are per animal. The animal is either moved with an electric prod or is not. Either it is silent, or it vocalizes. Devices that paralyze animals using electricity should not be used as a method of

restraint. Studies[65–68] clearly indicate that electroimmobilization is highly aversive and should not be used. Electroimmobilization must not be confused with electric stunning that causes unconsciousness. Animals that have been immobilized with electricity will not be able to vocalize to show their distress.

8. Corrective action

i. Arrival at the plant

It is best practice to have an emergency program either to divert incoming trucks to other slaughter facilities or to unload animals at auction markets, feedlots, or fairgrounds. This will require a coordinated program that facilitates immediate cancellation of animal loading on the farm and diverts loads that are en route to other facilities.

ii. Unloading

Nonslip flooring in the unloading area is essential for all species.[5,26–28] Quiet handling and good welfare are impossible if animals slip and fall. For all species (with the possible exception of birds), a rough broom finish is not a satisfactory nonslip floor. A rough broom finish quickly wears down and becomes smooth and slick. For cattle and bison, and other large animals, an 8 X 8-inch (20 X 20-cm) diamond pattern with 1-inch (2.5-cm) or deeper V grooves is recommended.[5] There are other suitable finishes for stamping concrete, and all of them are rougher than a broom finish. Epoxy or grit finishes work well for smaller species, but they will not provide sufficient traction for large animals that have become agitated. For existing slick floors, there are several options. In high-traffic areas, such as unloading ramps and scales, rubber mats made from woven tire treads can be used. Many new types of nonslip mats are now available. Another option is to construct a steel grating from 1-inch-diameter steel rods welded in a 12 X 12-inch (30 X 30-cm) square pattern.[26] The rods must not be crisscrossed over the top of each other. They must be welded into a flat metal grid to prevent the hooves from catching under the raised rods that can cause hoof injury. Grooving tools can be rented from a concrete supply firm for regrooving concrete. More information on flooring and the design of unloading ramps can be found in various reports.[16,26,27]

iii. Receiving

Provide nonslip flooring for all bovids.

iv. Lairage

When fighting occurs, there is usually 1 animal that is the main perpetrator. This animal should be removed from the group and placed in a separate pen. Intact males of many species will often mount and ride other animals. Ideally, bulls should be separated from cull cows. However, if animals are penned together and there is a bull that is knocking down cull cows during mounting, it should be removed from the pen. In small plants, some of the worst fights are caused by singly raised backyard animals that have never learned how to socialize with other animals.[23] To prevent fighting, bulls and singly raised animals should be slaughtered within one hour after arrival, allowing them a minimum of 30 minutes to calm down. When bulls are finished for beef, they should be kept in the same groups in which they were raised. Mixing bulls in the lairage pens can cause meat-quality problems.[69] A lairage time that is too long or no lairage time at all is detrimental to both meat quality and welfare.

The regulations forbid dragging of nonambulatory animals unless they have first been stunned.[18] If a nonambulatory bovine cannot stand and walk, regulations require that it be humanely euthanized. In the US, the only acceptable methods for moving nonambulatory animals are sleds, skid steer loaders, or specialized carts. In Canada, nonambulatory animals must be euthanized on the trailer and cannot be moved with sleds, skid steers, or specialized carts.[70] The AVMA's policy on disabled livestock[48] provides recommendations for downed animals including but not limited to the following: nonambulatory animals may be moved using a sled, mat, cart, or mechanized equipment that supports the full length and weight of the animal. A nonambulatory animal should not be dragged or lifted by the limbs, tail, neck, or ears. The AVMA's policy on disabled animals states that at slaughterhouses or packing plants, nonambulatory animals should be euthanized immediately, rather than moved prior to.[48]

v. Handling

Crowd pens that lead to the single-file race (chute) should not be overloaded—For cattle, bison, and many other animals, the crowd pen that leads to the single-file chute should be half full.[5,16,26] Cattle and bison should be moved into the crowd pen in small, separate groups.

Handlers should work alongside the tub and single-file chute, and overhead catwalks should be avoided. Overfilling the tub or overcrowding with the gate will cause animals to bunch up and turn back from the single-file entry.[16,23] Animals should be allowed time to move through the system without being rushed. When the animals are moving through the systems themselves, they should be left alone. If the lead animal balks, allow it time to investigate and move forward.[16,23]

Use natural following behavior—The next group of cattle or bison should not be brought into the crowd pen that leads to the single-file chute until there is space in the single-file chute. This enables the animals to immediately enter, promotes natural following behavior,[16] and prevents them from turning around. Unlike domestic cattle, bison often become agitated while standing and waiting in single file. Therefore, it may be best to put only 1 or 2 bison in the single-file race at a time.

Teach handlers behavioral principles—Training of stock people will improve handling.[47,71,72] In the US, many stock people have received training, and handling has improved. There is always a need to train people on basic principles. Handlers need to understand behavioral principles such as flight zone and point of balance.[16,23,73] The most common mistake when moving animals through chutes is a handler who stands at the head of an animal and pokes its rear in an attempt to make it move forward. Standing in front of an animal prevents it from mov-

ing forward. A recent survey[74] showed that 45% of handlers still made this mistake. Handlers should be taught to use the movement pattern shown in **Figure 2**. When a person quickly walks back past the shoulder of an animal in the opposite direction of the desired movement, the animal will move forward. This is an effective method for all bovids.

Bison have some behavioral characteristics that are different from cattle. When a handler enters the flight zone of a group of cattle, they will usually move away in an orderly manner and stop moving when the handler backs out of the flight zone. Bison are more likely to charge suddenly at people who invade their flight zone. When bison become extremely stressed, they may lie down and become immobile. It is recommended to leave the bison alone and allow it to calm down and get up. Both bison and cattle may rear up while waiting in the single-file chute. If this occurs, the handler should back up and remove themselves from the animal's flight zone.[23] Bison will often have greater stress during handling than cattle.[75,76] Bison stress is high to severe if they ram fences, attack, or become immobile.[76]

Prohibit routine carrying and use of electric prods—In most plants that have adequate facilities, the only place where an electric prod is occasionally needed is at the entrance to the stun box or restrainer. The prod should be kept in a convenient location and only used when needed. After it is used to move the occasional stubborn animal, it should be put away. Alternatives, such as vibrating prods or plastic paddles, should be the handler's primary driving tool. A vibrating prod can be made from a pneumatic engraving tool where the sharp tip has been removed. A total prohibition of electric prods is not recommended, as a single shock from an electric prod is preferable to hard tail twisting or hitting.

Use powered gates carefully—When a powered gate is used to move animals, it should be equipped with controls that enable a person to immediately stop its movement if an animal falls down. Automated powered gates must be equipped with pressure-limiting devices to prevent the gate from either knocking animals over or dragging animals along the floor.

Remove distractions that cause balking—Movement of animals through a handling facility can often be greatly improved by making many small changes in the facility that remove visual and aural distractions that cause animals to balk and refuse to move.[16,23,51]

1. When an animal enters a stun box or restrainer, it must not have air blowing in its face.[26,49]
2. Use a directional lamp to provide indirect lighting to light up dark chute entrances. Animals have a tendency to move from a dark place to a brighter place.[51,77]
3. Eliminate reflections on shiny metal or wet floors. Moving a light source may eliminate a reflection on a wet floor.[49] Reflected glare from shiny metal surfaces increases balking of cattle in plants.[78]
4. Cover the sides of chutes or install solid barriers to prevent approaching animals from seeing people, vehicles, or moving machinery ahead.[51,79] Large pieces of cardboard can be used experimentally to determine where solid shields are needed. The outer perimeter of a handling facility is one of the most important areas to cover. Cattle will remain calmer if there is a solid barrier to prevent them from seeing people standing close to them.[80] For flighty species, such as bison, the use of solid sides and low lighting will keep them calmer.
5. Animals often refuse to walk over changes in floor type, such as moving from a concrete to a metal floor. Cattle are also likely to balk at shadows and stop at sharp shadows on the floor.[51,73,81,82]
6. Reduce noise made by equipment, such as air hissing and metal-on-metal banging and clanging. A noisy truck parked alongside the lairage increased handling difficulty.[82] Sudden intermittent sounds and movements are more likely to cause agitation.[83] Many slaughter plants have high noise levels.[84,85]
7. The origin of the cattle or bison can have an effect on ease of handling. Cattle that have been exclusively handled on horseback may have a larger flight zone and be more difficult for people to handle on foot.[23] The stress level of bison varied by herd of origin.[76]

vi. Conditions that cause welfare problems

Failure to provide nonslip flooring—One of the most common problems in stun boxes is slippery floors.[51] When animals are continuously slipping, they cannot stand still for stunning. Designs for nonslip floors can be found in in this chapter in the Unloading section. Metal grating or rubber mats work well to prevent slipping in stun boxes.

Overloading equipment beyond its design capacity—One of the most common mistakes is overloading a single conveyor restrainer.

1. A single center-track restrainer will work well to process 390 fed feedlot cattle/h if it is free of the distractions discussed previously, because this allows 390 cattle/h to move at a normal walking speed.[86] For both electric prod use and vocalization, there are few differences among different line speeds when equipment is designed and operated correctly.[52]
2. Overloading single-animal stun boxes and restrainers. Single-animal stun boxes or restraint boxes have a maximum speed of approximately 100 animals/h.[55] Boxes designed to hold single animals result in slower line speeds than conveyor systems because they use a start-stop process to put each animal in the box and then remove it. The signs of an overloaded box are as follows:
   - Slamming the rear gate on animals.
   - Increased electric prod use.
   - More than one animal in the box for stunning.
   - An increase in rough handling.

   For all bovids, when the line speed exceeds 100 animals/h, the use of a conveyor system that handles a continuous stream of animals or 2 or more single-animal boxes is recommended.[55]

3. Designs for appropriate crowd pens for cattle have been described by Grandin.[16] The best funnel-shaped crowd pen has one straight side, and the other side is on a 30° angle. The handler should be positioned on the angled side.
4. Stun boxes and single-file chutes that are too wide—The appropriate width for stun boxes and chutes tends to be overestimated. Stun boxes and chutes that are too wide result in animals turning around and becoming caught beside each other. The recommended width is 76 cm (30 inches) for cattle.[55] Chute width may need to be adjusted for exceptionally large or small animals.
5. Vertical overhead gate clearance is too low—Animals will often refuse to walk under a vertical slide gate or other apparatus that allows for scant clearance or touches their back. Raising the opening height 16 cm (6 inches) will usually fix this problem. On center-track restrainers, the solid hold-down cover may need to be raised to prevent bumping of the animal's shoulder when it is entering.
6. Single-file chute is too short—The single-file chute has to be long enough that a sufficient number of animals can be held within it to allow the time to refill the crowd pen. The recommended lengths should be used for systems in which animals are handled in a continuous flow to the processing line. In systems where animals are handled rapidly in separate batches, shorter chutes (races) can be used.
7. Animals left to stand in a stun box too long—Animals should be stunned immediately after they enter the stun box or restrainer. Holding an animal alone in a stun box can cause isolation stress. This is especially important for bison. Isolated bison may become highly agitated.[75]

9. Religious slaughter restraint

There are various methods used to restrain and position the animal for religious slaughter. In the US, there is an exemption from the HMSA for religious slaughter,[6] and methods for restraining the animal for religious slaughter are outside the jurisdiction of USDA FSIS regulations,[86] although Congress has also declared religious slaughter to be humane.[6] The area covered by the handling exemption has been called the area of "intimate" restraint by the FSIS.[87] The HMSA specifically declares intimate restrain to be "humane by slaughtering in accordance with the ritual requirements of the Jewish faith or any other religious faith that prescribes a method of slaughter whereby the animal suffers loss of consciousness by anemia of the brain caused by the simultaneous and instantaneous severance of the carotid arteries with a sharp instrument and handling in connection with such slaughtering."[6] However, all procedures outside this area, which many meat inspectors call the "bubble," are beyond the area of intimate restraint and are subject to FSIS oversight the same as conventional slaughter.[86] Both before and after the actual slaughter, such procedures remain under FSIS jurisdiction.[18] Ensuring that the animal is unconscious before shackling and is insensitive with no corneal reflex before invasive dressing procedures begin is under FSIS jurisdiction,[86] the same as conventional slaughter.

10. Detection of problems for religious slaughter

From an animal welfare standpoint, there are 3 issues that occur during religious slaughter, when it uses a horizontal neck cut to lead to unconsciousness and subsequent insensibility. They are as follows: (1) stress, (2) pain or discomfort caused by how the animal is held and positioned for religious slaughter, and (3) the throat cut itself. Because the HMSA regulations exempt restraint of animals for religious slaughter from the regulations that apply to restraint for conventional slaughter,[6] some small religious slaughter plants use stressful methods of restraint such as shackling and hoisting of live animals even though more welfare-friendly restraint equipment is available. Research has clearly shown that upright restraint is less stressful than shackling and hoisting for sheep and calves.[88] In 1 study,[52] restraining cattle on their backs for over a minute caused more vocalization and a greater increase in cortisol than upright restraint in a standing position for a shorter period of time. Another study[89] showed that cattle vocalized less in upright restraint compared to rotating boxes.

The WOAH also recommends that stressful methods of restraint, such as shackling and hoisting, shackling and dragging, and leg-clamping boxes should not be used, and suspension of live cattle, sheep, goats, or other mammals by their legs is not permitted in the UK, Canada, Western Europe, and many other countries. Fortunately, most midsize to large religious slaughter plants in the US have stopped this practice because of concerns for both animal welfare and worker safety.

Upright restraint is less stressful for both mammals and poultry. For example, many farmers routinely handle chickens by carrying them upside down, which has been compared with being suspended upside down.[88,90,91] In 2 different plants where cattle were suspended by 1 back leg, the percentage of cattle that vocalized varied from 30% to 100% (T Grandin, PhD, College of Agricultural Sciences, Colorado State University, personal communication, 2022). Increased percentages of cattle that vocalize (mooing or bellowing) during restraint were associated with increased cortisol levels.[52] In 1 study,[10] 99% of the cattle vocalizations during handling and restraint were associated with an obvious aversive event such as the use of an electric prod or excessive pressure from a restraint device. In cattle, vocalization scoring is routinely used to monitor handling and restraint stress,[27,92] and no more than 5% vocalization at the restraint box (3% for nonreligious animal slaughter) is acceptable according to the North American Meat Institute standards.[92] The difference in the percentages for acceptability relates to the differences in handling and processing between the 2 procedures. The following methods of restraint are highly stressful for conscious mammals and should not be used: hoisting and suspension by

1 or more limbs; shackling by 1 or more limbs and dragging; shackling, hoisting, moving, and casting; trip floor boxes that are designed to make animals fall; and leg-clamping boxes.

11. Corrective actions for religious slaughter

For the religious slaughter of cattle, restraining devices are available that hold the animal in an upright position **(Figure 3)**, inverted onto their backs, or occasionally at 90° on their side.

Cattle and bison must be held in a mechanical device that holds them in an upright position, holds them in a sideways position, or inverts them onto their backs. Vocalization scoring of cattle can be used both to detect serious welfare problems during restraint of cattle and to document improvements in either design or operation of restraint devices.

In cattle, when restraint devices for religious slaughter are operated poorly or have design problems, such as excessive pressure applied to the animal, 25% to 32% of the cattle vocalized.[54,93] In 1 study,[94] reducing pressure applied by a head-holding device reduced cattle vocalizations from 23% of the cattle to 0%. These problems can occur in both upright and rotating boxes. When the equipment is operated correctly, the percentage of cattle that vocalize will be under 5%.[27,95,96] Inversion for over 90 seconds in a poorly designed rotating box had a higher percentage of cattle vocalizing and higher cortisol levels compared with holding in an upright restraint box.[52]

Information on the correct operation and design of upright restraint devices for religious slaughter can be found in reports by Grandin,[22,49] Grandin and Regenstein,[97] and Giger et al.[98] Upright restraint in a comfortable upright position is preferable. When a device that inverts an animal is required by some religious leaders, it should have adjustable sides that support the animal and prevent its body from slipping, twisting, or falling during inversion. Inversion onto the back facilitates the downward cutting stroke, which is ergonomically easier. Upright or sideways (lying on the side) restraint may be less aversive than full inversion.

It is important to minimize the time that an animal is held firmly by a head restraint. A head restraint using a mechanized device that tightly holds the head is more aversive than the body restraint.[22] Before the throat cut, cattle that were held firmly in a head restraint often struggle more than cattle held in a body restraint with no head restraint.[22] Resistance to the head restraint occurs after approximately 30 seconds; therefore, it is important to perform the throat cut before struggling or vocalization begins. When struggling is being evaluated from an animal welfare standpoint, only struggling that occurs before loss of posture should be assessed. But a head restraint does keep the animal's head in place so that it does not move during the cutting, which otherwise would result in a miscut and likely unnecessary pain. The actual amount of pressure applied using the head restraint does need further research.

When Velarde et al[89] evaluated struggling in different types of restraint devices, they did not differentiate between struggling before and after loss of consciousness. Struggling while the animal is conscious is a welfare concern, and struggling from convulsions after an animal loses posture and becomes unconscious has no effect on welfare. Restraint devices should be equipped with pressure-limiting devices to prevent excessive pressure from being applied, which then causes either struggling or vocalization.[22] The percentage of cattle vocalizing (mooing or bellowing) either while in a restraint device or while entering it, as previously mentioned, should be 5% or less.[27,96] Restraint devices should not cause animals to struggle or vocalize.[99]

E. Techniques

1. Physical methods

i. Penetrating captive bolt guns

Penetrating captive bolt guns' mode of action is concussion and trauma to the cerebral hemisphere and brainstem.[20,100,101] Properly done captive bolt stunning will instantly abolish visual evoked potentials and somatosensory evoked potentials from the brain.[102,103] This indicates that the animal's brain is no longer able to respond to a visual or tactile stimulus because it was instantly rendered insensible. Adequate restraint is important to ensure proper placement of the captive bolt. A cerebral hemisphere and the brainstem must be sufficiently disrupted by the projectile to induce sudden loss of consciousness and subsequent death.[104,105] Cattle can be effectively rendered unconscious with a powerful pneumatic penetrating captive bolt, and the brainstem may remain intact.[19] Appropriate placement of captive bolts for various species has been described.[101,106,107] Signs of effective captive bolt penetration and death are immediate collapse and a several-second period of tetanic spasm, followed by slow hind limb movements of increasing frequency.[20,104] The corneal reflex must be absent, and the eyes must open into a wide, blank stare and not be rotated.[20,108,109]

There are 2 types of captive bolt guns—a penetrating captive bolt with a rod that penetrates deep into the brain and a nonpenetrating captive bolt that is equipped with a convex mushroom head. These 2 types are the most common types used in commercial slaughter plants. Both types of captive bolts can be powered by either powder cartridges (9 mm, .22 caliber, or .25 caliber) or compressed air. Captive bolts powered by compressed air must be designed so that they never inject air into the brain, because of concerns about contamination of the meat with specified risk materials (neurologic).

All captive bolt guns require careful maintenance and cleaning after each day of use. Lack of maintenance is a major cause of captive bolt gun failure for both powder-activated and pneumatic captive bolt guns.[109] Cartridges for powder-activated captive bolt guns must be stored in a dry location because damp cartridges will reduce effectiveness.[110]

General recommendations—Use of the penetrating captive bolt is acceptable for mature animals, and it is the most common method used in beef slaughter plants. Ruminants used for food should not be pithed to avoid contamination of the carcass with specified risk materials. Captive bolt guns used for larger species must have the properly matched caliber and cartridge size. Both penetrating and nonpenetrating captive bolts cause focal as well as diffuse injury. On the basis of electrophysiologic evidence,[100] researchers determined that the primary determinant of effective stunning is impact of the bolt and not penetration of the bolt into brain tissues. In contrast, 1 report[111] credits structural changes including focal damage adjacent to the wound track and damage to peripheral tissues of the cerebrum, cerebellum, and brainstem as the predominant factors affecting the effectiveness of the stun. Both penetrating and nonpenetrating captive bolt guns are effective for inducing instantaneous unconsciousness. Nonpenetrating captive bolt requires more careful placement, compared with penetrating captive bolt, to be effective.[110] The use of a head restraint device is strongly recommended for nonpenetrating captive bolt. In a test on fed steers, a Jarvis pneumatic nonpenetrating captive bolt rendered 70 out of 75 steers instantly unconscious with a single shot.[112] The 5 failures were due to the gun being shot on an angle that was not recommended. The nonpenetrating captive bolt must be positioned perpendicular to the animal's forehead.

Detection of problems—Lack of maintenance is a major cause of captive bolt gun failure for both powder-activated and pneumatic captive bolt guns.[56] When a pneumatic captive bolt is used, there are 3 parts that will require maintenance. They are the captive bolt tool, the air compressor that powers it, and the balancer device that supports the weight of the heavy pneumatic stunner. If the balancer does not function properly, it will be more difficult for the operator to position the pneumatic stunner correctly. Damp cartridges can result in underpowered shots that are less effective. Soft-sounding shots were less effective.[108] Another issue is variation in the manufacture of the cartridges. This may have an effect on their performance.[113,114] It is recommended to purchase cartridges from a source that produces consistent quality.

Studies have found that a well-trained operator can easily render 95% or more of the animals unconscious with a single shot from a captive bolt gun,[110,115] and advise that there is a problem if the effective first-shot rate falls below 95%.[115] The best plants have a 99% first-shot efficacy[55] (FSIS has a zero-tolerance policy for missed first shot). Results of a European study[116] of 8,879 cattle skulls in 2 plants indicated poor precision in 4% and 3% of shot locations. Both studies show that the error rate in captive bolt stunners is easily kept below 5%. To ensure that animals are rendered unconscious, some slaughter plants routinely shoot all animals twice. These security stuns are part of plants' systematic approach to animal welfare.

Corrective action for problems—The following actions should be taken to correct and prevent problems:

1. Store cartridges for powder-activated captive bolt guns in a dry location. Cartridges stored in a damp location were more likely to produce ineffective "soft" shots.[110]
2. Minimize movement of the animal's head. This can be achieved with either a head-holding device or behavioral methods such as changing lighting in the stun box. Head holders must be used with care; if poorly designed, they can increase cortisol levels and balking.[117] In the center-track conveyor system, the head will typically remain still without head restraint. This is due to having a long overhead solid top, which prevents the animal from seeing out until its feet are off the entrance ramp and it is riding on the conveyor.[60]
3. A nonslip floor in the stun box is essential to prevent slipping. Slipping causes animals to become agitated. The stun box floor should be flat or have a slight slope. Steeply sloped or stepped floors should not be used in stun boxes.
4. Maintain the captive bolt gun per the instructions from the manufacturer. Captive bolt guns are precision machine tools, and daily cleaning and maintenance are essential.
5. Use a test stand to determine whether the captive bolt has sufficient bolt velocity. Most captive bolt manufacturers have test stands for their captive bolt guns.
6. For pneumatic captive bolt guns, the air compressor that powers the gun must provide the air pressure and volume specified by the captive bolt manufacturer throughout the entire production shift. Air accumulation tanks or an undersized compressor will not provide sufficient power for the gun.
7. Heavy pneumatic captive bolt guns must be hung on a well-designed balancer so that the operator can easily position the gun without lifting its full weight. There are many balancer types and designs. Balancers must be well maintained; a partially broken balancer will make it difficult to position the pneumatic captive bolt, causing the operator to exert more effort to move the gun.
8. Ergonomic design is especially important with pneumatic captive bolt guns because they are heavy and bulky. Small changes in handle location or the angle that the pneumatic gun hangs on the balancer can greatly improve ease of operation and lessen the effort required to position the gun.
9. Switches and valves that operate gates or start and stop conveyors must be located in a convenient location. On a conveyor restrainer, the operator should be able to start and stop the conveyor without moving from the normal position for stunning.
10. All the valves and switches for operating conveyors and gates must be kept in good repair. Par-

tially broken hydraulic or pneumatic valves often require excessive effort to operate.

11. All plants that use cartridge-fired captive bolt guns should have more than 1 gun be available to allow for both gun rotation and having a second gun available if the initial shot is not effective. Cartridge-fired captive bolts are less effective when they get too hot. Rotating the guns and allowing hot guns to cool will prolong their useful life. If a second stun attempt is needed, it must be performed immediately to minimize pain, suffering and distress. Plants should have a written protocol in place for the use of the backup stunner and second stun attempts.
12. Orientation toward the foramen magnum is critical in calves, lambs, and kids because the head is often rotated during restraint and a direction perpendicular to the skull may be too rostral, resulting in penetration of the frontal sinus. For adult cattle, the gun should be placed perpendicular to the skull to enable the bolt to hit with maximum force.

ii. Nonpenetrating captive bolt guns

The nonpenetrating captive bolt gun has either a wide mushroom-shaped head or a flat head that does not penetrate the brain of large mammals, such as adult cattle. Correct positioning is critical for an effective stun of an adult cow. When a nonpenetrating captive bolt gun is used, there is little margin for error. The stun-to-stick interval must not exceed 60 seconds. To be effective on cows and steers, the shot must be more accurately positioned, compared with the positioning of a penetrating captive bolt. Nonpenetrating captive bolts are not effective for stunning bulls or cattle with long hair. The use of nonpenetrating captive bolts on large fed cattle was less effective than a penetrating captive bolt.[118,119] For bulls, cows, and large fed cattle, a penetrating captive bolt is recommended.

Detection of problems—Refer to Penetrating captive bolt guns—Detection of problems. Be aware that the nonpenetrating captive bolt has a much smaller margin of error on aim than does the penetrating captive bolt.

Corrective action for problems—Refer to Penetrating captive bolt guns—Corrective action for problems.

iii. Gunshot

A properly placed gunshot can cause immediate unconsciousness. Under some conditions, a gunshot may be the only practical method of inducing unconsciousness in animals with extremely heavy skulls, such as bulls, large boars, or buffalo.

The use of firearms should be limited to personnel trained in the use of firearms and only in jurisdictions that allow for legal firearm use. The safety of personnel, the public, and other animals nearby should be considered. In packing plants, a fully enclosed box that will contain a bullet that may perforate through the skull or ricochet is strongly recommended.

In applying a gunshot to the head for the purposes of slaughter for captive animals, the firearm should be aimed so that the projectile enters the brain, causing instant loss of consciousness.[120–125] This must take into account differences in brain position and skull conformation between species, as well as the energy requirement for skull bone and sinus penetration.[100,122] Accurate targeting for a gunshot to the head in various species has been described.[122,123,126] The appropriate firearm should be selected for the situation, with the goal being penetration and destruction of brain tissue without emergence from the contralateral side of the head.[127,128]

Basic ballistic concepts—Terminology commonly used in the discussion of firearms and ammunition for slaughter or euthanasia includes *muzzle velocity* (MV), *muzzle energy* (ME), and *energy density* or *sectional density*, the latter of which pertains to a bullet's capacity to penetrate its target. They are briefly discussed here for the purposes of assisting readers who may be less familiar with these concepts.

MV is the speed of a projectile (bullet, shot from a shotgun, or bolt) with respect to the muzzle at the moment it leaves the end of a gun's barrel (ie, the muzzle). It is generally stated as feet per second (fps) or meters per second (mps). With reference to firearms, the higher the MV, the flatter the bullet's trajectory. In most cases, the larger the bullet, the slower the velocity. Heavier bullets require more energy to be launched at high speeds.

The second concept is ME, which is the kinetic energy of a bullet as it leaves the muzzle of a firearm. The ME of a bullet is a rough measure of its destructive potential. The heavier the bullet and the greater its MV, the higher its ME and capacity for destruction of objects in its path. ME can be expressed as the mass of the bullet (M) times its velocity (V) squared, divided by 2.83. However, to accommodate units of measure commonly used in the US for civilian firearms, ME is expressed in foot-pounds. This is calculated by multiplication of the bullet's weight (W) times its velocity in feet per second (V) squared, divided by 450. The International System of Units expresses ME in joules after the English physicist James Prescott Joule (1818 to 1889). It is important to understand that as a bullet travels beyond the muzzle of the firearm, its MV and ME gradually begin to decrease.

While this is not a concern for the use of firearms in close proximity to the animal, when attempting to shoot an animal from a distance, to ensure accuracy and an acceptable level of ME, a high-powered rifle may be the better choice.

The third concept that pertains to firearms and bullets is energy density, which describes the ability of a bullet to penetrate its target. Bullets with a larger cross-sectional area (higher energy density) penetrate deeper. In the hunting literature, energy density is sometimes referred to as sectional density and calculated as the ratio of a bullet's weight (in lb) to the square of its diameter (in inches squared).

ME requirements—The ME requirements necessary to traverse the skulls of animals to induce unconsciousness or for the purpose of euthanasia are poorly understood. The previous edition of this doc-

ument suggested a minimum ME of 300 foot-pounds for animals up to 400 lb and as much as 1,000 foot-pounds for animals over 400 lb. These recommendations are considered to be well in excess of the required ME requirements. A study by Blackmore[100] found that a projectile with 94 foot-pounds (127 J) was sufficient to penetrate the frontal bone of a 3-year-old Angus cow. The .22 LR is one of the most popular firearms in North America. It is able to consistently deliver bullets at a velocity of 1,200 feet/s with an ME in the range of 120 to 130 foot-pounds (162 to 176 J), which based upon the Blackmore study[100] should be sufficient for most slaughter and euthanasia situations.

Determination of the ME necessary to penetrate a specific target depends upon characteristics of the target (hard vs soft), distance of the target from the shooter, and type of bullet (ie, hollow or solid point). A Canadian study[129] designed to evaluate firearm use for euthanasia of cattle found that both the .22 LR standard-velocity and .22 LR high-velocity bullets failed to yield adequate penetration of cadaveric skulls when fired from a distance of 25 m.[129] In a US study,[48] fresh cadaveric heads from *Bos taurus* beef feedlot steers 12 to 18 months old were used to evaluate 7 combinations of firearms and ammunitions (.22-caliber rifle firing a long-rifle 30-grain plated lead solid- or hollow-point round, .223-caliber carbine firing a 50-grain ballistic-tip round, 9-mm pistol firing a 124-grain total metal jacket round, .45-caliber automatic Colt pistol [ACP] firing a 230-grain full metal jacket round, and 12-gauge shotgun firing a 2.75-inch, 1.25- ounce No. 4 birdshot shell or a 1-ounce rifled slug). All heads were shot from a distance of 3 m and oriented so that the projectiles would contact the skull at a 90° angle. Of the 7 firearm- ammunition combinations, the .22-caliber rifle firing a .22-caliber solid-point cartridge and the 12-gauge shotgun firing a No. 4 birdshot shell or a 1-ounce rifled slug were the combinations that most frequently caused brainstem lesions and trauma sufficient to cause instantaneous death. The mean depth of penetration for the .22-caliber hollow-point cartridge was significantly less than that of other firearms evaluated. The 9-mm pistol firing a total metal jacketed round caused the least amount of brain tissue or brainstem trauma. It was determined that only 2 of the 6 heads shot with this firearm and ammunition combination would have likely resulted in instantaneous death. Researchers concluded that the rifle-fired .22-caliber hollow-point rounds and the pistol-fired 9-mm rounds were not viable options for euthanasia of feedlot cattle.[130]

Firearm selection—Based upon available information, if a .22 LR is to be used for humane slaughter or euthanasia of a mature bovine, a solid-point bullet fired from a rifle within a range of 3 m (10 feet) is recommended.[130] The use of a hollow-point bullet in a .22 LR is unlikely to yield consistent results. Similarly, although custom-loaded bullets may yield different results than those observed in the above-cited study, use of a 9-mm with a jacketed bullet cannot be recommended.[130]

Bullets from a rifle compared to a handgun yield higher MV and ME. A longer barrel allows the bullet propellants (gunpowder) to burn more completely, thereby maximizing the bullet's velocity as it exits the muzzle. The shorter barrel of a handgun generally results in reduced MV since much of the pressure occurring from the combustion of gunpowder that propels the bullet is dissipated into the air as the bullet leaves the muzzle. If a .22 LR is to be used for humane slaughter or euthanasia, it is best fired from a rifle. The Humane Slaughter Association lists multiple firearms for humane slaughter of livestock, including shotguns (12, 16, 20, 28, and .410 gauges), handguns (.32 to .45 caliber), and rifles (.22, .243, .270, and .308 caliber).[131] The .22 LR is not recommended for use on aged bulls or bison.[131]

To improve safety and reduce the possibility of a bullet passing through the animal's head or in the event that the bullet misses the animal in the packing plant environment, many plant managers prefer the .22 LR. Some may also prefer to use a pistol because it can be held closer to the head. While a .22 caliber handgun cannot be specifically recommended, if used, it is suggested that a high-velocity 40-grain solid-point bullet be used with the understanding that the ME may be less than desired for consistent results. There are 2 main differences between the use of a firearm in a slaughter plant and its use for on-farm euthanasia. In a slaughter plant, gunshot is followed by exsanguination, so it is not the sole agent used to cause death. Another difference is that an animal in a slaughter plant is shot at a close range of 1 to 2 feet (0.3 to 0.6 m). When slaughter is done in less controlled situations where it may be necessary to shoot from a distance, a firearm larger than a .22 LR is recommended. It is essential to aim the shot correctly so that the brain is penetrated.[132]

Bullet selection—Bullet selection is quite possibly the most important consideration for slaughter of livestock by gunshot. There are 3 basic types of bullets pertinent to this discussion: solid points, hollow points, and full metal jacketed bullets. Solid-point bullets are preferred for shooting livestock since they are designed for greater penetration of their targets. Under ideal conditions, this type of bullet will also undergo moderate expansion to a mushroom shape that increases its destructive characteristics. Hollow-point bullets are designed with a hollowed-out tip that causes rapid expansion and fragmentation of the bullet on impact. The hollow-point design allows maximum transfer of energy with a lower risk of overpenetration. However, for the purposes of humane slaughter of livestock, the first requirement is that the bullet possesses sufficient energy to penetrate the skull and enter the underlying brain tissue.

The other extreme is represented by full metal jacket bullets, which do not expand or fragment on impact with their targets. These bullets have a lead core with a thin metal jacket cover that completely covers (surrounds) the bullet. Full metal jacket bullets generally achieve maximum penetration, which may have benefits for humane slaughter but also create additional safety hazards for bystanders from

perforation (ie, pass-through) of the bullet. For this reason, full metal jackets are not recommended for use in slaughter plants. Shotguns loaded with shot shells (No. 4, 5, or 6 or slugs) have sufficient energy to traverse the skull but are less likely to exit.

Firearm safety—Firearm safety cannot be overemphasized. Guns are inherently dangerous and must be handled with caution at all times. Common recommendations include the following: (1) always assume that all firearms are loaded, (2) always know where the muzzle is and never allow it to point in the direction of oneself or bystanders, (3) keep fingers away from the trigger and out of the trigger guard until ready to fire, (4) be sure of the target and what lies beyond it, (5) always be sure that the gun is unloaded when not in use, and (6) keep the safety on until ready to fire. To improve safety, many gun owners prefer a single-shot rifle with either a bolt or break-open action. The action remains open until the operator is ready to fire. For those desiring more information or training on proper use of firearms, readers are advised to contact local hunter safety programs. These programs offer training in firearm safety and also provide information on rules and regulations for firearm use.

Firearms should never be held flush to the skull. Discharge of the firearm when the barrel is occluded or blocked results in the development of extreme pressure within the barrel that when fired may cause the barrel of the gun to explode, placing the shooter and observers at great risk of injury. Ideally, the muzzle of the firearm should be held within 1 m (3 feet) of the animal's forehead and perpendicular to the skull with the intended path of the bullet roughly in the direction of the foramen magnum. This will direct the bullet toward the brainstem, which will assure immediate loss of consciousness and rapid death.

When other methods cannot be used, an accurately delivered bullet from a firearm is acceptable for humane slaughter.[123,133,134] When an animal can be appropriately restrained, the penetrating captive bolt, preferably one designed for euthanasia, is preferred to a gunshot because it is safer for personnel. Prior to shooting, animals accustomed to the presence of humans should be treated in a calm and reassuring manner to minimize anxiety. In the case of nondomesticated animals, gunshots should be delivered with the least amount of prior human contact necessary.

Anatomic landmarks for use of the penetrating captive bolt and gunshot—In bovines, the point of entry of the projectile should be at the intersection of two imaginary lines, each drawn from the outside corner of the eye to the center of the base of the opposite horn **(Figure 4)**.[135] Alternatively, in long-faced cattle or young-stock, a point on the midline of the forehead that is halfway between the top of the poll and an imaginary line connecting the outside corners of the eyes can be used **(Figure 5)**. Firearms should be held 1 m (3 feet) from the intended anatomic site and positioned so that the muzzle is perpendicular to the skull.

iv. Electric stunning

Electric stunning for humane slaughter causes immediate loss of consciousness.[105,136] Alternating current has been used to euthanize dogs, cattle, sheep, goats, swine, chickens, foxes, mink, and fish.[20,121,125,126–145] When done correctly, electric stunning produces grand mal seizures, which have a tonic (rigid) action followed by clonic (paddling) action. These seizures occur prior to the electric transmission of pain stimuli to the CNS, so the procedure is not painful or distressful.

To produce the grand mal seizure, electrodes must be placed so that the current goes through the brain.[146] In mammals, reliable induction of an epileptic seizure may require a greater amount of current than that required for induction of cardiac arrest.[147] If killing is not performed quickly, then consciousness is regained.[148]

Principles—Ohm's law involves current, potential difference (ie, resistance), and frequency. Current, or what flows through a wire, is measured in terms of amps (A). Current is proportional to the potential difference across 2 points. Voltage (V) is a measure of that difference in electric potential between 2 points in a wire. Resistance, which determines how much current will flow, is measured in terms of ohms. Power, or current multiplied by voltage, is measured in watts (W). Frequency, or the number of cycles per second, is measured in hertz (Hz).

When electric stunning is used for humane slaughter, appropriate electric parameters must be used. These parameters vary with species and size. The effectiveness of electric stunning, in general, increases with increasing current and decreasing frequency. A minimum of 1.25 A is required for cattle.[149] Amperage must be maintained for at least 1 second. Insufficient amperage can cause an animal to be paralyzed without losing consciousness.[150] Electronic equipment designed to provide constant amperage, which sets the amperage and allows voltage to vary according to animal resistance, may prevent amperage spiking.[150,151] Older voltage-regulated electronic units allow changes in amperage (spiking), which may cause injury and blood spotting.

The minimum current required to induce an epileptic response depends on the stunning frequency.[152] Unconsciousness is most effectively induced at a frequency of 50 cycles (50 Hz).[142,153] Plant managers will often use higher frequencies to reduce damage to the meat caused by petechial hemorrhages (blood spotting). It is generally accepted that higher frequencies (800 Hz or greater) do not result in better stunning.[154] That is, the duration of clonic-tonic seizures increases with higher stunning frequencies and incurs a delay in time to unconsciousness. Animals stunned using higher frequencies will regain sensibility more quickly.[155] In other studies,[142,150,156] frequencies of 2,000 to 3,000 Hz failed to induce unconsciousness. Grandin[150] recommends that higher frequencies only be used when they are passed through at least 2 electrodes to the head. Eight hundred hertz applied to the head with 50 Hz applied to the body is also acceptable.[157]

Proper electric stunning must not be confused with electric immobilization that paralyzes an animal without inducing unconsciousness.[158] Immobilization

without unconsciousness is highly aversive and must not be used.[66,67] Electrocution induces death by cardiac fibrillation, which causes cerebral hypoxia.[143–145] However, animals do not lose consciousness for 10 to 30 seconds or more after onset of cardiac fibrillation. It is imperative that animals be unconscious before being electrocuted.

Methods—Three methods are used to perform electric stunning: the head-only reversible method; the 1-step head-to-body cardiac arrest method; and the 2-step method consisting of a current applied only to the head, followed by a current applied to the body, which stops the heart.[159] The head-only method does not cause cardiac arrest and will result in a return to consciousness in 15 to 30 seconds.[105,160] In the head-only method, animals should be bled within 15 seconds.[160] Tongs must be placed so that the current only goes through the head, which can be accomplished by placing tongs either on both sides of the head or on the top and bottom of the head.

The 2-step method **(Figure 6)** uses the head-only method followed by a second application of the tongs to the chest. This method causes unconsciousness first and then death by cardiac arrest. Applying the second current by placing the electrode on the chest behind the foreleg has been reported to be effective.[161] A 2-step electric stun method must be used with grown cattle[150,162] owing to the large size of this species. Current must be applied to the head to induce unconsciousness before a second current is applied to the body to induce cardiac arrest.[163] Because grown cattle are so large, the head must be properly restrained before electrodes are firmly affixed to it. A frequency of 50 to 60 Hz should be used for the stun[150] if head-only stunning is used. A 3-second application of 1.15 A at 50 Hz applied between the nose and the neck is effective to induce epileptiform activity in the brain.[164]

Signs of effective stunning—Unconsciousness occurs when electricity inhibits impulses from both the reticular activating and the somatosensory systems of the brain.[165] Signs of effective seizure induction include extension of the legs, opisthotonos, and downward rotation of the eyeballs as well as epileptic seizures or the clonic tonic syndrome described above. The presence of an epileptic state has been considered to be a guarantee of an effective electric stun.[105,149]

On a more practical level, signs of effective stunning have been described.[115] Although the legs may move, it is the head that must be examined when the animal is hung on the rail after the rigid phase of the epileptic seizure stops. The head and neck should be limp and floppy, and the tongue should hang out. Cattle heads should hang straight down. If natural blinking occurs, the animal is not stunned. Nystagmus may occur in electric stunning, especially when frequencies > 50 Hz are used. Rhythmic breathing must cease, and vocalizations should not occur. Gasping is permissible after electric stunning, but it must not be confused with rhythmic breathing where the animal's ribs move in and out. Animals electrically stunned with the head-only method will start to recover when kicking stops.

General recommendations—Electric stunning requires special skills and equipment that will ensure passage of sufficient current through the brain to induce loss of consciousness and tonic and clonic epileptic spasms. Unconsciousness must be induced before cardiac fibrillation or simultaneously with cardiac fibrillation. Cardiac fibrillation must never occur before the animal is rendered unconscious. The 2-step method should be used in situations where there may be questions about sufficient current to induce a grand mal seizure with tonic and clonic spasms. This approach enables observation of tonic and clonic spasms before a second current is applied to induce cardiac arrest. Electroimmobilization that paralyzes an animal without first inducing unconsciousness is extremely aversive and is unacceptable.[66,67] For both humane and safety reasons, the use of household electric cords is not acceptable.

Meat quality—The head-only method has both animal welfare and meat-quality issues.[166] Negative meat effects include decreased tenderness, increased drip-loss (water-binding capacity; syneresis leading to water puddling), and pale muscle color due to more intense muscular contractions compared with either 1-step or 2-step cardiac arrest stunning. Plant management may be tempted to lower the amperage and increase frequency to reduce blood splash (petechial hemorrhages) and broken backs. Stunner settings that reliably induce epileptic activity in the brain must be used.

Detection of problems—Failure to cause immediate unconsciousness is highly stressful and may be painful. Humans experience pain when electroconvulsive shock therapy fails.[167] Several causes of electric stunning failure have been noted. The most common causes of return to consciousness after any type of electric stunning are incorrect electrode placement and poor bleeding.[168,169] Another cause of failure that has been noted in cattle is dehydration of the animal prior to stunning.[159] And finally, poor equipment maintenance can also cause procedure failures.

Another common cause of failure to induce unconsciousness is incorrect placement of the electrodes.[165] Electrodes must never be placed on eyeballs, ears, or other sensitive areas of the body. Likewise, electrodes must not be placed on wet metal plates on which the animal stands. Experiments with dogs showed that electrode positions where the brain is bypassed do not cause instantaneous unconsciousness. When electricity passes only between the forelimbs and hind limbs or neck and feet, it causes the heart to fibrillate but does not induce sudden loss of consciousness.[143] The animal will be electrocuted but will remain conscious until it dies from cardiac fibrillation.

Four options are available for correct electrode placement for the head-only method, including on both sides of the head between the eye and ear, the base of the ear on both sides of the head, and diagonally below one ear and above the eye on the opposite side of the head. For cattle, neck to nose is effective.[163,164] When the 2-step procedure is used,

placement of the body electrode behind the forelimb is effective.[161]

Even when electric methods that stop the heart are used, there are a few animals where cardiac arrest is not induced. This is the reason that good bleeding technique is essential.[169]

When electric methods are used, the following signs of return to consciousness must be absent: rhythmic breathing, righting reflex, vocalization, natural eyeblink (menace reflex), and tracking of a moving object.[161] There are definite problems with electric stunning if cattle moo or bellow when the electrodes are applied.[115] A well-trained operator should be able to place the electrodes in the correct position on 99% or more of the animals. There is a problem if more than 1% of the cattle vocalize during electrode application.[169,170]

Proper equipment maintenance is essential. At a minimum, electrodes should be cleaned once daily and regularly maintained.[150] Old, worn, or rusted equipment should be replaced on a regular schedule.

Corrective action for problems—The following actions should be taken to correct and prevent problems:

1. Check to ensure that the electric stunner is inducing a grand mal epileptic seizure. The tonic and clonic spasm is clearly visible after head-only stunning. If electroimmobilization is used to keep the carcass still after stunning, it must be turned off because it will totally mask the tonic and clonic spasms.
2. The electric stunner should be equipped with a meter so that amperage levels can be monitored.
3. Monitor stunner operations for electrode placement and vocalization during electric stunner placement. Appropriate plant monitoring programs for evaluating the effectiveness of electric stunning should be implemented. For cattle and other animals with hair, a small stream of water should be applied either through the electrode or right beside it to wet the application area.
4. Make sure animals are not dehydrated. Dehydrated animals are more difficult to render unconscious with electricity.
5. Use a bleeding knife and techniques that will produce a copious blood stream, which helps prevent problems with return to consciousness.[169]
6. When head-only stunning is used, equipment should be designed so that the animals are bled within 15 seconds after stunning. Well-designed commercial plants that perform religious slaughter with head-only stunning have equipment that is capable of achieving this goal. The 2 main methods for achieving rapid bleeding are either high-speed hoists or bleeding the animal on a table immediately after it is ejected from the stun box or restrainer.
7. The electrodes must be kept clean. A wire brush should be used to clean the electrodes several times each day.
8. Stunning tongs or wands should be ergonomically designed to reduce operator fatigue.
9. Rotate the operators to help prevent fatigue. Data collected from an electronically monitored stunning unit showed that after 3 hours, the operator was more likely to fail to firmly press the electrode against the animal. Firm contact is essential for an effective stun.[171]
10. Both sides of a V conveyor restrainer should run at the same speed. If one side runs faster than the other, the animals will become agitated.
11. Use insulated restraint equipment. Plastic slats are recommended on V conveyor restrainers, and there should be no exposed bolts. When single-animal restrainers are used, they should be insulated with plastic meat cutting board.
12. For operator safety, all electric stunners should be equipped with an isolation transformer or other device that will prevent electricity from flowing from a single electrode to ground. The electricity should only flow between the 2 electrodes. The metal frame of the restrainer and operator catwalk must be connected to a good ground.
13. All electric components such as the stunner switch, plugs, cords, and control box should be kept dry. The only part of the stunner that should be wetted is the electrodes. When the plant is cleaned, the stunning tongs or wand should be removed and stored in a dry location. The stunner control box should be either placed in a separate dry room or kept covered during plant wash down.
14. Several types of restrainers (for head and body) can be employed for a variety of species. Cattle, for example, must have a properly designed head restraint.
15. Employee training is essential.

2. Atmospheric methods

These methods are currently not applicable to bovids.

3. Immersion methods

These methods are currently not applicable to bovids.

4. Religious

There are 3 basic ways that religious slaughter is performed: (1) preslaughter stunning before the throat cut with either a nonpenetrating captive bolt or electric stunning, (2) immediate postcut stunning with a captive bolt, or (3) slaughter without stunning (traditional hand slaughter). Some religious authorities who supervise either kosher (Jewish) or halal (Muslim) religious slaughter will allow either preslaughter or immediate postslaughter stunning.[172] For halal slaughter, electric head-only stunning is used in many large cattle and sheep plants in New Zealand, Australia, and the UK. Head-only electric stunning is acceptable to many Muslim religious authorities because it is fully reversible and induces temporary unconsciousness (refer to Electric stunning). If preslaughter stunning is done, there will be no animal welfare concerns about the throat cut in a conscious animal. Since most preslaughter

stunning methods that are approved for religious slaughter produce a lighter reversible stun, greater attention will be required to the details of procedures to ensure that the animals are and remain unconscious during the throat cut. Some halal certifiers will accept nonpenetrating captive bolt because the heart will continue to beat after stunning.[173] Some religious communities will accept immediate postcut stunning, and others require slaughter without stunning (traditional hand slaughter). Stunning methods are covered in Techniques.

i. Detection of problems

The greatest welfare concerns may occur during traditional religious hand slaughter. There are 2 main issues: (1) Does cutting the throat of a conscious animal cause pain? (2) What is the maximum appropriate time that is required for the animal to become unconscious after a properly done throat cut? The throat cut done during both kosher and halal slaughter simultaneously severs both carotid arteries and jugular veins and the trachea. For halal slaughter, a sharp knife is required. Kosher slaughter has more strict specifications for how the cut is performed and the design and sharpening of the knife.[174,175] A kosher slaughter knife is long enough to span the full width of the neck (ie, double the width of the neck) and is sharpened on multiple whetstones. Before and after each animal is cut, the knife is checked for nicks that could cause pain.[174,175] Any nick in the knife makes the animal nonkosher, so there is a strong incentive to keep the knife razor sharp and nick free.

ii. Painfulness of the cut

Researchers have reported that cutting the throat of 107- to 109-kg (236- to 240-lb) veal calves with a knife that was 24.5 cm (9.6 inches) long caused pain comparable to dehorning.[176,177] The knife may have been too short to fully span the throat, and it had been sharpened on a mechanical grinder. A grinder may create nicks on the blade and may not be comparable to a knife sharpened on a set of whetstones. (The assumption is that the nicks are responsible for the pain.) Slaughter without stunning of cattle with a knife that is too short will result in violent struggling because the tip makes gouging cuts in the wound.[49] One of the rules of kosher slaughter is that the incision must remain open during the cut.[174,175] When the wound is allowed to close back over the knife, cattle will violently struggle.[97] When an animal is restrained in a comfortable upright position, it becomes possible to observe how the animal reacts to the throat cut. When a kosher knife was used by a skilled slaughter man (shochet), there was little behavioral reaction in cattle during the cut.[49,97] In calves, there has been a similar observation.[178] Grandin[49] reports that people invading the animal's flight zone by getting near to the animal's face caused a bigger reaction. An ear-tag punch has also caused a bigger reaction than a good kosher cut.[97]

iii. Time to lose consciousness

Unconsciousness, as defined in the general introduction of these Guidelines, is the loss of individual awareness that occurs when the brain's ability to integrate information is blocked or disrupted. At this point the animal no longer feels pain. Once unconsciousness has been ascertained, the animal may be shackled and hoist to further bleed out. Currently, the best practical indicator of unconsciousness is loss of posture.

Before invasive dressing begins, all signs of brainstem function such as the corneal reflex must be abolished by the bleeding. Thus, insensibility follows unconsciousness. In cattle, when the carotid arteries are severed, the brain can still receive blood from the vertebral arteries.[179,180] After the cut, most cattle will lose consciousness and no longer be able to stand within 17 to 85 seconds.[103,181–186] In these studies,[103,181–186] time to onset of unconsciousness was measured with either electroencephalography (EEG) or loss of the ability to stand. Allowing the wound to close up after a transverse halal throat cut with a 20-cm-long (7.9-inch-long) knife may delay the onset of unconsciousness. In a study[187] where a rotating box was used to invert veal calves onto their backs, unconsciousness was measured via EEG. It occurred at an average of 80 seconds.

There is a large amount of biological variability, and possibly differences in workmanship, so that a few cattle, calves, or sheep have extended periods of sensibility (> 4 minutes).[188,189] If the animals can stand and walk, they are conscious. In veal calves, corneal reflexes were still present at 135 ± 57 seconds after the throat cut.[187] The methods section of Lambooij et al[187] did not describe the type of knife. However, that study was done in a slaughter plant that performed halal slaughter, which permits knives of different sizes to be used. Corneal reflexes can also occur in electrically stunned or CO_2-stunned animals where other indicators of return to consciousness, such as the righting reflex, rhythmic breathing, and eye tracking, are absent.[161] Corneal reflexes occur during a state of surgical anesthesia[190] or when visual potentials and somatosensory evoked potentials are abolished.[138] One of the best indicators for determining onset of unconsciousness is the loss of the ability to stand or walk. In cattle, a major cause of prolonged periods of consciousness after the throat cut is sealing off of the ends of the severed arteries (false aneurysms).[191]

iv. Aspiration of blood

Another welfare concern is aspiration of blood into the trachea and lungs after the cut.[192] In 1 study[193] when cattle were held in a well-designed upright restraint, 36% (for kosher) and 69% (for halal) aspirated blood. It is likely that in a rotating box where the animal is held on its back, blood aspiration will be higher (T Grandin, PhD, College of Agricultural Sciences, Colorado State University, personal communication, 2022).

v. Corrective action for problems

To reduce the painfulness of the act, a knife that is long enough to span the neck where the tip will remain outside the neck during the cut should be used.[99] It is also essential that the knife be extremely sharp, and the use of appropriate whetstones is recommended. A good method for testing a knife for minimal sharpness is the paper test. To perform

this test, a single sheet of standard letter-size (8.5 X 11-inch) printer paper is dangled in a vertical position by being held by a thumb and forefinger by 1 corner. A dry knife held in the other hand should be able to start cutting at the edge of the paper and slice it in half. This method can eliminate the worst dull knives, but it may not evaluate the sharpness of the knives and certainly does not address the issue of nicks. The Jewish slaughtermen are extensively trained to test their knives for nicks by running the knife over a fingernail.

It is also essential to not allow the wound to close back over the knife during the cut. To prevent sealing off of the arteries in cattle, the cut should be angled so it is close to the first cervical vertebra (C1) position[194,195] as long as such a cut is accepted by the religious authorities. This will also cut a sensory nerve, which may prevent the cattle from experiencing distressful sensations from aspirating blood.[194,195] The cut should be located posterior to the larynx and angled toward the C1 position.

Before invasive dressing procedures such as skinning or leg removal are started, the corneal reflexes (representing insensibility) must be absent. Even though an animal showing only a corneal reflex is unconscious, to provide a good margin of safety, it should be absent before dressing procedures start. Absence of the corneal reflex and complete unconsciousness before dressing procedures are started are best practices for all slaughter plants that undertake both conventional slaughter and religious slaughter.

vi. Microwave stunning

A new technique that has been developed in Australia uses microwave energy inputted directly into the brain of cattle (and sheep) to cause them to become rapidly unconscious.[196–199] At the appropriate energy application, brain damage does not occur, and the animal can recover consciousness.[198] Research shows that the loss of consciousness is fully reversible and that animals will return to the equipment, suggesting that the procedure is not aversive. The method is highly controllable using the incorporated software system and may provide greater certainty of outcome than current reversible stunning techniques such as nonpenetrating stunning and electrical stunning, both of which are used mainly for the halal slaughter of animals by those Muslims who accept such practices. The software system also retains data on each application allowing for post hoc auditing and verification.

F. Unique Species Issues

1. Bulls, bison, and water buffalo

Large bulls, bison, and water buffalo with very thick and heavy skulls create challenges for stunning with captive bolt. Some plants have solved this problem by electing to shoot all bulls twice or by switching to the use of a large-caliber firearm. While the latter option has been found to be effective, use of a firearm within the confines of a packing plant is dangerous. The newer, more powerful Jarvis pneumatic captive bolt gun has largely overcome these problems, but because of its size and weight, it must be properly mounted on a balancer for effective positioning over the proper anatomic site.[200,201] This has caused some to consider use of the poll position rather than the frontal site. Studies indicate that the poll position can be effective if the appropriate captive bolt gun is used and when the muzzle is directed so that the discharged bolt will enter the brain.[107,116]

However, use of the poll position for penetrating captive bolt stunning is prone to operator error resulting in misdirection of the bolt (eg, into the spinal cord) and a failure to render animals unconscious owing to a shallow depth of concussion (ie, failure of the bolt to sufficiently penetrate the skull).[107,200] Consciousness in bovids is maintained by thalamocortical pathways that provide a 2-way connection between the thalamus, brainstem, and cortical regions of the brain. For this reason, placement of the captive bolt is most effective when placed on the frontal region of the head directing the muzzle toward the brainstem. Damage to the brain in this region causes immediate loss of consciousness.[116,200,202] The poll position is better used when the need arises for a second shot.[203]

Bison are generally not accustomed to close human contact and therefore usually stunned and subsequently killed by the delivery of a well-placed bullet from a firearm. The Canadian Code of Practice describes the desired anatomic site for entry of a projectile as centered approximately 2.5 cm (1 inch) higher than an imaginary line connecting the bottom edge of the horns. The recommended angle of trajectory is perpendicular to the skull. Because the skull is thick and surrounded by frontal sinuses, a solid-point bullet from a 30:30 (or similar) caliber rifle is recommended for yearlings, cows, and bulls.[188] When a high-powered rifle is used, bison held in a stunning box can be shot in the poll position.

Water buffalo present similar stunning challenges. Although less common in North America, they fulfill a niche market for their meat and milk, the latter of which is richer in fat and protein and famous for its use in the production of mozzarella cheese. There are 2 types of domesticated water buffalo: (1) the river buffalo, which originated in India and Pakistan, and (2) the swamp buffalo, typically found in China, Southeast Asia, the Philippines, and Indonesia. Water buffalo have extensive frontal sinuses and thick frontal and parietal bones over the rostrodorsal region of the skull. Conventional captive bolt guns, including those with extended bolts, lose energy and fail to achieve sufficient penetration for consistent stunning of water buffalo when used over the frontal and parietal regions of the skull.[204] Studies comparing the frontal regions of the skulls of water buffalos with bulls found a median distance from the frontal skin surface to the thalamus of 144.8 mm (117.1 to 172.0 mm) compared to 102.0 mm (101.0 to 121.0 mm), respectively. Much of the observed difference was due to the size of the frontal sinus and the distance between the inner and outer tables of compact bone, which were 74.0 mm

(56.0 to 100.0 mm) in water buffalo versus 36.6 mm (29.3 to 44.3 mm) in bulls studied.[200]

An alternative method for overcoming the limitations of conventional captive bolt guns is by use of an appropriate caliber of firearm and bullet. Using bisected heads, forehead plates, and soap blocks, researchers conducted a series of handgun shooting experiments with semijacketed soft-point bullets with the following calibers: .44 Remington Magnum, .357 Magnum, and .38 Special. A 9-mm Luger loaded with a full metal jacketed bullet was also tested. These calibers and bullets were chosen because they are widely available and in common use by slaughterhouses processing water buffalo. Results of the study showed that the lighter 9-mm Luger or .38 Special bullets as well as large deformable .44 Remington Magnum bullets should be avoided in favor of heavier .357 Magnum deformation ammunition.[204]

Although firearms generally yield good results, they do not meet safety or legal requirements in all venues. Acting upon the previous observations suggesting better results with the .357 Magnum loaded with heavier deformable bullets, researchers developed and validated a bullet casing gun that fires a .357 Magnum 10.2 hollow-point bullet. In tests with this device, with the exception of one 9-year-old bull, the use of this gun resulted in a deep state of unconsciousness in 19 out of 20 water buffalo.[189] A recent study[205] of a similar type of stunner (called a ball flash stunner) found that a .357 MAG FTX bullet resulted in adequate stunning of water buffalo with a low risk of bullet overpenetration.

2. Cull cows

Culling is a management decision designed to remove animals with undesirable characteristics or poor performance. For example, when choosing which animals to cull, cattlemen consider pregnancy status, performance of a cow's previous calves, age and teeth wear, udder health and teat conformation, structural soundness of feet and legs, evidence of health problems, and the animal's disposition. The primary reasons dairy cows are marketed for slaughter are failure to become pregnant, mastitis, and lameness. From the packer's standpoint, the most desirable (or most profitable) cull cows are those that leave herds for failure to become pregnant, since these animals are usually in the best (fattest) body condition. Most of these animals, along with culled bulls, enter packing plants that process ground beef. Culling of cows needs to be done proactively to ensure that culled cows are suitable for transport to slaughter. This is important to ensure that the well-being of the cows is not compromised and is more likely to result in useable product. Cows should be culled before they become weak and debilitated. Unfortunately, there are still too many cull cows that are shipped after they deteriorate to a poor condition.[206] Another major welfare concern is shipping cull cows that have not been dried up prior to shipping.[206,207] A recent estimate is over half a million dairy cows that are unfit for transport are shipped every year to slaughter.[208] Many of the compromised cows move through auction barns to go to slaughter,[209] and these issues will require the dairy industry to come up with solutions to address this problem.[210]

Successful stunning of cattle (ie, cow rendered insensible between stunning and death by exsanguination) requires a penetrating captive bolt with sufficient bolt speed and power to penetrate the cow's skull. It also requires accurate placement of the captive bolt device over the intended site. When stunning procedures are properly applied, the likelihood of a return to sensibility is believed to be low. However, a Canadian study[211] designed to assess the likelihood of a return to sensibility following penetrating captive bolt stunning suggests differently. Thirty-two cull dairy cows were assigned to either group A (20 cows), which received penetrating captive bolt stunning followed by pithing (within 10 minutes of stunning), or group B, which consisted of 12 animals that were stunned but not pithed. Researchers observed that none of the 20 animals in the captive bolt plus pithing group (group A) regained consciousness, whereas 5 of 12 (42%) animals in group B (animals that were not pithed) exhibited signs of a return to sensibility (cattle that have been pithed are not considered acceptable or a safe product for the human food supply). Four animals were described as having clinical signs consistent with reversible stunning, and 1 demonstrated signs consistent with consciousness 20 minutes after being stunned with the captive bolt.[211] Because it is common practice to exsanguinate animals in the packing plant environment, there may be less likelihood that cows will return to consciousness. However, these results do confirm the need for an adjunctive step whether the objective is slaughter or euthanasia.

Grandin[55] reports that the best packing plants can achieve a successful first shot stun on average 97% to 98% of the time. In an earlier study by Grandin[110] involving 21 packing plants, 17 successfully rendered all cattle insensible before they were hoisted onto the bleeding rail, whereas 4 plants had cattle showing evidence of a return to sensibility that required restunning. Of 692 bulls and cull cows, 8 (1.2%) returned to sensibility after stunning. Stunning failure was attributed to storage of stunner cartridges in damp locations, poor cleaning and maintenance of the captive bolt guns, dirty triggers that resulted in misfire of the captive bolt, an inexperienced captive bolt operator who shot cattle too high on the forehead, and stunning of cattle with thick and heavy skulls.[110] A UK study[212] found that 1.7% of 628 cull cows were stunned poorly.

3. Nonambulatory cattle

On the basis of nonfed cattle reports[213–215] from federally inspected plants, the incidence of nonambulatory animals during 1994 and 1999 was 1.1% to 1.5% for dairy cows and 0.7% to 1.1% for beef cattle. During 2001, of 7,382 nonambulatory fed and nonfed cattle arriving at 19 packing plants in Canada, 90% were dairy cattle.[216] Furthermore, this study reported that < 1% of the nonambulatory cases devel-

oped during the transit process. Nearly all developed the nonambulatory condition on the farm of origin. A survey of auction markets where slaughter buyers purchase cull cows indicated that 13.3% of the dairy cows and 3.9% of the beef cows were severely emaciated.[39] Severe emaciation and weakness are factors that make cows more likely to become nonambulatory. While there are a few medical reasons why the downer cow condition is more common in dairy cattle, there is no good justification for the transportation of animals with a high probability of becoming recumbent. Producers must be vigilant in their efforts to avoid transporting animals unfit for travel.

Cattle that are nonambulatory for a period of more than 24 hours are commonly referred to as downers. Occurrence is highest in dairy cattle and often traced to metabolic disorders, injuries, and infectious or toxic disease conditions. Periparturient hypocalcemia (milk fever) and complications associated with calving are the most common predisposing causes of the downer cow condition. One study[217] identified the 3 major causes of downer cow problems in dairy cattle as hypocalcemia (19%), calving-related injuries (22%), and injuries from slipping and falling (15%). The primary cause of the downer cow syndrome in beef cattle is calving paralysis.[218]

4. Downer cow syndrome

Cows that are recumbent for prolonged periods are also subject to peripheral nerve injury and muscle damage that can increase the odds of a permanent nonambulatory state. Because of its sheer size and weight, a nonambulatory cow develops tremendous pressure on tissues of the downed leg, leading to decreased blood flow, hypoxia, and pressure necrosis of muscle and peripheral nervous system tissues. Because of its anatomic location, injury to distal branches of the sciatic nerve is particularly common in recumbent cattle. Ischemic damage to heavy muscles of the rear legs results in varying degrees of paresis that complicate the possibilities of recovery in affected animals. The corollary to this condition in humans as it is in animals is compartment syndrome.[219] The threshold for induction of permanent recumbency (down and unable to rise) in dairy cattle seems to be as short as 6 hours. Of 84 periparturient cows down with hypocalcemia, 83 (98.8%) recovered when treatment was instituted within 6 hours after they became recumbent.[220] Similarly, a survey[11] of dairy producers indicated that nonambulatory cattle that recovered and remained in the herd were down for < 6 hours. While good footing, attitude of the cow, and body condition are fundamental to care for nonambulatory animals, research from a UK study[221] suggests that good nursing care may have the single greatest effect on improving the prognosis for nonambulatory cattle.

i. The prevention of nonambulatory cattle and downer cow syndrome

Many of the conditions that predispose to nonambulatory cattle occur around the time of calving. As indicated previously, the primary risk factors for recumbency are hypocalcemia, complications associated with calving, and injuries. Close observation of cattle during the transition period (4 weeks before and after calving) and particularly during the periparturient period is essential to correct or treat problems promptly and as necessary. Transition cow personnel should be well trained and knowledgeable of transition cow problems. Early detection and treatment of hypocalcemia (ie, before the cow goes down) will reduce the potential for hypocalcemia-related complications. Cattlemen, dairymen, and dairy personnel who manage calving cows need continual training and updates on proper ways to assist cows with dystocia problems.

Finally, since many of the problems are related to injuries from slipping and falling, it is important that dairy operators be aware of flooring conditions that might predispose to falls. Some operations keep a log of areas where slips and falls commonly occur. This information can be used to determine when or whether corrective action must be taken (eg, altering of the flooring surface to increase traction). Owners and managers should also ensure that personnel move animals with care to avoid needless injury associated with careless handling and cattle-driving procedures. No one should assume that such information is common knowledge. Good operations continually review their cattle-handling procedures to avoid unnecessary injury to cattle as well as personnel.[215]

5. Bob veal

Calves fitting the definition of bob veal are those slaughtered within the first few days of life. Most are male calves from the dairy industry. These are to be distinguished from formula-fed (or milk-fed) veal, which are older calves raised on a milk formula supplement. About 20% of the neonatal bobby calves arrive at the slaughter plant with compromised welfare.[222] Dehydration is a major problem. Surplus bobby calves are a welfare issue that needs to be addressed.[223] It appears to be a regional issue. Throughout the US, huge numbers of Holstein dairy calves or Holstein Angus calves are entering feedlots to become finished beef cattle. This has increased the economic value of the calves and has resulted in improved care and treatment.

Veal is one of the most controversial welfare issues in modern agriculture. Those who oppose the raising of veal generally cite tethering of formula-fed calves in individual stalls that do not permit the calf freedom to turn around as one of the major breaches of animal welfare in veal production. Housing of veal calves has changed in recent years. Today, most start out in individual pens where they can be fed and managed more carefully, thereafter being moved to group pens of 4 to 6 animals.

Neonatal (or bob veal) calves require greater effort and care in handling. Since they are removed from the dam at birth, they tend to imprint on humans. They have little natural fear of humans and do not exhibit the flight-or-fight responses normally observed in older calves. Moving them requires actually picking them up or carefully pointing them in the desired direction. They are incapable of responding

to an electric prod, and use of such devices becomes little more than torture. For busy stockpeople unaccustomed to neonatal calf handling, the process can be painfully slow and cumbersome.

Bob veal calves are typically transported from the dairy to a packing plant or other gathering location within 24 to 48 hours of birth. Transport to slaughter may require as much as 12 to 24 hours; animals that have not received an initial feeding of colostrum or milk will arrive at the plant with varying degrees of hypoglycemia, dehydration, and physical exhaustion. Some of these calves will be nonambulatory on arrival at the plant. Under its current rules, the FSIS will permit these animals to be set apart and held for treatment before being moved to slaughter. The Humane Society of the United States petitioned the FSIS to amend the regulations to require that nonambulatory disabled veal calves be condemned and promptly and humanely euthanized. On April 4, 2011, the AVMA sided with the Humane Society of the United States and recommended that this provision be repealed to be consistent with the AVMA's current policy on disabled livestock, which states the following:

> **Down livestock at terminal markets (e.g., slaughterhouse or packing plant)**
> Animals that are down should be euthanized immediately and not taken to slaughter.[48]

On March 13, 2013, the FSIS decided to grant the petition, resolving one of the more challenging problems for regulators and others concerned about ensuring the welfare of nonambulatory calves at slaughter.

6. Pregnant animals

The USDA prohibits the transport of pregnant farm animals in the final 10% of their gestation period. In situations where transport of heavily pregnant cattle is unavoidable, a veterinarian's advice on the animal's fitness for travel should be sought. If the veterinarian finds the animal fit for travel, transport must be kept to periods of 8 hours or less, and feed and water must be available upon arrival at the destination. In theory, tight adherence to these rules would preserve the welfare of late-term pregnant animals, but they are difficult to enforce. The number of pregnant cattle entering packing plants in the US is unknown but could be estimated to be in the range of 25% or more. This estimate is based upon a report[224] published in 1954—the only study in the US from a group of researchers studying bovine genitalia at slaughter. In that study, of 1,000 cows slaughtered, 255 (25.5%) were pregnant. Since there are no federal laws prohibiting the slaughter of pregnant animals in the US, it is assumed that the rate has changed very little since this original study.

Although the study by Perkins et al[224] is nearly 70 years old, it is similar to a more recent Danish study by Nielsen et al[225] in 2017, where approximately 23% of cows entering slaughterhouses were observed to be pregnant. In that study,[225] 28% of pregnant cows were in the first trimester, 49% in the second trimester, and 22% in the third trimester of pregnancy. A significantly lower prevalence of cattle pregnant at slaughter was reported recently by Austrian researchers. In their study of 1,633 female cattle, 104 (6.4%) animals were reported to be pregnant, and only 16 (1%) were in the last third of gestation.[226]

The slaughter of pregnant animals presents an ethical dilemma for some, particularly when conducted in cattle during the third trimester. Since it is known that the fetus has the neurological capacity for sentience in late gestation, some are concerned that the fetus may suffer as a result of the death of the dam. Despite a few studies[227,228] that question or suggest differently, the preponderance of scientific information indicates that although sentient, the fetus remains incapable of experiencing pain or distress.[229–234]

The movement of pregnant animals to slaughter is not a matter of insensitivity on the part of farmers. Pregnant animals are sometimes presented for slaughter because owners are unaware of their pregnancy status. Not all farmers pregnancy test animals prior to transport to market or slaughter. For those who knowingly send pregnant animals to slaughter, it is often justified for the sake of animal health and welfare or for economic reasons. For example, an animal that is ill or injured, yet still able to be safely slaughtered for human use, can be spared additional suffering through emergency slaughter. The economic realities of animals that are no longer productive yet may be pregnant may require slaughter to reduce continued economic loss. Although ethically problematic, Danish dairy farmers sometimes opted for slaughter of pregnant cows because they felt slaughter was likely better for the cow than having to endure the stress of calving and a potentially stressful lactation period.[225]

i. Fetal effects

Fetal bovine serum (FBS) is a key ingredient in biomedical research. It contains a unique blend of both growth-stimulating and growth-inhibiting factors that are necessary for the maintenance of cells in cell culture media. Despite attempts to match or find a suitable equivalent, FBS remains the gold standard for research and development requiring cell culture techniques. The worldwide demand for new and improved human and animal vaccines along with many other biopharmaceutical products indicates that the need for FBS will increase significantly in the years to come. The fetal bovine (calf) serum market was valued at $879.9 million in 2021, with an estimated growth over the next 10 years to more than $1.6 billion by 2031.[235]

The collection of FBS occurs at slaughter when the carcass of the cow is eviscerated and found to be pregnant. The reproductive tract is isolated from the abdominal tissues where the fetus is removed, cleaned, and disinfected. Blood is drawn from the fetus by cardiac puncture into a sterile container where it is cooled and allowed to clot. The final step is refrigerated centrifugation where the serum is separated from the clotted blood.[227] The slaughter of pregnant cows with respect to their stage of

pregnancy has implications for the amount of FBS that can be collected. For example, the yield from a 3-month-old fetus is about 150 mL of raw FBS, the yield from a 6-month-old fetus is 350 mL, and the yield from a 9-month-old-fetus is approximately 550 mL of raw FBS.[227]

As mentioned earlier, concerns for safeguarding the welfare of fetuses at slaughter and at the point of FBS collection is important for at least 2 reasons: (1) sentience of the fetus and possible capacity to experience pain and (2) the resistance of mammalian fetuses to anoxia. Behavioral and EEG evidence to date indicates that mammalian fetuses are insentient and unconscious throughout the first 75% to 80% of gestation.[234] As neuronal pathways between the cerebral cortex and thalamus become better established, the fetus develops the capacity for sentience. However, within the protected environment of the uterus, the fetus remains in an unconscious state due to the presence of 8 or more neuroinhibitors that act on the cerebral cortex to maintain it in a sleep-like state of unconsciousness. At birth, the combined effects of reduced neuroinhibition and onset of neuroactivation contribute to gradual arousal of the mammalian newborn into a state of consciousness.[234]

These observations indicate that the fetus does not suffer as if drowning in amniotic fluid when the dam is slaughtered; instead, the fetus simply passes from its unconscious state to death. Likewise, the sleep-like unconscious state prevents it from experiencing pain associated with other types of invasive procedures while in utero. These studies also support the rationale for international guidelines on the handling of fetuses suggesting that fetuses should not be removed from the uterus before the EEG is found to be isoelectric. For example, when the dam is killed by physical methods that include exsanguination, delaying removal of the fetus from the uterus for a minimum of 5 minutes after hemorrhaging from exsanguination has ceased generally assures an amount of anoxia-induced damage to the cerebral cortex of the fetus sufficient to prevent progression toward a return to consciousness.[135] If there is any doubt as to the fetus's level of consciousness when removed from the uterus, it should be euthanized immediately by captive bolt.

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H. Figures

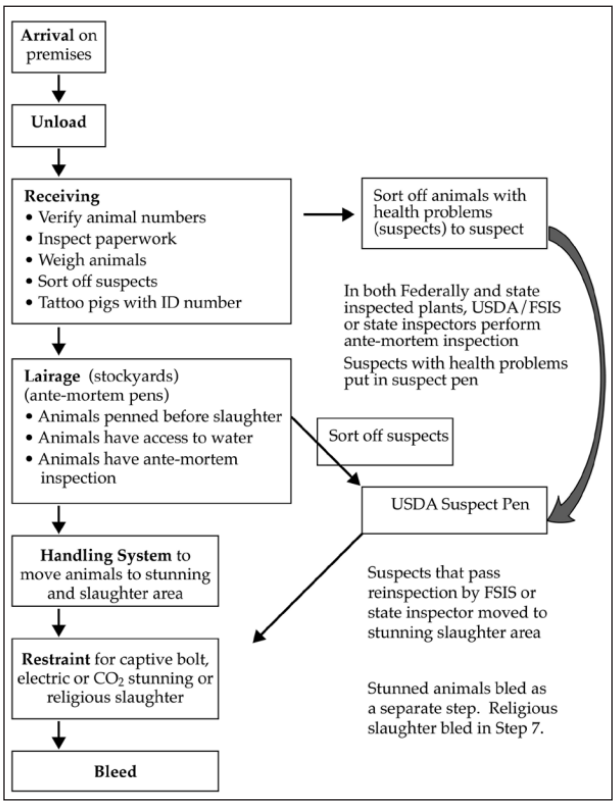


Figure 1

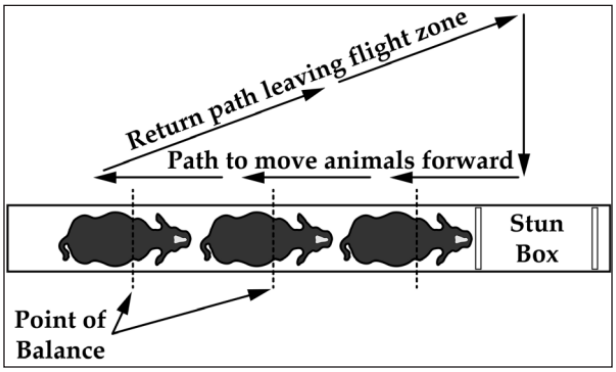
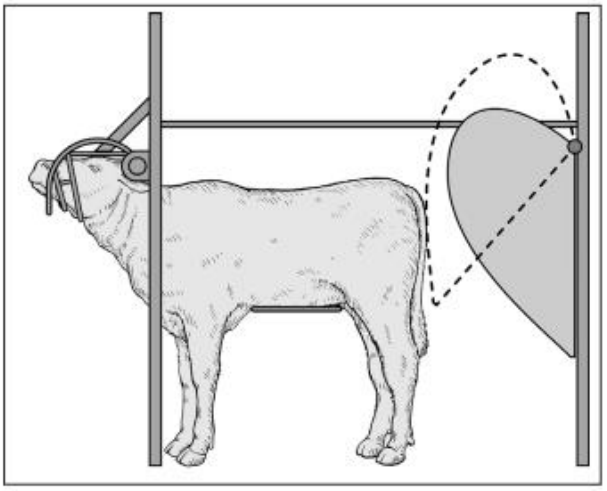


Figure 2



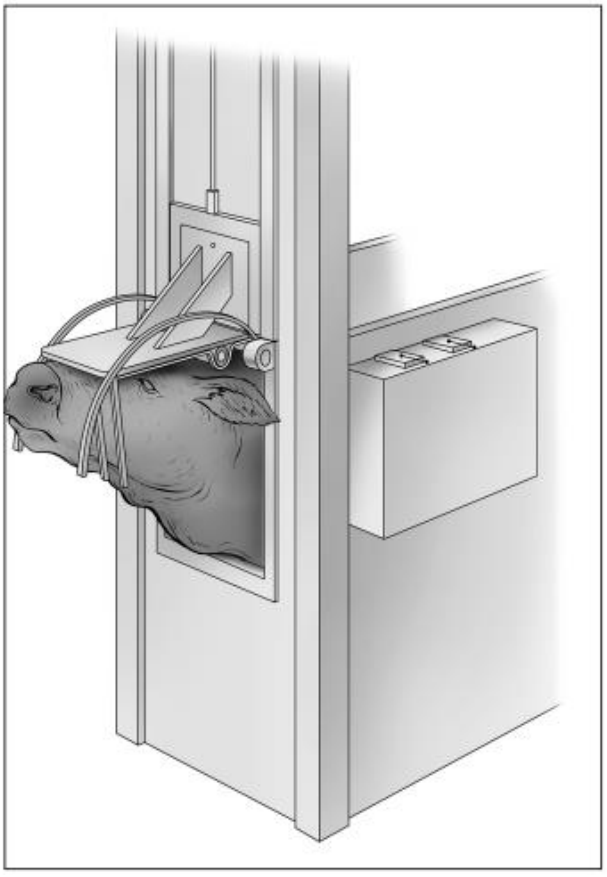


Figure 3

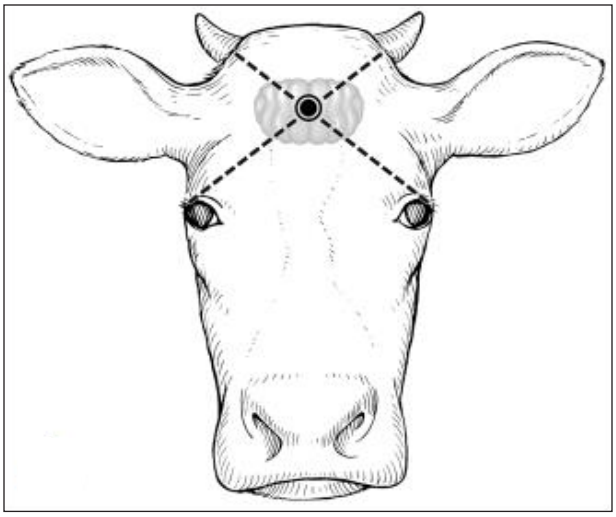


Figure 4

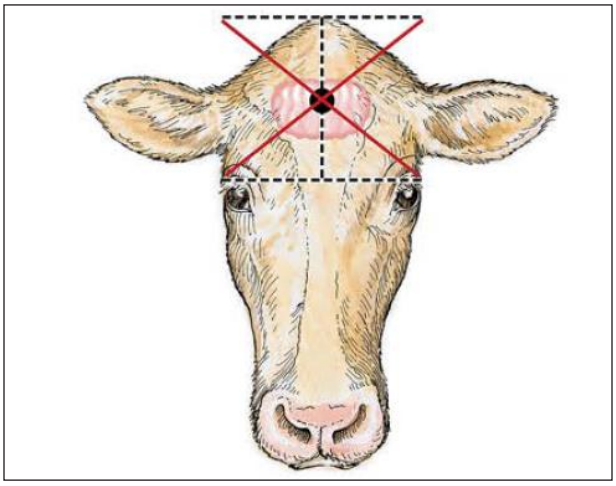


Figure 5

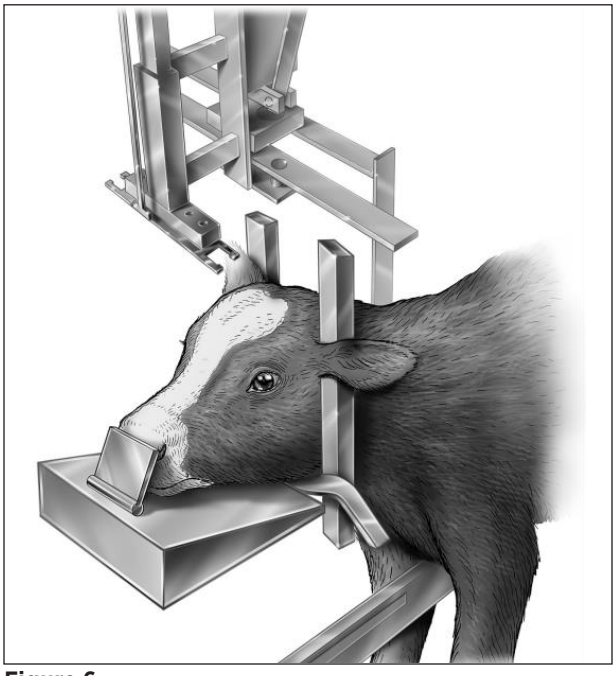


Figure 6

Chapter IV: Equids

A. General Considerations

The Panel on Humane Slaughter has worked diligently to identify and apply the best research and empirical information available to promote the humane slaughter of horses, donkeys, and mules. Equid slaughter has not existed in the US since 2007. Equid slaughter is not illegal in the US; however, Congress has defunded USDA inspections of equid slaughter plants. It is USDA veterinarians who are responsible for ensuring the welfare of animals at slaughter as well as the purity and safety of the meat for human consumption. Due to the inability for federal inspections and subsequent closure of US equid slaughter plants, a number of equids are transported across US borders for slaughter. There is also increasing international concern about increased numbers of donkeys going to slaughter. Donkey hides are a source of a traditional medicine.[1] Drug residues are a concern. The threat of residues is handled differently in different countries. The Canadian Food Inspection Agency verifies compliance by performing daily inspections of all federally licensed slaughter establishments. The Canadian Food Inspection Agency randomly tests meat for pesticides, environmental contaminants, and drug residues. In addition, they observe all animals before stunning and postslaughter for clinical signs of medical conditions that may have been treated with phenylbutazone. In addition, the Canadians have set maximum residue limits.[2]

The European Union (EU) also has strict residue requirements, and the EU follows rigid protocols.[3] Phenylbutazone is not allowed in the human food chain.

Equids designated for slaughter should be treated with respect and handled appropriately. The slaughter process should limit the stresses experienced by these animals through the use of slaughter methods designed for a rapid loss of consciousness and ultimately a complete loss of brain function. Humane slaughter methods commonly utilized on equids produce unconsciousness via physical disruption of brain activity (penetrating captive bolt, gunshot to the brain). It is imperative that all individuals involved in the slaughter process be well educated in understanding equine behavior so that problems can be immediately detected and corrected to minimize stress and suffering to the horse. This includes handling conditions and care prior to slaughter. Individuals directly involved in the slaughter process must be highly skilled in the application of existing methods of euthanasia.[4]

B. Animal Behavioral Considerations

These Guidelines are concerned with minimizing animal distress, including negative affective or experientially based states such as fear, aversion, anxiety, and apprehension, during the slaughter process. They are also meant to promote human well-being and safety relative to the repeated termination of animals' lives. Veterinarians and other employees involved in slaughter should familiarize themselves with preslaughter protocols and be attentive to species and individual variability to mitigate distress in both animals and human handlers. The method for inducing unconsciousness and the handling and restraint methods associated with it must be evaluated as an entire system.[5]

Intentional violations of the Humane Methods of Livestock Slaughter Act (HMSA) must not be tolerated. Unintentional pain and/or distress at slaughter caused by mistakes by personnel or poorly designed facilities must be addressed promptly. At all stages of the process of termination, animals should be treated with respect. Compromises to animal welfare should be treated as unacceptable if not unlawful. Practitioners and stockpeople should ensure the following:

- No conscious animal is dragged, shackled, hoisted, cut, or treated inappropriately or disrespectfully. Before invasive dressing (eg, skinning or leg removal) begins, all signs of brainstem function, such as the corneal reflex, must be abolished.
- Excessive force or inappropriate use of electric prods to move animals off trucks, up and down ramps, or into slaughter facilities or restraint devices must be avoided. Animals should not be forced to move faster than a normal walking speed. Handlers should move animals quietly, without using driving devices that would cause unnecessary pain and/or distress.
- Nonambulatory, disabled, or down animals are euthanized immediately.
- Equids are provided with immediate access to water in the lairage pens. Sufficient good-quality food must be provided if animals are held. Animals should have sufficient room to move in accordance with state, federal, and local statues, and pens should have room for all the animals to lie down.
- Slaughter facilities and equipment are well maintained to minimize stress, injury, or pain to the animals and employees.
- The process of induction of unconsciousness (eg, stunning) must impart minimal distress to the animal.
- All personnel must be trained and highly skilled in both the application of stunning methods and behavioral principles of animal handling.

C. Human Behavioral Considerations and Training

Veterinarians may be asked to bridge the physical and psychological divide between current practices used in the care and management of animals used for food and consumers by communicating the realities of conventional food production. They may also be asked to provide an ethical accounting and monitoring of animals' welfare on the farm, in

feedlots, and at slaughterhouses to the public in a transparent fashion. Veterinarians are encouraged to continually increase their awareness of slaughter methods to enhance understanding of the science behind the methods currently used while being mindful of the complexities of managing animals humanely and the challenges facing our contemporary food animal sector. Likewise, industry agents, caretakers, and others engaged with the slaughter of animals for food are strongly encouraged to understand the diversity of public concerns and trending societal values and expectations related to how animals are farmed, transported, held, and slaughtered for food. The humane slaughter of horses is a complex learned skill that requires education, training, respect, self-awareness, observation, and continued research that must be maintained at the highest levels of ethical standards. Personnel performing humane slaughter must be technically proficient. Periodic professional continuing education on the latest methods, techniques, and equipment available for slaughter is imperative. Personnel must also possess a temperament that does not bolster brutality. Compassion fatigue, callousness, and insensitivity can result in individuals involved in the processing of animals for food; self-awareness is critical to ensure the welfare of the horse. While integrating good animal welfare practices, veterinarians may be torn among serving the best interest of the horse, client needs, and concerns of society for improving the quality of life for animals (social license). More studies on both the impact of animal slaughter on the personnel performing it and on attitudes toward the consumption of animals for food among the general public will go a long way toward promoting healthier and more respectful human–food animal relationships.

D. Facility Design and Slaughter Process

1. Arrival at the plant

The normal process is for the horses, donkeys, and mules to be unloaded promptly after a vehicle arrives at the plant. In the best operations, the vehicles are unloaded within 15 to 60 minutes after arrival, and industry guidelines recommend a maximum wait time of 60 minutes.[4] This requires the scheduling of an appointment between the plant and transporter. Scheduling vehicle arrival times prevents the problem of too many vehicles arriving at the same time, which results in long lines and delays at unloading. A recent survey[6] showed that 58% of horse owners viewed horses as companion animals. This may have been a factor in the stopping of horse slaughter in the US. Horses in the US that are destined for slaughter travel to plants in Mexico and Canada. Seventy-nine percent of the horses arriving in Mexico had bruised carcasses, and some of them may not have been fit for transportation.[7] Ocular discharge, nasal discharge, and lameness have potential to be key welfare indicators of fitness for travel.[8] There is a need to establish fitness-for-travel standards.[9] One survey[10] that was conducted before US horse slaughter plants closed showed a high prevalence of conditions that would have severely compromised welfare before the horse left the farm of origin. During hot weather, delayed unloading can result in severe animal welfare problems due to heat stress. **Figure 1** shows the step-by-step flow of animals through the plant.

i. Detection of problems

There have been unfortunate cases where many animals have died while waiting an entire day to unload. This serious problem is most likely to occur when there is an emergency condition such as a power failure or storm that either shuts down the plant or makes roads impassable.

ii.. Corrective action for problems

It is best practice to have an emergency program either to divert incoming trucks to other slaughter facilities or to unload animals at auction markets, feedlots, or fairgrounds. This will require a coordinated program that facilitates immediate cancellation of animal loading on the farm and diverts loads that are en route to other facilities.

2. Unloading

When unloading is done correctly, animals will move off the vehicle in a quiet, orderly manner. Handlers should be quiet and refrain from yelling, whistling, or repeatedly hitting the sides of the vehicle. The sound of people yelling has been shown to be very stressful for livestock.[11,12] Electric prods can be eliminated during unloading of most equids. Use of electric prods on horses is strongly discouraged. They should only be used as a last resort when all other options have been exhausted. Acceptable handling tools for horses include flags and rattle paddles.[4,5,13]

i. Detection of problems

Industry guidelines advise that if more than 1% of animals fall during unloading or more than 5% of animals are unloaded using an electric prod, there is a welfare problem in the unloading area.[14–16] Most plants can achieve this standard, as most larger plants have banned the use of the electric prod at unloading. There is a problem if animals in the unloading area run into fences or pile up. Quiet handling also provides the advantage of greatly reducing bruises, which is an economic incentive for the facility. Some references about cattle are included in the equids section because they illustrate problems that occur with all species.

At the time of unloading, plant employees should note whether the vehicle is overloaded. Vehicles should be loaded per industry and international guidelines.[4,5,17]

Overloading of trucks can lead to welfare concerns in addition to economic losses. Bruised meat cannot be used for human consumption. Overloading horses will lead to fighting, restlessness, falling, and injury.[18] Equids should also be observed for transport-induced welfare problems such as frostbite, heat stress, dehydration, lacerations, fractures, laminitis, pleuropneumonia, and urine scald.

Another problem that can seriously compromise animal welfare at the slaughter plant is when the animal

is in poor condition prior to leaving the farm. Animals that are weak, emaciated, or severely lame can make human handling difficult and potentially dangerous.

ii. Corrective action for problems

Nonslip flooring in the unloading area is essential for all species.[14–16] Quiet handling and good welfare will help to minimize the risk of animals slipping and falling. For all species (with the possible exception of birds), a rough broom finish is not a satisfactory nonslip floor. A rough broom finish quickly wears down and becomes smooth and slick. For cattle, horses, and other large animals, a 20 X 20-cm (8 X 8-inch) diamond pattern with 2.5-cm (1-inch) or deeper V grooves is recommended.[19] There are other suitable finishes for stamping concrete that are rougher than a broom finish. Epoxy or grit finishes work well for smaller species, but they will not provide sufficient traction for large animals that have become agitated. For existing slick floors, there are several options. In high-traffic areas, such as unloading ramps and scales, rubber traction mats can be used. Another option is to construct a flat steel grating that will not induce hoof injury. More information on flooring and the design of unloading ramps can be found in reports by Grandin and Deesing[19] and Grandin.[14,15]

Research[10] has shown that the number one welfare issue with horses arriving at slaughter is owner neglect that occurred on farm. Packers should clearly communicate back to producers that the shipment of unfit animals is unacceptable and implement a financial penalty for the practices.

3. Receiving

For horses, unloading areas for large trucks should be designed with at least a 3-m (10-foot) level unloading dock before the ramp starts.[20] After unloading, the normal practice in most plants is to verify that the number of animals on the vehicle matches the paperwork. In some plants, there is an extra handling step of weighing individual animals after unloading. However, many plants have eliminated this by weighing the entire truck before unloading. Weighing the entire truck has the advantage of reducing bruising of animals.

i. Detection of problems

The most likely problems that can occur during receiving is falling, piling up, or hitting fences. This would be an indicator that handling needs to be improved.

ii. Corrective actions for problems

Provide nonslip flooring for equids. If horses rear, they are frightened or resistant; this indicates a serious problem that must be corrected.

4. Lairage, stockyard, and antemortem pens

In most plants, animals are held in the same groups that they traveled with on the trucks, which is the ideal. In large plants, a typical lairage pen holds either 1 or 2 entire truckloads. It is important to design the pens to accommodate an entire truckload versus a truckload and a half, as this could lead to having 2 truckloads forced into a pen that is too small for the number of animals.

When new stockyards are being built, they should be laid out so that there is 1-way livestock movement through the yards. Ideally, the unloading ramps are at one end of the yards and the chutes to the stunner are at the other end. One good design is to have all the animals enter the pens from one alley and move to the stunner through the opposite end of the pens. Designs for lairage pens are in reports by Grandin and Deesing.[10,19,21] In smaller plants, there may be single or small groups of animals arriving from many different owners. Horses from each owner must either be held in their own small pen or have physical identification such as a tattoo, brand, or microchip. Hip numbers with marking pens can be helpful to prevent their identification from becoming mixed up with other animals.

The HMSA[22] requires that all lairage pens be equipped with water troughs or other suitable devices so that the animals have access to water. Well-designed and maintained lairage pens will be free of sharp edges that can injure animals. Industry recommendations for lairage pen space are 25 sq ft (2.3 m^2) to 30 sq ft (2.8 m^2), which is too small to fit many of the equids. The animals should be provided sufficient space that they can all lie down at the same time. Before animals can be moved to the slaughter area, they undergo antemortem inspection. After inspection, the lairage pen is tagged as ready for processing. The exception to this rule is custom-exempt plants, which process animals for personal use by the owner or producer.

i. Detection of problems

The 3 main problems that can occur in the lairage pens are overstocking of the pens, fighting between horses causing injuries, and animals that become nonambulatory.

ii. Corrective action for problems

When fighting occurs, there is usually 1 horse that is the main perpetrator. This animal should be removed from the group and placed in a separate pen that allows continued visual contact with conspecifics (to avoid the stress of social isolation). Similarly, fighting is a major cause of bruising in horses.[10] In small plants, some of the worst fights are caused by singly raised backyard animals that have never learned how to socialize with other animals.[10] To prevent fighting, singly raised animals should be slaughtered within 1 hour after arrival, after allowing them a minimum of 30 minutes to calm down.

The HMSA regulations forbid dragging of nonambulatory animals unless they have first been stunned. In the US, the only acceptable methods for moving nonambulatory animals are sleds, skid steer loaders, or specialized carts. In Canada, nonambulatory animals must be euthanized on the trailer and cannot be moved with sleds, skid steers, or specialized carts. The AVMA's policy on disabled livestock[23] provides recommendations for down animals including but not limited to the following: Nonambulatory animals may be moved using a sled, mat, cart or mechanized equipment that supports the full length and weight of the animal. A nonambulatory animal should not be dragged or lifted by the limbs, tail, neck, or ears.

5. Handling system

A wide variety of systems are available to move cattle from lairage pens to the place where they are stunned or ritually slaughtered.[13,19,24] Many of the cattle systems will work well for horses. When animals are handled correctly, they move in an orderly fashion with no falling or pileups and minimal vocalizing or use of electric prods. Horses should never be backed into the stun box.

i. Detection of problems

Both industry guidelines and USDA FSIS regulations prohibit abusive practices such as dragging downed nonambulatory animals: poking sensitive areas such as the eyes, anus, or udder; slamming gates deliberately on animals; deliberately driving animals over the top of a down animal; and beating animals.[4] Handling problems that compromise welfare can result from a facility problem or an employee training issue. Before modifications are made to a facility, employees should be trained to use behavioral principles of livestock handling.[19,21,25] When people handle equids in a calm, quiet manner, design problems in the facility can be easily located and corrected. For all species, if more than 1% of the animals fall at any point in the facility, there is a problem that needs to be corrected.[4,13,26] An automated powered gate that causes an animal to either fall or be dragged along the floor is a serious problem.

ii. Corrective actions for problems

Crowd pens that lead to the single-file chute (race) should not be overloaded—Horses should be moved into the crowd pen in small, separate groups.

When horses are handled in a tub system, the tub should be only half full, the crowd gate should never be used alongside the tub and single-file chute, and overhead catwalks should be avoided. Overfilling the tub or overcrowding with the gate will cause animals to bunch up and turn back from the single-file entry. Animals should be allowed time to move through the system without being rushed. When the animals are moving through the system themselves, they should be left alone. If the lead animal balks, allow it time to investigate and move forward.[5]

Use natural following behavior—The next group of horses or donkeys should not be brought into the crowd pen that leads to the single-file chute until there is space in the single-file chute. This enables the animals to immediately enter, promotes natural following behavior,[19] and prevents them from turning around.

Horses arriving at auction markets and processing plants come from a variety of backgrounds and with various degrees of training. This can make their behavior more unpredictable than that of other species. Handlers should always use caution and treat these animals as though they are untrained. Handlers should approach a horse on the left side, as traditionally horses are trained to be left-side dominant. This is because most humans are righthanded and must stand on the left side of the horse to lead with their right hand. It is important for horses to always have visual contact with other horses until they enter the kill box. This will aid in keeping them calm and will motivate them to move forward as their herdmates do.[5]

Teach handlers behavioral principles—Handlers need to understand behavioral principles such as flight zone and point of balance.[13,27,28] The most common mistake when moving animals through chutes is a handler who stands at the head of an animal and pokes its rear in an attempt to make it move forward. Standing in front of an animal prevents it from moving forward. Handlers should be taught to use the movement pattern shown in **Figure 2**.[13] When a person quickly walks back past the shoulder of an animal in the opposite direction of desired movement, the animal will move forward. This is an effective method for many species. For horses, it is recommended to have 2 people to handle and stun the horse. One person moves the horse into the stun box and the other person shoots it. This makes it possible to shoot the horse immediately and minimize the time it remains in the stun box. If only 1 handler is used, the horse is more likely to become stressed and agitated because the single handler has to walk from the tailgate to the stunning position.

Prohibit routine carrying and use of electric prods—In most plants that have adequate facilities, the only place where an electric prod is occasionally needed is at the entrance to the stun box or restrainer. The prod should be kept in a convenient location and only used when needed. After it is used to move the occasional reluctant, hesitant, or resistant animal, it should be put away. Alternatives, such as vibrating prods or plastic paddles, should be the handler's primary driving tool. A vibrating prod can be made from a pneumatic engraving tool where the sharp tip has been removed. A plastic bag on the end of a stick works well for horses; this is a common method used on horses reluctant to enter the trailer.

Use powered gates carefully—When a powered gate is used to move animals, it should be equipped with controls that enable a person to immediately stop its movement if an animal falls down. Automated powered gates must be equipped with pressure-limiting devices to prevent the gate from either knocking animals over or dragging animals along the floor.

Remove distractions that cause balking—Movement of animals through a handling facility can often be greatly improved by making many small changes in the facility that remove visual and aural distractions that cause animals to balk and refuse to move.[13,19,26]

- When an animal enters a stun box or restrainer, it must not have air blowing in its face.[13,21,25]
- Use a directional lamp to provide indirect lighting to light up dark chute entrances. Animals have a tendency to move from a dark place to a brighter place.[26]
- Eliminate reflections on shiny metal or wet floors. Moving a light source may eliminate a reflection on a wet floor.[25] Reflected glare from shiny metal surfaces increases balking of cattle in plants.[29]
- Cover the sides of chutes or install solid barriers to prevent approaching animals from seeing people, vehicles, or moving machinery ahead.[26,30] Large pieces of cardboard can be used experi-

mentally to determine where solid shields are needed. The outer perimeter of a handling facility is one of the most important areas to cover.
- Animals often refuse to walk over changes in floor type, such as moving from a concrete to a metal floor. Livestock are also likely to balk at sharp shadows.[31]
- Reduce noise made by equipment, such as air hissing and metal-on-metal banging and clanging. Sudden intermittent sounds and movements are more likely to cause agitation.[32,33] Many slaughter plants have high noise levels.[34,35]

6. Restraint

A list of design principles to reduce stress during restraint follows. These principles are applicable to conventional slaughter, which uses stunning before bleeding.

1. Ensure pressure applied is optimal. The device must apply enough pressure to make an animal feel restrained but avoid excessive pressure that will cause struggling or vocalization. A common mistake is to apply additional pressure when an animal struggles.[35]
2. Do not trigger fear of falling. This is why nonslip flooring is so important. For conventional stun boxes where the animal stands upright, nonslip flooring is critical. Stun boxes should never have a steeply sloped or stepped floor. Instead, a flat floor is recommended.
3. Ensure smooth, steady motion of parts of the restraint device that contact animals. Sudden jerky motion will cause animals to become agitated.[35]
4. Block animals' vision of people, moving equipment, and activity on the floor. To prevent balking and improve ease of entry into the restraint device, animals entering the device should not be able to see people, moving equipment, or activity on the processing floor. Horses are taller than cattle, and if horses and cattle are processed in the same facility, higher solid sides should be installed to prevent horses from looking over the top out onto the slaughter floor.
5. Ensure stun boxes are of appropriate size. Stun boxes must be the appropriate size for the animals being processed. Animals must not be able to turn around in the box.

i. Detection of problems

Vocalization can be easily measured in plants to detect problems with restrainers that are used for cattle, horses, or pigs. Animals will vocalize if excessive pressure is applied or another aversive event occurs.[36,37] If a horse struggles or vocalizes while being restrained, it is often an indication that the restraint is causing discomfort. Active head restraints are more stressful for horses than full-body restrainers and should be avoided.[5]

When a restraint system is overloaded beyond its design capacity, the use of electric prods may increase as handlers attempt to move animals through the plant. The following measures can be used to assess the performance of restraint devices:

1. Percentage of horses or donkeys that vocalize while they are held in the restraint device. The North American Meat Institute voluntary industry standard for vocalization is 5% or less of the animals.
2. Percentage of horses or donkeys that fall down to the extent that the body touches the ground. The voluntary industry standard is 1%.[4] However, the goal should be zero. Restraint devices that trip animals or that are designed to make animals fall are not permitted in the voluntary industry standard.[4]
3. Percentage of animals moved with an electric prod into the restraint device. The voluntary industry standard for cattle is < 5% for an excellent score and < 25% for an acceptable score. AVMA policy states that "electrical devices (e.g., stock prods) should be used judiciously and only in extreme circumstances when all other techniques have failed."[38]

All scores are per animal. Either the animal is moved with an electric prod or it is not. Either it is silent, or it vocalizes. Devices that paralyze animals using electricity should not be used as a method of restraint. Studies[39–42] clearly indicate that electroimmobilization is highly aversive and should not be used. Electric immobilization must not be confused with electric stunning that causes unconsciousness. Animals that have been immobilized with electricity will not be able to vocalize to show their distress.

ii. Conditions that cause welfare problems

Failure to provide nonslip flooring—One of the most common problems in stun boxes is slippery floors.[26] When animals are continuously slipping, they cannot stand still for stunning. Designs for nonslip floors can be found in the Unloading section. Metal grating or rubber mats work well to prevent slipping in stun boxes.

Overloading single-animal stun boxes and restrainers—Single-animal stun boxes or restraint boxes have a maximum speed of approximately 100 animals/h. Boxes designed to hold single animals result in slower line speeds than conveyor systems because they use a start-stop process to put each animal in the box and then remove it. Conveyor systems should not be used for equids. The signs of an overloaded box are as follows:

- Slamming the rear gate on animals.
- Increased electric prod use.
- More than one animal in the box for stunning.
- An increase in rough handling.

For all equids, when the line speed exceeds 100 animals/h, the use of 2 or more single-animal boxes is recommended.

Funnel-shaped crowd pens—Designs for appropriate crowd pens for cattle may be found in publications by Grandin[5,19,35] and the Horse Welfare Association of Canada.[5] Chute and crowd pen layouts designed for cattle will usually work well for horses. The single-file chute (race) should have straight sides with an inside width of 76 cm (30 inches) for most horses. If draft breeds are processed, the chute should be 81 cm (32 in). The use of V-shaped chutes designed for cattle is not recommended.

Stun boxes and single-file chutes that are too wide—The appropriate width for stun boxes and chutes tends to be overestimated. Stun boxes and chutes that are too wide result in animals turning around and becoming caught beside each other. Chute width may need to be adjusted for exceptionally large or small animals.

Vertical overhead gate clearance is too low—Animals will often refuse to walk under a vertical slide gate or other apparatus that allows for scant clearance or touches their back. Raising the opening height 16 cm (6 inches) will usually fix this problem. On center-track restrainers, the solid hold-down cover may need to be raised to prevent bumping of the animal's shoulder when it is entering.

Single-file chute is too short—The single-file chute has to be long enough that a sufficient number of animals can be held within it to allow the time to refill the crowd pen.

Animals allowed to stand in a stun box too long—Animals should be stunned immediately after they enter the stun box or restrainer. Holding an animal alone in a stun box can cause isolation stress. To reduce the time the horse waits in the stun box, 2 people should be used. One person should move the horse into the box and shut the tailgate while the other shoots it.

E. Techniques

1. Physical methods

A penetrating captive bolt gun accomplishes the same immediate brain death induced by gunshot. This method also requires careful technique to ensure humane treatment of the horse. Most bolt guns are designed to be placed firmly against the skull, but otherwise placement and precautions are nearly identical to euthanasia by gunshot. The site for entry **(Figure 3)** of the projectile is described as being on the intersection of 2 diagonal lines each running from the outer corner of the eye to the base of the opposite ear.[1]

F. Special Considerations

Facilities for donkeys should be adjusted to accommodate their smaller size. The negative societal impact of slaughter for the purpose of harvesting skin gelatin (ejiao) must be considered.

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H. Figures

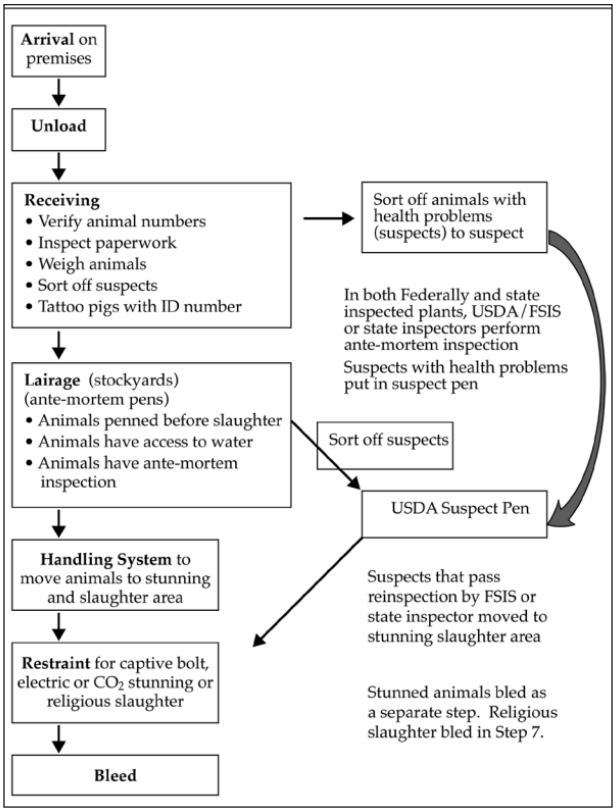

Figure 1

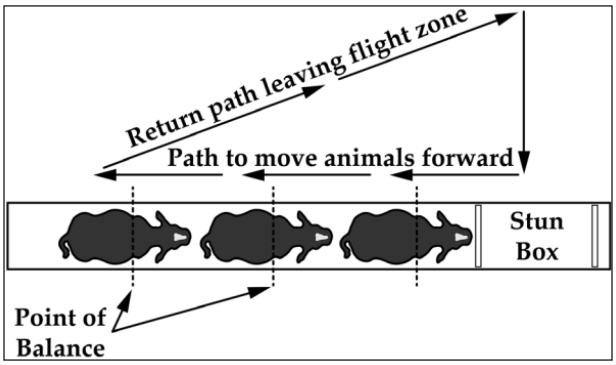

Figure 2

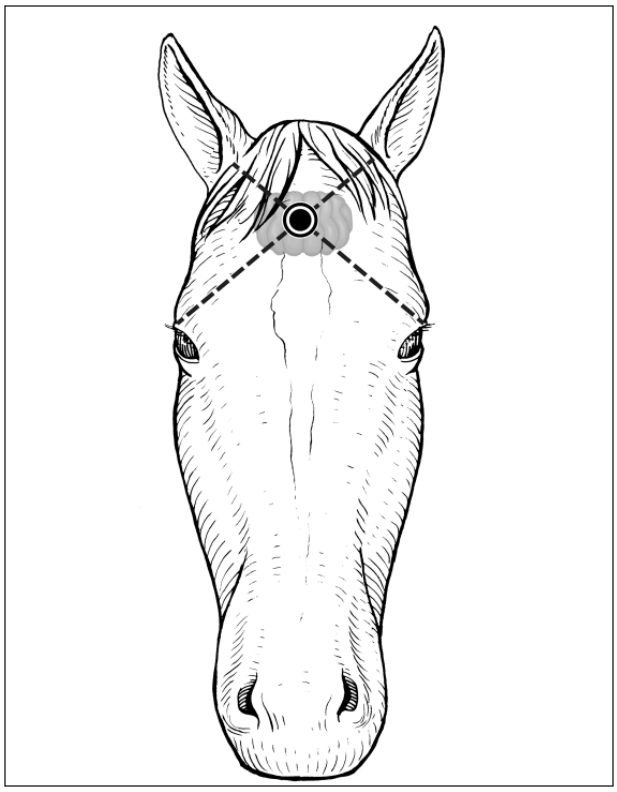

Figure 3

Chapter V: Furbearers

A. Rabbit (Meat and Fur)

1. General considerations

In the US, rabbits raised for food and fur are not covered by the Humane Methods of Livestock Slaughter Act or the Animal Welfare Act. While federal inspection of rabbit meat is voluntary, individual states may have rabbit-specific inspection requirements.[1] Because many rabbit producers in the US process their own rabbits on farm, there are few USDA-inspected plants that commercially process rabbits. Most of the available information on commercial rabbit processing comes from Europe, where commercial rabbit processing is more common. For interstate commerce, meat rabbits not voluntarily inspected at slaughter by the USDA are under the regulatory oversight of the FDA.

2. Animal behavior considerations

Rabbits are prey animals that retain behavioral patterns similar to their wild counterparts.[2] Therefore, the harvesting, transport, and handling of rabbits prior to slaughter are stressful.[3] A 2-fold increase in serum cortisol was seen in rabbits after transport regardless of whether they endured rough or careful handling during loading, indicating that the entire process was stressful.[4] Other biomarkers of stress in rabbits include elevations in serum glucose, serum triglycerides, serum aspartate aminotransferase, alanine aminotransferase, glutamyl transferase, lactate dehydrogenase, creatinine kinase, and myocardial creatinine kinase, as well as decreases in serum tetraiodothyronine.[5] Elevations of these values have been reported in rabbits during transport and lairage.[6]

3. Human behavioral considerations and training

Personnel handling rabbits should be familiar with basic rabbit behaviors, appropriate handling techniques, and the importance of animal welfare throughout the slaughter process.[7] Regular staff rotation between various tasks should be considered to minimize boredom and compassion fatigue, which can result in diminished attention to welfare concerns. Those workers directly involved in the slaughter process should be well trained in the processes used and should demonstrate proficiency in the skills required to perform humane killing. It is essential that line staff be adequately trained to recognize signs of consciousness, unconsciousness, and death in rabbits during stunning and killing. Line speeds should be adjusted as needed to ensure that staff have adequate time to perform their duties without compromising animal welfare.

4. Facility design and slaughter process

The preslaughter environment presents the combined effects of many emotional and physical factors. Multifactor (social and nonsocial) stressors involved in the preslaughter process can affect rabbit welfare as well as meat quality. Social and nonsocial stress may occur owing to changes of environment: for example, new or unfamiliar habitat, separation of familiar companions, presence of strangers or exposure to a strange group, destabilization of an established hierarchy, aggressive encounters, alarm vocalizations, social disturbances, handling, disruption of the social group, changes in social structure, mixing with unfamiliar animals, food deprivation, and climatic conditions. High stocking densities in crates should be avoided to minimize distress and trauma due to intraspecies aggression; the recommended minimum floor space for 12-week-old rabbits is 1,800 cm^2.[8]

i. Arrival at the plant

Upon arrival at the slaughter facility, personnel should be available to perform a welfare assessment, and further assessments should be made during each stage of the slaughter process.[7] Providing adequate ventilation, preventing exposure to extreme temperatures, providing food and water for prolonged lairage, and avoiding long delays between arrival and stunning are important factors in maintaining rabbit welfare in the preslaughter period.[8] Unloading of crates from the transport vehicle should occur rapidly following arrival and should occur quietly, avoiding loud noises, rough jarring of crates, or tipping of crates beyond the horizontal to minimize stress on the rabbits.[7] Extended lairage times should be avoided, and periodic welfare checks should be performed in situations where processing delays result in prolonged lairage. Rabbits that have been without water for 6 or more hours should be provided water during lairage, and food should be provided for rabbits if the time between transport and processing is expected to exceed 12 hours.[7,9] This not only is good for animal welfare but reduces live weight and carcass losses.[8]

ii. Lairage

Lairage areas should be protected from the elements to minimize exposure to temperature extremes. Ideal temperatures for rabbit lairage are between 15 and 25 °C (59 and 77 °F), and temperatures above 35 °C (95 °F) are detrimental to rabbit welfare.[7] It is important to remember that when crates are stacked, rabbits located centrally in the stack may be prone to hyperthermia and poor ventilation, while rabbits in crates on the periphery may be subject to hypothermia. Crates for transport and lairage should have solid floors to prevent urine and feces transfer from higher crates. Multifloor cage stands can adversely affect welfare if rabbits are left in them for long periods of time.

iii. Handling system

Removal of rabbits from crates and restraint in the processing area should be done quietly and gently to minimize the risk of stress and injury to the rabbits. Rabbits should never be lifted by the scruff of the neck or the ears, as these methods can cause distress, pain, and injury.[10] Rabbits should be lifted

from underneath the body and carried close to the handler's body to minimize struggling or scratching. Young rabbits may be lifted by grasping the loin area but should never be carried in this fashion. The hind end must always be supported to prevent kicking out with the back limbs, which can result in serious back injury, which can cause pain as well as result in diminished carcass quality. Captive bolt restraining areas should include nonslip surfaces with backstops to prevent rabbits from backing away.

iv. Restraint

Commercial processing of rabbits in the US is generally performed in plants designed to process poultry.[11] Rabbits should be stunned prior to shackling; shackling and hanging of conscious rabbits must be avoided. Shackling has been shown to be painful and distressful to poultry,[12,13] and without additional research to show differently, it must be assumed that it is also painful and distressing to conscious rabbits.

5. Techniques

Successful stunning is characterized by cessation of respiration, excessive salivation, and increased motor activity (eg, immediate onset of tonic spasm followed by weak to heavy clonic spasms).[14,15] Not all animals develop convulsive muscle activity, and cessation of rhythmic breathing is considered a more reliable indicator of a successful stun, although some consider lack of corneal reflex as the best measure of insensibility in rabbits.[16]

i. Physical methods

Proper technique is essential when utilizing physical methods of slaughter to avoid pain or distress to the animal. Ideally, rapid stunning is followed in < 10 seconds by severing of carotid arteries resulting in rapid exsanguination and death. Personnel must be skilled at determination of signs of unconsciousness and death in rabbits to avoid unnecessary animal suffering.[7]

Electrical stunning must be performed using skilled personnel and properly mounted electrodes. Electrodes should be cleaned as needed to provide an unimpeded current, and the rabbit head must be positioned such that the current does not pass through the eyes.[7]

Maria et al[17] studied 5 methods of electrostunning for commercial rabbits (n > 50) using variable voltages and frequencies. Voltages < 19 V were not recommended.[17] The most common parameters used in commercial facilities were 49 V, 5.6 milliseconds, and 189 Hz for 3 seconds. These parameters did not produce changes in muscle pH.[18] Anil et al[14] recommend a minimum current of 140 mA by application of 100 V to obtain adequate stunning. The European Food Safety Authority recommends that a power of 100 to 117 V, current of 140 to 400 mA, frequency of 50 Hz, and duration of 1 to 3 seconds be used in head-only stunning devices.[7,19] Impedance from rabbit fur can result in a wide range of achieved currents, resulting in variation in the effectiveness of the stun. Stunning devices should employ an impedance- or resistance-sensing device that will prevent discharge in the event of insufficient stunning current; this will minimize the risk of inadequate and painful mis-stunning. The stunned state lasts for at least 22 seconds, although in adequately stunned rabbits, insensibility lasts for at least 71 seconds.[14]

A captive bolt apparatus designed for waterfowl can be used on rabbits.[15] Captive bolt application requires skilled operators and well-maintained equipment. With penetrating captive bolts, the best stunning results are obtained with a shot to the parietal bone near the sagittal line but without hitting bone sutures.[15] This is achieved by placing the captive bolt slightly paramedian on the front as close to the ears as possible **(Figure 1)**. It is essential to stabilize the head to prevent misses.

Following electric or captive bolt stunning, rabbits are immediately shackled and exsanguinated by a throat cut that severs both carotid arteries in a single stroke.[7] Knives must be sharp to ensure that an adequate cut is made to avoid the necessity of multiple cuts and/or stimulation of wound edges. Rabbits must be killed within 35 seconds after electric stunning or they may recover consciousness.[8] In commercial rabbit plants in Europe, exsanguination commences within 5 to 8 seconds following stunning, with many managers allowing no more than an average of 15 seconds.[8,16] Bleeding time is reported to be 10 to 12 seconds to 2 to 3 minutes.[3]

ii. Atmospheric methods

Controlled atmosphere stunning using CO_2 has been studied in rabbits, but an effective CO_2 concentration that will provide adequate stunning without evidence of distress or pain in rabbits has not been determined.[7,20] Controlled atmosphere stunning of rabbits is not permitted in the European Union and is currently not recommended.

iii. Immersion methods

Not applicable.

6. Special considerations

i. On-the-farm slaughter

The use of rabbit-sized nonpenetrating captive bolts have been shown to result in immediate insensibility in 100% of rabbits when utilized for on-the-farm slaughter.[21] Animals should be restrained on nonslip flooring, preferably in an open-top container allowing the area of the rabbit to be pressed against the container wall. Using the nondominant hand, the operator should restrain the rabbit by pressing on the shoulder blades, and the thumb and forefinger should be placed gently around the neck of the rabbit. The device must be maintained in clean working order, positioned correctly (Figure 1) and discharged twice in rapid succession at the pressure recommended for the age and size of the rabbit (55 psi for preweaned kits, 70 psi for growers, 90 psi for adults).[21] Operators must be trained, preferably on cadavers.

Blunt force trauma by means of striking the head with a heavy object or against a hard surface is difficult to perform properly, has an unacceptably high failure rate, is aesthetically displeasing, and can lead to operator fatigue.[21] For these reasons, it is not recommended for on-the-farm slaughter of rabbits.

Cervical dislocation is also used for on-the-farm slaughter of rabbits.[22] Cervical dislocation may induce rapid loss of consciousness, does not chemically contaminate tissue, and can be rapidly accomplished.[23,24] However, manual cervical dislocation may be aesthetically displeasing to personnel performing or observing the method, and it requires mastering technical skills to ensure loss of consciousness is rapidly induced. The use of a mechanical cervical dislocation device that secures the rabbit's head prior to the operator applying downward force to the hips and back legs was > 97% effective in producing immediate insensitivity in growing and adult rabbits.[21]

Data suggest that electric activity in the brain persists for 13 seconds following cervical dislocation in rats,[23] and unlike decapitation, rapid exsanguination does not contribute to loss of consciousness.[25,26]

However, there may be species differences in responses to cervical dislocation, as the use of a mechanical cervical dislocation device in rabbits resulted in apparent immediate insensibility as measured by loss of pupillary reflex, rhythmic breathing, palpebral reflex, toe/ear pinch withdrawal, and corneal reflex.[21]

Individuals performing mechanical cervical dislocation must be trained in the appropriate use of the specific mechanical device, ideally using cadavers. Manual cervical dislocation must be performed by individuals with a demonstrated high degree of technical proficiency. In lieu of demonstrated technical competency, animals must be unconscious prior to cervical dislocation. For adult rabbits, the large muscle mass in the cervical region makes manual cervical dislocation physically more difficult.[27] For immature rabbits, the head is held in one hand and the hind limbs are held in the other. The animal is stretched, and the neck is hyperextended and dorsally twisted to separate the first cervical vertebra from the skull.[28,29] Those responsible for the use of this method must ensure that personnel performing cervical dislocation have been properly trained and consistently apply it humanely and effectively.

Decapitation is not commonly employed in the commercial slaughter of rabbits but is sometimes used for on-the-farm slaughter.[30] Operator competence is required to perform decapitation in a humane fashion. The operator must be familiar with the technique and able to accurately place the blade high on the neck, ideally at the level of the first vertebrae. Blades used for decapitation must be maintained properly; they must be sharp enough to sever the entire head without need for more than 1 blow. Rabbits must be restrained to prevent them from moving away from the blade.

B. Mink and Foxes

1. General considerations

Unlike other farmed species, animals bred for fur are essentially wild animals that have undergone only a very limited domestication process. Breeding has primarily focused on fur quality, not on tameness or adaptability to captive environments. As the primary animals raised commercially for fur in the US are mink and foxes,[31] this section will focus on these 2 species. However, the general guidelines should be considered applicable to other species that may be farmed for fur (eg, chinchillas). Rabbits are primarily raised for their meat, with fur as a possible by-product, and are therefore covered in a separate section.

In the US, regulation of fur animal production is scant. Fur-bearing animals are exempt from the federal Animal Welfare and Endangered Species Acts and the Humane Methods of Livestock Slaughter Act, and regulation is largely left to the individual states. States vary in their regulation of fur farming, primarily under the oversight of the state Department of Agriculture.[31] Due to general lack of federal and state regulations, US fur-farming industries are largely self-regulated via national organizations whose members (fur ranchers) are expected to adhere to established guidelines on husbandry and humane treatment of foxes (US Fox Shipper's Council) and mink (Fur Commission USA).[32–34] Both organizations recommend that killing methods used prior to fox and mink pelting adhere to the AVMA Guidelines for the Euthanasia of Animals.[35]

2. Animal behavioral considerations

i. Foxes

Under normal farm conditions, foxes tend to demonstrate aggression or fear-aggression toward humans.[36] Selective breeding for "tameness" can produce strains of foxes that are more tolerant of, or even friendly toward, humans, making handling of individual foxes easier.[37] Pedersen et al[38] found that handling of fox pups during preweaning and early postweaning stages improved their acceptance of human handling later in life, although biochemical markers for stress during handling (eg, serum cortisol levels) were not significantly improved over foxes that had not had early handling. Other behavioral characteristics such as confidence and exploratory behavior were positively impacted by early-age handling, so the authors concluded that early handling was overall beneficial to farmed fox welfare and ease of handling.[38]

ii. Mink

Farmed mink are not as domesticated compared to other livestock, and they maintain a level of innate fear of humans.[39] This innate fear coupled with sporadic contact with humans can make handling a stressful event for mink, so killing methods that entail minimal restraint and handling of individual mink are recommended.

3. Human behavioral considerations and training

Personnel performing slaughter must be fully trained in species-appropriate animal-handling techniques, application of the killing method, and methods of confirming that death has occurred.[34] Personnel must be proficient with the proper use and

maintenance of the equipment used, including appropriate safety practices necessary to prevent human injury or death.[34]

4. Facility design and slaughter process

Killing and pelting of fur animals is performed on farm.[40,41] Although early handling can improve the tolerance of foxes for handling, implementation of euthanasia techniques for foxes or mink that require significant levels of restraint (eg, IV injection, electricity) should be preceded by sedation to reduce animal stress and allow proper application of the method.[42]

5. Techniques

In the US, the most common killing methods for farmed foxes for pelting include electrocution and CO. In the US, the industry-recommended method of killing farmed mink for pelting is CO, with CO_2 listed as an alternative method.[33] Regardless of method, it is essential that each individual animal be examined upon completion of the technique to ensure that death has occurred.

i. Physical methods

Electrocution of foxes using commercially available equipment specifically designed for foxes is acceptable.[40] Homemade or "jury-rigged" apparatus are not acceptable. Ideally, equipment will include a meter and display that allow monitoring of proper function.[43] Equipment must be maintained and used according to manufacturer instructions, and battery recharging should occur as often as necessary to maintain optimal performance.[35,43] To facilitate proper restraint and reduce stress, foxes may be sedated prior to application of electrical current.[44] A current of 0.32 to 0.69 A administered for 2.34 to 5.21 seconds via rectal and oral electrodes induced immediate unconsciousness and electroencephalographic evidence of status epilepticus with no return to normal brain pattern before death was confirmed.[44] For humane slaughter of farmed foxes, Korhonen[43] has recommended a minimum current of 0.3 A, 110 V, and 100 Hz applied for at least 3 seconds (preferably ≥ 5 seconds) using oral and rectal rod-shaped electrodes.[43]

ii. Atmospheric methods

Killing of foxes and mink by means of CO_2 or CO should be performed in accordance with the AVMA Guidelines for the Euthanasia of Animals.[35] Personnel should be thoroughly trained in the use of the specific gas and equipment, including hazards, appropriate safety precautions, and indicators of excessive human exposure. Pursuant to these Guidelines, purified, compressed gas in cylinders with appropriate pressure-reducing regulators and flow meters (or equivalent equipment) must be used; the use of gases generated from internal combustion motors (CO) or dry ice, fire extinguishers, or chemical means (CO_2) is unacceptable. Gases must be used in compliance with state and federal occupational health and safety regulations. Flow rates of gas must allow the chamber to achieve species-appropriate gas concentrations. Animals must remain in the chambers for a sufficient time to ensure death has occurred, and trained personnel must evaluate each animal to ensure death has occurred immediately after removal from the chamber.

Chambers **(Figure 2)** must be of high-quality construction, be utilized in well-ventilated environments or outdoors, and be well lit with a view.[35] Chambers should be mobile, should be easily cleaned, should provide consistent performance, and should be constructed for ease of operation and personnel safety.[33] The mink industry believes that a dark chamber results in easier and less stressful placement into the chamber and that the darkness appears to calm the mink.

Carbon dioxide—As diving animals, mink have inconsistent responses to CO_2.[35] In farmed mink, concentrations of 70% CO_2 were not uniformly effective, while > 80% effectively killed farmed mink within 4 to 5 minutes.[44] In many species, exposure to high concentrations (> 50%) of CO_2 can cause 10 to 15 seconds of mucosal pain prior to loss of consciousness.[45] Available studies differ on the aversiveness of high CO_2 concentrations in this species. Cooper et al[46] found that mink introduced to a chamber precharged to 80% CO_2 showed signs of aversion including reluctance to enter, sneezing, and coughing. Conversely, Korhonen et al[44] found no evidence of coughing, sneezing, or other signs of distress in mink placed in a chamber containing 2% to 3% CO_2 that was then gradually filled to 80% CO_2. Some countries consider CO_2 to be unacceptable,[45] while Fur Commission USA allows for use of CO_2 using chambers charged with a minimum of 80% by gradual fill.[33] However, because of the potential for CO_2 to be aversive, the use of CO_2 is not recommended in mink; CO is the preferred atmospheric method for foxes and mink.

Carbon monoxide—Concentrations of 4% to 6% CO can result in rapid death; flow rates should be sufficient to rapidly reach target concentration after animals are placed in the chamber.[35] CO poses significant hazards to personnel if safety measures are not followed and equipment is not properly used or maintained; concentrated CO is highly flammable/explosive.[35] The use of CO detectors is recommended in any confined area where CO is in use or stored.

iii. Immersion methods

Not applicable.

iv. Injectable methods

The use of barbiturate-based euthanasia solutions administered by a trained, licensed professional via IV injection is acceptable; prior sedation is necessary for restraint.[35] When IV administration is impractical or impossible, IP injection of a nonirritating barbiturate may be used.[35] Euthanasia solutions are controlled drugs that must be administered by a licensed professional, which generally makes their routine use impractical for large-scale on-farm humane killing of mink for pelting.[40] Carcasses of animals euthanized with barbiturate-based euthanasia solutions must not be rendered or in any way enter animal or human food chains and must be disposed of in accordance with local, state, and federal laws.[35]

6. Special considerations

There is a lack of reliable scientific research on humane methods of slaughter for animals raised for fur. Further relevant studies are needed to make science-informed decisions on humane slaughter of these animals. Other methods such as percussive blow to the head, captive bolt, cervical dislocation, and gunshot are generally neither used nor considered appropriate for killing of fur-bearing animals for harvesting at pelting.[47]

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D. Figures

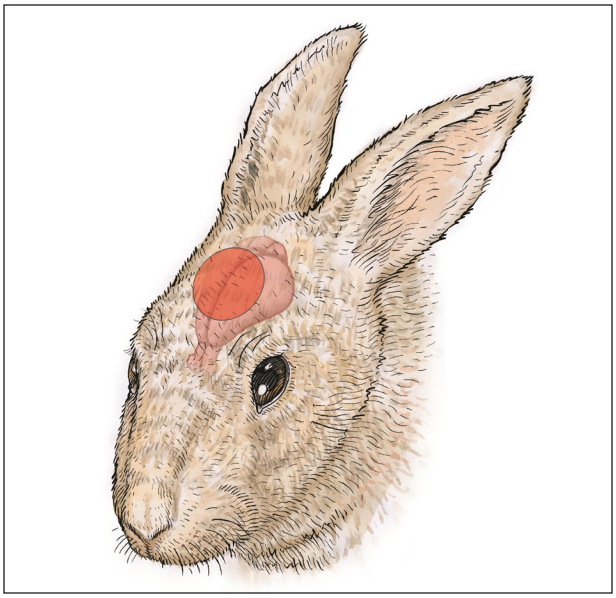

Figure 1

Figure 2

Chapter VI: Reptiles and Amphibians

A. Crocodilians

1. General considerations

In the US, alligators are not covered by the Humane Methods of Livestock Slaughter Act and are classified as seafood for federal meat inspection purposes.[1] A small fraction of alligators is harvested from the wild, but the vast majority of alligators entering the hide and meat markets are raised on alligator farms, primarily in the Southern and Gulf Coast states. Historically, alligators have been farmed primarily for their valuable hides, although in recent years the value of alligator meat has increased substantially.[2,3] Most, if not all, farmed alligators are slaughtered on farm prior to either processing onsite or shipment to processing facilities.[4] This minimizes the damage to hides that might occur during mass shipment of live animals.

2. Animal behavioral considerations

Reptiles represent a taxa with a diverse range of anatomic and physiologic characteristics such that it is often difficult to ascertain that a reptile such as an alligator is, in fact, dead. Reflexes commonly used to monitor consciousness in mammals (eg, corneal reflex) are not consistent in reptiles.[5] Although reptiles respond to noxious stimuli and are presumed to feel pain, our understanding of their nociception and response to stimuli is incomplete. Nevertheless, there is increasing taxa-specific evidence of the efficacy of analgesics to minimize the impact of noxious stimuli on these species.[6] Consequently, slaughter techniques that result in rapid loss of consciousness and minimize pain and distress should be strived for, even where it is difficult to determine that these criteria have been met.[6]

3. Human behavioral considerations

Because of the potential of alligators to inflict significant injury to humans, it is essential that personnel involved in handling alligators be thoroughly trained in basic alligator behavior and appropriate means of safely working with the animals. Handling of alligators prior to killing should follow standard welfare guidelines and best practices for alligator management to minimize stress to the alligators and to minimize the risk of injury to alligators and human personnel.[4] Personnel should have appropriate training on the humane handling of alligators, and every effort should be made to avoid stress or overheating of the animals.

4. Facility design and slaughter process

Not applicable, as slaughter is done on farm.

5. Techniques

Alligators possess unique anatomic and physiologic traits that can make it difficult to ensure quick and humane death. Reptiles have a relatively high tolerance for hypoxia compared with mammals, making techniques that deprive the brain of oxygen (eg, exsanguination, decapitation) less effective at inducing rapid death[7]; some reptiles may remain conscious up to an hour following decapitation. Studies of varying physical methods of euthanasia of American alligators indicate that penetrating captive bolt, nonpenetrating captive bolt, and pithing reduce brain wave activity to levels equivalent to or below those of anesthetized alligators; these methods were considered to be appropriate methods for euthanasia.[5] In contrast, severance of the spinal cord alone resulted in brain wave activity that did not significantly differ from that of awake animals; for this reason, spinal cord severance alone (as occurs during decapitation) is considered an inappropriate technique for American alligators. Percussive stunning by a blow to the head with a hard implement is unlikely to cause death because of the size and thickness of the alligator skull in market-size animals (> 3 feet in length). Cervical dislocation is not considered an acceptable method in alligators owing to the resistance of the reptilian brain to hypoxia and to the thickness of neck muscles making vertebral dislocation very difficult.[7,8]

i. Physical methods

For purposes of humane slaughter, the following methods are considered acceptable provided that they are performed with proper equipment that is properly maintained by trained personnel who are regularly monitored for proficiency:

Penetrating or nonpenetrating captive bolt firearms targeting the brain of the alligator—Care must be used to ensure proper placement to ensure destruction of brain tissue.

Gunshot delivered to the brain—This method may be used provided that the legal and safety concerns (eg, ricocheting bullet fragments) of using firearms are addressed. Care must be used to ensure proper placement to ensure destruction of brain tissue.

Decapitation or spinal cord severance—This method is acceptable only if preceded by a stunning method to induce unconsciousness and immediately followed by pithing to ensure destruction of brain tissue.[8]

Proper placement of captive bolts or gunshots is imperative to ensure a rapid and humane death in alligators, and proper restraint of the animals is essential to minimize the risk of mistargeting, as well as ensure the safety of personnel. Brain destruction should occur during or immediately after a stunning method. The brain of the alligator is relatively small and is located immediately behind the orbits and extends caudally between the supratemporal fossae. To ensure destruction of brain tissue, the captive bolt or gunshot must be placed on the midline between the orbits and the cranial aspect of the supratemporal fossae. Although an approach from behind the skull plate aiming forward through the occipital bone is sometimes used in wild alligator harvests, this ap-

proach is likely to only sever the spinal cord without destroying the brain and is therefore not appropriate. **Figure 1** illustrates the appropriate positioning for captive bolt or gunshot placement and the appropriate site for decapitation following stunning.

ii. Atmospheric methods

Not applicable, as these methods are not utilized.

iii. Immersion methods

Not applicable, as these methods are not utilized.

6. Special considerations

The following killing methods are considered unacceptable for slaughter of alligators: cervical dislocation, exsanguination, hypothermia, hyperthermia, suffocation, asphyxiation or drowning, and decapitation or spinal cord severance without prior stunning method (eg, captive bolt) followed by pithing.

B. Frogs

1. General considerations

Although there are several species of frog that are consumed by humans, the North American bullfrog (*Aquarana catesbeiana*, *Lithobates catesbeianus*, *Rana catesbeiana*) is the species most commonly farmed for commercial production due to its ease of handling, rapid growth, large size, prolificacy, and meaty legs.[9] The largest producers of farmed bullfrogs are Taiwan and Brazil, with other contributors including several southeast Asian, Latin American, and South American countries. Little to no commercial frog farming occurs in the US, and frog meat marketed in the US is either imported or obtained through harvesting of wild North American bullfrogs.[9,10]

2. Animal behavioral considerations

Although historically amphibians have been viewed as having little to no sentience, recent research has found that amphibians are capable of experiencing negative states such as pain, fear, distress, and anxiety.[9,11,12] Housing of captive African clawed frogs (*Xenopus laevis*) with white backgrounds in their tanks subverted the frogs' instincts to utilize their normally protective camouflage against darker backgrounds and resulted in elevations of waterborne corticosterone, atypical behaviors, and weight loss.[13] Environmental parameters such as temperature, water quality, stocking density, food availability, and sanitation can significantly affect animal welfare; these parameters should be adjusted as needed for frog species and life stages.

3. Human behavioral considerations and training

A main obstacle to the institution of humane handling and slaughter of frogs is the historically apathetic attitude toward the potential for the animals to experience pain or distress.[14] Adequate training of personnel is necessary to maximize the welfare of frogs throughout the slaughter process, as optimization of preslaughter welfare of frogs can have significant influences on productivity and meat quality.[15]

4. Facility design and slaughter process

Although both the United Nations Food and Agriculture Organization (FAO) and Brazil have standards of frog slaughter that attempt to address welfare issues, in many countries the welfare of frogs raised or harvested for slaughter is not a priority.[9,14,16] Brazil appears to be the only country with formal processing (slaughter) facilities and regulations for frogs; in most other areas, slaughter occurs on farm or during harvest and is poorly regulated.[9,17] Specific information on transportation and handling of frogs produced for slaughter is lacking, but basic welfare information for frogs used in laboratory research can be utilized as a starting point, with adjustments made for differences in species requirements for parameters such as stocking density and temperature ranges.[18] As with other species, handling and transportation of frogs should be targeted to avoid excessive physical or environmental stressors that would have negative impacts on animal welfare.

5. Techniques

Brazilian slaughter standards for frogs require electric or thermal stunning,[15] while the FAO suggests electrical stunning as the acceptable method to use on frogs immediately prior to bleeding, decapitation, or pithing.[16] A comparison between electrical and thermal stunning suggested that electrical stunning may be less stressful than thermal stunning.[15] Ramos et al[19] showed that meat pigment and heme concentration were similar between frogs exposed to electrical versus thermal stunning.

i. Physical methods

For purposes of humane slaughter, the following method is considered acceptable provided that it is performed with proper equipment that is properly maintained by trained personnel who are regularly monitored for proficiency:

Stunning followed by pithing, bleeding, or decapitation—Electrical stunning should be prioritized over thermal stunning.

Electrical stunning—Alves et al[15] utilized a 45.5-V, 10-A electrical current with a resistive filter for 4 seconds to electrically stun bullfrogs, and blood for analysis was taken immediately after stunning. Electrodes were positioned with one electrode in contact with the center of the head and another electrode at the bottom in contact with the gular region of the bullfrog. Hematological and biochemical parameters from these frogs were not significantly different from bullfrogs kept in a holding pen, suggesting that the process was of relatively low stress. The authors concluded that the electrical stunning was efficient and provided for acceptable animal welfare as well as high meat quality. The authors state that more research is needed to determine whether electrical stunning achieves instant unconsciousness as well as the ideal electrical parameters required.

Thermal stunning—Alves et al[15] studied thermal stunning of bullfrogs using 1-°C water in 20-L buckets containing 5 kg of crushed ice, 5 L of water, and 0.5 kg of salt. Bullfrogs were submerged in the ice water for 15 minutes until complete paralysis

occurred, then blood samples were obtained. Hematological and biochemical parameters indicated that thermal stunning resulted in significantly more stress in the bullfrogs compared to electrical stunning. The FAO specifically mentions that using 10% salt solutions for thermal stunning of frogs is unacceptable.[16]

ii. Atmospheric methods

Not applicable, as these methods are not utilized.

iii. Immersion methods

Not applicable, as these methods are not utilized.

6. Special considerations

The following methods are considered unacceptable for the humane slaughter of frogs:

- Use of 10% salt solutions for thermal stunning
- Bleeding, evisceration, or severing the legs of conscious frogs.

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D. Figures

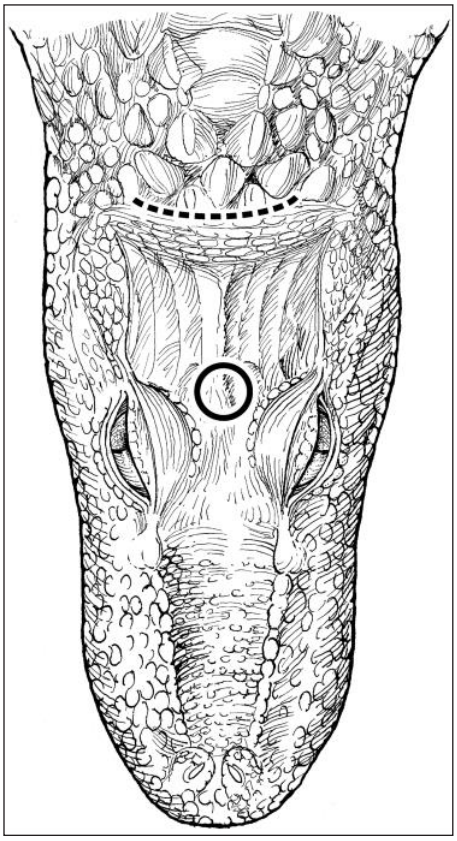

Figure 1

Chapter VII: Small Ruminants, Camelids, and Cervids

A. Goats and Sheep

1. General considerations

While still relatively minor sources of animal protein in the US, slaughter of sheep and goats is increasing.[1] Consumption of small ruminant meat is growing, particularly in ethnically diverse communities. However, consolidation of the processing capacity for slaughter for these animals has impacted the industry. There are a limited—and declining—number of slaughter facilities that focus on sheep in the US. The implications of this trend are that animals are often transported greater distances and over longer periods of time than they have previously. In contrast to sheep, there are even fewer goat processing plants. In fact, in some states a significant percentage of the goats slaughtered are actually slaughtered and processed by the end consumer. Federal inspected slaughter of goats in the US is limited. Small local processors slaughtering under state inspection play a significant role in small ruminant slaughter, as does "on-farm" slaughter. Concurrent with these trends, there is a significant percentage of sheep and goats that are slaughtered following a system based on religious principles.

2. Animal behavioral considerations

These Guidelines are concerned with minimizing animal distress, including negative affective or experientially based states such as fear, aversion, anxiety, and apprehension during the slaughter process. They are also meant to promote human well-being and safety as regards the repeated termination of animals' lives. Veterinarians and other employees conducting slaughter should familiarize themselves with preslaughter protocols and be attentive to species and individual variability to mitigate distress in sheep and goats as well as the human handlers. The method for inducing unconsciousness and the handling and restraint methods associated with it must be evaluated as an entire system.

Physical methods require handling and restraint of individual animals, but they induce instantaneous unconsciousness. There may be a tradeoff between possible distress during a longer time to induce unconsciousness and the benefits of reduced handling of individual animals.

Intentional violations of the Humane Methods of Livestock Slaughter Act (HMSA)[2] must not be tolerated. Unintentional pain and/or distress at slaughter caused by mistakes by personnel or poorly designed facilities must be addressed promptly. At all stages of the process of termination, animals should be treated with respect and compromises to animal welfare should be treated as unacceptable if not unlawful. Practitioners and stockpersons should ensure the following:

- No conscious animal is dragged, shackled, hoisted, or cut inappropriately. Before invasive dressing (eg, skinning, leg removal, scalding) begins, all signs of brainstem function, such as the corneal reflex, must be abolished. Currently, shackling and hoisting is used with sheep and goats immediately prior to religious slaughter. The goal is to move more small-scale religious slaughter to the use of a properly designed restraining pen as shown in **Figure 1**.
- Excessive force or frequent use of electric prods to move animals off trucks, up and down ramps, or into slaughter facilities or restraint devices is avoided. Animals should not be forced to move faster than at normal walking speed. Handlers should move animals quietly, without using driving devices that would cause unnecessary pain and/or distress.
- Nonambulatory or disabled animals are isolated and moved with suitable equipment (eg, bucket of a loader, sled) and provided appropriate veterinary attention. Conscious nonambulatory animals must never be dragged.
- Animals are provided with access to water in the lairage pens. Animals should have sufficient room to move in accordance with state, federal, and local statutes, and pens should have room for all animals to lie down.
- Slaughter facilities and equipment are well maintained to minimize injury or pain to the animals and employees.
- The induction of unconsciousness (eg, stunning) causes minimal distress to the animal.
- All personnel are trained in both the application of stunning methods and behavioral principles of animal handling.

3. Human behavioral considerations and training

Small ruminant veterinarians may be asked to bridge the physical and psychological divide between current practices used in the care and management of food animals and consumers by communicating the realities of conventional food production. They may also be asked to provide an ethical accounting and monitoring of animals' welfare on the farm and at slaughterhouses to the public in a transparent fashion. Food animal veterinarians are encouraged to increase their awareness of slaughter methods and to enhance understanding of the science behind the methods currently used with a view toward the day-to-day complexities of managing food animals and the range of challenges facing our contemporary food animal sector. Likewise, industry agents, veterinarians, caretakers, and others engaged with the slaughter of animals for food should be encouraged to understand the diversity of public concerns and trending societal values and expectations related to how animals are farmed and slaughtered for food. The humane slaughter of animals is a learned skill that requires training, respect, and self-awareness. Personnel performing humane slaughter must be technically proficient. Periodic professional continu-

ing education on the latest methods, techniques, and equipment available for slaughter is highly encouraged. Personnel must also possess a temperament that does not bolster brutality. Self-awareness when it comes to processing animals for food will help to mitigate compassion fatigue and callousness. The slaughter of individual livestock or poultry by farm workers who are also responsible for providing husbandry can substantially impact emotions.

Therefore, appropriate oversight of the psychological well-being of slaughter employees is paramount to mitigate guilt, distress, sadness, fatigue, alienation, anxiety, and behaviors that lack consideration of others or may lead to harming themselves, animals, or other people. People may have individual differences in how they psychologically react to the job of killing animals. It is difficult to care about animals when they have to be killed. This is called the "caring-killing paradox."

In small ruminants, "on-farm" slaughter by the end consumer is frequently practiced. This does have implications for training, as it is difficult to assure the knowledge and expertise of the individual performing the slaughter. Training in slaughter processes and safety is available in some states and jurisdictions.

Veterinarians and staff who are regularly exposed to the slaughter process should also be monitored for emotional burnout, psychological distress, or compassion fatigue and be encouraged to seek appropriate psychological counseling. While integrating good animal welfare in the food chain, some food animal practitioners may be torn among serving the best interest of the farmed animal, the human client (individual), personal professional interests, and societal concerns about improving quality of life for animals and ensuring the availability of safe and affordable animal protein. More studies on both the impact of animal slaughter on the personnel performing it and on attitudes toward the consumption of animals for food among the general public will go a long way toward promoting healthier and more respectful human–food animal relationships.

4. Facility design and slaughter process

i. Arrival at the plant

The normal process is for the animals to be unloaded promptly after a vehicle arrives at the plant. In the best operations, the vehicles are unloaded within 15 to 60 minutes after arrival, and industry guidelines recommend a maximum wait time of 60 minutes.[3] This requires the scheduling of an appointment between the plant and transporter. Scheduling vehicle arrival times prevents the problem of too many vehicles arriving at the same time, which results in long lines and delays at unloading. During hot weather, delayed unloading can result in severe animal welfare problems due to heat stress. A panting score has been developed to detect heat stress in sheep.[4] It can be used to help prevent severe heat stress.

Detection of problems—There have been unfortunate cases in which many animals have died while waiting an entire day to unload. This serious problem is most likely to occur when there is an emergency condition such as a power failure or storm that either shuts down the plant or makes roads impassable.

Corrective action for problems—It is best practice to have an emergency program to either divert incoming trucks to other slaughter facilities or unload animals at auction markets, feedlots, or fairgrounds. This will require a coordinated program that facilitates immediate cancellation of animal loading on the farm and diverts loads that are en route to other facilities.

ii. Unloading

When unloading is done correctly, animals will move off the vehicle in a quiet, orderly manner. Handlers should be quiet and refrain from yelling, whistling, or repeatedly hitting the sides of the vehicle. The sound of people yelling has been shown to be very stressful for livestock.[5,6] Electric prods can be completely eliminated during unloading of most hoofstock. The best US sheep plants use trained sheep to lead the animals off the vehicle.[7] Sheep that have become accustomed to handling and contact with humans on the farm had lower cortisol levels at the slaughter plant.[8] Acceptable handling tools for livestock include flags and rattle paddles.[3,9]

Detection of problems—Industry guidelines advise that if more than 1% of animals fall during unloading or more than 5% of animals are unloaded using an electric prod, there is a welfare problem in the unloading area.[9–11] Most plants can achieve this standard, as the majority of larger plants have banned the use of the electric prod at unloading. There is a problem if animals in the unloading area run into fences or pile up. Quiet handling also provides the advantage of greatly reducing bruises,[5] which is an economic incentive for the facility.

At the time of unloading, plant employees should note whether the vehicle is overloaded. Vehicles should be loaded per industry and international guidelines.[3,12] Overloading of trucks can cause severe economic losses. Bruised meat cannot be used for human consumption. In cattle, overloading of trucks will increase bruises, lameness, and the likelihood of nonambulatory cattle (for US transport regulations, refer to 49 USC Section 80502).[13–20] Research[17] with sheep indicated that packing sheep too tightly on a vehicle results in an increase in animals falling down. Animals should also be observed for transport-induced welfare problems such as frostbite, lacerations, heat stress, and urine scald.

Another problem that can seriously compromise animal welfare at the slaughter plant is when the animal is in poor condition prior to leaving the farm. Weak, emaciated animals or severe lameness can make humane handling difficult. Scoring tools to assess lameness and poor body condition are available for sheep and goats.[18–20] The USDA does not permit the slaughter of nonambulatory downed or emaciated cattle. However, pigs and sheep that are not able to walk may be slaughtered. In Canada, slaughter is not permitted of any downed livestock.

Corrective action for problems—Nonslip flooring in the unloading area is essential for all spe-

cies.[9–11] Quiet handling and good welfare are impossible if animals slip and fall. A rough broom finish is not a satisfactory nonslip floor and quickly wears down and becomes smooth and slick. For the smaller species, such as sheep, goats, or cervids, a good floor finish is to stamp the pattern of a 2.5-cm–wide opening (1-inch) expanded-metal mesh pattern into the concrete. There are other suitable finishes for stamping concrete, and all of them are rougher than a broom finish. Epoxy or grit finishes work well for smaller species, but they will not provide sufficient traction for large animals that have become agitated. For existing slick floors, there are several options. In high-traffic areas, such as unloading ramps and scales, mats made from either woven tire treads or rubber mats provide a nonslip surface. Another option is to construct a steel grating from 1-inch-diameter steel rods welded in a 30 X 30-cm (12 X 12-inch) square pattern.[9] The rods must not be crisscrossed over the top of each other. They must be welded into a flat metal grid to prevent hooves from catching under the raised rods, which can cause hoof injury. Grooving tools can be rented from a concrete supply firm for regrooving concrete. More information on flooring and the design of unloading ramps can be found in various reports.[9,10,21]

Meat packers should work with producers and buyers to reduce the numbers of unfit animals.[22] Packers should clearly communicate back to producers that the shipment of unfit animals is unacceptable and implement a financial penalty for the practice.

iii. Receiving

After unloading, the normal practice in most plants is to verify that the number of animals on the vehicle matches the paperwork. In some plants, there is an extra handling step of weighing individual animals after unloading. However, many plants have eliminated this by weighing the entire truck before unloading; weighing the entire truck has the advantage of reducing bruising. Animal identification is maintained by placing the animals from each trailer in their own pen and placing their identification paperwork in a holder on the fence.

Detection of problems—For all small ruminants, falling, piling up, or hitting fences would be an indicator that handling needs to be improved.

Corrective actions for problems—Provide nonslip flooring for all small ruminants and cervids.

iv. Lairage

This may also be called for stockyards or antemortem pens. In most plants, animals are held in the same groups that they traveled with on the trucks, which is ideal. In large plants, a typical lairage pen holds either 1 or 2 entire truckloads. It is important to design the pens to hold a whole number of truckloads, as a pen designed to hold 1.5 truckloads will invariably end up having 2 loads forced into it. When new stockyards are being built, they should be laid out so that there is 1-way livestock movement through the yards. Ideally, the unloading ramps are at one end of the yards and the chutes to the stunner are at the other end. One good design is to have all the animals enter the pens from 1 alley and move to the stunner through the opposite end of the pens. Designs for lairage pens are available in various reports.[21,23,24] In smaller plants, there may be a single group or small groups of animals arriving from many different owners. Each animal's owner must either be held in their own small pen or have physical identification (such as ear tags or electronic identification) to prevent their identification from becoming mixed up with other animals.

The HMSA 9 CFR 313.2 requires that all lairage pens be equipped with water troughs or other suitable devices so that the animals have access to water.[25] Well-designed and maintained lairage pens will be free of sharp edges that can injure animals. Industry recommendations for lairage pen space for sheep is 0.46 to 0.55 m^2 (5 to 6 sq ft) depending on size. The animals should be provided sufficient space that they can all lie down at the same time. Before animals can be moved to the slaughter area, they undergo antemortem inspection. After inspection, the lairage pen is tagged as ready for processing. The exception to this rule is custom-exempt plants, which process animals for personal use by the owner or producer.

Detection of problems—The 3 main problems that can occur in the lairage pens are overstocking of the pens, fighting between animals causing injuries, and animals that become nonambulatory. Another problem is animals mounting each other, which may result in weak animals falling down.

Corrective action for problems—When fighting occurs, there is usually 1 animal that is the main perpetrator. This animal should be removed from the group and placed in a separate pen. Intact males of many species will often mount and ride other animals. In small plants, some of the worst fights are caused by singly raised backyard animals that have never learned how to socialize with other animals.[21] To prevent fighting, singly raised animals should be slaughtered within 1 hour after arrival, after allowing them a minimum of 30 minutes to calm down. A lairage time that is too long or no lairage time at all is detrimental to both meat quality and welfare.

The regulations attendant to the HMSA forbids dragging of nonambulatory animals unless they have first been stunned.[25] Nonambulatory sheep and goats may be moved to either the suspect pen or the cripple area in the plant. In the US, the only acceptable methods for moving nonambulatory animals are sleds, skid steer loaders, or specialized carts. In Canada, nonambulatory animals must be euthanized on the trailer and cannot be moved with sleds, skid steers, or specialized carts. The AVMA's policy on disabled livestock[26] provides recommendations for down animals including but not limited to the following: nonambulatory animals may be moved using a sled, mat, cart, or mechanized equipment that supports the full length and weight of the animal. A nonambulatory animal should not be dragged or lifted by the limbs, tail, neck, or ears. Sheep must never be lifted by their wool.

v. Handling system

A wide variety of systems are available to move sheep from lairage pens to the place where they are

stunned or ritually slaughtered.[7,21,27] When animals are handled correctly, they move in an orderly fashion with no falling or pileups and minimal vocalizing or use of electric prods. During the last few minutes before slaughter, excessive use of electric prods can seriously affect meat quality. In a study by Warner et al,[28] multiple shocks on beef cattle produced tougher meat. Animals should never be backed into the stun box. Isolation stress is highly stressful for sheep and goats.[29,30]

Detection of problems—Both industry guidelines and USDA Food Safety and Inspection Service (FSIS) regulations prohibit abusive practices such as dragging downed nonambulatory animals; poking sensitive areas such as the eyes, anus, or udder; slamming gates deliberately on animals; deliberately driving animals over the top of a down animal; and beating animals.[3] Handling problems that compromise welfare can result from a facility problem or employee training issue. Before modifications are made to a facility, employees should be trained to use behavioral principles of livestock handling.[21,24,31] When people handle livestock in a calm, quiet manner, design problems in the facility can be easily located and corrected. For all species, if > 1% of the animals fall at any point in the facility, there is a problem that needs to be corrected.[3,9,32] An automated powered gate that causes an animal to either fall down or be dragged along the floor is a serious problem.

Vocalization during cattle (and calf) handling and restraint at slaughter plants was associated with obvious aversive events such as electric prods, excessive pressure from a restraint device, and sharp edges.[33] Unfortunately, vocalization scoring cannot be used to locate handling or restraint problems in sheep. Sheep do not vocalize in direct response to electric prods or a painful event, but goats often do. Research is needed to determine whether vocalization scoring can be used for goats or camelids. More recent research in slaughter plants shows that vocalizations in cattle are associated with electric prod use.[34] The use of electric prods should be avoided in sheep. US industry guidelines recommend that electric prod use should be on 5% or fewer of sheep.[1]

Corrective actions for handling problems—The following actions should be taken to correct problems:

1. Crowd pens that lead to the single-file race (chute) should not be overloaded
   Goats should be moved into the crowd pen in small, separate groups. This principle does not apply to sheep. They would be moved in a large, continuous group due to their intense following behavior.
   For all species, handlers should work alongside the tub (crowd pen) and single-file chute, and overhead catwalks should be avoided. Overfilling the tub or overcrowding with the gate will cause goats and deer to bunch up and turn back from the single-file entry. Animals should be allowed time to move through the system without being rushed. When the animals are moving through the system themselves, they should be left alone. If the lead animal balks, allow it time to investigate and move forward.[21]
2. Use natural following behavior
   The next group of goats should not be brought into the crowd pen that leads to the single-file chute until there is space in the single-file chute. This enables the goats to immediately enter, promotes natural following behavior,[21] and prevents them from turning around. Sheep can be handled in continuous flow because they have a very strong instinct to follow the leader.
3. Teach handlers behavioral principles
   Handlers need to understand behavioral principles such as flight zone and point of balance.[7,35,36] The most common mistake when moving animals through chutes is a handler who stands at the head of an animal and pokes its rear in an attempt to make it move forward. Standing in front of an animal prevents it from moving forward. Handlers should be taught to use the movement pattern shown in **Figure 2**. When a person quickly walks back past the shoulder of an animal in the opposite direction of the desired movement, the animal will move forward. This is an effective method for many species.
4. Prohibit routine carrying and use of electric prods
   Alternatives to electric prods, such as vibrating prods or plastic paddles, should be the handler's primary driving tool. A vibrating prod can be made from a pneumatic engraving tool in which the sharp tip has been removed. A total prohibition of electric prods is not recommended, as a single shock from an electric prod is preferable to hitting. Sheep must never be grabbed or picked up by the wool. This will cause severe bruising.
5. Use powered gates carefully
   When a powered gate is used to move animals, it should be equipped with controls that enable a person to immediately stop its movement if an animal falls. Automated powered gates must be equipped with pressure-limiting devices to prevent the gate from either knocking animals over or dragging animals along the floor.
6. Remove distractions that cause balking
   Movement of animals through a handling facility can often be greatly improved by making many small changes in the facility that remove visual and aural distractions that cause animals to balk and refuse to move.[7,21]
   a. When an animal enters a stun box or restrainer, it must not have air blowing in its face.[9,22,31]
   b. Use a directional lamp to provide indirect lighting to light up dark chute entrances. Animals have a tendency to move from a dark place to a brighter place.[32]
   c. Eliminate reflections on shiny metal or wet floors. Moving a light source may eliminate a reflection on a wet floor.[31] Reflected glare from shiny metal surfaces increases balking of cattle in plants.[37]
   d. Cover the sides of chutes or install solid barriers to prevent approaching animals from

seeing people, vehicles, or moving machinery ahead.[32,38] Large pieces of cardboard can be used experimentally to determine where solid shields are needed. The outer perimeter of a handling facility is one of the most important areas to cover. Animals will remain calmer if there is a solid barrier to prevent them from seeing people standing close to them.[39] For flighty species, such as deer, the use of solid sides and low lighting will keep them calmer.[40]

e. Animals often refuse to walk over changes in floor type, such as moving from concrete to a metal floor.[7] Pigs and cattle are also likely to balk at shadows.[41] Sheep will often jump over shadows.[42]

f. Reduce noise made by equipment, such as air hissing and metal-on-metal banging and clanging. Sudden intermittent sounds and movements are more likely to cause agitation.[43] Many slaughter plants have high noise levels.[44]

A list of design principles to reduce stress during restraint follows. These principles are applicable to conventional slaughter, which uses stunning before bleeding, and religious slaughter.

1. Ensure pressure applied is optimal—The device must apply enough pressure to make an animal feel restrained but avoid excessive pressure that will cause struggling or vocalization. A common mistake is to apply additional pressure when an animal struggles.[45]
2. Do not trigger fear of falling—This is why nonslip flooring is so important. When devices are used that hold an animal with its feet off the floor, the animal must be held in a balanced, comfortable upright position. When a device is used that rotates an animal from an upright position, the body must be securely held and supported to prevent struggling and slipping within the device. Restrainer conveyors should be equipped with a false floor to prevent animals from seeing a visual cliff under the restrainer,[7,46] as animals have depth perception.[47] For conventional stun boxes where the animal stands upright, nonslip flooring is critical. Stun boxes should never have a steeply sloped or stepped floor. Instead, a flat floor is recommended.
3. Ensure smooth, steady motion of parts of the restraint device that contact animals—Sudden jerky motion will cause animals to become agitated.[45]
4. Block animals' vision of people, moving equipment, and activity on the floor[22]—To prevent balking and improve ease of entry into the restraint device, animals entering the device should not be able to see people, moving equipment, or activity on the processing floor.
5. Ensure stun boxes are of appropriate size—Stun boxes must be the appropriate size for the animals being processed. Animals must not be able to turn around in the box.

Restraint (religious)—There are various methods used to restrain and position the animal for religious slaughter. In the US, there is an exemption from the HMSA[2] for religious slaughter, and methods for restraining the animal for religious slaughter are outside the jurisdiction of USDA FSIS regulations, although Congress has also declared religious slaughter to be humane. The area covered by the handling exemption has been called the area of "intimate" restraint by the FSIS.[48,49] The HMSA specifically declares "humane by slaughtering in accordance with the ritual requirements of the Jewish faith or any other religious faith that prescribes a method of slaughter whereby the animal suffers loss of consciousness by anemia of the brain caused by the simultaneous and instantaneous severance of the carotid arteries with a sharp instrument and handling in connection with such slaughtering."[48,49] However, all procedures outside the intimate restraint area, which many meat inspectors call the "bubble," are beyond the area of intimate restraint and are subject to FSIS oversight, the same as conventional slaughter. Both before and after the actual slaughter remain under FSIS. Ensuring that the animal is unconscious before shackling and is insensitive with no corneal reflex before invasive dressing procedures begin are under FSIS jurisdiction,[48,49] the same as conventional slaughter.

Detection of problems—Vocalization scoring is not an effective assessment tool for sheep, because they often do not vocalize in response to painful procedures. However, sheep will often struggle when aversive restraint methods are used. Goats will vocalize in response to isolation or aversive handling.

Research is needed to create a scientifically verified system for scoring vocalization in goats.

When a restraint system is overloaded beyond its design capacity, the use of electric prods may increase as handlers attempt to move animals through the plant. The following measures can be used to assess the performance of restraint devices:

1. Percentage of goats that vocalize while entering the restraint device and while they are held in the restraint device.
2. Percentage of animals (all species) that fall down to the extent that the body touches the ground. The voluntary industry standard is 1%.[3] However, the goal should be zero. Restraint devices that trip animals or that are designed to make animals fall are not permitted in the voluntary industry standard.[3]
3. Percentage of animals moved with an electric prod into the restraint device. For sheep, the voluntary standard for electric prod use is < 5%. The World Organisation for Animal Health[50] recommends that electric prods should not be used on sheep. American Veterinary Medical Association policy states that "electrical devices (eg, stock prods) should be used judiciously and only in extreme circumstances when all other techniques have failed."[51]

All scores are per animal. The animal is either moved with an electric prod or it is not. A goat either

is silent or vocalizes. Devices that paralyze animals using electricity should not be used as a method of restraint. Studies[52–55] clearly indicated that electric immobilization is highly aversive and should not be used. Electric immobilization must not be confused with electric stunning that causes unconsciousness. Animals that have been immobilized with electricity will not be able to vocalize to show their distress.

Conditions that cause welfare problems— The following conditions cause welfare problems:

1. Failure to provide nonslip flooring—One of the most common problems in stun boxes is slippery floors.[32] When animals are continuously slipping, they cannot stand still for stunning. Designs for nonslip floors can be found in the section of the document that describes unloading. Metal grating or rubber mats work well to prevent slipping in stun boxes.
2. Overloading equipment beyond its design capacity—One of the most common mistakes is overloading a single conveyor restrainer.
   a. Overloading a single conveyor restrainer. There are almost no data for sheep or goats but extensive data for cattle and pigs that illustrate the severe welfare problems that can occur when systems are overloaded.[22] A single center-track restrainer will work well to process 390 cattle/h if it is free of the distractions discussed previously. At 390 fed feedlot cattle/h, the cattle are still moving at a normal walking speed. For both electric prod use and vocalization, there are few differences among different line speeds when equipment is designed and operated correctly.
   b. Overloading single-animal stun boxes and restrainers. Single-animal stun boxes or restraint boxes have maximum speed of approximately 100 animals/h. Boxes designed to hold single animals result in slower line speeds than conveyor systems because they use a start-stop process to put each animal in the box and then remove it. The signs of an overloaded box are the following:
      i. Slamming the rear gate on animals.
      ii. Increased electric prod use.
      iii. More than 1 animal in the box for stunning.
      iv. An increase in rough handling.

   For all species, when the line speed exceeds 100 animals/h, the use of a conveyor system that handles a continuous stream of animals or 2 or more single-animal boxes is recommended.
3. Funnel-shaped crowd pens with one straight side and the other side on a 30° angle will work well for sheep or goats. The handler should work on the angled side. Round tub designs are also effective. Designs for appropriate crowd pens for sheep and goats may be found in various publications.[7,21,56,57]
4. Stun boxes and single-file chutes that are too wide—The appropriate width for stun boxes and chutes tends to be overestimated. Stun boxes and chutes that are too wide result in animals turning around and becoming caught beside each other. The recommended width is 40 cm (16 inches) for sheep and 70 cm (27 inches) for deer. Chute width may need to be adjusted for exceptionally large or small animals.
5. Vertical overhead gate clearance is too low—Animals will often refuse to walk under a vertical slide gate or other apparatus that allows for scant clearance or touches their back. Raising the opening height 16 cm (6 inches) will usually fix this problem. On center-track restrainers, the solid hold-down cover may need to be raised to prevent bumping of the animal's shoulder when it is entering.
6. Single-file chute is too short—The single-file chute has to be long enough that a sufficient number of animals can be held within it to allow the time to refill the crowd pen. The recommended lengths should be used for systems in which animals are handled in a continuous flow to the processing line. In systems where animals are handled rapidly in separate batches, shorter chutes (races) can be used.
7. Animals standing in a stun box too long—Animals should be stunned immediately after they enter the stun box or restrainer. Holding an animal alone in a stun box can cause isolation stress. In goats, remaining isolated is highly stressful.[29,30]

Detection of problems with religious restraint— From an animal welfare standpoint, there are 3 issues that occur during religious slaughter, when a horizontal neck cut is used to lead to unconsciousness and subsequent insensibility. They are as follows: (1) stress, (2) pain or discomfort caused by how the animal is held and positioned for religious slaughter, and (3) the throat cut itself. Because the HMSA regulations exempt restraint of animals for religious slaughter from the regulations that apply to restraint for conventional slaughter,[48,49] some small religious slaughter plants use stressful methods of restraint such as shackling and hoisting of live animals even though more welfare-friendly restraint equipment is available. Research has clearly shown that upright restraint is less stressful than shackling and hoisting for sheep and calves.[58] The World Organisation for Animal Health also recommends that stressful methods of restraint, such as shackling and hoisting, shackling and dragging, and leg-clamping boxes should not be used, and suspension of live cattle, sheep, goats, or other mammals by their legs is not permitted in the UK, Canada, Western Europe, and many other countries. Fortunately, most mid-to-large religious slaughter plants in the US have stopped this practice because of concerns for both animal welfare and worker safety.

Vocalization scoring does not work for evaluating the handling and restraint stress in sheep because they usually do not vocalize in response to pain or stress. This may be due to an instinctual inhibition of vocalization in response to the presence of predators.[59] Research is needed to evaluate vocalization as a method to evaluate stress in goats. The following methods of restraint are highly stressful for conscious mammals and should not be used: hoisting

and suspension by 1 or more limbs; shackling by 1 or more limbs and dragging; shackling, hoisting, moving, and casting; trip floor boxes that are designed to make animals fall; and leg-clamping boxes.

Corrective actions (religious)—Small ruminants, such as sheep, goats, or calves of a similar size can be held in an upright position by people or placed in a simple restraint device such as the device shown in Figure 1.

Information on the correct operation and design of upright restraint devices for religious slaughter can be found in reports by Grandin,[31,45] Grandin and Regenstein,[60] and Giger et al.[61] Upright restraint in a comfortable upright position is preferable. When a device that inverts an animal is required by some religious leaders, it should have adjustable sides that support the animal and prevent its body from slipping, twisting, or falling during inversion. Inversion onto the back facilitates the downward cutting stroke, which is ergometrically easier. Upright or sideways (lying on the side) restraint may be less aversive than full inversion. Hutson[62] found that full inversion was more aversive to sheep than being held in an upright position. Sheep can be easily trained to voluntarily enter a tilt table, which tilts them sideways.[63]

It is important to minimize the time that an animal is held firmly by a head restraint. A head restraint using a mechanized device that tightly holds the head is more aversive than the body restraint.[45] Resistance to the head restraint occurs after approximately 30 seconds; therefore, it is important to perform the throat cut before struggling or vocalization begins. When struggling is being evaluated from an animal welfare standpoint, only struggling that occurs before loss of posture (LOP) should be assessed. But a head restraint does keep the animal's head in place so that it does not move during the cutting, which otherwise would result in a miscut and likely unnecessary pain. The actual amount of pressure applied using the head restraint does need further research.

When Velarde et al[64] evaluated struggling in different types of restraint devices, they did not differentiate between struggling before or after loss of consciousness. Struggling while the animal is conscious is a welfare concern, and struggling from convulsions after an animal loses posture and becomes unconscious has no effect on welfare. Restraint devices should be equipped with pressure-limiting devices to prevent excessive pressure from being applied, which then causes either struggling or vocalization.[45] Restraint devices should not cause animals to struggle or vocalize.[65]

5. Techniques

i. Physical methods

Penetrating captive bolt guns—Penetrating captive bolts can be used for small ruminants in commercial slaughter plants. Their mode of action is concussion and trauma to the cerebral hemisphere and brainstem.[27,66,67] Properly done captive bolt stunning will instantly abolish visual evoked potentials and somatosensory evoked potentials (SEPs) from the brain.[68,69] This indicates that the animal's brain is no longer able to respond to a visual or tactile stimulus. Adequate restraint is important to ensure proper placement of the captive bolt. A cerebral hemisphere and the brainstem must be sufficiently disrupted by the projectile to induce sudden loss of consciousness and subsequent death.[70,71] Appropriate placement of captive bolts for various species has been described.[57,61–65,67,72,73] Signs of effective captive bolt penetration and death are immediate collapse and a several-second period of tetanic spasm, followed by slow hind limb movements of increasing frequency.[27,70] Corneal reflexes are absent, and the eyes open into a wide, blank stare and are not rotated.[27,74,75]

There are 2 types of captive bolt guns: a penetrating captive bolt with a rod that penetrates deep into the brain and a nonpenetrating captive bolt that is equipped with a convex mushroom head. These 2 types are the most common types used in commercial slaughter plants. Both types of captive bolts can be powered by either powder cartridges (9 mm, .22 caliber, or .25 caliber) or compressed air. Captive bolts powered by compressed air must be designed so that they never inject air into the brain because of concerns about contamination of the meat with specified risk materials. Specified risk material includes tissues thought to be high risk for prion contamination, the cause of a group of diseases called transmissible spongiform encephalopathies.

All captive bolt guns require careful maintenance and cleaning after each day of use. Lack of maintenance is a major cause of captive bolt gun failure for both powder-activated and pneumatic captive bolt guns.[75] Cartridges for powder-activated captive bolt guns must be stored in a dry location because damp cartridges will reduce effectiveness.[76]

General recommendations—Use of the penetrating captive bolt is acceptable for stunning of mature animals and is a common method used in slaughter plants. Ruminants used for food should not be pithed to avoid contamination of the carcass with specified risk materials. Captive bolt guns used for larger animals must have the properly matched caliber and cartridge size. Both penetrating and nonpenetrating captive bolts cause focal as well as diffuse injury to the brain. Injury caused by penetrating and nonpenetrating captive bolt pistols is similar and sufficient for both to be considered effective for lambs.[70] On the basis of electrophysiologic evidence,[67] researchers determined that the primary determinant of effective stunning is impact of the bolt and not penetration of the bolt into brain tissues. In contrast, a single report[77] credits structural changes including focal damage adjacent to the wound track and damage to peripheral tissues of the cerebrum, cerebellum, and brainstem as the predominant factors affecting effectiveness of the stun. Both penetrating and nonpenetrating captive bolt guns are effective for inducing instantaneous unconsciousness. Nonpenetrating captive bolt requires more careful placement, compared with penetrating captive bolt, to be effective **(Figures 3 and 4)**.[76] The use of a head re-

straint device is strongly recommended for nonpenetrating captive bolt.

Detection of problems—Lack of maintenance is a major cause of captive bolt gun failure for both powder-activated and pneumatic captive bolt guns.[78] Damp cartridges can result in soft-sounding, underpowered shots that are less effective.[66] Studies have found that a well-trained operator can easily render 95% or more of the animals unconscious with a single shot from a captive bolt gun.[76,79] It is advised that there is a problem if the effective first-shot rate falls below 95%.[37] The best plants have a 99% first-shot efficacy[80] (FSIS has a zero-tolerance policy for missed first shot, which falls under "egregious inhumane treatment").[81] Studies show that the error rate in captive bolt stunners is easily kept below 5%.

Corrective action for problems—Store cartridges for powder-activated captive bolt guns in a dry location. Cartridges stored in a damp location are more likely to produce ineffective "soft" shots.[76] Minimize movement of the animal's head. This can be achieved with either a head-holding device or behavioral methods such as changing lighting in the stun box. Head holders must be used with care; if poorly designed, they can increase cortisol levels and balking.[82] In the center-track conveyor system, the head will typically remain still without head restraint. This is due to having a long overhead solid top, which prevents the animal from seeing out until its feet are off the entrance ramp and it is riding on the conveyor.[46]

A nonslip floor in the stun box is essential to prevent slipping. Slipping causes animals to become agitated. The stun box floor should be flat or have a slight slope. Steeply sloped or stepped floors should not be used in stun boxes.

Maintain the captive bolt gun per the instructions from the manufacturer. Captive bolt guns are precision machine tools, and daily cleaning and maintenance are essential.

Use a test stand to determine whether the captive bolt has sufficient bolt velocity. Most captive bolt manufacturers market test stands for their captive bolt guns.

For pneumatic captive bolt guns, the air compressor that powers the gun must provide the air pressure and volume specified by the captive bolt manufacturer throughout the entire production shift. Air accumulation tanks or an undersized compressor will not provide sufficient power for the gun.

Heavy pneumatic captive bolt guns must be hung on a well-designed balancer so that the operator can easily position the gun without lifting its full weight. There are many balancer types and designs. Balancers must be well maintained; a partially broken balancer will make it difficult to position the pneumatic captive bolt, causing the operator to exert more effort to move the gun. Ergonomic design is especially important with pneumatic captive bolt guns because they are heavy and bulky. Small changes in handle location or the angle that the pneumatic gun hangs on the balancer can greatly improve ease of operation and lessen the effort required to position the gun.

Switches and valves that operate gates or start and stop conveyors must be located in a convenient location. On a conveyor restrainer, the operator should be able to start and stop the conveyor without moving from the normal position for stunning.

All the valves and switches for operating conveyors and gates must be kept in good repair. Partially broken hydraulic or pneumatic valves often require excessive effort to operate. In large plants that use cartridge-fired captive bolt guns, more than 1 gun should be available to allow for both gun rotation and having a second gun available if the initial shot is not effective. Cartridge-fired captive bolts are less effective when they get too hot. Rotating the guns and allowing hot guns to cool will prolong their useful life. If a second stun attempt is needed, it must be performed immediately to minimize pain, suffering, and distress. Plants should have a written protocol in place for the use of the backup stunner and second stun attempts.

Nonpenetrating captive bolt guns—The nonpenetrating captive bolt gun has either a wide mushroom-shaped head or a flat head that does not penetrate the brain of large mammals, such as adult sheep. In general, regular nonpenetrating captive bolt guns only stun animals. When a nonpenetrating captive bolt gun is used, there is little margin for error. The stun-to-stick interval must not exceed 60 seconds.

Detection of problems—Refer to the section Penetrating captive bolt guns—Detection of problems. Be aware that the nonpenetrating captive bolt has a much smaller margin of error on aim.

Corrective action for problems—Refer to the section Penetrating captive bolt guns—Corrective action for problems.

Gunshot—A properly placed gunshot can cause immediate unconsciousness. Under some conditions, a gunshot may be the only practical method of rendering animals unconscious with extremely heavy skulls, such as bulls, large boars, or buffalo.

Shooting should only be performed by highly skilled personnel trained in the use of firearms and only in jurisdictions that allow for legal firearm use. The safety of personnel, the public, and other animals that are nearby should be considered. For safety, a fully closed box that will contain a bullet that perforates through the skull or ricochets is strongly recommended.

In applying a gunshot to the head for the purposes of slaughter for captive animals, the firearm should be aimed so that the projectile enters the brain, causing instant loss of consciousness.[65,83–86] This must take into account differences in brain position and skull conformation between species, as well as the energy required for skull bone and sinus penetration.[66,83] Accurate targeting for a gunshot to the head in various species has been described.[83,84,87] The appropriate firearm should be selected for the situation, with the goal being penetration and destruction of brain tissue without emergence of the projectile from the contralateral side of the head.[63,74,78,79]

Basic principles of firearms—To determine whether a firearm or type of ammunition is appropri-

ate for slaughtering animals, some basic principles must be understood. The kinetic energy of an object increases as the speed and weight or mass of the object increase. In reference to firearms, the bullet's kinetic energy (muzzle energy) is the energy of a bullet as it leaves the end of the barrel when the firearm is discharged. Muzzle energy is an indicator of a bullet's destructive potential. The heavier the bullet and the greater its velocity, the higher its muzzle energy and capacity for destruction of objects in its path.

Muzzle energy (E) can be expressed as the mass of the bullet (M) times its velocity (V) squared, divided by 2. However, to accommodate units of measure commonly used in the US for civilian firearms, energy (E) is expressed in foot-pounds. This is calculated by multiplication of the bullet's weight (W) times its velocity in feet per second (V) squared, divided by 450. The International System of Units expresses muzzle energy in joules after the English physicist James Prescott Joule (1818 to 1889).

The muzzle energy of commercially available ammunition varies greatly. For example, the difference in muzzle energy generated from a .357 Magnum handgun loaded with a 180-grain compared with a 110-grain bullet may differ by as much as 180 foot-pounds. Velocity has an even greater impact on bullet energy than bullet mass. Selection of an appropriate bullet and firearm is critically important for conducting euthanasia procedures. Lighter-weight, higher-velocity bullets can have high muzzle energy but decreased penetration, which can be an issue when penetrating thick bones.

As the bullet travels beyond the muzzle of the firearm, its energy gradually begins to decrease. While this is not a concern for the use of firearms in close proximity to the animal, when attempting to shoot an animal from a distance, to ensure accuracy and that an acceptable level of muzzle energy is achieved, a high-powered rifle may be the better choice for rendering an animal unconscious. In all cases, the most important factors in ensuring a successful shot are the experience and skill of the shooter.

Muzzle energy requirements—Anecdotal evidence suggests that the .22 LR is one of the most frequently used firearms to euthanize livestock. A Canadian study designed to evaluate firearm use for euthanasia of cattle in the event of a foreign animal disease outbreak found that both the .22 LR standard-velocity and .22 LR high-velocity bullets failed to yield adequate penetration of the skull. It should be noted that the distance between the shooter and the target (cadaveric skulls) was 25 m. Researchers concluded that the .22 LR was not an appropriate choice for euthanasia under these conditions.[46]

In a US study,[45] fresh cadaveric heads from *Bos taurus* beef feedlot steers 12 to 18 months old were used to evaluate 7 combinations of firearms and ammunitions (.22-caliber rifle firing a long rifle 30-grain plated lead solid- or hollow-point round, .223-caliber carbine firing a 50-grain ballistic-tip round, 9-mm pistol firing a 124-grain total metal jacket round, .45-caliber automatic Colt pistol [ACP] firing a 230-grain full metal jacket round, and 12-gauge shotgun firing a 2.75- inch 1.25-ounce No. 4 birdshot shell or a 1-ounce rifled slug). All heads were shot from a distance of 3 m and oriented to make contact with the skull at a 90° angle. Of the 18 heads shot, only 6 shot with the pistol-fired 9-mm and .45-caliber ACP rounds and rifle-fired .22-caliber "hollow-point rounds" had brainstem lesions. The mean depth of penetration for the .22-caliber "hollow-point" cartridge was significantly less than that of other firearms evaluated. The 9-mm pistol firing a total metal jacket round caused the least amount of brain tissue or brainstem trauma. It was determined that only 2 of the 6 heads shot with this firearm and ammunition combination would have likely resulted in instantaneous death. Researchers concluded that the rifle-fired .22 caliber hollow-point and the pistol-fired 9-mm rounds were not viable options for euthanasia of feedlot cattle.[88]

On the basis of the previous information, if a .22 LR is to be used for euthanasia of a mature bovine, a solid-point bullet fired from a rifle within a range of 3 m is recommended. Use of a .22-caliber handgun loaded with a hollow-point bullet or shooting from distances beyond 3 m is not advised. Similarly, although custom loaded bullets may yield different results than those observed in the above cited study, use of a 9 mm with a jacketed bullet cannot be recommended.[88]

There is little doubt that success or failure is partially related to firearm and bullet characteristics but probably more so to selection of the ideal anatomic site (ie, a site more likely to affect the brainstem) for conducting the procedure. The Humane Slaughter Association lists multiple firearms for humane slaughter of livestock, including shotguns (12, 16, 20, 28, and .410 gauges), handguns (.32 to .45 caliber), and rifles (.22, .243, .270, and .308). In general, when comparing handguns with rifles, the longer the barrel, the higher the muzzle velocity. Heavier rounds with larger propellant loads such as those used in 9-mm and 0.45-caliber pistols generally require greater barrel length for bullets to reach maximum muzzle velocity. A longer barrel length permits additional time for the combustion of propellants and the expansion of gasses that push the bullet through the barrel. For this reason, if a .22 is used for humane slaughter, it is best fired from a rifle. The .22 should never be used on aged bulls, boars, or rams.[89] To improve safety and reduce the possibility of the bullet passing through the animal's head or in the event that the bullet misses the animal, many plant managers prefer the .22 LR. Some may prefer to use a pistol because it can be held closer to the head and many people find it easier to aim. For reasons described above, if a .22 handgun must be used, a high-velocity solid-point 40-grain bullet or a larger-caliber firearm should be considered.

There are 2 main differences between use of a firearm in a slaughter plant and its use for on-farm euthanasia. In a slaughter plant, gunshot is followed by exsanguination, so it is not the sole agent used to cause death. Another difference is an animal in a slaughter plant is shot at a close range of 0.3 to

0.6 m (1 to 2 feet). When slaughter is done in less-controlled situations out on the farm, a firearm larger than a .22 LR is recommended. It is essential to aim the shot correctly so that the brain is penetrated. If an animal is injured and is not rendered unconscious with a single shot, it is sometimes much more difficult to kill thereafter. The nervous system may go into a state of arousal, and multiple shots may fail.[88,90]

Bullet selection is quite possibly the most important consideration for slaughter of livestock by gunshot. There are 3 basic types of bullets pertinent to this discussion: solid points, hollow points, and full metal jacketed bullets. Solid-point bullets are preferred for shooting livestock since they are designed for greater penetration of their targets. Under ideal conditions, this type of bullet will also undergo moderate expansion to a mushroom shape that increases its destructive characteristics. Hollow-point bullets are designed with a hollowed-out tip that causes rapid expansion and fragmentation of the bullet on impact. The hollow-point design allows maximum transfer of energy with a lower risk of overpenetration. Hollow points are less likely to ricochet, but if the free bullet hits a person, it is more dangerous than other bullets.

For applications such as slaughter plants, where it may be desirable to control or reduce the degree of bullet penetration, hollow-point bullets are preferred. However, for the purposes of humane slaughter of livestock, the first requirement is that the bullet possesses sufficient energy to penetrate the skull and enter the underlying brain tissue. The concern with hollow-point bullets is that since the majority of their energy is released on impact through fragmentation, they may not have sufficient energy to traverse the skull. Hollow points would be safer in a slaughter plant, but they may need to be used with a larger firearm than would solid points. The other extreme is represented by full metal jacket bullets, which do not expand or fragment on impact with their targets. These bullets have a lead core with a thin metal jacket cover that completely covers (surrounds) the bullet. Full metal jacket bullets generally achieve maximum penetration, which may have benefits for humane slaughter but also creates additional safety hazards for bystanders from perforation (ie, pass through) of the bullet. For this reason, full metal jackets are not recommended for use in slaughter plants. Shotguns loaded with shot shells (No. 4, 5, or 6 or slugs) have sufficient energy to traverse the skull but, unlike bullets from either a handgun or a rifle, rarely exit the skull.

Firearm safety—Firearm safety cannot be overemphasized. Guns are inherently dangerous and must be always handled with caution. Common recommendations include the following: (1) assume that all firearms are loaded, (2) always know where the muzzle is and never allow it to point in the direction of oneself or bystanders, (3) keep fingers away from the trigger and out of the trigger guard until ready to fire, (4) be sure of the target and what lies beyond it, (5) always be sure that the gun is unloaded when not in use, and (6) keep the safety on until ready to fire. To improve safety, many gun owners prefer a single-shot rifle with either a bolt or break-open action. The action remains open until the operator is ready to fire. For those desiring more information or training on proper use of firearms, readers are advised to contact local hunter safety programs. These programs offer training in firearm safety and also provide information on rules and regulations for firearm use.

Firearms should never be held flush to the skull. Discharge of the firearm when the barrel is occluded or blocked results in the development of extreme pressure within the barrel that, when fired, may cause the barrel of the gun to explode, placing the shooter and observers at great risk of injury. Ideally, the muzzle of the firearm should be held within 60 to 90 cm (2 to 3 feet) of the animal's forehead and perpendicular to the skull with the intended path of the bullet roughly in the direction of the foramen magnum. This will reduce the potential for ricochet while directing the bullet toward the cerebrum, midbrain, and medulla oblongata, which will assure immediate loss of consciousness and rapid death.

When other methods cannot be used, an accurately delivered bullet from a firearm is acceptable for humane slaughter.[84,91,92] When an animal can be appropriately restrained, the penetrating captive bolt, preferably one designed for euthanasia, is preferred to a gunshot because it is safer for personnel. Prior to shooting, animals accustomed to the presence of humans should be treated in a calm and reassuring manner to minimize anxiety. In the case of nondomesticated animals, gunshots should be delivered with the least amount of prior human contact necessary.

Religious slaughter—The following considerations should be kept in mind regarding the performance of religious slaughter.

Performing the throat cut—There are 3 basic ways that religious slaughter is performed: (1) preslaughter stunning before the throat cut with either a nonpenetrating captive bolt or electric stunning, (2) immediate postcut stunning with a captive bolt, or (3) slaughter without stunning (traditional hand slaughter). Some religious authorities who supervise either kosher (Jewish) or halal (Muslim) religious slaughter will allow either preslaughter or immediate postslaughter stunning.[93] For halal slaughter, electric head-only stunning is used in many large cattle and sheep plants in New Zealand, Australia, and the UK. Head-only electric stunning is acceptable to many Muslim religious authorities because it is fully reversible and induces temporary unconsciousness. If preslaughter stunning is done, there will be no animal welfare concerns about the throat cut in a conscious animal. Since most preslaughter stunning methods that are approved for religious slaughter produce a lighter reversible stun, greater attention will be required to the details of procedures to ensure that the animals are and remain unconscious during the throat cut. An effective reversible precut stun in sheep can be easily achieved with 1.25 to 2 A at a frequency range of 50 to 400 Hz. According to Grandin (T Grandin, PhD, College of Agricultural Sci-

ences, Colorado State University, personal communication, 2012), when the stunner was applied to the head for 1.5 seconds at 300 Hz, it produced a clear tonic rigid phase followed by a clonic kicking phase representative of an epileptic seizure. This pattern is an indicator that it produced unconsciousness. A modified New Zealand head-to-body stunner **(Figure 5)** with the rear body electrode removed worked well because the design of the handle facilitated positioning of the stunner on the sheep's head. The preceding stunning methods are acceptable to a number of halal certifiers. Some halal certifiers will accept nonpenetrating captive bolt because the heart will continue to beat after stunning.[94] Some religious communities will accept immediate postcut stunning, and others require slaughter without stunning (traditional hand slaughter). Stunning methods are covered in the Techniques chapter of these Guidelines.

Detection of problems—Important welfare concerns may occur during traditional religious hand slaughter. There are 2 main issues: (1) Does cutting the throat of a conscious animal cause pain? (2) What is the maximum appropriate time that is required for the animal to become unconscious after a properly done throat cut? The throat cut done during both kosher and halal slaughter simultaneously severs both carotid arteries and jugular veins and the trachea. For halal slaughter, a sharp knife is required. Kosher slaughter has more strict specifications for how the cut is performed and the design and sharpening of the knife.[95,96] A kosher slaughter knife is long enough to span the full width of the neck (ie, double the width of the neck) and is sharpened on multiple whetstones. Before and after each animal is cut, the knife is checked for nicks that could cause pain.[95,96] Any nick in the knife makes the animal nonkosher, so there is a strong incentive to keep the knife razor sharp and nick free.

Painfulness of the cut—Researchers have reported that cutting the throat of 107- to 109-kg (236- to 240-lb) veal calves with a knife that was 24.5 cm (9.6 inches) long caused pain comparable to dehorning.[97,98] The knife may have been too short to fully span the throat, and it had been sharpened on a mechanical grinder. A grinder may create nicks on the blade and may not be comparable to a knife sharpened on a set of whetstones. Slaughter without stunning of cattle with a knife that is too short will result in violent struggling because the tip makes gouging cuts in the wound.[31] One of the rules of kosher slaughter is that the incision must remain open during the cut.[95,96] When the wound is allowed to close back over the knife, cattle will violently struggle.[62] When an animal is restrained in a comfortable upright position; it becomes possible to observe how the animal reacts to the throat cut. When a kosher knife is used by a skilled slaughterman (shochet), there is little behavioral reaction in cattle during the cut.[20,21] In calves, there has been a similar observation.[99] Grandin[31] reports that people invading the animal's flight zone by getting near the animal's face caused a bigger reaction. An ear-tag punch has also caused a bigger reaction than a good kosher cut.[60]

Time to lose consciousness—Unconsciousness, as defined in the General Introduction of these Guidelines, is the loss of individual awareness that occurs when the brain's ability to integrate information is blocked or disrupted. At this point, the animal no longer feels pain. Before invasive dressing begins, all signs of brainstem function such as the corneal reflex must be abolished by the bleeding. Thus, insensibility follows unconsciousness. Sheep will lose consciousness as determined by their EEG more quickly than cattle because of differences in the anatomy of the blood vessels that supply the brain.[100,101] In cattle when the carotid arteries are severed, the brain can still receive blood from the vertebral arteries.[100,101] After the cut, sheep will become unconscious, observed as LOP, and no longer be able to stand within 2 to 14 seconds, while most cattle will lose consciousness and no longer be able to stand within 17 to 85 seconds.[69,102–107] In these studies,[69,102–107] time to onset of unconsciousness was measured using either EEG or loss of the ability to stand (LOP). Allowing the wound to close after a transverse halal throat cut with a 20-cm-long (7.9-inch) knife may delay the onset of unconsciousness. Electroencephalographic measurements on sheep indicated consciousness could last 60 seconds.[108] In a study[109] in which a rotating box was used to invert veal calves onto their backs, unconsciousness was measured using EEG and occurred at an average of 80 seconds. In sheep, unconsciousness as measured by time to eye rotation was 15 seconds.[110]

There is a large amount of biological variability and possibly differences in workmanship, so that a few cattle, calves, or sheep have extended periods of sensibility > 4 minutes.[107,111] If the animals can stand and walk, they are conscious. In sheep, the corneal reflexes, which are a brainstem reflex, may be present for up to 65 seconds after the cut.[110] In veal calves, corneal reflexes were still present at 135 ± 57 seconds after the throat cut.[109] The methods section of Lambooij et al[109] did not describe the type of knife. However, that study was done in a slaughter plant that performed halal slaughter, which permits knives of different sizes to be used. Corneal reflexes can also occur in electrically stunned or CO_2-stunned animals where other indicators of return to consciousness, such as the righting reflex, rhythmic breathing, and eye tracking, are absent.[112] Corneal reflexes occur during a state of surgical anesthesia[113] or when visual potentials and SEP are abolished.[114] One of the best indicators for determining onset of unconsciousness is the loss of the ability to stand or walk (LOP). In cattle, a major cause of prolonged periods of consciousness after the throat cut is sealing off the ends of the severed arteries (false aneurysms).[115] This problem does not occur in sheep.

Aspiration of blood—Another welfare concern is aspiration of blood into the trachea and lungs after the cut.[116] In 1 study,[117] when cattle were held in a well-designed upright restraint, 36% (for kosher) and 69% (for halal) aspirated blood. It is likely that in a rotating box where the animal is held on its back, aspiration of blood will be higher (T Grandin, PhD,

College of Agricultural Sciences, Colorado State University, personal communication, 2015).

Corrective action for problems—To reduce the painfulness of the act, a knife that is long enough to span the neck where the tip will remain outside the neck during the cut should be used.[65] It is also essential that the knife be extremely sharp, and the use of appropriate whetstones is recommended. A good method for testing a knife for sharpness is the paper test. To perform this test, a single sheet of standard letter-size (8.5 X 11-inch) printer paper is dangled in a vertical position by being held by a thumb and forefinger by one corner. A dry knife held in the other hand should be able to start cutting at the edge of the paper and slice it in half. This method can eliminate the worst dull knives, but it may not evaluate the sharpness of the knives and certainly does not address the issue of nicks. The Jewish slaughtermen are extensively trained to test their knives for nicks by running the knife over a fingernail.

It is also essential to not allow the wound to close back over the knife during the cut. To prevent sealing off the arteries in cattle, the cut should be angled so it is close to the first cervical vertebra (C1) position[66,111] as long as such a cut is accepted by the religious authorities. This will also cut a sensory nerve, which may prevent the cattle from experiencing distressful sensations from aspirating blood.[66,111] The cut should be located posterior to the larynx and angled toward the C1 position.

Before invasive dressing procedures such as skinning or leg removal are started, the corneal reflexes (representing insensibility) must be absent. Even though an animal showing only a corneal reflex is unconscious, to provide a good margin of safety, it should be absent before dressing procedures start. Absence of the corneal reflex and complete unconsciousness before dressing procedures are started are best practices for all slaughter plants that undertake both conventional slaughter and religious slaughter.

6. Special considerations

Although not commonly practiced in the US, some parts of the world slaughter neonatal goats for human consumption. For additional information related to neonatal procedures, please see the AVMA Guidelines for Euthanasia of Animals.[118]

B. Camelids

1. General considerations

Unlike some countries, slaughter of camelids in the US is rarely done in large-scale commercial settings. Custom slaughter or on-farm slaughter occurs at a small scale.

2. Animal behavioral considerations

These Guidelines are concerned with minimizing animal distress, including negative affective or experientially based states such as fear, aversion, anxiety, and apprehension, during the slaughter process. They are also meant to promote human well-being and safety as regards the repeated termination of animals' lives. Veterinarians and other employees conducting slaughter should familiarize themselves with preslaughter protocols and be attentive to species and individual variability to mitigate distress in camelids as well as the human handlers. The method for inducing unconsciousness and the handling and restraint methods associated with it must be evaluated as an entire system. Physical methods require handling and restraint of individual animals, but they induce instantaneous unconsciousness. There may be a tradeoff between possible distress during a longer time to induce unconsciousness and the benefits of reduced handling of individual animals.

Intentional violations of the HMSA must not be tolerated. Unintentional pain and/or distress at slaughter caused by mistakes by personnel or poorly designed facilities must be addressed promptly.[2] At all stages of the process of termination, animals should be treated with respect, and compromises to animal welfare should be treated as unacceptable if not unlawful. Practitioners and stockpersons should ensure the following:

- No conscious animal is dragged, shackled, hoisted, or cut inappropriately. Before invasive dressing (eg, skinning, leg removal, scalding) begins, all signs of brainstem function, such as the corneal reflex, must be abolished.
- Excessive force or frequent use of electric prods to move animals off trucks, up and down ramps, or into slaughter facilities or restraint devices is avoided. Animals should not be forced to move faster than a normal walking speed. Handlers should move animals quietly, without using driving devices that would cause unnecessary pain and/or distress.
- Nonambulatory or disabled animals are isolated and moved with suitable equipment (eg, bucket of a loader, sled) and provided appropriate veterinary attention. Conscious nonambulatory animals must never be dragged.
- Animals are provided with access to water in the lairage pens. Animals should have sufficient room to move in accordance with state, federal, and local statutes, and pens should have room for all the animals to lie down.
- Slaughter facilities and equipment are well maintained to minimize injury or pain to the animals and employees.
- The induction of unconsciousness (eg, stunning) causes minimal distress to the animal.
- All personnel are trained in both the application of stunning methods and behavioral principles of animal handling.

3. Human behavioral considerations and training

Small ruminant veterinarians may be asked to bridge the physical and psychological divide between current practices used in the care and management of food animals and consumers by communicating the realities of conventional food production. They

may also be asked to provide an ethical accounting and monitoring of animals' welfare on the farm and at slaughterhouses to the public in a transparent fashion. Food animal veterinarians are encouraged to increase their awareness of slaughter methods and enhance understanding of the science behind the methods currently used with a view toward the day-to-day complexities of managing food animals and the range of challenges facing our contemporary food animal sector. Likewise, industry agents, veterinarians, caretakers, and others engaged with the slaughter of animals for food should be encouraged to understand the diversity of public concerns and trending societal values and expectations related to how animals are farmed and slaughtered for food.

The humane slaughter of animals is a learned skill that requires training, respect, and self-awareness. Personnel performing humane slaughter must be technically proficient. Periodic professional continuing education on the latest methods, techniques, and equipment available for slaughter is highly encouraged. Personnel must also possess a temperament that does not bolster brutality. Self-awareness when it comes to processing animals for food will help to mitigate compassion fatigue and callousness. The slaughter of individual livestock or poultry by farm workers who are also responsible for providing husbandry can substantially impact emotions. Therefore, appropriate oversight of the psychological well-being of slaughter employees is paramount to mitigate guilt, distress, sadness, fatigue, alienation, anxiety, and behaviors that lack consideration of others or may lead to harming themselves, animals, or other people. People may have individual differences in how they psychologically react to the job of killing animals. It is difficult to care about animals when they must be killed. This is called the "caring-killing paradox."

Veterinarians and staff who are regularly exposed to the slaughter process should also be monitored for emotional burnout, psychological distress, or compassion fatigue and be encouraged to seek appropriate psychological counseling. While integrating good animal welfare in the food chain, some food animal practitioners may be torn among serving the best interest of the farmed animal, the human client (individual), personal professional interests, and societal concerns about improving quality of life for animals and ensuring the availability of safe and affordable animal protein. More studies on both the impact of animal slaughter on the personnel performing it and on attitudes toward the consumption of animals for food among the public will go a long way toward promoting healthier and more respectful human–food animal relationships.

4. Facility design and slaughter process

1. Arrival at the Plant: Generally, not relevant in the US due to minimal slaughter of camelids. When animals are transported to slaughter, the normal process is for the animals to be unloaded promptly after a vehicle arrives at the plant. In the best operations, the vehicles are unloaded within 15 to 60 minutes after arrival, and industry guidelines recommend a maximum wait time of 60 minutes.[3] This requires the scheduling of an appointment between the plant and transporter. Scheduling vehicle arrival times prevents the problem of too many vehicles arriving at the same time, which results in long lines and delays at unloading. During hot weather, delayed unloading can result in severe animal welfare problems due to heat stress.
2. Unloading: Generally, not relevant in the US due to minimal slaughter of camelids. When animals are moved to slaughter it is generally only 1 animal that is unloaded as an individual animal. Nonslip flooring in the unloading area is appropriate and necessary. Handlers should be quiet and refrain from yelling, whistling, or repeatedly hitting the sides of the vehicle. The sound of people yelling has been shown to be very stressful for livestock.[5,6]
3. Lairage: Generally, not relevant in the US due to minimal slaughter of camelids.
4. Handling System: Generally, not relevant in the US due to minimal slaughter of camelids.
5. Restraint (include religious [nonstun]): Unlike other ruminants, the rostral portion of the muzzle of camelids has minimal cartilage and can unintentionally be completely collapsed when restrained using halters or some mechanical restraints. Care should be taken to assure that normal breathing is not impeded by any restraint.

5. Techniques

i. Physical methods

Slaughter of domestic camelids is normally performed with penetrating captive bolt gun stunning, immediately followed by exsanguination. Evidence suggests that the midline on the crown of the head **(Figure 6)** is the preferred site for captive bolting.[119] This site resulted in the most consistent results.

ii. Religious

Camelids are acceptable for halal but not for kosher. Muslims use a stab in the neck (called nahr) to begin bleeding, and once the animal loses posture, a traditional horizontal cut is undertaken. The knife for stabbing should be appropriate for that purpose and would be different from the knife used for the horizontal cut as described for sheep and goats.

6. Special considerations

In some countries, traditional slaughter uses a method that involves inserting a knife in the back of the neck to sever the spinal cord. This method is often referred to as puntilla. Given evidence that this method is often ineffective and allows for continued brain and spinal activity, the method is not recommended.[120]

C. Cervids (Elk, Red Deer, Whitetail Deer, and Caribous/Reindeer)

1. General considerations

Due to the number of cervid species (over 30), differences in sizes and temperaments must be taken into consideration for each species. Every attempt to handle these animals should be done by persons knowledgeable in the individual characteristics of that species. Facilities should be designed to reduce stress and ease of handling as much as possible. General principles of animal husbandry should apply to handling and welfare. Of special note, several species (whitetail deer, mule deer, red deer, elk, moose, sika deer, and reindeer) will usually require a brainstem sample to be taken for chronic wasting disease testing, and stun or kill techniques to the brain may damage the sampling of such. Techniques that reduce the amount of damage or alternative sites (neck or heart/lung) may have to be used to enable proper sampling. This may also be true on some sites when the animals must be killed by gunshot from a distance. Quiet handling is essential to decrease stress, and the number of people (especially untrained) should be limited to just essential personnel.

2. Animal behavioral considerations

These Guidelines are concerned with minimizing animal distress, including negative affective or experientially based states such as fear, aversion, anxiety, and apprehension during the slaughter process. They are also meant to promote human well-being and safety as regards the repeated termination of animals' lives. Veterinarians and other employees conducting slaughter should familiarize themselves with preslaughter protocols and be attentive to species and individual variability to mitigate distress in both food animals and human handlers. The method for inducing unconsciousness and the handling and restraint methods associated with it must be evaluated as an entire system.

Intentional violations of the HMSA must not be tolerated. Unintentional pain and/or distress at slaughter caused by mistakes by personnel or poorly designed facilities must be addressed promptly.[2] At all stages of the process of termination, animals should be treated with respect, and compromises to animal welfare should be treated as unacceptable if not unlawful. Practitioners and stockpersons should ensure the following:

- No conscious animal is dragged, shackled, hoisted, or cut inappropriately. Before invasive dressing (eg, skinning, leg removal, scalding) begins, all signs of brainstem function, such as the corneal reflex, must be abolished.
- Excessive force or frequent use of electric prods to move animals off trucks, up and down ramps, or into slaughter facilities or restraint devices is avoided. Animals should not be forced to move faster than a normal walking speed. Handlers should move animals quietly, without using driving devices that would cause unnecessary pain and/or distress.
- Nonambulatory or disabled animals are isolated and moved with suitable equipment (eg, bucket of a loader, sled) and provided appropriate veterinary attention. Conscious nonambulatory animals must never be dragged.
- Terrestrial animals are provided with access to water in the lairage pens. Animals should have sufficient room to move in accordance with state, federal, and local statutes, and pens should have room for all the animals to lie down.
- Slaughter facilities and equipment are well maintained to minimize injury or pain to the animals and employees.
- The induction of unconsciousness (eg, stunning) causes minimal distress to the animal.
- All personnel are trained in both the application of stunning methods and behavioral principles of animal handling.

3. Human behavioral considerations and training

Food animal veterinarians may be asked to bridge the physical and psychological divide between current practices used in the care and management of food animals and consumers by communicating the realities of conventional food production. They may also be asked to provide an ethical accounting and monitoring of animals' welfare on the farm, in feedlots, in aqua-farms, and at slaughterhouses to the public in a transparent fashion. Food animal veterinarians are encouraged to increase their awareness of slaughter methods and enhance understanding of the science behind the methods currently used with a view toward the day-to-day complexities of managing food animals and the range of challenges facing our contemporary food animal sector. Likewise, industry agents, veterinarians, caretakers, and others engaged with the slaughter of animals for food should be encouraged to understand the diversity of public concerns and trending societal values and expectations related to how animals are farmed and slaughtered for food.

The humane slaughter of animals is a learned skill that requires training, respect, and self-awareness. Personnel performing humane slaughter must be technically proficient. Periodic professional continuing education on the latest methods, techniques, and equipment available for slaughter is highly encouraged. Personnel must also possess a temperament that does not bolster brutality. Self-awareness when it comes to processing animals for food will help to mitigate compassion fatigue and callousness. The slaughter of individual livestock by farm workers who are also responsible for providing husbandry can substantially impact emotions. Therefore, appropriate oversight of the psychological well-being of slaughter employees is paramount to mitigate guilt, distress, sadness, fatigue, alienation, anxiety, and behaviors that lack consideration of others or may lead to harming themselves, animals, or other people. People may have individual differences in how they psychologically react to the job of killing animals. It is difficult to care about

animals when they must be killed. This is called the "caring-killing paradox."

Veterinarians and staff who are regularly exposed to the slaughter process should also be monitored for emotional burnout, psychological distress, or compassion fatigue and be encouraged to seek appropriate psychological counseling. While integrating good animal welfare in the food chain, some food animal practitioners may be torn among serving the best interest of the farmed animal, the human client (individual), personal professional interests, and societal concerns about improving quality of life for animals and ensuring the availability of safe and affordable animal protein. More studies on both the impact of animal slaughter on the personnel performing it and on attitudes toward the consumption of animals for food among the public will go a long way toward promoting healthier and more respectful human–food animal relationships.

4. Facility design and slaughter process

i. Arrival at the plant

The normal process is for the animals to be unloaded promptly after a vehicle arrives at the plant. In the best operations, the vehicles are unloaded within 15 to 60 minutes after arrival, and industry guidelines recommend a maximum wait time of 60 minutes.[3] This requires the scheduling of an appointment between the plant and transporter. Scheduling vehicle arrival times prevents the problem of too many vehicles arriving at the same time, which results in long lines and delays at unloading. During hot weather, delayed unloading can result in severe animal welfare problems due to heat stress.

Detection of problems—There have been unfortunate cases in which many animals have died while waiting an entire day to unload. This serious problem is most likely to occur when there is an emergency condition such as power failure or storm, which either shuts down the plant or makes roads impassable.

Corrective action for problems—It is best practice to have an emergency program either to divert incoming trucks to other slaughter facilities or to unload animals at auction markets, feedlots, or fairgrounds. This will require a coordinated program that facilitates immediate cancellation of animal loading on the farm and diverts loads that are en route to other facilities.

ii. Unloading

When unloading is done correctly, animals will move off the vehicle in a quiet, orderly manner. When unloading cervids, it is particularly important that employees be familiar with and used to moving captive cervids. Flight zones, awareness of normal handling, and risk for severe injury during unloading are much higher for cervids than most other species. Handlers should be quiet and refrain from yelling, whistling, or repeatedly hitting the sides of the vehicle. The sound of people yelling has been shown to be very stressful for livestock.[5,6]

Detection of problems—Industry guidelines for cervids do not exist. There is a problem if animals in the unloading area run into fences or pile up. Quiet handling also provides the advantage of greatly reducing bruises,[5] which is an economic incentive for the facility.

At the time of unloading, plant employees should note whether the vehicle is overloaded. Vehicles should be loaded per industry and international guidelines.[3,12] Animals should also be observed for transport-induced welfare problems such as frostbite, lacerations, heat stress, and urine scald. Another problem that can seriously compromise animal welfare at the slaughter plant is when the animal is in poor condition prior to leaving the farm. Weak, emaciated animals or severe lameness can make humane handling difficult.

Corrective action for problems—Nonslip flooring in the unloading area is essential for all species.[9–11] Quiet handling and good welfare are impossible of animals slip and fall. For all species (with the possible exception of birds), a rough broom finish is not a satisfactory nonslip floor. A rough broom finish quickly wears down and becomes smooth and slick. For the smaller species, such as sheep, goats, or cervids, a good floor finish is to stamp the pattern of a 1-inch-wide–opening (2.5-cm) expanded-metal mesh pattern into the concrete. There are other suitable finishes for stamping concrete, and all of them are rougher than a broom finish. Epoxy or grit finishes work well for smaller species, but they will not provide sufficient traction for large animals that have become agitated. For existing slick floors, there are several options. In high-traffic areas, such as unloading ramps and scales, mats made from woven tire treads or rubber mats with a nonslip surface can be used. Another option is to construct a steel grating from 1-inch-diameter steel rods welded in a 12 X 12-inch (30 X 30-cm) square pattern.[9] The rods must not be crisscrossed over the top of each other. They must be welded into a flat metal grid to prevent the hooves from catching under the raised rods that can cause hoof injury. Grooving tools can be rented from a concrete supply firm for regrooving concrete. More information on flooring and the design of unloading ramps can be found in reports by Grandin and Deesing[21] and Grandin.[9,10]

Meat packers should work with producers and buyers to reduce the numbers of unfit animals.[22] Packers should clearly communicate back to producers that the shipment of unfit animals are unacceptable and implement a financial penalty for the practice.

iii. Receiving

After unloading, the normal practice in most plants is to verify that the number of animals on the vehicle matches the paperwork. In some plants, there is an extra handling step of weighing individual animals after unloading. However, many plants have eliminated this step by weighing the entire truck before unloading; weighing the entire truck has the advantage of reducing bruising. Animal identification is maintained by placing the animals from each trailer in their own pen and placing their identification paperwork in a holder on the fence.

Detection of problems—For all cervids, falling, piling up, or hitting fences would be an indicator that handling needs to be improved.

Corrective actions for problems—Provide nonslip flooring for all cervids.

iv. Lairage

This may also be called for stockyards or antemortem pens. In most plants, animals are held in the same groups that they traveled with on the trucks, which is the ideal situation. In large plants, a typical lairage pen holds either 1 or 2 entire truckloads; it is important to design the pens to hold a whole number of truckloads, as a pen designed to hold one and a half truckloads will invariably end up having 2 loads forced into it. When new stockyards are being built, they should be laid out so that there is 1-way livestock movement through the yards. Ideally, the unloading ramps are at one end of the yards and the chutes to the stunner are at the other end. One good design is to have all the animals enter the pens from one alley and move to the stunner through the opposite end of the pens. Designs for lairage pens are in several reports.[21,23,24,27] In smaller plants, there may be single or small groups of animals arriving from many different owners. Each animal's owner must either be held in their own small pen or have physical identification (such as ear tags or electronic identification) to prevent their identification from becoming mixed up with other animals.

The HMSA 9 CFR 313.2 (e) requires that all lairage pens be equipped with water troughs or other suitable devices so that the animals have access to water.[25] Well-designed and maintained lairage pens will be free of sharp edges that can injure animals. Industry recommendations for lairage pen space for sheep is 5 to 6 square feet (0.46 to 0.55 m^2) depending on size. The animals should be provided sufficient space that they can all lie down at the same time. Before animals can be moved to the slaughter area, they undergo antemortem inspection. After inspection, the lairage pen is tagged as ready for processing. The exception to this rule is custom-exempt plants, which process animals for personal use by the owner or producer.

Detection of problems—The 3 main problems that can occur in the lairage pens are overstocking of the pens, fighting between animals causing injuries, and animals that become nonambulatory. Another problem is animals mounting each other, which may result in weak animals falling down.

Corrective action for problems—When fighting occurs, there is usually 1 animal that is the main perpetrator. This animal should be removed from the group and placed in a separate pen. Intact males of many species will often mount and ride other animals. In small plants, some of the worst fights are caused by singly raised backyard animals that have never learned how to socialize with other animals.[21] To prevent fighting, singly raised animals should be slaughtered within 1 hour after arrival, after allowing them a minimum of 30 minutes to calm down. A lairage time that is too long or no lairage time at all is detrimental to both meat quality and welfare.

The regulations attendant to the HMSA forbids dragging of nonambulatory animals unless they have first been stunned. If a nonambulatory animal cannot stand and walk, regulations require that it be humanely euthanized. Nonambulatory sheep and other hoofstock may be moved to either the suspect pen or the cripple area in the plant. In the US, the only acceptable methods for moving nonambulatory animals are sleds, skid steer loaders, or specialized carts. In Canada, nonambulatory animals must be euthanized on the trailer and cannot be moved with sleds, skid steers, or specialized carts. The AVMA's policy on disabled livestock[26] provides recommendations for down animals including but not limited to the following: nonambulatory animals may be moved using a sled, mat, cart, or mechanized equipment that supports the full length and weight of the animal. A nonambulatory animal should not be dragged or lifted by the limbs, tail, neck, or ears. Sheep must never be lifted by their wool.

v. Handling system

Systems for deer and other cervids can be found in reports by Matthews[40] and Haigh.[121,122] When animals are handled correctly, they move in an orderly fashion with no falling or pileups and minimal vocalizing or use of electric prods.

Detection of problems—Both industry guidelines and USDA FSIS regulations prohibit abusive practices such as dragging downed nonambulatory animals; poking sensitive areas such as the eyes, anus, or udder; deliberately slamming gates on animals; deliberately driving animals over the top of a down animal; and beating animals.[3] Handling problems that compromise welfare can result from a facility problem or an employee training issue. Before modifications are made to a facility, employees should be trained to use behavioral principles of livestock handling.[21,24,31] When people handle livestock in a calm, quiet manner, design problems in the facility can be easily located and corrected. For all species, if > 1% of the animals fall at any point in the facility, there is a problem that needs to be corrected.[3,9,32] An automated powered gate that causes an animal to either fall or be dragged along the floor is a serious problem.

Corrective actions for handling problems—Crowd pens that lead to the single file race (chute) should not be overloaded.

1. Cervids should be moved into the crowd pen in small, separate groups. This principle does not apply to sheep. They should be moved in a large, continuous group due to their intense following behavior.
2. For all species, handlers should work alongside the tub (crowd pen) and single-file chute, and overhead catwalks should be avoided. Overfilling the tub or overcrowding with the gate will cause goats and deer to bunch up and turn back from the single-file entry. Animals should be allowed time to move through the system without being rushed. When the animals are moving through the system themselves, they should be left alone. If the lead animal balks, allow it time to investigate and move forward.[123]
3. Teach handlers behavioral principles
   Handlers need to understand behavioral prin-

ciples such as flight zone and point of balance.[7,35,36]

Captive cervids tend to respond more quickly and with less pressure. Handlers of cervids should receive specialized training and be experienced in handling cervids before being used to work with the animals.

4. Prohibit routine carrying and use of electric prods

   Alternatives to electric prods, such as vibrating prods or plastic paddles, should be the handler's primary driving tool. However, in most cases cervids should not be prodded.

5. Use powered gates carefully

   When a powered gate is used to move animals, it should be equipped with controls that enable a person to immediately stop its movement if an animal falls. Automated powered gates must be equipped with pressure-limiting devices to prevent the gate from either knocking animals over or dragging animals along the floor.

6. Remove distractions that cause balking

   Movement of animals through a handling facility can often be greatly improved by making many small changes in the facility that remove visual and aural distractions that cause animals to balk and refuse to move.[7,21,125]

   a. When an animal enters a stun box or restrainer, it must not have air blowing in its face.[9,22,31]
   b. Use a directional lamp to provide indirect lighting to light up dark chute entrances. Animals have a tendency to move from a dark place to a brighter place.[32]
   c. Eliminate reflections on shiny metal or wet floors. Moving a light source may eliminate a reflection on a wet floor.[31] Reflected glare from shiny metal surfaces increases balking of cattle in plants.[37]
   d. Cover the sides of chutes or install solid barriers to prevent approaching animals from seeing people, vehicles, or moving machinery ahead.[32,38] Large pieces of cardboard can be used experimentally to determine where solid shields are needed. The outer perimeter of a handling facility is one of the most important areas to cover. Animals will remain calmer if there is a solid barrier to prevent them from seeing people standing close to them.[39] For flighty species, such as deer, the use of solid sides and low lighting will keep them calmer.[40]
   e. Animals often refuse to walk over changes in floor type, such as moving from concrete to a metal floor. Sheep will often jump over shadows.[42]
   f. Reduce noise made by equipment, such as air hissing and metal-on-metal banging and clanging. Sudden intermittent sounds and movements are more likely to cause agitation.[43] Many slaughter plants have high noise levels.[44]

vi. Restraint (religious)

A list of design principles to reduce stress during restraint follows. These principles are applicable to conventional slaughter, which uses stunning before bleeding, and religious slaughter.

1. Ensure pressure applied is optimal—The device must apply enough pressure to make an animal feel restrained but avoid excessive pressure that will cause struggling or vocalization. A common mistake is to apply additional pressure when an animal struggles.[45]
2. Do not trigger fear of falling—This is why nonslip flooring is so important. When devices are used that hold an animal with its feet off the floor, the animal must be held in a balanced, comfortable upright position. When a device is used that rotates an animal from an upright position, the body must be securely held and supported to prevent struggling and slipping within the device. Restrainer conveyors should be equipped with a false floor to prevent animals from seeing a visual cliff under the restrainer,[7,46] as animals have depth perception.[44] For conventional stun boxes where the animal stands upright, nonslip flooring is critical. Stun boxes should never have a steeply sloped or stepped floor. Instead, a flat floor is recommended.
3. Ensure smooth, steady motion of parts of the restraint device that contact animals—Sudden jerky motion will cause animals to become agitated.[45]
4. Block the animals' vision of people, moving equipment, and activity on the floor[22]—To prevent balking and improve ease of entry into the restraint device, animals entering the device should not be able to see people, moving equipment, or activity on the processing floor.
5. Ensure stun boxes are of appropriate size—Stun boxes must be the appropriate size for the animals being processed. Animals must not be able to turn around in the box. There is limited religious slaughter of cervids; often boxes used for small ruminants or cattle are used. The boxes need to be designed to allow the animals to enter without entangling their horns, and the head-holder needs to be adjusted as well.

Detection of problems—Research is needed to create a scientifically verified system for scoring vocalization in cervids.

Conditions that cause welfare problems—The following conditions cause welfare problems:

1. Failure to provide nonslip flooring—One of the most common problems in stun boxes is slippery floors.[32] When animals are continuously slipping, they cannot stand still for stunning. Designs for nonslip floors can be found in the section of the document that describes unloading. Metal grating or rubber mats work well to prevent slipping in stun boxes.
2. Overloading equipment beyond its design capacity—One of the most common mistakes is overloading a single conveyor restrainer.

5. Techniques

i. Physical methods

Penetrating captive bolt guns—Penetrating captive bolts can be used for small ruminants in commercial slaughter plants. Their mode of action is concussion and trauma to the cerebral hemisphere and brainstem.[27,66,67] Properly done captive bolt stunning will instantly abolish visual evoked potentials and SEPs from the brain.[45,59] This indicates that the animal's brain is no longer able to respond to a visual or tactile stimulus. Adequate restraint is important to ensure proper placement of the captive bolt **(Figure 7)**. A cerebral hemisphere and the brainstem must be sufficiently disrupted by the projectile to induce sudden loss of consciousness and subsequent death.[70,71] Appropriate placements of captive bolts for various species have been described.[67,72,73] Signs of effective captive bolt penetration and death are immediate collapse and a several-second period of tetanic spasm, followed by slow hind limb movements of increasing frequency.[27,70] Corneal reflexes are absent, and the eyes open into a wide, blank stare and are not rotated.[27,74,75]

There are 2 types of captive bolt guns: a penetrating captive bolt with a rod that penetrates deep into the brain and a nonpenetrating captive bolt that is equipped with a convex mushroom head. These 2 types are the most common used in commercial slaughter plants. Both types of captive bolts can be powered by either powder cartridges (9 mm, .22 caliber, or .25 caliber) or compressed air. Captive bolts powered by compressed air must be designed so that they never inject air into the brain, because of concerns about contamination of the meat with specified risk materials. Specified risk material includes tissues thought to be high risk for prion contamination, the cause of a group of diseases called transmissible spongiform encephalopathies.

All captive bolt guns require careful maintenance and cleaning after each day of use. Lack of maintenance is a major cause of captive bolt gun failure for both powder-activated and pneumatic captive bolt guns.[75] Cartridges for powder-activated captive bolt guns must be stored in a dry location because damp cartridges will reduce effectiveness.[76]

General recommendations—Use of the penetrating captive bolt is acceptable for stunning of mature animals and is a common method used in slaughter plants. Ruminants used for food should not be pithed to avoid contamination of the carcass with specified risk materials. Captive bolt guns used for larger animals must have the properly matched caliber and cartridge size. Both penetrating and nonpenetrating captive bolts cause focal as well as diffuse injury to the brain. Injury caused by penetrating and nonpenetrating captive bolt pistols was similar and sufficient for both to be considered effective for euthanasia of lambs.[70] On the basis of electrophysiologic evidence,[67] researchers determined that the primary determinant of effective stunning is impact of the bolt and not penetration of the bolt into brain tissues. In contrast, 1 report[77] credited structural changes including focal damage adjacent to the wound track and damage to peripheral tissues of the cerebrum, cerebellum, and brainstem as the predominant factors affecting effectiveness of the stun. Both penetrating and nonpenetrating captive bolt guns are effective for inducing instantaneous unconsciousness. Nonpenetrating captive bolt requires more careful placement, compared with penetrating captive bolt, to be effective.[76] The use of a head restraint device is strongly recommended for nonpenetrating captive bolt.

Detection of problems—Lack of maintenance is a major cause of captive bolt gun failure for both powder-activated and pneumatic captive bolt guns.[78,79] Damp cartridges can result in soft-sounding, underpowered shots that are less effective.[74] Studies have found that a well-trained operator can easily render 95% or more of the animals unconscious with a single shot from a captive bolt gun.[78,79] It is advised that there is a problem if the effective first-shot rate falls below 95%.[78,79] The best plants have a 99% first-shot efficacy[71] (The FSIS has a zero-tolerance policy for missed first shot.) Evidence shows that the error rate in captive bolt stunners is easily kept below 5%.

Corrective action for problem—Store cartridges for powder-activated captive bolt guns in a dry location. Cartridges stored in a damp location are more likely to produce ineffective "soft" shots.[76]

Minimize movement of the animal's head. This can be achieved with either a head-holding device or behavioral methods such as changing lighting in the stun box. Head holders must be used with care; if poorly designed, they can increase cortisol levels and balking.[81] In the center-track conveyor system, the head will typically remain still without head restraint. This is due to having a long overhead solid top, which prevents the animal from seeing out until its feet are off the entrance ramp and it is riding on the conveyor.[46]

A nonslip floor in the stun box is essential to prevent slipping. Slipping causes animals to become agitated. The stun box floor should be flat or have a slight slope. Steeply sloped or stepped floors should not be used in stun boxes.

Maintain the captive bolt gun per the instructions from the manufacturer. Captive bolt guns are precision machine tools, and daily cleaning and maintenance are essential.

Use a test stand to determine whether the captive bolt has sufficient bolt velocity. Most captive bolt manufacturers market test stands for their captive bolt guns.

For pneumatic captive bolt guns, the air compressor that powers the gun must provide the air pressure and volume specified by the captive bolt manufacturer throughout the entire production shift. Air accumulation tanks or an undersized compressor will not provide sufficient power for the gun.

Heavy pneumatic captive bolt guns must be hung on a well-designed balancer so that the operator can easily position the gun without lifting its full weight. There are many balancer types and designs. Balancers must be well maintained; a partially broken balancer will make it difficult to position the

pneumatic captive bolt, causing the operator to exert more effort to move the gun.

Ergonomic design is especially important with pneumatic captive bolt guns because they are heavy and bulky. Small changes in handle location or the angle that the pneumatic gun hangs on the balancer can greatly improve ease of operation and lessen the effort required to position the gun.

Switches and valves that operate gates or start and stop conveyors must be located in a convenient location. On a conveyor restrainer, the operator should be able to start and stop the conveyor without moving from the normal position for stunning.

All the valves and switches for operating conveyors and gates must be kept in good repair. Partially broken hydraulic or pneumatic valves often require excessive effort to operate.

In large plants that use cartridge-fired captive bolt guns, more than one gun should be available to allow for both gun rotation and having a second gun available if the initial shot is not effective. Cartridge-fired captive bolts are less effective when they get too hot. Rotating the guns and allowing hot guns to cool will prolong their useful life. If a second stun attempt is needed, it must be performed immediately to minimize pain, suffering, and distress. Plants should have a written protocol in place for the use of the backup stunner and second stun attempts.

Gunshot—A properly placed gunshot can cause immediate unconsciousness (Figure 7). Under some conditions, a gunshot may be the only practical method of rendering animals unconscious with extremely heavy skulls, such as bulls, large boars, or buffalo.

Shooting should only be performed by highly skilled personnel trained in the use of firearms and only in jurisdictions that allow for legal firearm use. The safety of personnel, the public, and other animals that are nearby should be considered. For safety, a fully closed box that will contain a bullet that perforates through the skull or ricochets is strongly recommended.

In applying a gunshot to the head for the purposes of slaughter for captive animals, the firearm should be aimed so that the projectile enters the brain, causing instant loss of consciousness.[65,83–86] This must take into account differences in brain position and skull conformation between species, as well as the energy requirement for skull bone and sinus penetration.[66,83] Accurate targeting for a gunshot to the head in various species has been described.[83,84,87] The appropriate firearm should be selected for the situation, with the goal being penetration and destruction of brain tissue without emergence of the projectile from the contralateral side of the head.[86,87]

Basic principles of firearms—To determine whether a firearm or type of ammunition is appropriate for slaughtering animals, some basic principles must be understood. The kinetic energy of an object increases as the speed and weight or mass of the object increase. In reference to firearms, the bullet's kinetic energy (muzzle energy) is the energy of a bullet as it leaves the end of the barrel when the firearm is discharged. Muzzle energy is an indicator of a bullet's destructive potential. The heavier the bullet and the greater its velocity, the higher its muzzle energy and capacity for destruction of objects in its path.

Muzzle energy (E) can be expressed as the mass of the bullet (M) times its velocity (V) squared, divided by 2. However, to accommodate units of measure commonly used in the US for civilian firearms, energy (E) is expressed in foot-pounds. This is calculated by multiplication of the bullet's weight (W) times its velocity in feet per second (V) squared, divided by 450. The International System of Units expresses muzzle energy in joules after the English physicist James Prescott Joule (1818 to 1889).

The muzzle energy of commercially available ammunition varies greatly. For example, the difference in muzzle energy generated from a .357 Magnum handgun loaded with a 180-grain compared with a 110-grain bullet may differ by as much as 180 foot-pounds. Velocity has an even greater impact on bullet energy than bullet mass. Selection of an appropriate bullet and firearm is critically important for conducting euthanasia procedures. Lighter-weight, higher-velocity bullets can have high muzzle energy but decreased penetration, which can be an issue when penetrating thick bones.

As the bullet travels beyond the muzzle of the firearm, its energy gradually begins to decrease. While this is not a concern for the use of firearms near the animal, when attempting to shoot an animal from a distance, to ensure accuracy and that an acceptable level of muzzle energy is achieved, a high-powered rifle may be the better choice for rendering an animal unconscious. In all cases, the most important factors in ensuring a successful shot are the experience and skill of the shooter.

Muzzle energy requirements—Anecdotal evidence suggests that the .22 LR is one of the most frequently used firearms to euthanize livestock. A Canadian study[46] designed to evaluate firearm use for euthanasia of cattle in the event of a foreign animal disease outbreak found that both the .22 LR standard-velocity and .22 LR high-velocity bullets failed to yield adequate penetration of the skull. It should be noted that the distance between the shooter and the target (cadaveric skulls) was 25 m. Researchers concluded that the .22 LR was not an appropriate choice for euthanasia under these conditions.[46]

In a US study, 42 fresh cadaveric heads from *B taurus* beef feedlot steers 12 to 18 months old were used to evaluate 7 combinations of firearms and ammunitions (.22-caliber rifle firing a long rifle 30-grain plated lead solid- or hollow-point round, .223-caliber carbine firing a 50-grain ballistic-tip round, 9-mm pistol firing a 124-grain total metal jacket round, .45-caliber ACP firing a 230-grain full metal jacket round, and 12-gauge shotgun firing a 2.75-inch 1.25-ounce No. 4 birdshot shell or a 1-ounce rifled slug). All heads were shot from a distance of 3 m and oriented to make contact with the skull at a 90° angle. Of the 18 heads shot, only 6 shot with the pistol-fired 9-mm and .45-caliber ACP rounds and rifle-fired .22-caliber "hollow-point rounds" had brainstem lesions. The mean depth of penetration

for the .22-caliber "hollow-point" cartridge was significantly less than that of other firearms evaluated. The 9-mm pistol firing a total metal jacket round caused the least amount of brain tissue or brainstem trauma. It was determined that only 2 of the 6 heads shot with this firearm and ammunition combination would have likely resulted in instantaneous death. Researchers concluded that the rifle-fired .22 caliber hollow-point and the pistol-fired 9-mm rounds were not viable options for euthanasia of feedlot cattle.[88]

On the basis of the previous information, if a .22 LR is to be used for euthanasia of a mature bovine, a solid-point bullet fired from a rifle within a range of 3 m is recommended. Use of a .22 caliber handgun loaded with a hollow-point bullet or shooting from distances beyond 3 m is not advised. Similarly, although custom loaded bullets may yield different results than those observed in the above cited study, use of a 9 mm with a jacketed bullet cannot be recommended.[88]

There is little doubt that success or failure is partially related to firearm and bullet characteristics but probably more so to selection of the ideal anatomic site (ie, a site more likely to affect the brainstem) for conducting the procedure. The Humane Slaughter Association lists multiple firearms for humane slaughter of livestock, including shotguns (12, 16, 20, 28, and .410 gauges), handguns (.32 to .45 caliber), and rifles (.22, .243, .270, and .308). In general, when comparing handguns with rifles, the longer the barrel, the higher the muzzle velocity. Heavier rounds with larger propellant loads such as those used in 9-mm and 0.45-caliber pistols generally require greater barrel length for bullets to reach maximum muzzle velocity. A longer barrel length permits additional time for the combustion of propellants and the expansion of gasses that push the bullet through the barrel. For this reason, if a .22 is used for humane slaughter, it is best fired from a rifle. The .22 should never be used on aged bulls, boars, or rams.

To improve safety and reduce the possibility of the bullet passing through the animal's head or if the bullet misses the animal, many plant managers prefer the .22 LR. Some may prefer to use a pistol because it can be held closer to the head and many people find it easier to aim. For reasons described above, if a .22 handgun must be used, a high-velocity solid point 40-grain bullet or a larger-caliber firearm should be considered.

There are 2 main differences between use of a firearm in a slaughter plant and its use for on-farm euthanasia. In a slaughter plant, gunshot is followed by exsanguination, so it is not the sole agent used to cause death. Another difference is an animal in a slaughter plant is shot at a close range of 1 to 2 feet (0.3 to 0.6 m). When slaughter is done in less controlled situations out on the farm, a firearm larger than a .22 LR is recommended. It is essential to aim the shot correctly so that the brain is penetrated. If an animal is injured and is not rendered unconscious with a single shot, it is sometimes much more difficult to kill thereafter. The nervous system may go into a state of arousal, and multiple shots may fail.[88,90]

Bullet selection—Bullet selection is quite possibly the most important consideration for slaughter of livestock by gunshot. There are 3 basic types of bullets pertinent to this discussion: solid points, hollow points, and full metal jacketed bullets. Solid-point bullets are preferred for shooting livestock since they are designed for greater penetration of their targets. Under ideal conditions, this type of bullet will also undergo moderate expansion to a mushroom shape that increases its destructive characteristics. Hollow-point bullets are designed with a hollowed-out tip that causes rapid expansion and fragmentation of the bullet on impact. The hollow-point design allows maximum transfer of energy with a lower risk of overpenetration. Hollow points are less likely to ricochet, but if the free bullet hits a person, it is more dangerous than other bullets.

For applications such as slaughter plants, where it may be desirable to control or reduce the degree of bullet penetration, hollow-point bullets are preferred. However, for the purposes of humane slaughter of livestock, the first requirement is that the bullet possesses sufficient energy to penetrate the skull and enter the underlying brain tissue. The concern with hollow-point bullets is that since most of their energy is released on impact through fragmentation, they may not have sufficient energy to traverse the skull. Hollow points would be safer in a slaughter plant, but they may need to be used with a larger firearm than would solid points. The other extreme is represented by full metal jacket bullets, which do not expand or fragment on impact with their targets. These bullets have a lead core with a thin metal jacket cover that completely covers (surrounds) the bullet. Full metal jacket bullets generally achieve maximum penetration, which may have benefits for humane slaughter but also creates additional safety hazards for bystanders from perforation (ie, pass through) of the bullet. For this reason, full metal jackets are not recommended for use in slaughter plants. Shotguns loaded with shot shells (No. 4, 5, or 6 or slugs) have sufficient energy to traverse the skull but, unlike bullets from either a handgun or a rifle, rarely exit the skull.

Firearm safety cannot be overemphasized. Guns are inherently dangerous and must be always handled with caution. Common recommendations include the following: (1) assume that all firearms are loaded, (2) always know where the muzzle is and never allow it to point in the direction of oneself or bystanders, (3) keep fingers away from the trigger and out of the trigger guard until ready to fire, (4) be sure of the target and what lies beyond it, (5) always be sure that the gun is unloaded when not in use, and (6) keep the safety on until ready to fire. To improve safety, many gun owners prefer a single-shot rifle with either a bolt or break-open action. The action remains open until the operator is ready to fire. For those desiring more information or training on proper use of firearms, readers are advised to contact local hunter safety programs. These programs offer training in firearm safety and also provide information on rules and regulations for firearm use.

Firearms should never be held flush to the skull. Discharge of the firearm when the barrel is occluded or blocked results in the development of extreme pressure within the barrel that, when fired, may cause the barrel of the gun to explode, placing the shooter and observers at great risk of injury. Ideally, the muzzle of the firearm should be held within 2 to 3 feet (60 to 90 cm) of the animal's forehead and perpendicular to the skull, with the intended path of the bullet roughly in the direction of the foramen magnum. This will reduce the potential for ricochet while directing the bullet toward the cerebrum, midbrain, and medulla oblongata, which will assure immediate loss of consciousness and rapid death.

When other methods cannot be used, an accurately delivered bullet from a firearm is acceptable for humane slaughter.[84,91,92] When an animal can be appropriately restrained, the penetrating captive bolt, preferably one designed for euthanasia, is preferred to a gunshot because it is safer for personnel. Prior to shooting, animals accustomed to the presence of humans should be treated in a calm and reassuring manner to minimize anxiety. In the case of nondomesticated animals, gunshots should be delivered with the least amount of prior human contact necessary.

ii. Religious (nonstun)

The sharpness and nick-free status of the knife is important. The details are discussed above in the section on sheep and goats. For some of these animals, the knife length may need to be between that for sheep and goats and that for cattle, although the longer cattle knife can always be used if there is a concern.

6. Special considerations

Not applicable currently.

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E. Figures

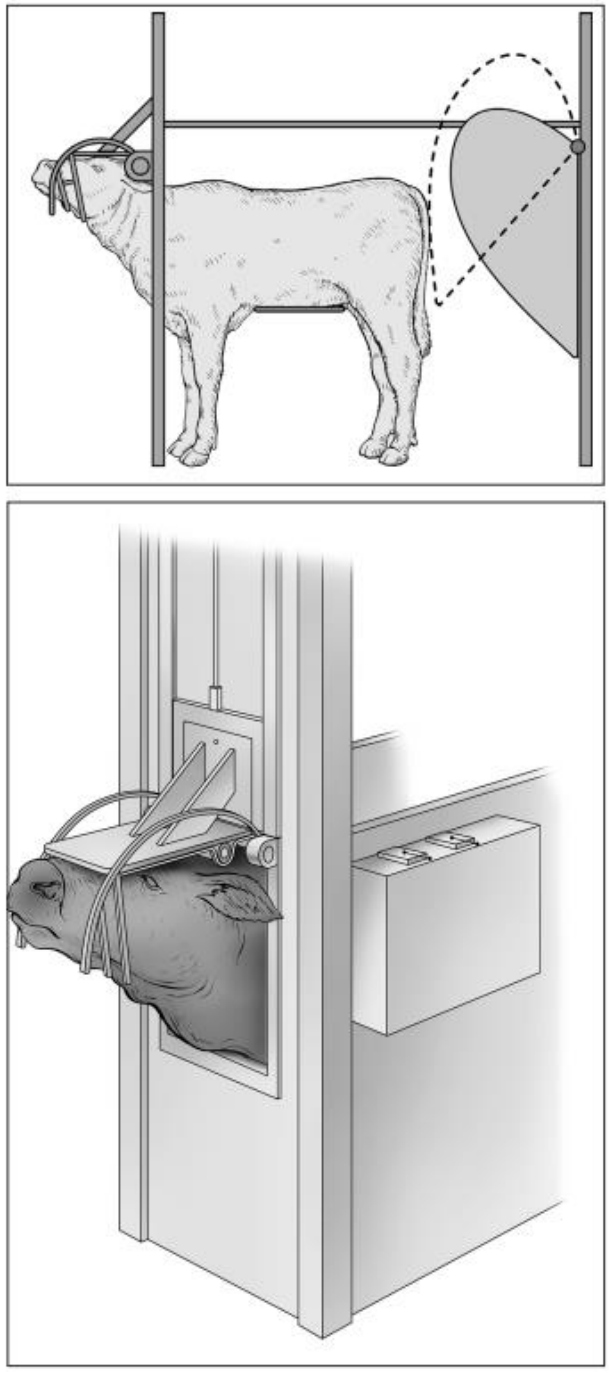


Figure 1

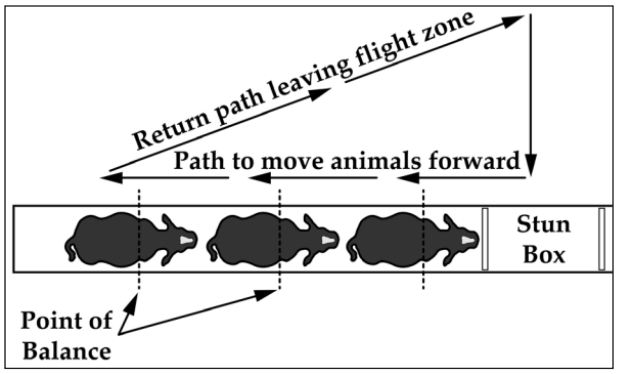
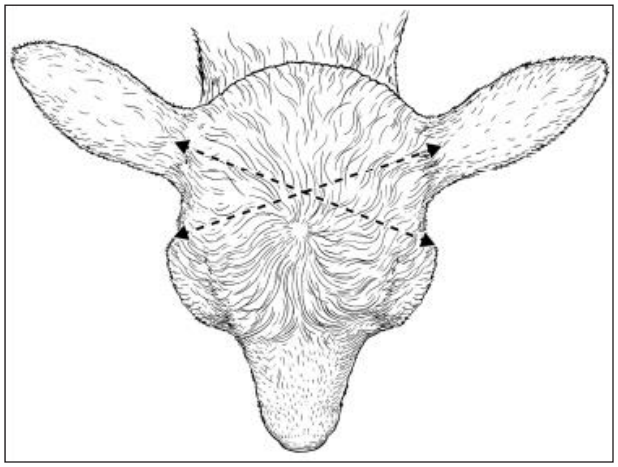


Figure 2



Figures 3 and 4—For polled sheep or goats (A), place the penetrating captive bolt (PCB) perpendicular to the skull over the anatomic site identified as slightly caudal to the poll (the crown or the highest point on the head) at the intersection of 2 lines drawn from the outside corner of each eye to the middle of the base of the opposite ear. Alternatively, a site located on the dorsal midline of the head, corresponding with the external occipital protuberance of the skull, may be used. When using the site associated with the external occipital protuberance, place the PCB flush with the skull at the external occipital protuberance while angling or aiming the muzzle of the PCB toward the mouth. Panel B indicates direction.

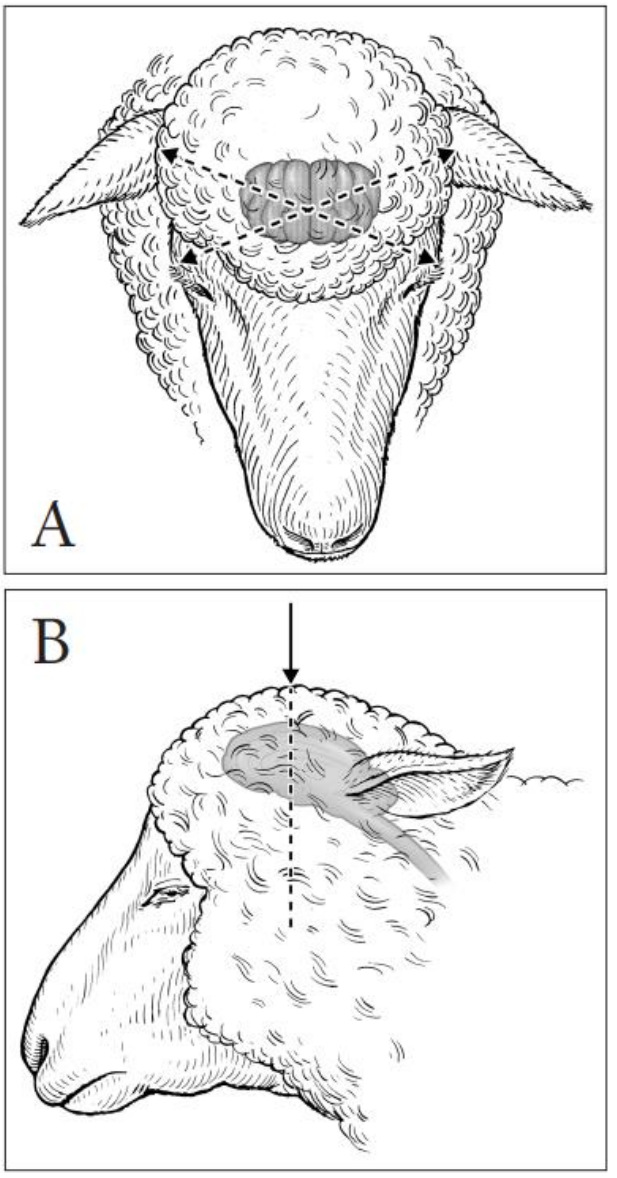


Figure 4

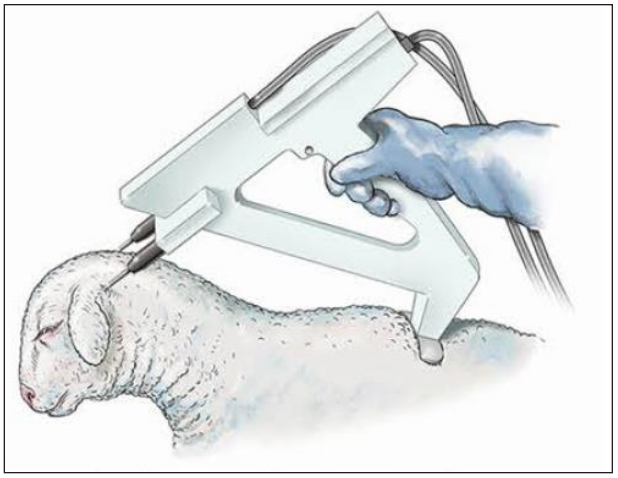


Figure 5

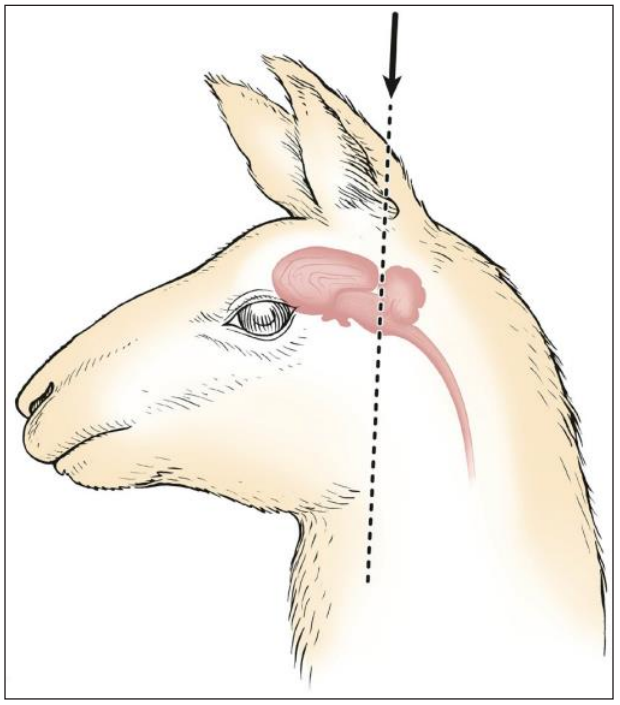


Figure 6

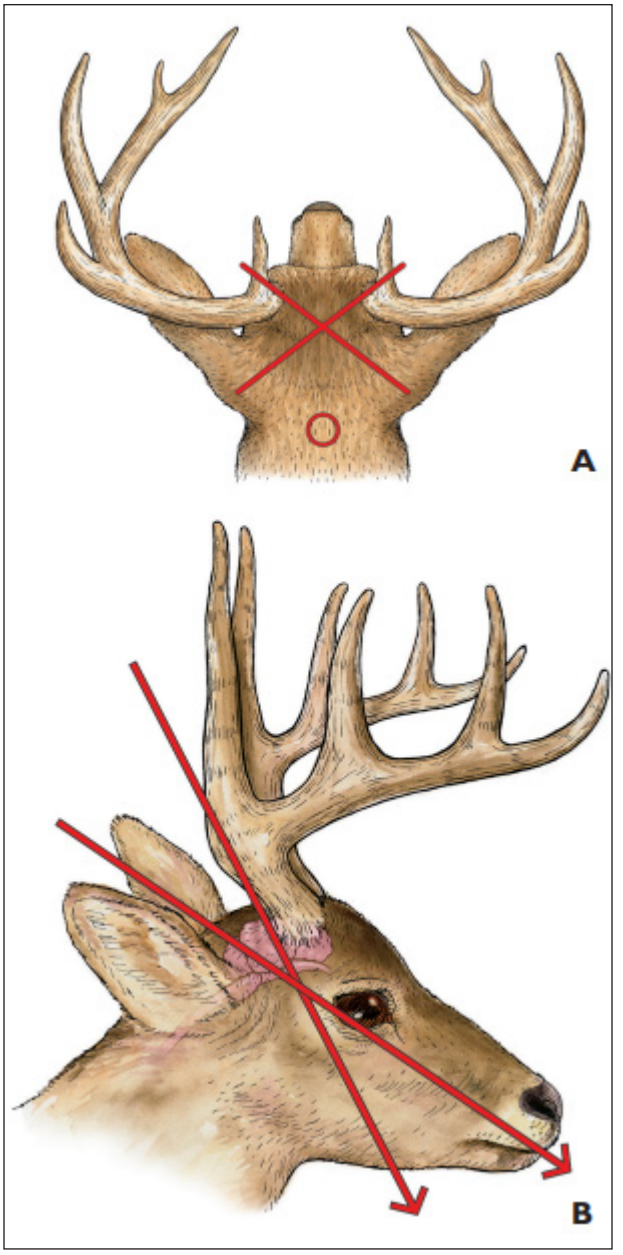


Figure 7—For slaughter of captive farmed cervids, several options exist. For animals accustomed to being worked through drop chutes, the animals can be restrained in a drop chute and shot with a captive bolt. For deer without antlers, the proper site for entry of a bolt from a PCB is the same as that described for goats and sheep previously: on the intersection of 2 lines drawn from the lateral canthus to the base or top of the opposite ear. For antlered deer (bucks), a frontal site may be necessary but may require a longer bolt length. The frontal site may be determined as on the intersection of 2 lines drawn from the lateral canthus of each eye to the top of the base of the ear or base of the antler.

Chapter VIII: Swine

A. General Considerations

The USDA regulates the foundational requirements for the humane slaughter of swine via the Humane Methods of Slaughter Act (HMSA).[1] The HMSA gives the USDA authority to make regulations to implement and enforce the law by issuing the Humane Methods of Slaughter Regulations,[2] which provide detailed guidance and standards.

B. Animal Behavior Considerations

These Guidelines are concerned with minimizing animal distress, including negative affective or experientially based states such as fear, aversion, anxiety, and apprehension, during the slaughter process. They are also meant to promote human well-being and safety as regards the repeated termination of animals' lives. The method for inducing unconsciousness and the handling and restraint methods associated with it must be evaluated as an entire system.[3] Physical methods require more handling and restraint of individual animals, compared with controlled atmosphere stunning (CAS), but they induce instantaneous unconsciousness. Controlled atmosphere stunning does not induce instantaneous unconsciousness, but possible distress during handling may be reduced. There may be a tradeoff between possible distress during a longer time to induce unconsciousness and the benefits of reduced handling of individual animals. Intentional violations of the HMSA[1] must not be tolerated. Unintentional pain and/or distress at slaughter caused by mistakes by personnel or poorly designed facilities must be addressed promptly. At all stages of the process of termination, animals should be treated with respect, and compromises to animal welfare should be treated as unacceptable if not unlawful. Veterinarians and stockpersons should ensure the following:

- No conscious animal is dragged, shackled, hoisted, or cut inappropriately. Before invasive dressing (eg, skinning, leg removal, scalding) begins, all signs of brainstem function, such as the corneal reflex, must be abolished.
- Excessive force or use of electric prods to move animals off trucks, up and down ramps, or into slaughter facilities or restraint devices should be avoided. Animals should not be forced to move faster than a normal walking speed. Handlers should move animals quietly, without using driving devices that would cause unnecessary pain and/or distress.
- Nonambulatory or disabled animals are isolated and moved with suitable equipment (eg, bucket of a loader, sled) and provided appropriate veterinary attention. Conscious nonambulatory animals must never be dragged.
- Swine are provided with access to water in the lairage pens. Animals should have sufficient room to move in accordance with state, federal, and local statues, and pens should have room for all the animals to lie down.
- Slaughter facilities and equipment are well maintained to minimize injury or pain to the animals and employees.
- The induction of unconsciousness (eg, stunning) causes minimal distress to the animal.
- All personnel are trained in both the application of stunning methods and behavioral principles of animal handling.

C. Human Behavioral Considerations and Training

Food animal veterinarians may be asked to bridge the physical and psychological divide between current practices used in the care and management of food animals and consumers by communicating the realities of conventional food production. They may also be asked to provide an ethical accounting and monitoring of animals' welfare on the farm, in feedlots, in aquafarms, and at slaughterhouses to the public in a transparent fashion. Food animal veterinarians are encouraged to increase their awareness of slaughter methods and enhance understanding of the science behind the methods currently used with a view toward the day-to-day complexities of managing food animals and the range of challenges facing our contemporary food animal sector. Likewise, industry agents, veterinarians, caretakers, and others engaged with the slaughter of animals for food should be encouraged to understand the diversity of public concerns and trending societal values and expectations related to how animals are farmed and slaughtered for food.

The humane slaughter of animals is a learned skill that requires training, respect, and self-awareness. Personnel performing humane slaughter must be technically proficient. Periodic professional continuing education on the latest methods, techniques, and equipment available for slaughter is highly encouraged. Personnel must also possess a temperament that does not bolster brutality. Self-awareness when it comes to processing animals for food will help to mitigate compassion fatigue and callousness.

The slaughter of individual livestock or poultry by farm workers who are also responsible for providing husbandry can substantially impact emotions.[4] Therefore, appropriate oversight of the psychological well-being of slaughter employees is paramount to mitigate guilt, distress, sadness, fatigue, alienation, anxiety, and behaviors that lack consideration of others or may lead to harming themselves, animals, or other people. People may have individual differences in how they psychologically react to the job of killing animals.[5] It is difficult to care about animals when they must be killed. This is called the "caring-killing paradox."[6]

Veterinarians and staff who are regularly exposed to the slaughter process should also be moni-

tored for emotional burnout, psychological distress, or compassion fatigue and be encouraged to seek appropriate psychological counseling.[7,8] While integrating good animal welfare in the food chain, some food animal practitioners may be torn among serving the best interest of the farmed animal, the human client (individual), personal professional interests, and societal concerns about improving quality of life for animals and ensuring the availability of safe and affordable animal protein. More studies on both the impact of animal slaughter on the personnel performing it and attitudes toward the consumption of animals for food among the general public will go a long way toward promoting healthier and more respectful human–food animal relationships.

D. Facility Design and Slaughter Process

1. Arrival at the plant

The standard process is for the pigs to be unloaded promptly after a vehicle arrives at the plant. In the best operations, the vehicles are unloaded within 15 to 60 minutes after arrival, and industry guidelines recommend a maximum wait time of 60 minutes.[9] Timely unloading requires scheduling an appointment between the plant and the transporter. Scheduling vehicle arrival times prevents the problem of too many vehicles arriving at the same time, which results in long lines and delays at unloading. Death losses in pigs increase as the internal temperature of the trailer increases.[10] The most recent data collected at 20 large US slaughter plants indicated that in market weight pens, 0.15% died either on the truck or shortly after arrival.[11] When a trailer arrives at a slaughter plant, thermal stress can be reduced by the use of misting banks of fans beside where the trailer is parked.[12] In Europe, trailers with internal misters and fans are used. These systems were not sufficient to cool pigs in very hot weather.[13] A US survey of buying stations showed that many cull sows and boars arrived in poor condition.[14] Another problem that reduces the fitness of transport for sows is the failure to dry them up after lactating prior to shipment. A Danish study[15] showed that 40% were shipped while lactating. **Figure 1** shows the step-by-step flow of animals through the plant.

i. Detection of problems

There have been unfortunate cases where many pigs have died while waiting an entire day to unload. This serious problem is most likely to occur when an emergency condition such as power failure or a storm either shuts down the plant or makes roads impassable.

ii. Corrective action for problems

It is best practice to have an emergency program to divert incoming trucks to other slaughter facilities or unload animals at auction markets, feedlots, or fairgrounds. This will require a coordinated program that facilitates immediate cancellation of animal loading on the farm and diverts loads that are en route to other facilities.

2. Unloading

When unloading is done correctly, pigs will move off the vehicle in a quiet, orderly manner. Handlers should be quiet and refrain from yelling, whistling, or repeatedly hitting the sides of the vehicle. The sound of people yelling is very stressful for livestock.[9] Electric prods can be eliminated during the unloading of most pigs. However, an electric prod may occasionally be necessary to move pigs out of a vehicle with multiple decks. Some pigs may find it very difficult to move if they have never had the experience of people walking through their pens on the farm. Handling experiences on the farm can affect pig movement in the future.[16–18] Pigs that have become accustomed to people walking through their pens on the farm will be easier to move and less likely to pile up when handled at the plant.

i. Detection of problems

Industry guidelines advise that if > 1% of animals fall during unloading or > 5% of animals are unloaded using an electric prod, there is a welfare problem in the unloading area.[19–21] Most plants can achieve this standard, as many larger plants have banned the use of electric prods at unloading. Additionally, there is a problem if animals in the unloading area run into fences or pile up. Quiet handling also significantly reduces bruises, which is an economic incentive for the facility. When unloading pigs from the trucks, plant employees should note whether the vehicle is overloaded. Vehicles should be loaded per industry and international guidelines.[9,22,23]

Overloading of trucks can cause severe economic losses. Bruised meat cannot be used for human consumption. Overloading trucks with pigs will increase death losses.[24] Animals should also be observed for transport-induced welfare problems such as frostbite, lacerations, heat stress, and urine scald.

Another problem that can seriously compromise animal welfare at the slaughter plant is when the animal is in poor condition prior to leaving the farm. Weak, emaciated animals or severe lameness can make humane handling difficult. The USDA does not permit the slaughter of nonambulatory downed or emaciated cattle.[2] However, US pigs that are not able to walk may be slaughtered. In Canada, they are euthanized and sent to rendering. Fatigued pigs that are unable to walk will recover if they are rested. There are often big differences between producers in the percentage of fatigued pigs arriving at the plant. Pigs fed high doses (9 mg/ton) of the β agonist ractopamine were more difficult to handle and had more hoof problems.[25,26]

ii. Corrective action for problems

Nonslip flooring in the unloading area is essential.[19–21] Quiet handling and good welfare are impossible if an animal slips and/or falls. A rough broom finish is not a satisfactory nonslip floor. A rough broom finish quickly wears down and becomes smooth and slick. For pigs, a good floor finish is to stamp the pattern of a 2.5-cm–wide opening (1 inch) expanded-metal mesh pattern into the concrete. There are other suitable finishes for stamping concrete, all rougher than a broom finish. For existing slick floors,

there are several options. In high-traffic areas, such as unloading ramps and scales, rubber mats made from woven tire treads can be used. There are many different types of nonslip rubber mats that can be used. Grooving tools can be rented from a concrete supply firm for regrooving concrete.

Meat packers should work with producers and buyers to reduce the number of fatigued pigs and unfit animals. Practical experience has shown that the percentage of fatigued pigs can be drastically reduced by making 3 changes in farm production practices: (1) walking regularly through finishing pens on the farm to make pigs calmer and easier to handle,[27] (2) changing genetic selection criteria to breed pigs with good leg conformation, and (3) using ractopamine responsibly.[3] In addition, packers should communicate to producers that the shipment of unfit animals is unacceptable and implement a financial penalty for the practice.

3. Receiving

The minimum acceptable level dock for pigs is 1.5 m (5 feet) in length.[28] After unloading, the standard practice in most plants is to verify that the number of animals on the vehicle matches the paperwork. Some plants have an extra handling step of weighing individual animals after unloading. However, many plants have eliminated this by weighing the entire truck before unloading. Additionally, in many plants, pigs are tattooed with an identification number as they walk off the truck.

i. Detection of problems

The most likely problems that can occur during receiving are pigs piling up and falling during tattooing.

ii. Corrective actions for problems

Provide nonslip flooring. For pigs, redesign the tattoo area. A funnel-shaped chute will result in the jamming of animals.[19,29–31] Plants with the calmest, quietest pig tattooing apply a slap tattoo as pigs exit the 76-cm (30-inch) truck door side by side.

4. Lairage

In most plants, animals are held in the same groups they traveled with on the trucks, which is ideal. In large plants, a typical lairage pen holds either 1 or 2 entire truckloads. It is important to design the pens to hold a whole number of truckloads, as a pen designed to hold one and a half truckloads will invariably end up having 2 loads forced into it. When new stockyards are being built, they should be laid out so that there is 1-way livestock movement through the yards. Ideally, the unloading ramps are at one end of the yards and the chutes to the stunner are at the other end. One good design is to have all the animals enter the pens from one alley and move to the stunner through the opposite end of the pens. Designs for lairage pens are in reports by Grandin and Deesing,[28] Grandin,[3] and Grandin and Cockram.[27] Smaller plants may have single or small groups of animals arriving from many different owners. Animals from each owner must either be held in their own small pen or have physical identification (such as ear tags, electronic identification, or tattoo) to prevent their identification from becoming mixed up with other animals.

The HMSA 9 CFR 313.22 requires that all lairage pens be equipped with water troughs, nipples, or other suitable devices so that the animals have access to water; if animals are being held longer than 24 hours, access to feed must be provided.[2] Well-designed and maintained lairage pens will be free of sharp edges that can injure animals. Industry recommendations for lairage pen space are 6 sq ft (0.55 m^2) for market-weight pigs under 114 kg (250 lb), 1 to 1.2 m^2 (11 to 12 sq ft) for sows, and 0.46 to 0.55 m^2 (5 to 6 sq ft) for mature boars. The animals should be provided sufficient space so they can all lie down simultaneously if held overnight. Before animals can be moved to the slaughter area, they undergo antemortem inspection. After inspection, the lairage pen is tagged as ready for processing. The exception to this rule is custom-exempt plants, which process animals for personal use by the owner or producer.

i. Detection of problems

The 3 main problems that can occur in the lairage pens are overstocking of the pens, fighting between animals causing injuries, and animals that become nonambulatory. Practical experiences with pigs have shown that large groups (over 100 pigs) fight less than small groups. A small group of 5 or 6 pigs in a small pen will sometimes result in prolonged fights. Another problem is animals mounting each other, which may result in weak animals falling down.

ii. Corrective action for problems

When fighting occurs, 1 animal is usually the main perpetrator. This animal should be removed from the group and placed in a separate pen. Intact males will often mount and ride other animals. Some of the worst fights in small plants are caused by singly raised backyard animals that have never learned how to socialize with other animals.[31] To prevent fighting, singly raised animals should be slaughtered within 1 hour after arrival, after allowing them a minimum of 30 minutes to calm down. For pigs, rest in the lairage pens after unloading for 2 or 6 hours will enable them to recover from transport stress.[32–34] A lairage time that is too long or no lairage time at all is detrimental to both meat quality and welfare.[35] There may be welfare disadvantages to having pigs spend the night in the lairage. One study indicated that spending the night in the lairage resulted in more skin lesions.[36] Monitoring of skin damage can be used as a measure of poor welfare.[37,38] Twelve to 18 hours of fasting from feed removal at the farm until stunning is ideal.[39]

The regulations within the 9 CFR 313.22 forbid dragging of nonambulatory animals unless they have first been stunned.[2] Nonambulatory pigs may be moved to either the suspect pen or the cripple area in the plant. The only acceptable methods for moving nonambulatory animals in the US are sleds, skid steer loaders, or specialized carts. In Canada, nonambulatory animals must be euthanized on the trailer and cannot be moved with sleds, skid steers, or specialized carts. The AVMA's policy on disabled

livestock[40] provides recommendations for down animals, including but not limited to the following: nonambulatory animals may be moved using a sled, mat, cart, or mechanized equipment that supports the full length and weight of the animal. A nonambulatory animal should not be dragged or lifted by the limbs, tail, neck, or ears.

5. Handling system

A wide variety of systems are available to move pigs from lairage pens to where they are stunned.[28,31,41] When animals are handled correctly, they move in an orderly fashion with no falling or pileups and minimal vocalizing or use of electric prods.[42] During the last few minutes before slaughter, excessive use of electric prods can seriously affect meat quality. Electric prod use in pigs raises lactate levels, and high lactate levels during the last few minutes before slaughter will result in lower pork quality.[43,44] Jamming animals in the chute that leads to the stunner and electric prod use will increase lactate levels.[45] Animals should never be backed into the stun box.

i. Detection of problems

Both industry guidelines and USDA Food Safety and Inspection Service regulations prohibit abusive practices such as dragging downed nonambulatory animals; poking sensitive areas such as the eyes, anus, or udder; slamming gates deliberately on animals; deliberately driving animals over the top of a down animal; and beating animals.[2,9] Handling problems that compromise welfare can result from a facility problem or an employee training issue. Before modifications are made to a facility, employees should be trained to use behavioral principles of livestock handling.[27,28,46–48] When people handle livestock calmly and quietly, design problems in the facility can be easily identified and corrected. If > 1% of the pigs fall at any point in the facility, there is a problem that needs to be corrected.[20,36,49] An automated powered gate that causes an animal to either fall down or be dragged along the floor is a serious problem that must be corrected.

In pigs, vocalization during restraint, handling, or painful procedures (squealing) is associated with physiologic measures of stress.[50–52] In a study of pigs,[51] high levels of squealing in the stunning area were associated with meat quality problems. In plants where there is no supervision, electric prod use can be excessive and problematic. In another study,[19] electric prod use in pigs varied greatly depending on whether a group of pigs was easy or difficult to drive. On easy-to-drive pigs, an electric prod was used on 4% of the pigs, and on a difficult group of pigs, 20% had to be electrically prodded to move them into the single-file chute.[19]

ii. Corrective actions for handling problems

1. Crowd pens that lead to the single-file race (chute) should not be overloaded
   For pigs, the crowd pen that leads to the single-file chute should be half full.[3,19,28] Pigs should be moved into the crowd pen in small separate groups. This is because moving small groups of pigs reduces stress.[53] During unloading, moving 4 or 5 pigs at a time also results in less stress and better meat quality compared to moving 10 pigs.[54] In addition, more pigs fell during handling when large groups were moved.
   Overfilling the crowd pen or overcrowding with the gate will cause animals to bunch up and turn back from the single file entry. Animals should be allowed time to move through the system without being rushed. When the animals move voluntarily through the system, they should be left alone. If the lead animal balks, allow it time to investigate and move forward.
2. Use natural following behavior and timing of bunches
   The next group of pigs should not be brought into the crowd pen that leads to the single-file chute until there is space in the single-file chute. This timing enables the animals to enter immediately, promotes their natural following behavior, and prevents them from turning around.[28]
3. Teach handlers behavioral principles
   Handlers must understand behavioral principles such as flight zone and point of balance.[27,29] The most common mistake when moving animals through chutes is a handler who stands at the head of an animal and pokes its rear in an attempt to make it move forward. Standing in front of an animal prevents it from moving forward. A recent survey[55] showed that 45% of handlers still made this mistake. Instead, handlers should be taught to use the movement pattern shown in **Figure 2**.[3] When a person quickly walks past the pig's shoulder in the opposite direction of the desired movement, the pig will move forward.
4. Prohibit routine carrying and use of electric prods
   In most plants with adequate facilities, the only place where an electric prod is occasionally needed is the entrance to the stun box or restrainer. Therefore, the prod should be kept in a convenient location and only used when needed. After it is used to move the occasional stubborn animal, it should be put away. Alternatives, such as vibrating prods or plastic paddles, should be the handler's primary driving tool. A vibrating prod can be made from a pneumatic engraving tool in which the sharp tip has been removed. A total prohibition of electric prods is not recommended, as a single shock from an electric prod is preferable to hard or repetitive hitting.
5. Use powered gates carefully
   When a powered gate is used to move pigs, it should be equipped with controls that enable a person to immediately stop its movement if an animal falls down. In addition, automated powered gates must be equipped with pressure-limiting devices to prevent the gate from knocking animals over or dragging/pushing animals along the floor.
6. Remove distractions that cause balking
   The movement of animals through a handling facility can often be greatly improved by making

small changes that remove visual and aural distractions that cause animals to balk and refuse to move.[28,31,47,49,56]

a. When an animal enters a stun box or restrainer, it must not have air blowing in its face.[19,46]
b. Use a directional lamp to provide indirect lighting to light up dark chute entrances. Animals tend to move from a dark place to a brighter place.[31,49,57]
c. Eliminate reflections on shiny metal or wet floors. Moving a light source may eliminate a reflection on a wet floor.[46] Reflected glare from shiny metal surfaces will increase balking and stopping of animal movement in plants.[58]
d. Cover the sides of chutes or install solid barriers to prevent approaching animals from seeing people, vehicles, or moving machinery ahead.[49,59] Large pieces of cardboard can be used experimentally to determine where solid shields are needed. The outer perimeter of a handling facility is one of the most important areas to cover.
e. Animals often refuse to walk over changes in floor type, such as moving from concrete to a metal floor. Pigs are also likely to balk at shadows.[60]
f. Reduce noise made by equipment, such as air hissing and metal-on-metal banging and clanging. Sudden, intermittent sounds and movements are more likely to cause agitation.[61] Many slaughter plants have high noise levels.[62] An app for a smart phone has been used to measure and assess noise levels in a pork slaughter plant.[63]

6. Restraint

A list of design principles to reduce stress during handling and restraint follows:

1. Ensure pressure applied is optimal—The device must apply enough pressure to make an animal feel restrained but avoid excessive pressure that will cause struggling or vocalization. A common mistake is to apply additional pressure when an animal struggles.
2. Do not trigger the fear of falling—This is why nonslip flooring is so important. When devices are used that hold an animal with its feet off the floor, the animal must be held in a balanced, comfortable upright position. For example, restrainer conveyors should be equipped with a false floor to prevent animals from seeing a visual cliff under the restrainer, as animals have depth perception.[54,64] For conventional stun boxes where the animal stands upright, nonslip flooring is critical. Stun boxes should never have a steeply sloped or stepped floor. Instead, a flat floor is recommended.
3. Ensure smooth, steady motion of parts of the restraint device that contact animals—Sudden jerky motion will cause animals to become agitated.
4. Block the animal's vision of people, moving equipment, and activity on the floor—To prevent balking and improve ease of entry into the restraint device, animals entering the device should not be able to see people, moving equipment, or activity on the processing floor.
5. Ensure stun boxes are of appropriate size—Stun boxes must be the appropriate size for the animals being processed. Animals must not be able to turn around in the box.
6. Group stunning pens—Many small plants stun pigs in small groups. The shackling area of a beef stunning box is often used for this purpose. Either electrical or captive bolt stunning can be used in these pens. Research has shown that when pigs watch other pigs being stunned with a captive bolt, it does not increase stress. Furthermore, blood lactate was shown to be lowest in the last 2 pigs that remained in the stunning pen the longest.[65] The last pigs were also more likely to grunt.[65]

i. Detection of problems

Vocalization can be easily measured in plants to detect problems with restrainers that are used for pigs. Animals will vocalize if excessive pressure is applied or another aversive event occurs.[9,66] Electric prod use may increase when a system is overloaded beyond its design capacity as handlers attempt to move animals through the plant. The following measures can be used to assess the performance of restraint devices:

1. Percentage of pigs that vocalize while held in the restraint device. The North American Meat Institute voluntary industry standard for vocalization is 5% or less of the animals.[3] Vocalization scoring is also used in the European Welfare Quality protocol.[67]
2. Percentage of animals (all species) that fall down to the extent that the body touches the ground. Scoring of animals falling is used in both the US and European voluntary scoring systems.[9,67] The voluntary industry standard is 1%.[9,68] However, the goal should be zero. Restraint devices that trip animals or those designed to make animals fall are not permitted in the voluntary industry standard.[9]
3. Percentage of animals moved with an electric prod into the restraint device. The voluntary industry standard for swine is < 5% for an acceptable score. If a group handling system is used for moving pigs into a CO_2 stunner, an excellent score would be 0% of the pigs.

AVMA policy states that "electrical devices (eg, stock prods) should be used judiciously and only in extreme circumstances when all other techniques have failed."[69]

All scores are per animal. The animal is either moved with an electric prod, or it is not. Either it is silent, or it vocalizes. Devices that paralyze animals using electricity should not be used as a method of restraint. Studies have clearly indicated that electroimmobilization is highly aversive and should not be used.[70–73] Electric immobilization must not be confused with electric stunning that causes uncon-

sciousness. Animals that have been immobilized with electricity will not be able to vocalize to show their distress.

ii. Conditions that cause welfare problems

1. Failure to provide nonslip flooring—One of the most common problems in stun boxes is slippery floors.[49] When animals are continuously slipping, they cannot stand still for stunning. Designs for nonslip floors can be found in the document section describing unloading. Metal grating or rubber mats work well to prevent slipping in stun boxes.
2. Overloading equipment beyond its design capacity—Two of the most common mistakes are overloading a single conveyor restrainer and overloading undersized CO_2 stunners.
   a. Overloading a single conveyor restrainer—If the goal is to have 1,000 pig carcasses/h enter the cooler, the restrainer will need to accommodate 1,200 live pigs/h. When pigs are forced to move faster than 850 pigs/h in a single line, they must move faster than their normal walking speed. Most large plants in which 1,000 pig carcasses/h enter the cooler have 2 conveyor restrainers with 2 single-file chutes and 2 crowd pens.
   b. Overloading of the undersized CO_2 stunners—Carbon dioxide stunning equipment is available in many sizes. One of the most common problems is when a plant's expansion causes it to outgrow its CO_2 stunning capacity. Unless the CO_2 stunner is replaced with another machine having a higher capacity, the following welfare problems are likely to emerge:
      i. Overloading gondolas by using electric prods to force excess pigs to load—Pigs should have sufficient room to stand in the gondola without being on top of each other.
      ii. Reducing gas exposure time in an attempt to increase the number of pigs the machine can handle per hour—Consequently, this decreased time will result in conscious pigs emerging from the stunner.
   c. Overloading single-animal stun boxes and restrainers—Single-animal stun boxes or restraint boxes have a maximum speed of approximately 100 animals/h. Boxes designed to hold single animals result in slower line speeds than conveyor systems because they use a start-stop process to put each animal in the box and then remove it. The signs of an overloaded box are as follows:
      i. Slamming the rear gate on animals
      ii. Increased electric prod use
      iii. More than 1 animal in the box for stunning
      iv. An increase in rough handling

      For all species, when the line speed exceeds 100 animals/h, using a conveyor system that handles a continuous stream of animals or 2 or more single-animal boxes is recommended.
3. Funnel-shaped crowd pens—The movement of pigs will be impeded in a funnel-shaped crowd pen. Therefore, a crowd pen that leads to a single-file chute should have an abrupt entrance.[19,30] In addition, the entrance to the single-file chute should be just wide enough to allow 1 pig to enter. If it is too wide, 2 pigs may become stuck beside each other entering the chute.
4. Stun boxes and single-file chutes too wide—The appropriate width for stun boxes and chutes tends to be overestimated. Stun boxes and chutes that are too wide result in animals turning around and becoming caught beside each other—46 cm (18 inches) for market-weight pigs. Chute width may need to be adjusted for exceptionally large or small animals.
5. Vertical overhead gate clearance is too low—Animals will often refuse to walk under a vertical slide gate or other apparatus that allows for scant clearance or touches their back.
6. Single-file chute length is too short—The single-file chute has to be long enough that a sufficient number of animals can be held within it to allow the time to refill the crowd pen.
7. Animals are required to stand in a stun box too long—Animals should be stunned immediately after they enter the stun box or restrainer. Holding an animal alone in a stun box can cause isolation stress.

E. Techniques

As noted in the Introduction, numerous humane methods exist for stunning pigs for slaughter; many of these methods are described in the following text.

1. Physical methods

i. Penetrating captive bolt guns

Penetrating captive bolts are used for swine in commercial slaughter plants. Their mode of action is concussion and trauma to the cerebral hemisphere and brainstem.[74,75] Properly done captive bolt stunning will instantly abolish visual evoked potentials and somatosensory evoked potentials from the brain.[42,76] This indicates that the animal's brain can no longer respond to a visual or tactile stimulus because it has been instantly rendered unconscious. Adequate restraint is important to ensure the proper placement of the captive bolt. The projectile must sufficiently disrupt a cerebral hemisphere and the brainstem to induce sudden loss of consciousness and subsequent death.[77,78] Appropriate placement of captive bolts for various species has been described.[74,79–83] Signs of effective captive bolt penetration and death are immediate collapse and a several-second period of tetanic spasm, followed by slow hind limb movements of increasing frequency.[75,77] The corneal reflex must be absent, and the eyes must open into a wide, blank stare and not be rotated.[77,84,85]

All penetrating captive bolt devices include a bolt that extends from the device, which is intended to enter the animal's skull and disrupt brain tissue. There is more variety with nonpenetrating captive bolt devices. The nonpenetrating head can be in

different shapes, primarily a mushroom (also called cone) shape or round (sometimes referred to as flat) shape (adapted from Accles and Shelvoke[86]) In addition, penetrating captive bolt devices can deliver an irreversible stun, by which the animal is rendered insensible resulting in death, while nonpenetrating captive bolt devices may only deliver a reversible stun, though this is dependent on the size and developmental age of the animal. For these reasons, the use of nonpenetrating captive bolt is generally limited to very young or small animals.[87]

There are 2 types of penetrating captive bolt guns: a penetrating captive bolt with a rod penetrating deep into the brain and a nonpenetrating captive bolt equipped with a convex mushroom head. These 2 types are the most common types used in commercial slaughter plants. Penetrating and nonpenetrating captive bolt devices can be powered by either powder cartridges (9 mm, .22 caliber, or .25 caliber) or compressed air.

All captive bolt guns require careful maintenance and cleaning after each day of use. Lack of maintenance is a major cause of captive bolt gun failure for both powder-activated and pneumatic captive bolt guns.[84,85] Cartridges for powder-activated captive bolt guns must be stored in a dry location because damp cartridges reduce effectiveness.[88]

General recommendations—The penetrating captive bolt is a practical method of humane slaughter for swine. Captive bolt guns used for larger species must have the properly matched caliber and cartridge size. Both penetrating and nonpenetrating captive bolts cause focal as well as diffuse injury. On the basis of electrophysiologic evidence, researchers determined that the primary determinant of effective stunning is the impact of the bolt and not penetration of the bolt into brain tissues.[74] In contrast, 1 report credits structural changes, including focal damage adjacent to the wound track and damage to peripheral tissues of the cerebrum, cerebellum, and brainstem, as the predominant factors affecting the effectiveness of the stun.[89] Both penetrating and nonpenetrating captive bolt guns are effective for inducing instantaneous unconsciousness.[88] Nonpenetrating captive bolt requires more careful placement than penetrating captive bolt to be effective.[87] A head restraint device is strongly recommended for the use of a nonpenetrating captive bolt. The nonpenetrating captive bolt must be positioned perpendicular to the animal's forehead.

Anderson et al[90] evaluated tissue depth measurements, brain area, and bolt-brain contact associated with the common frontal penetrating captive bolt placement and the alternative penetrating captive bolt placement that has been identified with a pistol-type penetrating captive bolt on cadaver heads from market hogs (estimated body weight, 136 kg [300 lb]). The authors concluded that the frontal placement appeared more reliable than the behind-ear placement due to less tissue thickness (soft tissue thickness, cranial thickness, and total tissue thickness) and a larger target area.[90]

The use of penetrating captive bolt in swine > 200 kg (440 lb) has been evaluated to determine the effectiveness of cranial location and type of captive bolt apparatus (cylinder or pistol type).[90,91] For swine > 200 kg, frontal placement may be more effective than temporal or behind the ear due to less soft tissue thickness, which may reduce concussive force.[91] Kramer[92] showed that the cylinder-style captive bolt was 100% effective in sows in all cranial locations (frontal, temporal, and behind the ear). However, the pistol-style captive bolt was only 100% effective behind the ear for sows. For boars, the cylinder style was 100% effective in frontal and behind-the-ear locations, but the pistol style was ineffective for any location.

Detection of problems—Lack of maintenance is a major cause of captive bolt gun failure for both powder-activated and pneumatic captive bolt guns.[43] Damp cartridges can result in underpowered shots that are less effective. Soft-sounding shots were an indication of less effective application.[81] Studies have found that a well-trained operator can render 95% or more of the animals unconscious with a single shot from a captive bolt gun, and there is a problem if the effective first-shot rate falls below 95%.[43,87] The best plants have a 99% first-shot efficacy (the Food Safety and Inspection Service has a zero-tolerance policy for missed first shot)[93]; self-auditing can assist with identifying problems.[94]

Corrective action for problems—The following actions should be taken to correct problems:

1. Store cartridges for powder-activated captive bolt guns in a dry location. Cartridges stored in a damp location are more likely to produce ineffective "soft" shots.[88]
2. Minimize movement of the animal's head. Immobilization can be achieved with either a head-holding device or behavioral methods such as changing the lighting in the stun box. Head holders must be used with care; if poorly designed, they can increase cortisol levels and balking.[95] In the center-track conveyor system, the head will typically remain still without head restraint. This is due to having a long overhead solid top, which prevents the animal from seeing out until its feet are off the entrance ramp and it is riding on the conveyor.[64]
3. A nonslip floor in the stun box is essential to prevent slipping. Slipping causes animals to become agitated. The stun box floor should be flat or have a slight slope. Steeply sloped or stepped floors should not be used in stun boxes.
5. Maintain the captive bolt gun per the instructions from the manufacturer. Captive bolt guns are precision machine tools, and daily cleaning and maintenance are essential.
6. Use a test stand to determine whether the captive bolt has sufficient bolt velocity. Most captive bolt manufacturers have test stands for their captive bolt guns.
7. For pneumatic captive bolt guns, the air compressor that powers the gun must provide the air pressure and volume specified by the captive bolt manufacturer throughout the entire pro-

duction shift. Air accumulation tanks or an undersized compressor will not provide sufficient power for the gun.

8. Heavy pneumatic captive bolt guns must be hung on a well-designed balancer so that the operator can easily position the gun without lifting its full weight. There are many balancer types and designs. Balancers must be well maintained; a partially broken balancer will make it difficult to position the pneumatic captive bolt, causing the operator to exert more effort to move the gun.
9. Ergonomic design is especially important with pneumatic captive bolt guns because they are heavy and bulky. Small changes in handle location or the angle that the pneumatic gun hangs on the balancer can greatly improve ease of operation and lessen the effort required to position the gun.
10. Switches and valves that operate gates or start and stop conveyors must be located conveniently. For example, on a conveyor restrainer, the operator should be able to start and stop the conveyor without moving from the normal position for stunning.
11. All the valves and switches for operating conveyors and gates must be kept in good repair. Partially broken hydraulic or pneumatic valves often require excessive effort to operate.
12. In large plants that use cartridge-fired captive bolt guns, more than 1 gun should be available to allow for both gun rotation and having a second gun available if the initial shot is not effective. Cartridge-fired captive bolts are less effective when they get too hot. Rotating the guns and allowing hot guns to cool will prolong their useful life. If a second stun attempt is needed, it must be performed immediately to minimize pain, suffering, and distress. Plants should have a written protocol for using the backup stunner and second stun attempts.

ii. Nonpenetrating captive bolt guns

The nonpenetrating captive bolt gun has either a wide mushroom-shaped head or a flat head that does not penetrate the brain of slaughter-weight pigs and sows. In general, regular nonpenetrating captive bolt guns only stun animals. Correct positioning is critical for an effective stun. When a nonpenetrating captive bolt gun is used, there is little margin for error. The stun-to- stick interval must not exceed 60 seconds. Nonpenetrating captive bolts are not effective for stunning adult swine.

Detection of problems—Refer to the section Penetrating captive bolt guns—Detection of problems. Be aware that the nonpenetrating captive bolt has a much smaller margin of error on aim.

Corrective action for problems—Refer to the section Penetrating captive bolt guns—Corrective action for problems.

iii. Gunshot

A properly placed gunshot can cause immediate unconsciousness. Under some conditions, a gunshot may be the only practical method of rendering animals unconscious with extremely heavy skulls, such as large boars. Shooting should only be performed by highly skilled personnel trained in the use of firearms and only in jurisdictions that allow for legal firearm use. In addition, the safety of personnel, the public, and other nearby animals should be considered. For safety, a fully closed box that will contain a ricocheting bullet is strongly recommended. In applying a gunshot to the head for the purposes of slaughter, the firearm should be aimed so that the projectile enters the brain, causing instant loss of consciousness.[80,96–99] This must consider differences in brain position and skull conformation, as well as the energy requirement for skull bone and sinus penetration.[99,100] Accurate targeting for a gunshot to the head in various species has been described.[97,99,101] The appropriate firearm should be selected for the situation, with the goal being penetration and destruction of brain tissue without emergence from the contralateral side of the head.[4,80]

Basic principles of firearms—Some basic principles must be understood to determine whether a firearm or type of ammunition is appropriate for slaughtering animals. The kinetic energy of an object increases as the speed and weight, or mass, of the object increase. In reference to firearms, the bullet's kinetic energy (muzzle energy) is the energy of a bullet as it leaves the end of the barrel when the firearm is discharged. Muzzle energy is frequently used to indicate a bullet's destructive potential. The heavier the bullet and the greater its velocity, the higher its muzzle energy and capacity for destruction of objects in its path.

Muzzle energy (E) can be expressed as the mass of the bullet (M) times its velocity (V) squared, divided by 2.83. However, to accommodate units of measure commonly used in the US for civilian firearms, energy (E) is expressed in foot-pounds. This is calculated by multiplication of the bullet's weight (W) times its velocity in feet per second (V) squared, divided by 450. The International System of Units expresses muzzle energy in joules.

The muzzle energy of commercially available ammunition varies greatly. Also, velocity has an even greater impact on bullet energy than bullet mass. Therefore, selecting an appropriate bullet and firearm is critical to good performance when conducting euthanasia procedures. Lighter-weight, higher-velocity bullets can have high muzzle energy but decreased penetration, which can be an issue when penetrating thick skull bones.

Whereas most slaughter using firearms is conducted at close range, calculations of muzzle energy are useful for determining which firearms are appropriate for slaughtering animals of varying sizes. As the bullet travels beyond the firearm's muzzle, its energy gradually decreases. While this is not a concern for the use of firearms in close proximity to the animal, when attempting to shoot an animal from a distance, to ensure accuracy and that an acceptable level of muzzle energy is achieved, a high-powered rifle may be the better choice for rendering an animal unconscious. In all cases, the most critical factors in

ensuring a successful shot are the experience and skill of the shooter.

Muzzle energy requirements—The muzzle energy required to render animals up to 180 kg (400 lb) unconscious is a minimum of 300 foot-pounds (407 J). For animals larger than 180 kg, firearms capable of yielding muzzle energies of 1,000 foot-pounds (1,356 J) are required for satisfactory results.[80]

Some would argue that the muzzle energies recommended are well beyond what is necessary to achieve satisfactory results. Anecdotal comment suggests that the .22 LR is one of the most frequently used firearms to shoot livestock with varying degrees of success. There is little doubt that success or failure is partially related to firearm and bullet characteristics but probably more so to selecting the ideal anatomic site (ie, a site more likely to affect the brainstem) for conducting the procedure. The Humane Slaughter Association lists multiple firearms for humane slaughter of livestock, including shotguns (12, 16, 20, 28, and .410 gauges), handguns (.32 to .45 caliber), and rifles (.22, .243, .270, and .308).[102] In general, when comparing handguns with rifles, the longer the barrel, the higher the muzzle velocity. Therefore, if a .22 is used for humane slaughter, it is best fired from a rifle. The .22 should never be used on aged bulls, boars, or rams.[103]

To improve safety and reduce the dangerous ricochet of bullets that either pass through the animal's head or miss the animal, many plant managers prefer the .22 LR despite its low muzzle energy and inability to yield adequate penetration of the skull. Some may prefer a pistol because it can be held closer to the head, and many people find it easier to aim. Pistols must be larger than a .22. There are 2 main differences between using a firearm in a slaughter plant and using it for on-farm euthanasia. In a slaughter plant, gunshot is followed by exsanguination, so it is not the sole agent used to cause death. Another difference is that an animal in a slaughter plant is shot at a close range of 0.3 to 0.6 m (1 to 2 feet). When slaughter is done in less controlled situations out on the farm, a firearm larger than a .22 LR is recommended. It is essential to aim the shot correctly so that the brain is penetrated. If an animal is injured and not rendered unconscious with a single shot, it is sometimes much more difficult to kill thereafter. The nervous system may go into a state of arousal, and multiple shots may fail.

Bullet selection—Bullet selection is quite possibly the most important consideration for the slaughter of livestock by gunshot. Three basic types of bullets are pertinent to this discussion: solid points, hollow points, and full metal jacketed bullets. Solid-point bullets are preferred for shooting livestock since they are designed for greater penetration of their targets. Under ideal conditions, this type of bullet will also undergo moderate expansion to a mushroom shape, increasing its destructive characteristics.

Hollow-point bullets are designed with a hollowed-out tip that causes rapid expansion and fragmentation of the bullet on impact. The hollow-point design allows maximum transfer of energy without the risk of overpenetration. Hollow points are less likely to ricochet, but if the free bullet hits a person, it is more dangerous than other bullets. For applications such as slaughter plants, where it may be desirable to control or reduce the degree of bullet penetration, hollow-point bullets are preferred. However, for the humane slaughter of livestock, the first requirement is that the bullet possesses sufficient energy to penetrate the skull and enter the underlying brain tissue. The concern with hollow-point bullets is that since the majority of their energy is released on impact through fragmentation, they may not have sufficient energy to traverse the skull. Hollow points would be safer in a slaughter plant, but they may need to be used with a larger firearm than solid-point bullet options.

The other extreme is represented by full metal jacket bullets, which do not expand or fragment on impact with their targets. These bullets have a lead core with a thin metal jacket cover that completely covers (surrounds) the bullet. Full metal jacket bullets generally achieve maximum penetration, which may benefit humane slaughter but also create additional safety hazards for bystanders. Therefore, full metal jackets are not recommended in slaughter plants because of safety issues.

Shotguns loaded with shot shells (No. 4, 5, or 6 or slugs) have sufficient energy to traverse the skull but, unlike bullets from either a handgun or rifle, rarely exit the skull. These are important considerations when selecting a firearm for humane slaughter. Probably the most crucial point to be made relative to the use of gunshots for humane slaughter is that scientific information on firearm and bullet selection is lacking. There is an urgent need for research for the best animal welfare.

Firearm safety—Firearm safety cannot be overemphasized. Guns must be handled with caution at all times. Safety needs to be the mindset in the handling and use of firearms. Common recommendations include the following: (1) assume that all firearms are loaded, (2) always know where the muzzle is and never allow it to point in the direction of oneself or bystanders, (3) keep fingers away from the trigger and out of the trigger guard until ready to fire, (4) be sure of the target and what lies beyond it, (5) always be sure that the gun is unloaded when not in use, and (6) keep the safety on until ready to fire. Many managers prefer a single-shot rifle with either a bolt or break-open action to improve safety. The action remains open until the operator is ready to fire. Readers are advised to contact local hunter safety programs for those desiring more information or training on proper use of firearms. These programs offer firearm safety training and provide information on rules and regulations for firearm use.

Firearms should never be held flush to the animal's body. When fired, the pressure within the barrel may cause the gun's barrel to explode, placing the shooter and observers at great risk of injury. Ideally, the firearm's muzzle should be held within 30 to 60 cm (1 to 2 feet) of the animal's forehead and perpendicular to the skull, with the intended path of the

bullet roughly in the direction of the foramen magnum. This target will reduce the potential for ricochet while directing the bullet toward the cerebrum, midbrain, and medulla oblongata, assuring immediate loss of consciousness and rapid death.

When other methods cannot be used, an accurately delivered gunshot is acceptable for humane slaughter.[96,103,104] When an animal can be appropriately restrained, the penetrating captive bolt, preferably designed for euthanasia, is preferred to a gunshot because it is safer for personnel. Before shooting, animals accustomed to the presence of humans should be treated calmly and reassuringly to minimize anxiety. In the case of wild animals, gunshots should be delivered with the least amount of prior human contact necessary.

Detection of problems—A well-trained shooter can render 95% or more of the animals insensible with a single shot. There is a definite problem if the first-shot efficacy rate falls below 95%.[105] Safety is a major concern with firearms with a free bullet used in a slaughter plant. Using a firearm that is not sufficiently powerful is a common cause of failure of the first shot.

Corrective action for problems—The following actions should be taken to correct problems:

1. Minimize movement of the animal's head. Refer to the section Penetrating captive bolt guns—Corrective action for problems.
2. A nonslip floor in the stun box is essential to prevent slipping. Slipping causes animals to become agitated.
3. The firearms must be taken apart and thoroughly cleaned each day. The gun should be replaced when it becomes worn out. Some firearms are not designed for heavy continued shooting in a large slaughter plant. For each particular firearm, plant management needs to determine a schedule for replacement. Firearms in need of replacement should be returned to a licensed dealer.
4. Switch and valves: refer to the section Penetrating captive bolt guns—corrective action for problems.
5. Two people should be used to move and shoot fractious or difficult-to-handle animals. One person moves the animal into the kill box or restrainer, and the other shoots the animal. This process makes it possible for the animal to be shot before it has an opportunity to become agitated.
6. If the first shot fails to render the animal instantaneously unconscious, a second stun attempt must be performed immediately to minimize pain, suffering, and distress. Plants should have a written protocol for using the backup stunner and second stun attempts.

Anatomic landmarks for the use of the penetrating captive bolt and gunshot—There are 3 possible sites for shooting swine: frontal, temporal, and from behind the ear, toward the opposite eye **(Figure 3)**.[104] The frontal site is in the center of the forehead, slightly above a line drawn between the eyes. The projectile should be directed toward the spinal canal. The temporal site is slightly anterior and below the ear.[106]

iv. Electric

Electric stunning for humane slaughter causes immediate loss of consciousness.[107,108] Alternating current has been used to euthanize dogs, cattle, sheep, goats, swine, chickens, foxes, mink, and fish.[96,99,107] When done correctly, electric stunning produces grand mal seizures, which have a tonic (rigid) action followed by clonic (paddling) action. These seizures occur prior to the electric transmission of pain stimuli to the CNS, so the procedure is not painful or distressful. To produce a grand mal seizure, electrodes must be placed so the current goes through the brain.[109] In mammals, reliable induction of an epileptic seizure may require a greater amount of current than that required for induction of cardiac arrest.[110] If death is not achieved quickly, consciousness is regained.[111]

Principles—Ohm's law involves current, potential difference (ie, resistance), and frequency. Current, or what flows through a wire, is measured in terms of amps (A). Current is proportional to the potential difference across 2 points. Voltage (V) measures the difference in electric potential between 2 points in a wire. Resistance, which determines how much current will flow, is measured in terms of ohms. Power, or current multiplied by voltage, is measured in watts (W). Frequency, or the number of cycles per second, is measured in hertz (Hz).

When electric stunning is used for humane slaughter, appropriate electric parameters must be used. These parameters vary with species and size. The effectiveness of electric stunning, in general, increases with increasing current and decreasing frequency. A minimum of 1.25 A is required for marketweight pigs.[112,113] Amperage must be maintained for at least 1 second. Insufficient amperage can cause an animal to be paralyzed without losing insensibility.[112] Electronic equipment designed to provide constant amperage, which sets the amperage and allows voltage to vary according to animal resistance, may prevent amperage spiking.[112,113] Older voltage-regulated electronic units allow amperage (spiking) changes, which may cause injury and blood spotting.

The minimum current required to induce an epileptic response depends on the stunning frequency.[114] Unconsciousness is most effectively induced at a frequency of 50 cycles (50 Hz).[115,116] Plant managers will often use higher frequencies to reduce damage to the meat caused by petechial hemorrhages (blood spotting). Generally, higher frequencies (800 Hz or greater) do not result in better stunning. In fact, the duration of tonic-clonic seizures increases with higher stunning frequencies and incurs a delay in time to unconsciousness. Animals stunned using higher frequencies will regain sensibility more quickly.[117] In other studies, 2,000 to 3,000 Hz frequencies failed to induce unconsciousness.[109,118,119] Grandin[113] recommends that higher frequencies only be used when they are passed through at least 2 electrodes to the head. Frequencies of sine waves at 1,592 Hz

or square waves at 1,642 Hz are effective in pigs, but the period of unconsciousness will be shorter.[117] Eight hundred hertz applied to the head with 50 Hz applied to the body is also acceptable.[120]

Proper electric stunning must not be confused with electric immobilization that paralyzes an animal without inducing unconsciousness.[121] Immobilization without unconsciousness is highly aversive and must not be used.[72,73] Electrocution induces death by cardiac fibrillation, which causes cerebral hypoxia.[118,122,123] However, animals do not lose consciousness for 10 to 30 seconds or more after the onset of cardiac fibrillation.

Methods—Three methods are used to perform electric stunning: the head-only reversible method, the 1-step head-to-body cardiac arrest method, and the 2-step method consisting of a current applied only to the head, followed by a current applied to the body, which stops the heart.[124] The head-only method does not cause cardiac arrest and will result in a return to consciousness in 15 to 30 seconds.[108,125] In the head-only method, animals should be bled within 15 seconds.[125] Tongs must be placed so that the current only goes through the head. This can be accomplished by placing tongs on both sides of the head or on the top and bottom of the head.

The 1-step method uses current applied through the head to the body to induce cardiac arrest. Current is simultaneously passed through both the brain and the heart, which induces cardiac fibrillation and immediate loss of consciousness.[108,124] Wotton and Gregory[126] suggest that the induction of cardiac arrest provides a major animal welfare advantage because it promotes the start of death. The head-to-body (or -chest or -back) method is highly effective in inducing irreversible unconsciousness in over 98% of pigs evaluated.[126] Pork plants using V-shaped conveyor restrainers have achieved > 99% correct electrode placement when the 1-step head- to-body cardiac arrest method is used.[127] Grandin[113] recommends that the first 1-second treatment should be at least 1.25 A at 50 to 60 Hz when the 1-step method is used. One electrode must be placed on the head **(Figure 4)**, and the other electrode can be placed on any part of the body (except for sensitive areas such as the eye, ear, or rectum). However, the first electrode must not be placed on the neck or back of the neck because the current will bypass the brain and cause instant pain.

The 2-step method uses the head-only method followed by a second application of the tongs to the chest. This method causes unconsciousness first and then death by cardiac arrest. Applying the second current by placing the electrode on the chest behind the foreleg has been reported to be effective.[128]

Signs of effective stunning—Unconsciousness occurs when electricity inhibits impulses from both the brain's reticular activating and somatosensory systems.[129] Signs of effective seizure induction include an extension of the legs, opisthotonus, and downward rotation of the eyeballs, as well as epileptic seizures or the tonic-clonic syndrome described above. The presence of an epileptic state has been considered a guarantee of an effective electric stun.[104,105,108,112,113]

On a more practical level, signs of effective stunning have been described.[43] Although the legs may move, the head must be examined when the animal is hung on the rail after the rigid phase of the epileptic seizure stops. The head and neck should be limp and floppy, and the tongue should hang out. The pig's head should hang straight down. If natural blinking occurs, the animal is not stunned. Nystagmus may occur in electric stunning, especially when frequencies > 50 Hz are used. Rhythmic breathing must cease, and vocalizations should not occur. Gasping is permissible after electric stunning, but it must not be confused with rhythmic breathing in which the animal's ribs move in and out. Animals electrically stunned with the head-only method will start to recover when kicking stops.

General recommendations—Electric stunning requires special skills and equipment that will ensure the passage of sufficient current through the brain to induce loss of consciousness and tonic and clonic epileptic spasms. Unconsciousness must be induced before cardiac fibrillation or simultaneously with cardiac fibrillation. Cardiac fibrillation must never occur before the animal is rendered unconscious. One-step methods that apply electric current from head to tail, head to foot, or head to moistened metal plates on which the animal stands are unacceptable because they often bypass the brain. The 2-step method should be used when there may be questions about sufficient current to induce a grand mal seizure with tonic and clonic spasms. This approach enables observation of tonic and clonic spasms before a second current is applied to induce cardiac arrest. Electroimmobilization that paralyzes an animal without first inducing unconsciousness is extremely aversive and is unacceptable.[72,73] For both humane and safety reasons, household electric cords are not acceptable.

Meat quality—The head-only method has both animal welfare and meat-quality issues.[128] Negative meat effects include decreased tenderness, increased drip-loss (water-binding capacity; syneresis leading to water puddling), and pale muscle color due to more intense muscular contractions compared with either 1-step or 2-step cardiac arrest stunning. Plant management may be tempted to lower the amperage and increase frequency to reduce blood splash (petechial hemorrhages) and broken backs. Stunner settings that reliably induce epileptic activity in the brain must be used.

In the interest of animal welfare, electric stunning of pigs should be done with an amperage of at least 1.25 A for 100-kg (220-lb) animals.[112,130] In the US, market-weight pigs are much heavier, and more amperage may be required to induce unconsciousness in these animals reliably. Pigs weighing 130 kg (287 lb) live weight require 1.8 to 2.0 A.[130] More recent research has shown that amperage is the most important electric parameter, but using a single electric parameter such as amperage is insufficient to guarantee effective stunning.[131,132] Plant operators should also evaluate animals for signs of

a grand mal seizure using the methods described by Grandin.[43]

The time between stunning and bleeding is critical when head-only stunning is used. Animals should be bled within 15 seconds.[108,133] When cardiac arrest is induced, the animals should be bled within 60 seconds. Most commercial plants use head-to-body stunning in which the current is passed simultaneously through the brain and the heart.[43,124] In small plants, Grandin[127] has observed problems with animals returning to consciousness after head-only stunning because of slow hoisting procedures. To prevent a return to consciousness, a second current should be applied to the body immediately after the initial head stunning to stop the heart.[128] Proper restraint is critical to allow the correct placement of the electrodes. Electrodes should be cleaned daily and properly maintained.

Improper electric stunning of pigs can cause blood splash, pale muscle color, or broken bones. These problems are a meat-quality issue and not an animal welfare concern because the passage of the current through the brain has already induced unconsciousness. The tongs or wand should be pressed firmly against the animal before the current is turned on. If the wand is energized before it is firmly applied, pigs will produce a short squeal.[43] This is a welfare concern because the animal would feel the shock. When the wand or tong is only partially applied, the animal does not receive the full amount of current.[134] Electric stunners work best when they are equipped with an automatic timer.

Detection of problems—Failure to cause immediate unconsciousness is highly stressful and may be painful. Humans experience pain when electroconvulsive shock therapy fails.[135] Several causes of electric stunning failure have been noted. The most common causes of return to consciousness after any type of electric stunning are incorrect electrode placement and poor bleeding.[126,127] Another cause of failure that has been noted in pigs is dehydration of the animal prior to stunning.[27] And finally, poor equipment maintenance can also cause failures in the procedure.

Another common cause of failure to induce unconsciousness is incorrect placement of the electrodes.[136] Electrodes must never be placed on eyeballs, ears, or other sensitive areas of the body. Likewise, electrodes must not be placed on wet metal plates on which the animal stands. Experiments with dogs showed that electrode positions where the brain is bypassed do not cause instantaneous unconsciousness. When electricity passes only between the forelimbs and hind limbs or neck and feet, it causes the heart to fibrillate but does not induce sudden loss of consciousness.[122] The animal will be electrocuted but remain conscious until it dies from cardiac fibrillation.

Four options are available for correct electrode placement for the head-only method, including on both sides of the head between the eye and ear, the base of the ear on both sides of the head, and diagonally below one ear and above the eye on the opposite side of the head. The head electrode should never be placed on the neck because the brain will be bypassed.[127] Diagonal movement of the electric current through the body can be accomplished by placing the head electrode behind one ear and the body electrode on the opposite side. Another effective position is head to the back.[124] When the 2-step procedure is used, placement of the body electrode behind the forelimb is effective.[128] Electrodes consisting of a metal band or chain around the nose and a band or chain around the thorax appear to be effective for pigs weighing up to 125 kg (275.6 lb).[137]

Grandin[127] states that energizing the electrodes prior to placement should not be done because pigs will squeal, possibly because of poor electrode contact. However, when the electrode is energized after it is firmly applied, the pig will not squeal.[127]

Even when electric methods that stop the heart are used, there are a few animals in which cardiac arrest is not induced. This is the reason why good bleeding technique is essential.[127] The most common cause of return to sensibility after head-only stunning is a stun-to-bleed interval of > 15 seconds.

When electric methods are used, the following signs of return to consciousness must be absent: rhythmic breathing, righting reflex, vocalization, natural eyeblink (menace reflex), and tracking of a moving object.[128] There are definite problems with electric stunning if pigs squeal when the electrodes are applied.[43] Vocalization cannot be used in sheep because sheep often do not vocalize when they are in pain. A well-trained operator should be able to place the electrodes in the correct position on 99% or more of the animals. There is a problem if more than 1% of the pigs vocalize during electrode application.[105]

Proper equipment maintenance is essential. At a minimum, electrodes should be cleaned once daily and regularly maintained.[112] Old, worn, or rusted equipment should be replaced on a regular schedule.

Corrective action for problems—The following actions should be taken to correct problems:

1. Check to ensure that the electric stunner induces a grand mal epileptic seizure. The tonic and clonic spasm is visible after head-only stunning. When a 1-step head-to-body method is used, the seizure may be masked. Often a very weak tonic and clonic movement is still visible.[43] If electroimmobilization is used to keep the carcass still after stunning, it must be turned off because it will mask the tonic and clonic spasms.
2. The electric stunner should be equipped with a meter to monitor amperage levels.
3. Monitor stunner operations for electrode placement and vocalization during electric stunner placement. Appropriate plant monitoring programs for evaluating the effectiveness of electric stunning should be implemented.
4. Wet pigs to ensure good electric contact. They should be wet but not dripping with water. Large amounts of water dripping off the animal may cause the current to pass over the surface of the pig instead of through the brain.
5. Make sure animals are not dehydrated. Dehy-

drated animals are more difficult to render unconscious with electricity.

6. Use a bleeding knife and techniques to produce a stream of blood at least 2.5 cm wide in pigs. A copious blood stream helps prevent problems with return to consciousness.[127]
7. When head-only stunning is used, equipment should be designed so that the animals are bled within 15 seconds after stunning.
8. The electrodes must be kept clean. A wire brush should be used to clean the electrodes several times each day.
9. Stunning tongs or wands should be ergonomically designed to reduce operator fatigue.
10. Rotate the operators to help prevent fatigue. Data collected from an electronically monitored stunning unit showed that after 3 hours, the operator was more likely to fail to press the electrode against the animal firmly. Firm contact is essential for an effective stun.[134]
11. Both sides of a V conveyor restrainer should run at the same speed. If one side runs faster than the other, the animals will become agitated.
12. Use insulated restraint equipment. Plastic slats are recommended on V conveyor restrainers, and there should be no exposed bolts. When single-animal restrainers are used, they should be insulated with plastic meat cutting board.
13. For operator safety, all electric stunners should be equipped with an isolation transformer or other device to prevent electricity from flowing from a single electrode to the ground. The electricity should only flow between the 2 electrodes. The metal frame of the restrainer and operator catwalk must be connected to a good ground.
14. All electric components such as the stunner switch, plugs, cords, and control box should be kept dry. The only part of the stunner that should be wetted is the electrodes. When the plant is cleaned, the stunning tongs or wand should be removed and stored in a dry location. The stunner control box should be either placed in a separate dry room or covered during plant wash.
15. Several types of restrainers (for head and body) can be employed for various species. Cattle, for example, must have a properly designed head restraint. A head holding device is usually not required for pigs.
16. Employee training is essential.

2. Atmospheric methods

i. Controlled atmosphere

Controlled atmosphere stunning and killing methods, also called modified atmosphere stunning or killing, produce unconsciousness and can eventually lead to death by 1 of 2 methods: (1) by displacing air and the oxygen it contains to produce O_2 levels < 2% (eg, hypoxia or anoxia using inert gases such as N_2 or Ar, or LAPS), or (2) by rapidly inducing decreased intracellular pH and cellular function through acute hypercapnia (eg, CO_2 used either alone or together with inert gases and supplemental oxygen to produce hypercapnic anoxia, hypercapnic hypoxia, or hypercapnic hyperoxygenation). Sequential combinations of the 2 methods, also called 2-step or multiphase processes, may use 1 gas or a mixture of gases to induce unconsciousness prior to exposure to a different gas mixture or higher gas concentration.

Whether a CAS method is classified as stunning or killing depends on the amount of time the animal remains in the modified atmosphere. Killing methods eliminate the concern that animals may regain consciousness prior to exsanguination. In either case, animals are not lifted or shackled until unconscious, so pain, stress, and fear associated with handling are minimized. In addition to reducing live animal handling, CAS may facilitate the ability to process more animals.[1] As with all inhaled or atmospheric methods, unconsciousness is not immediate, and any perceived distress and discomfort by animals will vary depending on the species, process, and gases used.

There is controversy in the scientific community regarding the optimum CAS gas mixture and application conditions for humane slaughter. Distress during the administration of CO_2 and the inert gases N_2 and Ar has been evaluated using both behavioral assessment and aversion testing and reviewed in the context of euthanasia.[138] It is important to realize that aversion is a measure of preference and that while aversion does not necessarily imply the experience is painful, forcing animals into aversive situations creates stress. However, the exposure conditions used for aversion studies may differ from those used for stunning or killing. In addition, agents identified as being less aversive (eg, Ar or N_2 gas mixtures) can still produce overt signs of behavioral distress (eg, open mouth breathing) for extended time periods prior to loss of consciousness under certain conditions of administration (eg, gradual displacement).[139]

A distinction must be made between immersion, where animals are placed directly into a high concentration of a gas or vapor within a container, and commercial CAS processes employed for the stunning of poultry and pigs. Unlike immersion, in a commercial process, animals gradually experience their introduction into CAS atmospheres, either through transport at a controlled rate into a contained stunning atmosphere gradient or through the controlled introduction of stunning gases into an enclosed space **(Figure 5)**. The transport or introduction rate may be slow or relatively quick, depending on the process and gases used. Further, denser-than-air CAS gases, including CO_2, layer into gradients within an enclosed space.[140] Thus, animals are not immediately exposed to stunning conditions known to be aversive or painful.

In pigs, hypoxia produced by combining N_2 and Ar appears to reduce, but not eliminate, aversive responses. In 1 study,[141] pigs chose to place their head in a hypoxic (< 2% O_2, 90% Ar) chamber containing a food reward, remained with their head in the chamber until they became ataxic, and freely returned to the chamber once they regained posture. In contrast, in another study,[140] exposure to 90% Ar, 70% N_2/30%

CO_2, and 85% N_2/15% CO_2 all resulted in signs of aversion, defined by the authors as escape attempts and gasping; the proportion of pigs showing these behaviors was lowest with Ar. Early removal from a hypoxic Ar or N_2 stunning gas atmosphere results in a rapid return to consciousness, such that exposure times > 7 minutes are needed to ensure killing with these gases.[142]

Inhalation of CO_2 causes acute respiratory acidosis and produces a reversible anesthetic state by rapidly decreasing intracellular pH.[143] Both basal and evoked neural activities are depressed soon after inhalation of 100% CO_2.[143–146] For pigs, exposure to 60% to 90% CO_2 causes unconsciousness in 14 to 30 seconds, with unconsciousness occurring prior to the onset of signs of excitation.[143,144,146–148] Unlike N_2 and argon, which must be held within a very tight range of concentration to produce oxygen levels < 2%, CO_2 can render animals unconscious over a wide range of concentrations, even when O_2 is > 2%.[149]

Genetics may play a role in pig CO_2 response variability. Panic disorder in humans is genetically linked to enhanced sensitivity to CO_2.[150] The fear network, comprising the hippocampus, the medial prefrontal cortex, and the amygdala and its brainstem projections, appears to be abnormally sensitive to CO_2 in these patients.[151] The genetic background of some pigs, especially excitable lines such as the Hampshire and German Landrace, has been associated with animals that react poorly to CO_2 stunning, while calmer lines combining the Yorkshire or Dutch Landrace conformations show much milder reactions.[47] Given a choice, Duroc and Large White pigs will tolerate 30% CO_2 to gain access to a food reward but will forego the reward to avoid exposure to 90% CO_2, even after a 24-hour period of food deprivation.[141,148] A shock with an electric prod, however, is more aversive to Landrace X Large White pigs than inhaling 60% or 90% CO_2, with pigs inhaling 60% CO_2 willing to reenter the crate containing CO_2.[152] Until further research is conducted, one can conclude that use of CO_2 may be humane for certain genetic lines of pigs and stressful for others.[43]

Refer to section Restraint—Conditions that Cause Welfare Problems for conditions that may cause welfare issues during CAS in pigs. These conditions include overloading of undersized CO_2 stunners, reduced exposure time to increase line speed and plant throughput, and overloading of gondolas by using electric prods to force excess pigs to load. Stunning gas concentrations should be monitored and adjusted as necessary.

F. Special Considerations

1. Nonambulatory swine

Lameness disorders interfering with locomotion and contributing to nonambulatory conditions in pigs include foot disorders (foot rot, overgrown claws, and torn dewclaws), leg injuries, leg weakness (epiphysiolysis, apophysiolysis, osteochondritis, and arthrosis), osteomalacia, fractures, arthritis, and various neurologic disorders. Although many of these conditions don't always result in nonambulatory conditions, all are significant causes of lameness that, in their severest form or when complicated by other conditions, can lead to nonambulatory conditions.[153]

Foot problems are reportedly the single most important cause of lameness in sows.[154,155] Slatted concrete floors contribute to the trauma of claws as feet slide outward when the sow attempts to stand. Overgrowth of claws, particularly on the lateral digits, is a serious problem in which sows are kept on nonabrasive floors such as plastic or steel slats.[153] Foot rot and claw lesions (erosions, white line disease abscesses, and vertical wall cracks) are common disorders, with occurrence rates as high as 64% in slaughter-weight pigs.[156]

Results of several studies suggest that osteochondritis (a degenerative disease of the articular or joint cartilage) is the most common cause of lameness in breeding-age animals. The joints mature by age rather than weight. In rapidly growing animals, the excess load on joints leads to disturbed development of the joint cartilage on both the physeal and epiphyseal surfaces. This is followed by bony changes that form in response to damage caused by mechanical stress and load on the joints.[157] It is a major cause of leg weakness in growing boars and sows.

Fractures are most often the result of falls on slippery concrete or falls that may occur during transport. They also result from situations where an animal's foot or leg becomes trapped beneath a feeder, in a slat, or between pen rails. As the animal struggles to free itself, it fractures the limb. The lameness that results is severe and often manifests by carrying the affected limb. Failure to apply weight to a limb is a good indication of a fracture. Fortunately, these are not common causes of lameness or nonambulatory conditions in pigs.[158]

In addition to these causes, neurologic disorders affect the spinal cord and brain. For example, an early study by Vaughan[158] suggests that the most common cause of posterior paralysis in pigs of all ages is compression of the spinal cord secondary to abscess formation of an intervertebral disk, a vertebral body, or adjacent paravertebral tissues. Causes in adult animals are believed to be associated with an excess load on vertebral disks that causes premature disk degeneration or osteochondrosis of the vertebrae. In growing animals, spinal abscesses are secondary to tail biting. These cases usually require euthanasia.

The incidence of transport losses in marketweight pigs (dead and nonambulatory) is approximately 1%.[159] In a study to evaluate the effect of floor space on transport losses, Illinois researchers observed 74 loads of finishing pigs; one load had 0.39 m^2/pig and another 0.48 m^2/pig during transport.[24] Investigators monitored the incidence of nonambulatory pigs at the farm during loading and at the plant after unloading. Of 12,511 pigs transported, 32 (0.26%) were identified as nonambulatory on the truck at the farm, 29 (0.23%) were dead on arrival at the plant, and 106 (0.85%) were nonambulatory at the plant. For 65 of 74 loads, nonambulatory pigs

at the plant were divided into 2 groups: nonambulatory injured and nonambulatory noninjured. The ratio of noninjured (0.55%) to injured pigs (0.24%) was 2:1. Overall, the total number of pigs lost in 74 loads was 135 (1.08%), which is comparable to previous studies. Increasing floor space did not affect the incidence of nonambulatory injured pigs at the plant, but it did reduce the percentage of nonambulatory noninjured pigs and thus total losses at the plant.[24]

2. Preventing nonambulatory swine

Lameness disorders involving the foot and leg are complicated. There is no single solution to correcting or preventing these conditions. But floors are a major consideration in preventing foot and leg problems. Pigs housed on slatted floors had an injury rate of 44% compared with 28% of pigs housed on solid floors.[160] Concrete floors caused more foot and leg problems than softer earthen floors or deep straw-bedded surfaces, and perforated floors contributed to increased injuries.[161] In farrowing stalls, plastic and steel slats caused more lameness than solid floors.[161] Flooring surfaces should provide sound footing to prevent slips and falls; however, achieving the ideal balance between adequate traction and a slippery surface is difficult. When surfaces are too soft or nonabrasive, claw horn wear is reduced, then claws overgrow rapidly. Foot trimming is required in these conditions, or the overgrowth will lead to claw deformities that also create strain on tendons of the lower leg. On the other hand, excessively abrasive flooring surfaces accelerate wear and may contribute to foot problems from excessive sole wear.

Softer flooring conditions are also believed to be beneficial for decreasing the incidence of osteochondritis. Avoiding overfeeding gilts during the growing period is even more important to preventing leg weakness caused by osteochondritis. In 1 study,[157] gilts fed ad libitum were culled earlier and at a higher rate due to leg weakness compared with gilts fed on a controlled feeding schedule. Research also demonstrates that pigs need exercise to increase muscular strength and to develop proper agility on differing flooring systems.[162]

Another factor that can contribute to causing downer pigs is the Halothane gene. Market pigs that were carriers (heterozygotes) had 0.27% death losses, and if they were homozygous negative, 0.05% death loss.[163] Fortunately, the Halothane gene has been strategically bred out of many swine herds. Therefore, it is not now a major cause of losses in the US.[164] High doses of the β agonist ractopamine may contribute to downers and make pigs more challenging to handle.[25] It may also cause hoof cracking.[26] Pigs that have received little or no contact with people in their pens on the farm prior to loading may be more likely to pile up and be difficult to move. Swine that have had previous experiences with handlers will be easier to move.[17,165,166] Producers should walk their pens during finishing to get pigs acclimated to people walking through them. This regular interaction will make handling and loading easier.[167] Fatigued nonambulatory pigs may be reduced because the pigs will be less likely to become agitated during truck loading or handling at the plant.

G. References

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H. Figures

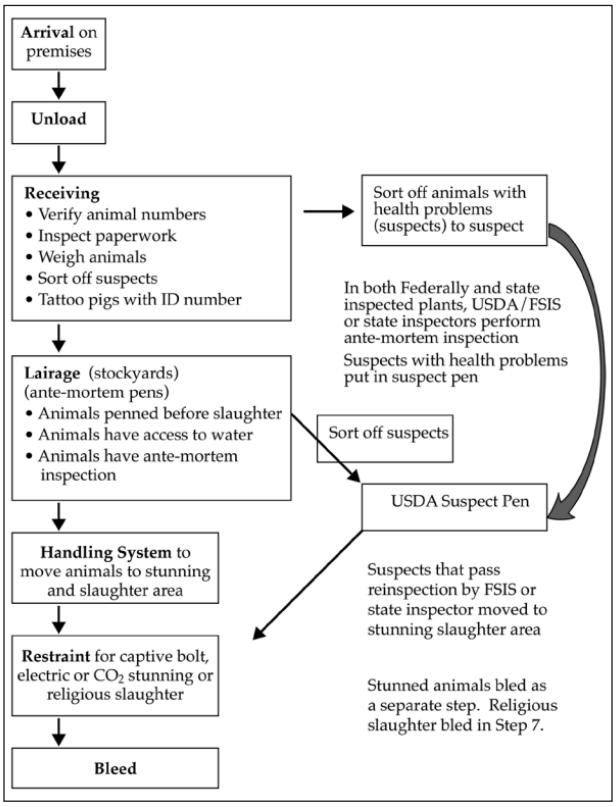


Figure 1

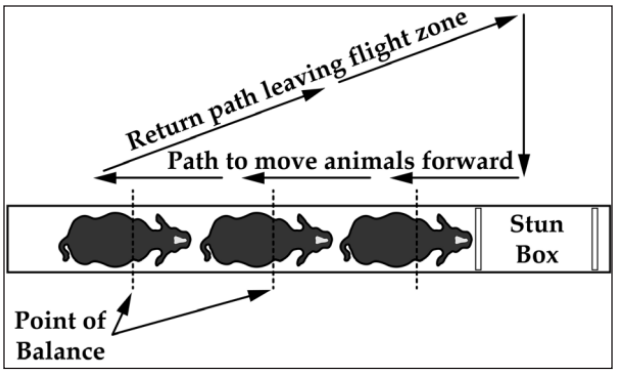
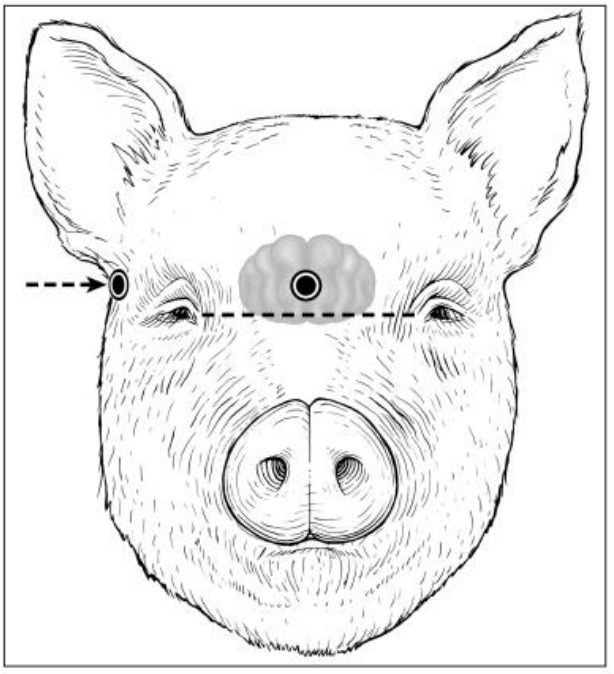


Figure 2



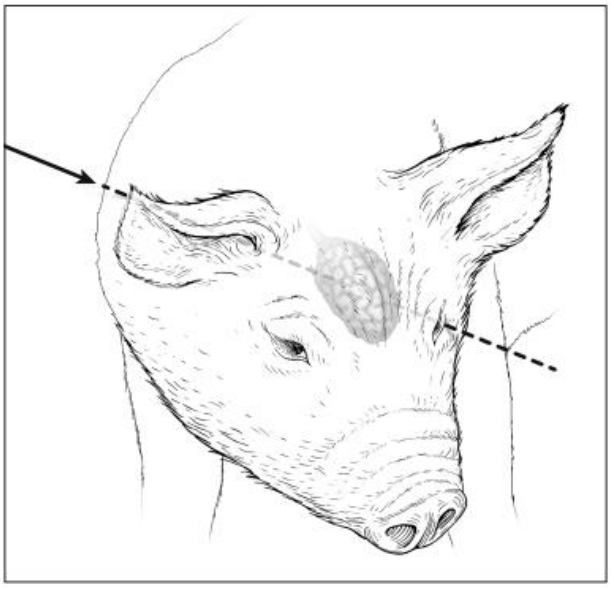


Figure 3

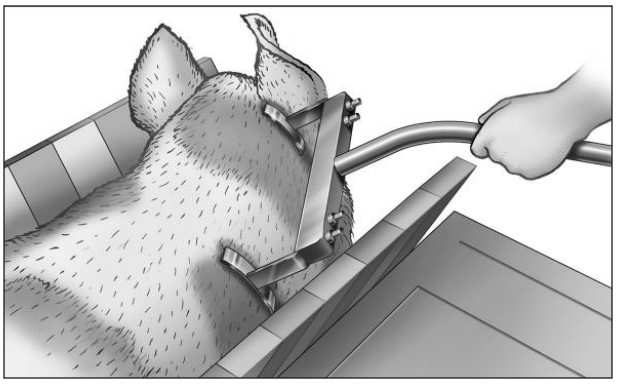


Figure 4

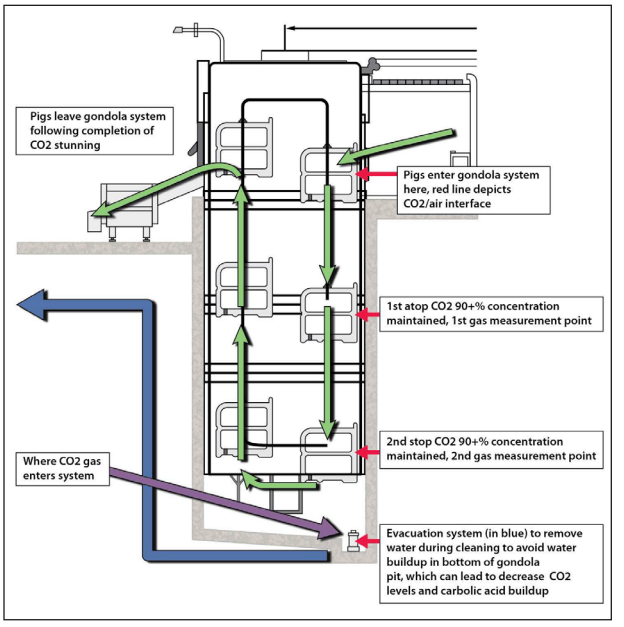


Figure 5