AVMA Guidelines for the Humane Slaughter of Animals: 2016 Edition

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Introduction

In 1963, the AVMA convened the first POE to provide guidance for veterinarians who perform or oversee the euthanasia of animals. In 2011, the AVMA POE determined there was a need to address and evaluate the methods and agents that veterinarians may encounter when animals are killed under conditions where meeting the POE definition of euthanasia may not be possible. The guidance contained within this document relates to the humane slaughter of animals intended for use as food.

The content of the AVMA Guidelines for the Humane Slaughter of Animals (Guidelines) reflects the AVMA's on-going commitment to ensure that the treatment of animals during every stage of life, including during the induction of death, is as humane and respectful as possible. 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. In interpreting that evidence, the POHS was committed to ensuring, to the best of its ability, that no unnecessary pain or distress is inflicted on conscious animals used for food prior to or during slaughter. These Guidelines are part of a triad of documents on humane killing—the other two being the AVMA Guidelines for the Euthanasia of Animals: 2013 Edition[1] and the anticipated AVMA Guidelines for the Depopulation of Animals.[2]

The latter half of the 20th century and the first two decades of the 21st century have seen the proliferation of the scientific study of animals' welfare to address public concerns regarding the ethical treatment of animals, especially those used in biomedical research and raised and slaughtered for food.[3] The treatment of animals is an important subject for public debate and discussion, especially in light of growing adoption of intensive forms of agricultural and aquacultural production and increased interest in food quality, safety, and quantity. Additionally, the scientific community and the public share an interest in the possibility of substantial cognitive, emotional, psychological, and social abilities in nonhuman species. Attention to questions about the moral status of animals has meant that veterinarians and others have had to demonstrate to the public due diligence in their professional roles. Approximately 10% to15% of veterinarians are involved in promoting the health and welfare of animals that will eventually become food.[4]

Commensurate with increased attention to how their meat is processed and prepared, the public has shown greater interest in the quality of life provided for animals raised for food, including the environments in which they are raised, how they are handled and managed, and how they are slaughtered and processed for human consumption. Contemporary slaughter practices are considerably improved over those of times past, but additional innovation is needed and possible. Careful attention to empirical issues is essential when assessing farming practices and slaughter methods from an ethical perspective.

Abbreviations

CAS	Controlled atmosphere stunning
CFIA	Canadian Food Inspection Agency
EEG	Electroencephalography
FSIS	Food Safety and Inspection Service
HMSA	Humane Methods of Livestock Slaughter Act
LAPS	Low-atmospheric-pressure stunning
LOP	Loss of position or posture
LORR	Loss of the righting reflex
OIE	World Organisation for Animal Health
POE	Panel on Euthanasia
POHS	Panel on Humane Slaughter
SEP	Somatosensory evoked potential

The POHS 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. Mechanical and physical methods, electrical methods, 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 food animals, and food security, will influence the recommendations in this and future editions of this document. The AVMA encourages its members to utilize their scientific knowledge and practical expertise to protect and promote the health and welfare of all animals.

The Guidelines do not venture into the morality of killing animals for food. The POHS's focus was on what should happen to animals when slaughter is their ultimate fate. When animals are designated for slaughter, they should be treated with respect and handled appropriately, and the slaughter process should limit the harms experienced by these animals. Humane slaughter methods and agents 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 minimizing (and, where possible, eliminating) anxiety, pain, and distress associated with terminating the lives of the following species of animals: hoofstock (cattle, bison, horses and mules, sheep, goats, swine, deer, elk), poultry (chickens, turkey, pheasants, ratites, geese, ducks), fish, alligators, and rabbits. The *process of termination*, as defined here, encompasses the period from which a farmed animal designated for human food consumption is off-loaded at a slaughter facility until it is verified to be unconscious and, ultimately, dead and ready for entry into the food chain.

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 slaughter of animals. These include, nonexhaustively, public health and safety, food safety and quality, environmental and economic sustainability, production adequacy and sustainability, occupational health and impact on the labor force, international animal welfare and trade standards, and religious and cultural expectations. These issues, however, are not the main 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 animals' welfare in the United States) should not be displaced by quality, quantity, or economic arguments.

The AVMA Guidelines for the Euthanasia of Animals: 2013 Edition should be consulted if individual animals are deemed inappropriate for the food chain. The anticipated AVMA Guidelines for the Depopulation of Animals should be consulted in the event that a zoonotic disease, a foreign animal disease, a natural disaster, or another concern for population health is the issue.

I1 Historical Context, Membership of the Panel, and Notes on the Current Edition

The membership of the POHS included considerable breadth and depth of 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 15 individuals, including veterinarians, animal scientists, and an animal ethicist. In reviewing the literature and formulating their recommendations, members of the Panel tapped the expertise ofcolleagues in pertinent fields and also 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 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 food.

The Guidelines acknowledge that the slaughter of animals used for food is a process involving more than what happens to the animal at the time of its death, and that veterinary responsibilities associated with slaughter are not limited to the moment or procedure of killing the animal. In addition to delineating appropriate methods and agents for slaughter, the Guidelines recognize the importance of considering and applying good preslaughter and animal-handling practices. Information about confirmation of death has also been included. While some slaughter methods may be utilized in euthanasia and depopulation, recommendations related to euthanasia and depopulation are addressed specifically in other documents created by their respective Panels.

I2 Statement of Use

The POHS has developed these Guidelines for use by members of the veterinary profession who have an interest in the humane slaughter of hoofstock, poultry, rabbits, alligators, and fish. 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. While we believe the Guidelines contains valuable information that can help assure and improve animals' welfare during slaughter, it is important to understand that the HMSA[5] and its regulations provide final federal authority regarding slaughter practices in the United States.

These Guidelines do not address methods and techniques involved in the termination of animals hunted for food (subsistence or otherwise) or animals raised primarily for their fur or fiber.

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). To minimize distress to animals and to 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 an animal 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. Human safety is of utmost importance, and appropriate safety equipment, protocols, and expertise must be available before animals are handled. Advance preparation of personnel must include training in the stipulated slaughter methods and assurance of understanding of and sensitivity toward animal welfare indices. 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. Slaughter must always be performed in accord with applicable federal, state, and local laws and regulations.

I3 Evaluating Slaughter Methods

Some methods of slaughter require physical handling of the animal. The amount of control and the kind of restraint required will be determined not only by the species, breed, and size of 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 pain and distress in animals and to ensuring the safety of the person performing slaughter, any bystanders, and other animals that are nearby.

Selection of the most appropriate method of humane slaughter in any situation will depend on the species and number of animals involved, available means of animal restraint, skill of personnel, and other considerations. Personnel who slaughter animals for food must demonstrate proficiency in the use of the technique in a closely supervised environment. Each facility where slaughter is performed is responsible for appropriately training its personnel. Experience in the humane restraint of the species of animal is critical. Training should include familiarity with the normal behavior of the species, an appreciation of how behavior affects handling and restraint, and an understanding of the mechanism by which the selected technique induces loss of consciousness and death.

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 POHS gave serious consideration to the following criteria in their assessment of the appropriateness of slaughter methods: 1) ability to induce loss of consciousness followed by death with a minimum of 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 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 in the best way possible. 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 her or his professional obligations and ethical commitment to society.

I4 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. Therefore, both the induction of unconsciousness and handling prior to slaughter must be considered. Criteria for determining the humaneness 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: 2013 Edition.

Humane slaughter methods produce unconsciousness through four 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) epilepitiform 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 three phases.[6] 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.[7] 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 are 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 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[8] 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."[9] Pain is therefore subjective in the sense that individuals can differ in their perceptions of pain intensity as well as in their physical and behavioral responses to it.

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 disconnection between one's sense of self and one's awareness of time and space.[10] Although we cannot know for certain the subjective experiences of animals, one can speculate 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).[11]

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 LORR, also called LOP.[8,12,13] 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.[8] 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 where both arousal and awareness in humans are low or absent.[14] Loss of consciousness should always precede loss of muscle movement.

Although measurements of brain electrical function have been used to quantify the unconscious state, 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.[15,16] Also, it is not always clear which EEG patterns are indicators of activation by stress or pain.[17] Reduction in alpha-to-delta brain wave ratios coincides with LOP in chickens,[18,19] reinforcing the usefulness of LOP or LORR as an easily observable proxy for loss of animal consciousness.

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.[20,21] In cattle, however, there is species variability in this response. The corneal reflex will also be absent.[22] 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.[21,23] Physical methods are inexpensive, humane, and 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 unconsciousness, 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.[24] 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,[25–27] has been controversial.[28] As indicated previously, EEG cannot provide definitive answers as to the exact onset of unconsciousness. Other studies[26,27,29–31] indicate 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.[32] Given that we are limited to applying slaughter methods based on these four 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.

I5 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.[33] 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 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.
- 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 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.

I6 Human Behavioral Considerations

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 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 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.[34] 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.[35] It is difficult to care about animals when they have to be killed. This is called the "caring-killing paradox."[36]

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.[37,38] 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.

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History of Regulations, Industry Guidance and Employee Training in the United States

H1 History of Regulation of Slaughter in the United States

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 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. 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 an electrical, chemical or other means that is rapid and effective before being shackled, 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. Additionally, Section 1906 exempts the handling or other preparation of livestock for slaughter under the second method from the terms of the Act. 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.[2]

Currently, the HMSA of 1978 does not cover poultry. 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).[2] 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. 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. 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.[2] Currently, this approach is voluntary on the part of industry. A provision in the USDA appropriations act for fiscal year 2001 (P.L. 106-387) amended the Poultry Products Inspection Act to include mandatory 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 U.S.C. 1621 et seq, which promotes distribution and marketing of agricultural products (includes exotic species not under the Federal Meat Inspection Act). Exotic animals that are defined by these regulations are reindeer, elk, deer, antelope, water buffalo, or bison. 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).

Many countries have set standards for welfare practices with regard to humane slaughter, and the OIE also includes standards for the humane conduct of slaughter in Chapter 7 of its Terrestial Animal Health Code.[3] 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.[4]

H2 Enforcement of Humane Slaughter in the United States

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 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.[5,6] Only three 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.[6] There were numerous other problems observed in the 22 beef, pork, lamb, and veal plants that were surveyed.[5,6] The FSIS recognized a need for improvement and produced a video that served as a correlation 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. 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 inspection program personnel spend to ensure humane handling and slaughter requirements are met.

In February 2010, the Government Accountability Office published a report[7] 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 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. 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.[8]

In October 2013, the FSIS published a new guidance on the systematic approach to the humane handling of livestock.[9] 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.

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 HMSA or the regulations. The goal is to prevent suffering of animals while protecting the food supply.

H3 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.[5,6] The first version was published in 1997, and the most recent complete version is by Grandin.[10] The guideline considers five outcome measures. The use of outcome-based measurements to assess animal welfare is recommended.[11–13] Following is a summary of the five major measurements[14]:

1. Percentage of animals rendered unconscious with a single shot from a captive bolt or percentage of animals where the electric stunner is placed on the head in the correct position. The minimum acceptable scores are 95% 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, 95% of the cattle or pigs must remain silent in the stun box or conveyor restrainer or during restraint for religious slaughter. Refer to Grandin[10] for more detailed information on scoring vocalization. Vocalization scoring should not be used for sheep.
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: 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.[15,16] The use of electric prods and the percentage of animals vocalizing were also greatly reduced.[16]

The AVMA PHS believes that important elements for best practice with regard to humane slaughter are: 1) maintenance logs on stunners, 2) training programs for employees, and 3) auditing using 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 ownprogram. 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 that 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 American Meat Institute objective scoring system to determine when a plant has a problem.

H3.1 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 return to sensibility is observed, it is essential to not confuse corneal reflex, nystagmus, and natural blinking (menace reflex). An animal that has a weak corneal reflex after electric stunning is usually unconscious, but after captive bolt or gunshot, the corneal reflex must be absent. An animal that has natural blinking 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 two excellent examples of clear descriptions of an egregious situation of inhumane handling in attachments 4 and 5 of Directive 6900.2, revision 2.[17]

H3.2 Video Auditing by Industry

Two 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.

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Design of Facilities and Slaughter Process

D1 Handling Procedures at Slaughter Plants for Hoofstock

D1.1 Step 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.[1] 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. Death losses in pigs increase as the internal temperature of the trailer increases.[2] **Figure 1** shows the step-by-step flow of animals through the plant.

D1.1.1 Detection of problems

There have been unfortunate cases where many cattle or pigs 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, which either shuts down the plant or makes roads impassable.

D1.1.2 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.

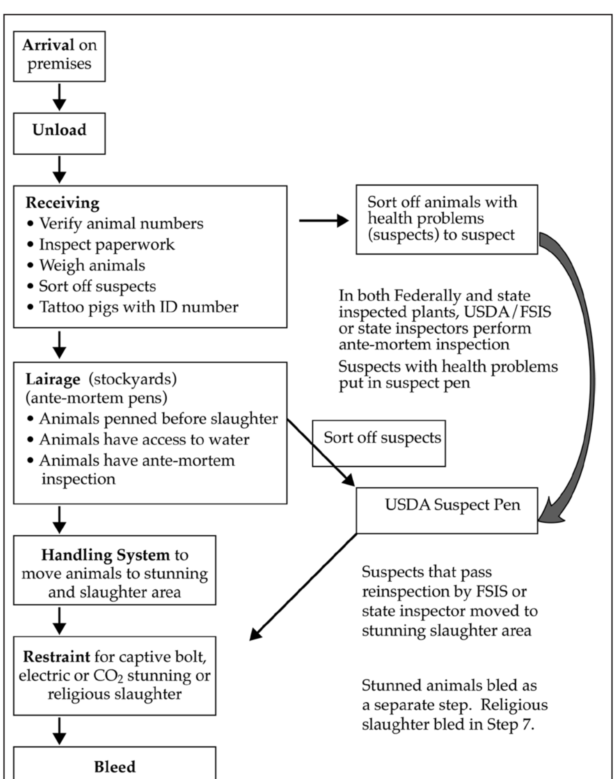

Figure 1—Step-by-step flow of animals through a slaughter plant.

D1.2 Step 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.[3,4] Electric prods can be completely eliminated during unloading of most hoofstock and ducks. The best US sheep plants use trained sheep to lead the animals off the vehicle.[5] An electric prod may occasionally be necessary to move pigs out of a vehicle with multiple decks. Some pigs may be 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.[6–8] 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 they are handled at the plant.[5] 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.[9]

D1.2.1 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.[10–12] 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,[a] 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.[1,9,13,14]

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[15–18] (for US transport regulations refer to 49 USC Section 80502[19]). A large survey[20] in both the United States and Canada showed that 49% of the cattle trucks arriving at processing plants were overloaded. Cattle that are heat stressed will breathe with their mouths open.[24] Overloading trucks with pigs will increase death losses,[21] and overloading horses will lead to fighting, restlessness, falling, and injury.[22] Research[23] with sheep indicated that packing sheep too tightly on a vehicle resulted 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. A survey[25] 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. 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. Fatigued pigs, which are unable to walk, will recover if they are rested. There are often big differences between producers on the percentage of fatigued pigs arriving at the plant. Pigs fed high doses (9 mg/ton) of the growth promotant ractopamine were harder to handle and had more hoof problems.[26,27]

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. 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.

D1.2.2 Corrective action for problems

Nonslip flooring in the unloading area is essential for all species.[10–12] 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, 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. For the smaller species, such as pigs, deer, or sheep, a good floor finish is to stamp the pattern of a 1-inch-wide-opening 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, rubber mats made from woven tire treads 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.[10] 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[28] and Grandin.[10,11]

Meat packers should work with producers and buyers to reduce the numbers of fatigued pigs and unfit animals. Practical experience has shown that the percentage of fatigued pigs can be drastically reduced by three changes in farm production practices: 1) walking regularly through finishing pens on the farm to make pigs calmer and easier to handle,[5] 2) changing genetic selection criteria to breed pigs with good leg conformation, and 3) using ractopamine responsibly.[29] Research[30] 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 practice.

D1.3 Step 3—Receiving

For cattle, unloading areas for large trucks should be designed with at least a 10-ft (3-m) level unloading dock before the ramp starts.[31] For hogs and sheep, the minimum acceptable level dock is 5 ft (1.5 m) long,[28] and for horses it is 7 ft (2.1 m).[9] 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 cattle.

In many pork plants, pigs are tattooed with an identification number as they walk off the truck. In most other species, 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.

D1.3.1 Detection of problems

The most likely problems that can occur during receiving is pigs piling up and falling during tattooing. For other species, falling, piling up, or hitting fences would be an indicator that handling needs to be improved.

D1.3.2 Corrective actions for problems

Provide nonslip flooring for all species. For pigs, redesign the tattoo area. A funnel-shaped chute will result in jamming of animals.[32,33] Plants with the calmest, quietest pig tattooing apply a slap tattoo as pigs exit the 30-inch (76-cm) truck door side by side.

D1.4 Step 4—Lairage

This may also be called the 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. In large plants, a typical lairage pen holds either one or two 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 two loads forced into it. When new stockyards are being built, they should be laid out so that there is one-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] and Grandin.[5] In smaller plants, there may be 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 eartags, electronic identification, or tattoo) 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, nipples 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 20 sq ft (1.87 m^2) for cattle, 6 sq ft (0.55 m^2) for market-weight pigs, 11 to 12 sq ft (1 to 1.12 m^2) for sows, 5 to 6 sq ft (0.46 to 0.55 m^2) for sheep depending on size, and 40 sq ft (3.74 m^2) for mature boars.[1] 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.

D1.4.1 Detection of problems

The three 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. Practical experiences with pigs have shown that large groups (over 100 pigs) fight less than small groups. A small group of five or six pigs in a small pen will sometimes result in prolonged fights. 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.

D1.4.2 Corrective action for problems

When fighting occurs, there is usually one 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 bull is knocking down cull cows during mounting, he should be removed from the pen. Similarly, fighting is a major cause of bruising in horses.[30] 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.[30] To prevent fighting, bulls and singly raised animals should be slaughtered within one hour after arrival, after 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.[34] For pigs, rest in the lairage pens after unloading for 2 to 6 hours will enable them to recover from transport stress.[35–37] A lairage time that is too long or no lairage time at all is detrimental to both meat quality and welfare.[38]

The regulations attendant to the HMSA forbid dragging of nonambulatory animals unless they have first been stunned. If a nonambulatory bovine cannot stand and walk, regulations require that it be humanely euthanized. Nonambulatory pigs, sheep, and other hoofstock may be moved to either the suspect pen or the cripple area in the plant. In the United States, 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[39] provides recommendations for down animals including but not limited to: 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.

D1.5 Step 5—Handling System

A wide variety of systems are available to move cattle, pigs, and sheep from lairage pens to the place where they are stunned or ritually slaughtered.[5,28,40] Systems for deer and other cervids can be found in reports by Matthews[41] and Haigh.[42,43] When animals area 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,[44] multiple shocks on beef cattle produced tougher meat. Electric prod use in pigs raises lactate levels,[b] and high lactate levels during the last few minutes before slaughter will result in lower pork quality.[45,46] Jamming of animals in the chute that leads to the stunner, along with electric prod use, will increase lactate levels.[47] Animals should never be backed into the stun box.

D1.5.1 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 downed animal; and beating animals.[1] 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 handing.[28,48] 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.[1,10,49] An automated powered gate that causes an animal to either fall down or be dragged along the floor is a serious problem.

In cattle and pigs, vocalization during restraint, handling, or painful procedures (eg, bellowing, mooing, or squealing) is associated with physiologic measures of stress.[9,50–53] In two studies,[54,55] vocalization during cattle 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. In other studies,[56] 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.[54,55,57] In a study[52] of pigs, high levels of squealing in the stunning area were associated with meat-quality problems. More recent research[58] in slaughter plants shows that vocalizations in cattle are associated with electric prod use. In well-managed beef plants in one report,[56] 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. In another study,[10] 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% of the pigs had to be electrically prodded to move them into the single-file chute.[10]

D1.5.2 Corrective actions for handling problems

1. *Crowd pens that lead to the single-file race (chute) should not be overloaded*

For pigs, cattle, bison, and many other animals, the crowd pen that leads to the single-file chute should be half full.[10,28,29] Cattle, pigs, deer, and bison 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 because of their intense following behavior.

When horses are handled in a tub system, the tub should only be half full, and the crowd gate should never be used to push animals. For all species, 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. 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.[9]

2. *Use natural following behavior and timing of bunches*

The next group of cattle or 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 enables the animals to immediately enter,promotes natural following behavior,[28] and prevents them from turning around. Unlike domestic cattle and pigs, bison often become agitated while standing and waiting in single file; therefore, it may be best to put only one or two bison in the single-file race at a time.

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 have visual contact with other horses at all times until they enter the kill box. This will aid in keeping them calm and will motivate them to move forward as their herdmates do.[9]

3. *Teach handlers behavioral principles*

Handlers need to understand behavioral principles such as flight zone and point of balance.[5,59,60] 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**.[55] 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.

4. *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.

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 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.

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.[5,28,33,49]

a. When an animal enters a stun box or restrainer, it must not have air blowing in its face.[10,48]

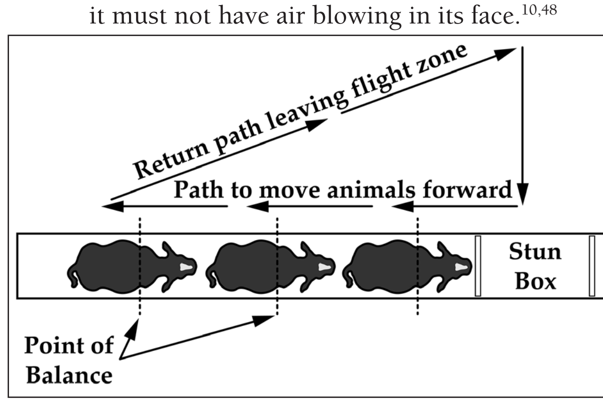

Figure 2—Handler movement pattern to move an animal into a stun box or restrainer. The handler walks quickly in the opposite direction of desired animal movement. The animal will typically walk forward as the handler crosses the point of balance at the shoulder.

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.[33,49,61]

c. Eliminate reflections on shiny metal or wet floors. Moving a light source may eliminate a reflection on a wet floor.[48] Reflected glare from shiny metal surfaces increases balking of cattle in plants.[62]

d. Cover the sides of chutes or install solid barriers to prevent approaching animals from seeing people, vehicles, or moving machinery ahead.[49,63] 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.[64] For flighty species such as deer, the use of solid sides and low lighting will keep them calmer.[41]

e. Animals often refuse to walk over changes in floor type, such as moving from a concrete to a metal floor. Pigs and cattle are also likely to balk at shadows.[60,65]

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.[66,67] Many slaughter plants have high noise levels.[68]

D1.6 Step 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.

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.[69]
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,[5,70] as animals have depth perception.[71] 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.[69]
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.
5. Ensue stun boxes are of an 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.

D1.6.1 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.[54,55] Devices that have serious problems, such as excessive pressure, will have high percentages (25% to 32%) of the cattle vocalizing.[54,55,57,72] Well-designed and skillfully operated cattle restraint devices that have a head holder will have 5% or less of animals vocalizing.[10,56] Vocalization scoring is not an effective assessment tool for sheep, because they often do not vocalize in response to painful procedures. 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.[9]

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

1. Percentage of cattle, horses or pigs that vocalize while entering the restraint device and while they are held in the restraint device. The American Meat Institute voluntary industry standard for vocalization is 5% or less of the animals.
2. Percentage of animals (all species) that fall down to the extent that the body touches the ground. The voluntary industry standard is 1%[1]; 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.[1]
3. Percentage of animals moved with an electric prod into the restraint device. The voluntary industry standard for cattle and pigs is ≤ 5% for an excellent score and ≤ 25% for an acceptable score. For sheep, the voluntary standard for electric prod use is ≤ 5%. The OIE[73] recommends that electric prods should not be used on sheep, horses, or young calves. American Veterinary Medical Association policy states that "[e]lectrical devices (e.g., stock prods) should be used judiciously and only in extreme circumstances when all other techniques have failed."[74]

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[75–78] 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.

D1.7 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 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—Two of the most common mistakes are overloading a single conveyor restrainer and overloading of undersized CO_2 stunners:
   a. Overloading a single conveyor restrainer. If the goal is to have 1,000 pig carcasses/h enter the coolerr, 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 are moving faster than their normal walking speed. Most large plants in which 1,000 pig carcasses/h enter the cooler have two conveyor restrainers with two single-file chutes and two crowd pens. A single center-track restrainer will work well to process 390 cattle/h if it is free of the distractions discussed previously. At 390 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.[56]
   b. Overloading of 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 stunner. Unless the CO_2 stunner is replaced with another machine having a higher capacity, the 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. This 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 than conveyer systems, because they use a start-stop process to put each animal in the box and then remove it. The signs of an overloadedbox are:
      i. Slamming the rear gate on animals,
      ii. Increased electric prod use,
      iii. More than one animal in the box for stunning, and
      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 two or more single-animal boxes is recommended.
3. Funnel-shaped crowd pens. 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.[32] The entrance to the single-file chute should be just wide enough to allow one pig to enter. If it is too wide, two pigs may become stuck beside each other entering the chute. Designs for appropriate crowd pens for cattle, sheep, and pigs may be found in publications by Grandin,[5,28,69] the Horse Welfare Association of Canada,[9] and the American Sheep Industry Association.[79]
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 appropriate width is 30 inches (76 cm) for cattle, 18 inches (46 cm) for market-weight pigs, 32 inches (81 cm) for horses, 16 inches (40 cm) for sheep, and 27 inches (70 cm) 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 6 inches (16 cm) 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 time to refill the crowd pen (**Table 1**). 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 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.

D.2 Handling Procedures at Slaughter Plants for Poultry

D2.1 Step 1—Electric Stunning, CAS, and LAPS: Arrival and Lairage

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

Table 1—Recommended single-file chute lengths for cattle.

Species	Line speed	Minimum length	Maximum length
Cattle	Under 25/h	20 ft (6 m)	75 ft (23 m)
Cattle	25–100/h	40 ft (12 m)	75 ft (23 m)
Cattle	200–390/h	80 ft (25 m)	200 ft (23 m)
Pigs and sheep	Under 100/h	10 ft (3 m)	25 ft (7.6 m)
Pigs	Over 100/h	25 ft (7.6 m)	50 ft (15 m)

Some systems with lengths longer than those recommended here may work well.

birds cool during hot weather. Holding time at the plant should be minimized and on aveage should not be more than six hours.[80]

D2.1.1 Detection of problems

The most common problems encountered in poultry slaughter are overloaded containers, heat stress, frost bite, and death due to exposure. Poorly maintained, broken containers may injure birds.

D2.1.2 Corrective action for problems

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 catching and loading of birds at the farm can be quickly cancelled before loading is started. Loaded shipments that are already en route should be diverted to nearby plants for processing.

D2.1.3 Handling and stunning

Three types of handling and stunning systems are shown in **Figure 3**.

D2.2 Step 2A—Birds Moved to Stunning Area and Stunning With CAS and LAPS

D2.2.1 CAS live unloading

Controlled atmosphere stunning with live unloading was one of the earliest CAS systems. In this system, live birds in dump module containers are loaded onto a conveyor that transports them into a gas stunning system. This type of handling is likely less stressful than that encountered when hanging live birds because the birds are shackled after they are anesthetized.

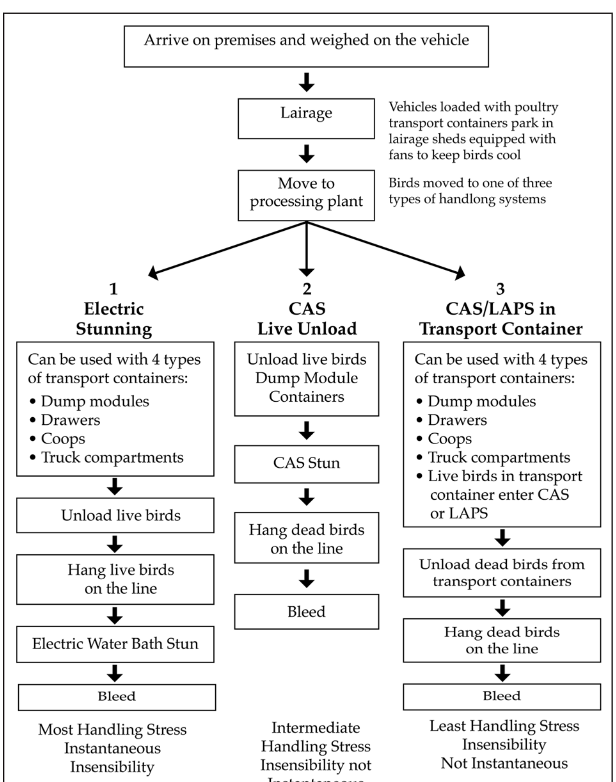

Figure 3—Principles of three types of handling and stunning systems.

D2.2.2 CAS or LAPS in transport containers

Most new CAS systems are now built as shown in Figure 3. The birds remain in the transport containers as they move through the system to be anesthetized. Shackling and handling are performed after the birds are anesthetized. There are various types of CAS or LAPS systems where the birds are kept during stunning.

D2.2.3 Types of CAS and LAPS chamber equipment

Anesthetized on the truck

This system is used mostly with turkeys that are transported on trucks with transport containers that cannot be removed from the vehicle. The vehicle loaded with transport containers pulls into a shed; metal panels clamp onto the side of the vehicle, and gas (CO_2 or N_2) is blown through. As each section is anesthetized, the truck is moved forward, and the next section is stunned while the previous section is being unloaded. The disadvantage of this system is the need to use a large amount of gas. Advantages include that the system is economical to build, the system could be used with many different types of gases, the system enables companies to use existing transport vehicles, and birds are not handled while conscious.

Drawers moved through a tunnel

In this system, drawers containing the chickens or turkeys are transferred out of the racks by automated equipment. The drawers are then transferred to a conveyor that moves the birds into gradually increasing concentrations of CO_2. This system uses less CO_2 than the on-truck system.

LAPS system

Entire racks of dump modules, drawer modules, or coops are rolled into a pressure vessel where the air is slowly removed during a 3-minute cycle. An advantage of LAPS is that it will work with all existing chicken transport systems. It is easy to maintain, there is no expensive gas to purchase, and there is no carbon environmental footprint. Most large chicken plants will require more than one chamber. Low-atmospheric-pressure stunning must have a full electric stunner backup.

D2.2.4 Detection of problems with CAS or LAPS of poultry

Maintaining the correct gas mixtures is essential for birds to have a smooth induction with a minimum amount of gasping or head shaking. If the birds flap wildly and attempt to escape from the chamber, it is not acceptable[11] and may indicate a problem with the gas mixture. 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 tradeoff to eliminate live shackling, as live shackling is highly stressful.[81–83] It is also essential to maintain the correct dwell times in the chamber to prevent return to consciousness due to a dwell time that is too short.

D2.2.5 Correction of problems with CAS or LAPS

Adjust gas mixtures or LAPS system to provide a smoother induction before loss of posture. 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 breaks. In systems where there is more than one 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.

D2.3 Step 3A—Removal of Birds From CAS or LAPS Chamber

The palletized containers or the drawers containing the birds are moved to the shackling area. The birds are unconscious at this point. There are no welfare issues unless the CAS or LAPS equipment malfunctioned.

D2.4 Step 2B—Birds Moved to Stunning Area for Electric Stunning

If a drawer system or individual coops are being used, the drawers or coops are removed from the palletized rack either manually or with use of automated equipment. They are placed on a conveyor that runs into the shackle room. Handlers pick up each individual bird and hang it on the shackle line. If a dump module system is used, a hydraulic platform operated by an employee tilts the entire palletized container to dump the live birds onto a conveyor that runs into the shackle room. Handlers pick up live birds and hang them on the shackle line. The birds are then moved by the shackle conveyor to the water-bath stunner.

D2.4.1 Detection of problems during unloading and shackling for electric stunning

One problem that can occur with dump modules is unloading the birds too fast; this results in pileups and excess birds falling off the conveyor may result in loose birds on the premises. Broken wings are more likely to occur in heavy birds unloaded from the dump modules, compared with lighter birds. In drawer systems, a common problem is head entrapment. This is caused by rough loading on the farm or poor design of the drawer rack. Another common problem is understaffing of the shackle line. This results in rough handling and employees attempting to work too fast, which makes careful handling difficult. When the shackle line is understaffed, bruised thighs may be observed because employees are slamming birds into the shackles.

D2.4.2 Correction of problems during unloading and shackling for electric stunning

A darkened room illuminated with blue lighting will help keep birds calm.[84] Training of the employees who operate the dumper of dump modules is essential. This employee must learn to wait until the receiving conveyor has space before dumping more birds. It is also important to never shake the module to unload birds. For heavier birds, it is strongly recommended to install slides, conveyors, and other devices so birds do not experience hard falls onto the conveyor. To prevent head entrapment in drawer systems, when closing the drawer on the farm, there should be a 1.5-inch gap between the top of the plastic drawer and the metal rack.

The live bird shackling area requires constant supervision to prevent rough handling and bird abuse. Hanging inverted on conventional shackles is stressful to chickens[81,83] however, new designs for poultry shackling systems may help reduce stress. In one design, the breasts of the birds are supported by a horizontal moving conveyor.[85] In another new commercially available system, the body of the shackled bird is supported by a plastic device attached to the shackle.

D2.5 Step 3B—Electric Stunning

The birds, which can be chickens, turkeys, or other poultry, are moved to the water-bath stunner while they are inverted and hanging by their feet on the shackle line. The bird's head has direct contact with the water bath, and an electric current is passed from the water to the leg shackle. The water bath and grounding equipment must be maintained to convey a sufficient electric current through the bird's body to permit adequate stunning and to complete the circuit.

D2.5.1 Detection of problems during electric stunning of poultry

One of the most common problems is birds missing the stunner water bath because they are extremely small or stunted and are mixed in with market-ready birds. These birds are too short to have direct contact with the water bath. Another problem is rapid return to consciousness after stunning. This is caused by setting the stunner amperage too low. Plant managers sometimes do this to prevent meat damage. Preshocks as birds are entering the stunner may happen if wing tips reach the water bath before the bird's head is in direct contact with the water bath. These shocks do not produce unconsciousness because they occur before the birds enter the water bath. If both the automatic throat-cutting machine and the backup bleeder person fail to cut a bird's throat, it may return to consciousness and enter the scalder while conscious. These 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.

D2.5.2 Correction of problems with electric 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. The rail should run smoothly because a bumpy ride may cause birds to flap and avoid the stunner. Preshocks can be reduced with a well-designed entrance ramp on the stunner and by adjusting the water level.

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Techniques

As noted in the Introduction, there are numerous humane methods for stunning animals for slaughter (**Appendix**); many of these methods are described in the following text.

T1 Atmospheric Methods

T1.1 Controlled Atmosphere

Controlled atmosphere stunning and killing methods, also called modified atmosphere stunning or killing, produce unconsciousness, and can eventually lead to death, by one of two 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 LAPS), or 2) by rapidly inducing decreased intracellular pH and cellular function through acute hypercapnea (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 two methods, also called two-step or multiphase processes, may use one gas or a mixture of gases to induce unconsciousness prior to exposure to a different gas mixture or higher gas concentration. Low-atmospheric-pressure stunning is discussed in a separate section.

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, such that pain, stress, and fear associated with handling are minimized. In addition to reducing live animal handling, CAS may facilitate the ability to process a greater numbers of 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 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 reviewed in the context of euthanasia.[2] 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. 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).[3]

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. Unlike immersion, in a commercial process animals experience their introduction into CAS atmospheres gradually, either through transport at a controlled rate into a contained stunning atmosphere gradient or through controlled introduction of stunning gases into an enclosed space. 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.[4] Thus, animals are not immediately exposed to stunning conditions known to be aversive or painful.

In studies of turkeys[5] and chickens,[6] 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 were lost at 24 to 34 seconds, and the EEG became isoelectric at 57 to 66 seconds.[7] 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.[8] Gerritzen et al[9] also reported that chickens did not avoid chambers containing < 2% O_2; birds gradually became unconscious without showing signs of distress.

Chickens[9–12] and turkeys[5] killed by hypoxia show less head shaking and open-beak breathing than birds exposed to CO_2. Respiratory disruption, defined as open-bill breathing with prolonged inspiration or prolonged open-bill gaping with apparent apnea or dyspnea, is less in anoxia-stunned birds compared with methods combining anoxia with CO_2.[9,13] Mandibulation, the rapid open and closing of the beak, may occur with anoxic systems, but may occur less than in other systems.[14] 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 two-step process using 40% CO_2, 30% O_2, and 30% N_2 followed by 80% CO_2 in air.[13] Failure to maintain < 2% O_2 when using hypoxic or anoxic inert gas methods prolongs survival.[15,16]

In pigs, hypoxia produced by combining N_2 and Ar appears to reduce, but not eliminate, aversive responses. In one study,[17] 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,[4] 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 rapid return to consciousness, such that exposure times > 7 minutes are needed to ensure killing with these gases.[18]

Inhalation of CO_2 causes acute respiratory acidosis and produces a reversible anesthetic state by rapidly decreasing intracellular pH.[19] Both basal and evoked neural activities are depressed soon after inhalation of 100% CO_2.[19–22] For pigs, exposure to 60% to 90% CO_2 causes unconsciousness in 14 to 30 seconds,[19,20,23,24] with unconsciousness occurring prior to onset of signs of excitation.[22,23] For light Manchego lambs, exposure to 90% CO_2 for 60 seconds results in 100% stun,[25] with observed levels of cortisol, epinephrine, and norepinephrine similar to electrically stunned animals.[26] A large proportion of chickens and turkeys will enter a chamber containing moderate concentrations of CO_2 (60%) to gain access to food or social contact.[5,6,9] Following incapacitation and prior to loss of consciousness, birds in these studies show behaviors such as open-beak breathing and head shaking; these behaviors, however, may not be associated with distress because birds do not withdraw from CO_2 when these behaviors occur.[10] 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%.[27]

Death via exposure to CO_2 has been described for individual and small groups of birds.[3,28] Carbon dioxide and its application to the humane slaughter of chickens, turkeys, and ducks has been studied extensively and has resulted 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.[29] Raj[16] found that 2 minutes' exposure to 90% CO_2 was sufficient to kill day-old chicks exposed in batches. Broilers 5 weeks of age collapsed an average of 17 seconds after entering a tunnel filled with 60% CO_2.[9] 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.[3] 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.[15] 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.[31] In turkeys,[32] EEG suppression took place in an average 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).

For humane slaughter of poultry, exposure to CO_2 concentrations producing a gradual induction of unconsciousness reduces convulsions, compared with anoxia with N_2 and Ar.[11,33] 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.[34] Carbon dioxide 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.[29] However, wing flapping is less with CO_2 than with N_2 or Ar.[13,33] A two-step or multiphase process combining inert gases and CO_2 is used commercially for humane slaughter of poultry, where birds are exposed initially to 40% CO_2, 30% O_2, and 30% N_2, followed by 80% CO_2 in air; the added O_2 during the anesthetic induction phase has both welfare and carcass-quality advantages.[13,35,36] Thus, vocalization and nonpurposeful movement observed after LORR 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.[37] Loss of consciousness should always precede loss of muscle movement.

Genetics may play a role in pig CO_2 response variability. Panic disorder in humans is genetically linked to enhanced sensitivity to CO_2.[38] 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.[39] 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.[34,40] 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.[17,24] 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.[41] 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.[34]

T1.1.1 CAS design

The mechanical design of commercial CAS systems has been reviewed by Grandin.[34] In open CAS systems (**Figure 4**), 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 two 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.[42,43] 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

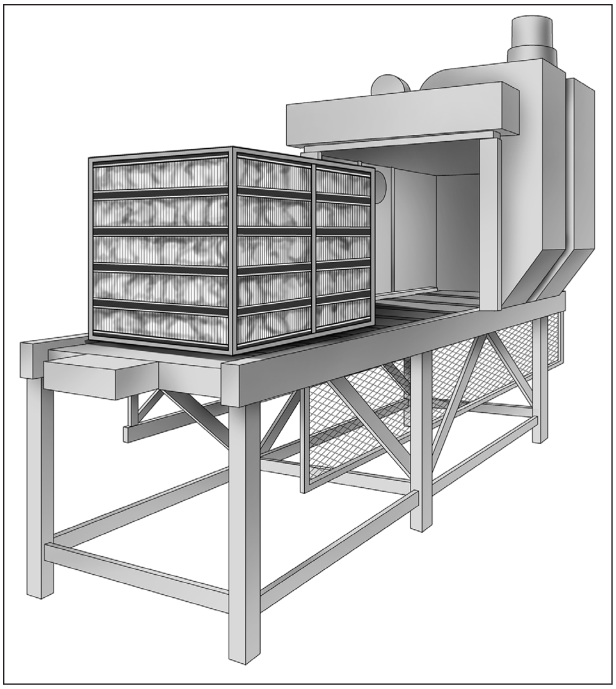


Figure 4—Animals are moved on continuous conveyors through a tunnel (as shown) or into a pit containing a heavier-than-air gas in open CAS systems.

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.

Detection of problems

Some of the most common problems are CO_2 concentration that is too low or insufficient dwell time in the chamber. These problems can result in either return to sensibility on the slaughter line or stressful anesthetic induction. Insufficient dwell time is most likely to occur in plants that have undersized equipment. Many CO_2 systems have automated powered gates to move animals into the chamber. There is a serious problem if the automated gates either knock animals over or drag them along the floor. If these gates cause more than 1% of the pigs to fall, that exceeds the industry voluntary guideline.[34] If powered gates drag animals, that is a violation of the HMSA. Another problem is overloaded gondolas where animals do not have room to stand without being on top of other animals. This is most likely to occur in equipment that does not have sufficient capacity.

Corrective action for problems

1. Maintain a CO_2 concentration of over 80%. A 90% concentration at either the bottom of the pit or at the final stage of the process is strongly recommended.
2. Increase dwell time if there are problems with return to sensibility.
3. Undersized equipment that has insufficient capacity is often the cause of insufficient dwell time or handlers overloading the gondolas with animals. Either a larger piece of equipment or an additional unit will be required to increase system capacity.
4. The pigs or poultry must have sufficient room in the gondolas or container to stand or lie down without being on top of each other.
5. When automated gates are used to move pigs up to and into the chamber, they must be equipped with pressure-limiting devices. This prevents the gates from knocking animals over or dragging them along the floor. Often, powered gates work best when they are equipped with a push button or other control that allows the handlers to control forward movement of the gate. When the handler lets go of the control, the gate stops. An automated control works well to return the gate to its start position after it has moved the animals.
6. Ventilation problems in the plant building can sometimes cause CO_2 to be sucked out of the chamber. Some commercial CO_2 equipment holds CO_2 in a pit that is not sealed, and sometimes, air pressure changes in the plant building can cause sensible pigs or birds to emerge from the chamber. Some of the factors that can suddenly lower CO_2 concentration are either turning off or turning on large ventilation fans in the plant building, wind blowing around the plant building, or leaving certain plant doors open. Careful observation will be required to correct this problem. It is often correctible and no equipment purchases are required.

T1.1.2 Conclusions

For humane slaughter of poultry, initial exposure to lower CO_2 concentrations and a gradual increase of CO_2 concentrations produce a smoother induction of unconsciousness and reduce convulsions, compared with anoxia with N_2 and Ar. Carbon dioxide 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. For humane slaughter of pigs, exposure to > 80% CO_2 is recommended.

Compared with electric stunning methods, CAS for poultry presents some animal welfare advantages because manual handling and shackling of live birds are eliminated. Some gas mixtures may cause unacceptable escape behaviors, such as attempting to climb up the sides of the container or vigorous flapping in chickens before LOP. In addition, CAS can also eliminate welfare issues associated with dumping live birds from their transport cages prior to stunning; however, this depends on the design and implementation of CAS at the processing plant. Controlled atmosphere stunning for pigs and lambs may also improve animal welfare by reducing animal handling.

T1.2 Low Atmospheric Pressure

Low-atmospheric-pressure stunning (**Figure 5**) is a recently described method for stunning birds prior to humane slaughter. Unconsciousness due to hypoxia occurs following a controlled and gradual reduction of barometric pressure.[44–46] At one time the European Union allowed the use of a vacuum chamber for slaughter of farmed quail, partridge, and pheasant,[47] however this approval was revoked with the adoption

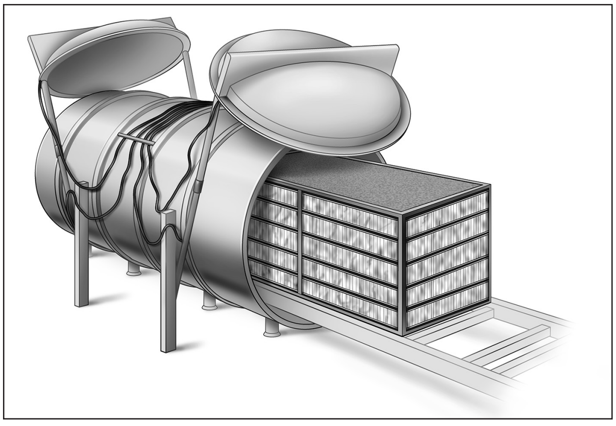


Figure 5—The low atmospheric pressure system is used to stun poultry via computer-controlled slow decompression. Controlled and slow precise changes in atmospheric pressure lead to hypoxia from high altitude simulation and result in a loss of consciousness and then irreversible stunning of the bird. This system does not use aversive gas mixtures and eliminates the shackling of sentient birds since birds remain in their transport containers during the stunning process.

of EU Council Directive 1099/2009.[48] The method is currently undergoing commercial testing for broiler stunning in the United States under a USDA Office of New Technology Testing Approval. It is not currently known whether the technology can be adapted for humane slaughter or depopulation of mammalian species, such as pigs; however, the insidious effects of altitude hypoxia on human flight crew performance, including unconsciousness, are well documented.[49]

Low-atmospheric-pressure stunning is not rapid decompression, as currently deemed unacceptable by the AVMA Guidelines for the Euthanasia of Animals: 2013 Edition, but rather it is negative atmospheric pressure applied gradually over time, typically 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 23.8 in Hg (604.5 mm Hg[a]); this corresponds to an atmospheric pressure of 155.5 mm Hg and an inspired PO_2 of 32.7 mm Hg (assuming barometric pressure of 760 – 604.5 mm Hg = 155.5 mm Hg X 0.21 = 32.7 mm Hg oxygen). Thus, LAPS PO_2 at maximum negative pressure is equivalent to a 4% oxygen atmosphere at sea level (32.7 mm Hg/760 mm Hg). For comparison, the atmospheric pressure (P_B) on top of Mount Everest (elevation, approx 30,000 ft) is 225 mm Hg and the PO_2 is 47.3 mm Hg; at 40,000 ft, P_B is 141 mm Hg and PO_2 is 29.6 mm Hg.

Rapid decompression can cause both pain and distress through expansion of gases present in enclosed spaces.[50] In the case of birds, however, 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. 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 nine 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 significant amounts of gas can be trapped within the avian lungs or abdomen unless the trachea is blocked for some reason.[51] In contrast to reports of hemorrhagic lesions in the lungs, brain, and heart of animals undergoing rapid decompression,[52] no such lesions were observed in birds undergoing LAPS.[45] No pathological evidence of ear damage has been noted in LAPS birds,[b] and corticosterone concentrations in LAPS-stunned broilers were nearly one-half the levels observed in electrically stunned birds.[45]

The LAPS target pressure for broilers is achieved within 1 minute from the start of the LAPS cycle and maintained for 4 minutes 40 seconds to assure recovery does not occur prior to exsanguination. Time to first coordinated animal movement was 58.7 ± 3.02 seconds, with light-headedness (defined as time from first head movement to first wing flap) noted within 69.3 ± 6.37 seconds and LOP (an indicator of loss of consciousness) occurring within 64.9 ± 6.09 seconds. Neither mandibulation nor deep open-bill breathing was observed in LAPS birds; bill breathing and mandibulation are commonly reported during CAS stunning with various gas mixtures.[13] Wing and leg paddling was infrequent, lasting 15.1 ±1.12 seconds following LOP.[45] On the basis of EEG studies, increasing slow (delta) wave activity consistent with a gradual loss of consciousness occurs within 10 seconds of the start of the LAPS cycle, peaking between 30 and 40 seconds and coincident with LOP and first brief movements.[46] The same research group also determined that heart rate decreases over time during LAPS, implying minimal additional sympathetic nervous system stimulation.

A significant advantage of LAPS over electric stunning and live-dump CAS is elimination of welfare issues associated with dumping live birds onto the conveyor line and elimination of manual handling and shackling of live birds prior to electric stunning. 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 fork lift. A computer in the control booth controls and displays the status of the individual LAPS units. Low-atmospheric-pressure stunning 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 dumping station. After dumping, 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.

T1.2.1 Conclusions

Low-atmospheric-pressure stunning produces a quiet transition to unconsciousness 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-dump CAS methods and electric stunning methods, LAPS may be better from an animal welfare standpoint because of elimination of welfare issues associated with dumping live birds onto the conveyor line, and elimination of manual handling and shackling of live birds prior to electric stunning. Low-atmospheric-pressure stunning 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.

T2 Physical Methods

T2.1 Concussive

T2.1.1 Penetrating captive bolt guns

Penetrating captive bolts are used for ruminants, horses, and swine in commercial slaughter plants. Their mode of action is concussion and trauma to the cerebral hemisphere and brainstem.[53–55] Properly done captive bolt stunning will instantly abolish visual evoked potentials and SEPs from the brain.[56,57] This indicates that the animal's brain is no longer able to respond to a visual or tactile stimulus because it was instantly rendered unconscious. 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.[58,59] Appropriate placement of captive bolts for various species has been described.[54,60-64] 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.[55,58] The corneal reflex must be absent, and the eyes must open into a wide, blank stare and not be rotated.[55,65,66]

There are two 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 two 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, becasue 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.[66] Cartridges for powder-activated captive bolt guns must be stored in a dry location because damp cartridges will reduce effectiveness.[68]

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. It is a practical method of humane slaughter for horses, ruminants, and swine. 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. Injury caused by penetrating and nonpenetrating captive bolt pistols was similar and sufficient for both to be considered effective for euthanasia of lambs.[58] On the basis of electrophysiologic evidence,[54] 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, one report[69] 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.[68] 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.[70] The five 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.[67] Damp cartridges can result in underpowered shots that are less effective. Soft-sounding shots were less effective.[65]

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,[34,68] and advise that there is a problem if the effective first-shot rate falls below 95%.[34] The best plants have a 99% first-shot efficacy[71] (FSIS has a zero tolerance policy for missed first shot). Results of a European study[72] of 8,879 cattle skulls in two 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%.

Corrective action for 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.[68]
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.[73] 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.[74]
3. Head holders cannot be used on horses. Active head restraint, where a horse's head is clamped by a mechanized device, should not be used. Passive

restraint, such as a tray to prevent the horse from putting its head down, is acceptable. Passive devices restrain movement without clamping the head.

4. 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. The minimum bolt velocity is 55 m/s for steers and 70 m/s for bulls.[55,57,75] 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 production 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 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.
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 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 back-up stunner and second stun attempts.
13. 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.

T2.1.2 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, slaughter-weight pigs, sows, and adult sheep. In general, regular nonpenetrating captive bolt guns only stun animals. 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, adult swine, or cattle with long hair.

<u>Detection of problems</u>

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.

<u>Corrective action for problems</u>

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

T2.1.3 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 unconscious, 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 ricocheting bullet 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.[61,76–80] 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.[53,77] Accurate targeting for a gunshot to the head in various species has been described.[77,78,81] 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.[62,82]

<u>Basic principles of firearms</u>

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 frequently used as 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.[83] However, to accommodate units of measure commonly used in the United States 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 450,450. The International System of Units expresses muzzle energy in joules after the English physicist James Prescott Joule (1818 to 1889).

Representative ballistics data for various types of firearms are provided in **Table 2**. 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.[83] Velocity has an even greater impact on bullet energy than bullet mass. Selection of 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 bones.

Whereas most slaughter using firearms is conducted at close range, calculations of muzzle energy are useful for determining which firearms are appropriate for slaughter of animals of varying sizes. 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.

Table 2—Average muzzle energies for common hand guns and rifles. (Adapted from USDA, 2004, National Animal Health Emergency Management System Guidelines, USDA, Washington, DC. Available at: www.dem.ri.gov/topics/erp/nahems_euthanasia.pdf [Accessed Aug 27, 2009] and cited by Woods J, Shearer JK, Hill J. Recommended on-farm euthanasia practices. In: Grandin T, ed. *Improving animal welfare: a practical approach.* Wallingford, Oxfordshire, England: CABI Publishing, 2010;194–195.)

Cartridge/firearm	Muzzle energy: In foot-pounds	Muzzle energy: In joules
Handguns		
.40 Smith and Wesson	408	553
.45 Automatic Colt Pistol	411	557
.357 Magnum	557	755
.41 Remington Magnum	607	823
10-mm Automatic	649	880
.44 Remington Magnum	729	988
Rifles		
.22 Long Rifle Rim Fire	117	159
.223 Remington	1,296	1,757
30-30 Winchester	1,902	2,579
.308	2,648	3,590
30-06 Springfield	2,841	3,852

<u>Muzzle energy requirements</u>

Muzzle energy required to render animals up to 400 lb (180 kg) unconscious is a minimum of 300 ft-lb (407 J). For animals larger than 400 lb, firearms capable of yielding muzzle energies of 1,000 ft-lb (1,356 J) are required for satisfactory results.[62]

As demonstrated by Table 2, handguns do not typically achieve the muzzle energy required to euthanize animals weighing more than 400 lb (180 kg), and therefore rifles must be used to render these animals unconscious.

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. Additionally, a Canadian study[84] found .22 LR standard-velocity and .22 LR high-velocity bullets failed to yield adequate penetration of the skull.[84] 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. 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.[85]

To improve safety and reduce 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 to use 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 two 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 ft. (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. In one case, a a gilt was shot multiple times with a captive bolt and firearm before it was rendered unconscious.[86]

<u>Bullet selection</u>

Bullet selection is quite possibly the most important consideration for slaughter of livestock by gunshot. There are three 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 without risk of overpenetration. Hollow points are less likely to richochet, 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. 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 a rifle, rarely exit the skull. These are important considerations when selecting a firearm for humane slaughter. Probably the most important point to be made relative to the use of gunshot for humane slaughter is that scientific information on firearm and bullet selection is lacking. There is an urgent need for research for best animal welfare.

Firearm safety

Firearm safety cannot be overemphasized. Guns are inherently dangerous and must be handled with caution at all times. This needs to be the mindset in handling and use of firearms. Common recommendations include 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 managers 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 an animal's body. The pressure within the barrel 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 to 2 ft (30 to 60 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 gunshot is acceptable for humane slaughter.[78,87,88] 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 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%.[89] Safety is a major concern with firearms with a free bullet when they are used in a slaughter plant. Use of a firearm that is not sufficiently powerful is a common cause of failure of the first shot.

Corrective action for 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 fully 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 otherwise difficult-to-handle animals such as bison and flighty animals such as horses or deer. One person moves the animal into the kill box or restrainer, and the other shoots the animal. This 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 unconsciousness, a second stun attempt must be performed immediately to minimize pain, suffering and distress. Plants should have a written protocol in place for the use of the back-up stunner and second stun attempts.

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 6a**).[90] Alternatively in long faced cattle or young-stock, a point on the midline of the face that is halfway between the top of the poll and an imaginary line connecting the outside corners of the eyes can be used (**Figure 6b**).[c] Firearms should be positioned so that the muzzle is perpendicular to the skull to avoid ricochet.

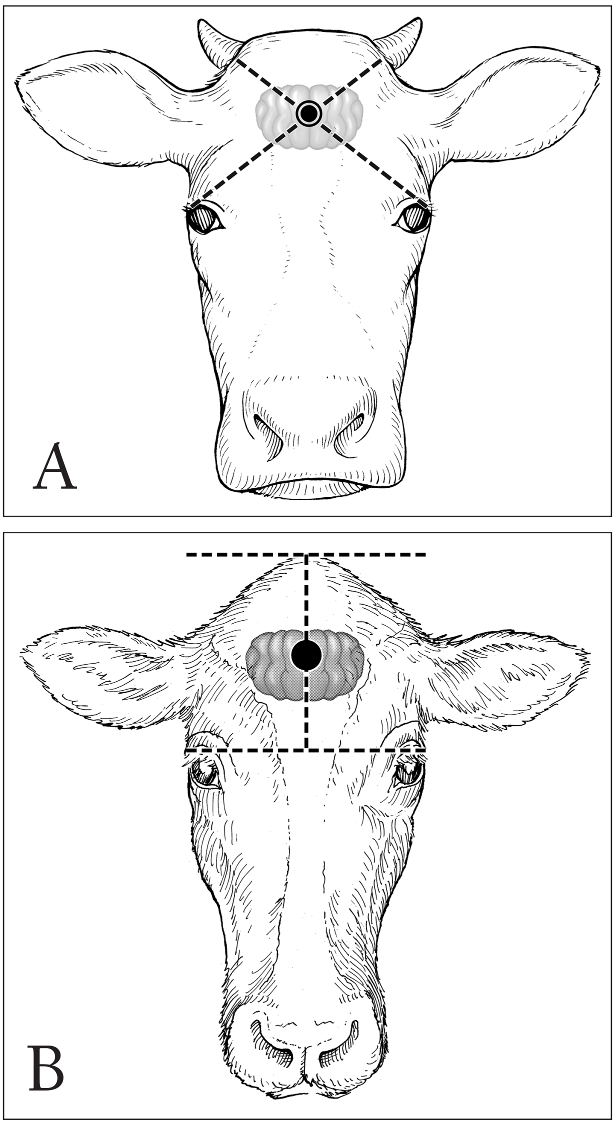


Figure 6—Anatomic site for gunshot or placement of a captive bolt and desired path of the projectile in cattle. The point of entry of the projectile should be at the intersection of two imaginary lines, each drawn from the outside corner of the eye to the center of the base of the opposite ear (A). Alternatively in long faced cattle or young-stock (B), a point on the midline of the face that is halfway between the top of the poll and an imaginary line connecting the outside corners of the eyes can be used. (Adapted with permission from Shearer JK, Nicoletti P. Anatomical landmarks. Available at: www.vetmed.iastate.edu/vdpam/extension/dairy/programs/humane-euthanasia/anatomical-landmarks. Accessed Jun 24, 2011.)

The location for placement of a captive bolt for entry of a free bullet or shooting goats is illustrated in **Figure 7**. The optimal position is approximately 1 ½ inches (3.8 cm) behind (toward the back of the head) an imaginary line connecting the outside corners of the eyes with the projectile directed toward the back of the throat. An alternate site may be determined by using the intersection of two imaginary lines, each drawn from the outside corner of the eye to the center of the base of the opposite ear with the projectile directed toward the back of the throat.[d] The location for placement of a captive bolt or entry of a free bullet for shooting of sheep is illustrated in **Figure 8**. The optimal position for hornless sheep is the top of the head on the midline.[90] An alternate site is the frontal region.[90] For heavily horned sheep, the optimal site is behind the poll aiming toward the angle of the jaw.[90]

There are three possible sites for shooting swine: frontal, temporal, and from behind the ear toward the opposite eye (**Figure 9**).[91] 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

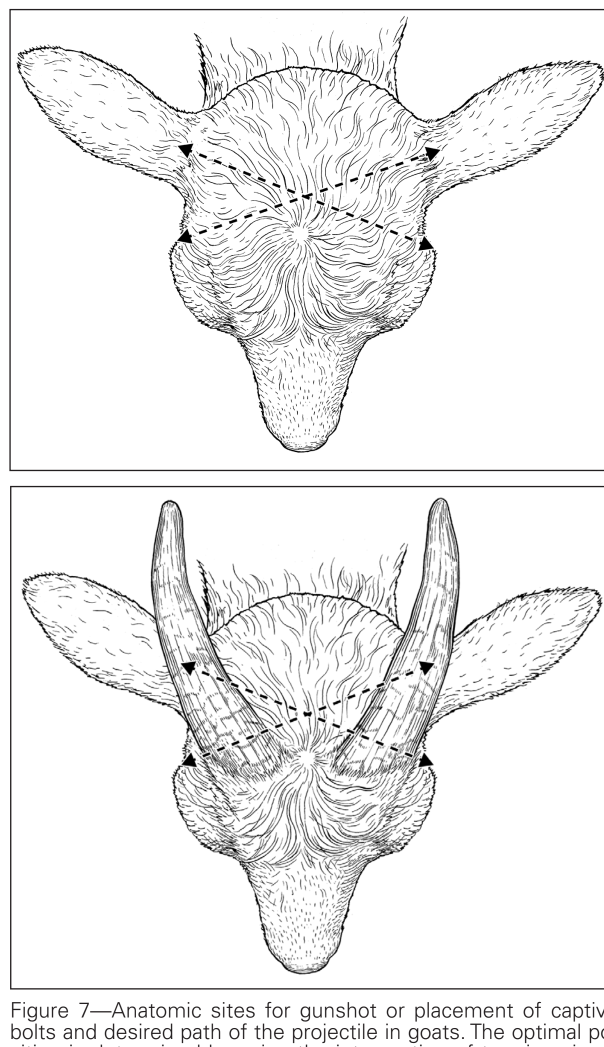


Figure 7—Anatomic sites for gunshot or placement of captive bolts and desired path of the projectile in goats. The optimal position is determined by using the intersection of two imaginary lines, each drawn from the outside corner of the eye to the center of the base of the opposite ear with the projectile directed toward the back of the throat. (Adapted with permission from Shearer JK).

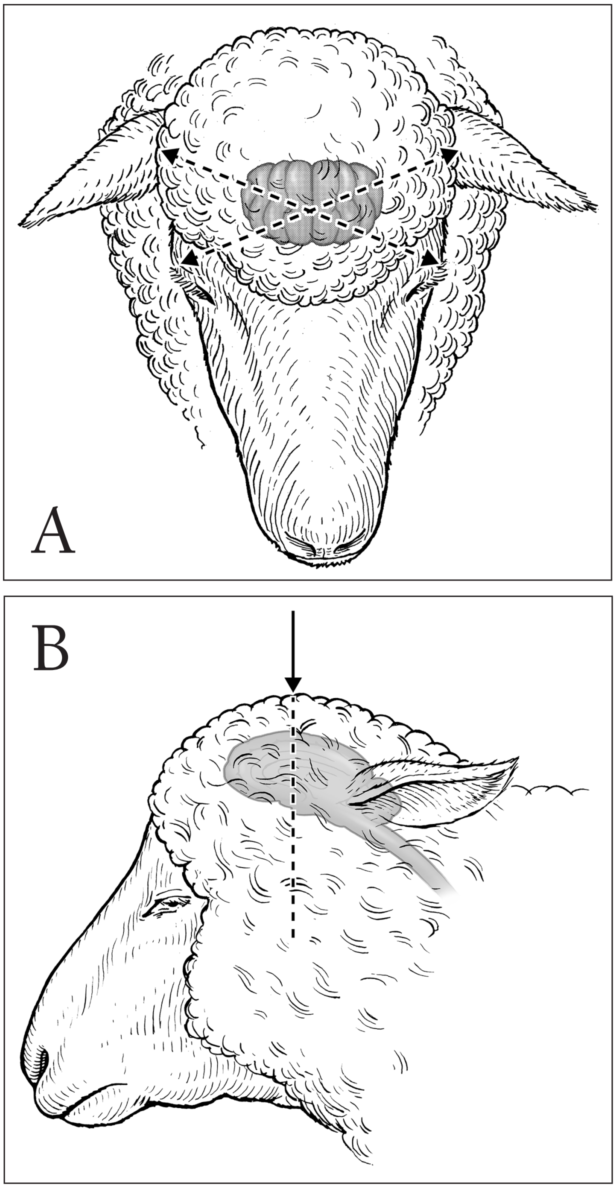


Figure 8—For polled sheep (A), the proper site is at or slightly behind the poll aiming toward the angle of the jaw (ie, base of the tongue). Alternatively, a site high on the forehead aiming toward the foramen magnum (or spinal canal; B) or aiming toward the angle of the jaw or base of the tongue may be used. (Adapted with permission from Shearer JK, Nicoletti P. Anatomical landmarks. Available at: www.vetmed.iastate.edu/vdpam/extension/dairy/programs/humane-euthanasia/anatomical-landmarks. Accessed Jun 24, 2011.)

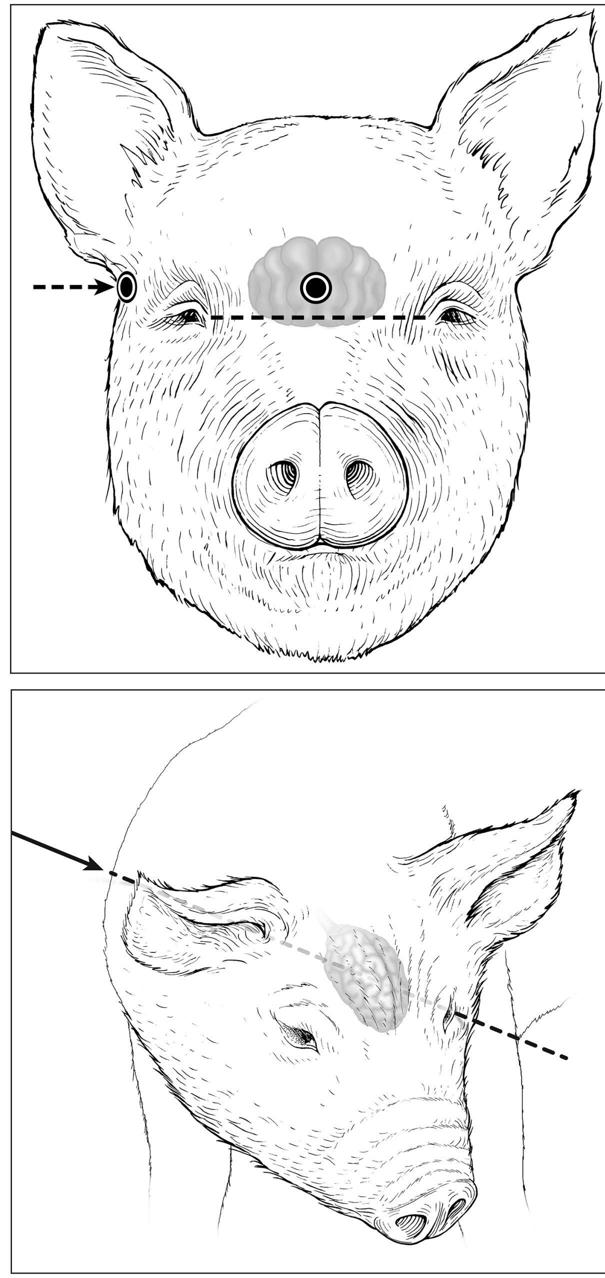


Figure 9— There are three possible anatomic sites for gunshot and penetrating captive bolt application in swine: frontal, temporal and from behind the ear toward the opposite eye. The frontal site is in the center of the forehead slightly above a line drawn between the eyes. The bolt or bullet should be directed toward the spinal canal. The temporal site is slightly anterior and below the ear. The ideal target location and direction of aim may vary slightly according to breed and the age of the animal (due to growth of the frontal sinuses). (Adapted with permission from Shearer JK, Nicoletti P. Anatomical landmarks. Available at: www.vetmed.iastate.edu/vdpam/extension/dairy/programs/humane-euthanasia/anatomical-landmarks.Accessed Jun 24, 2011.)

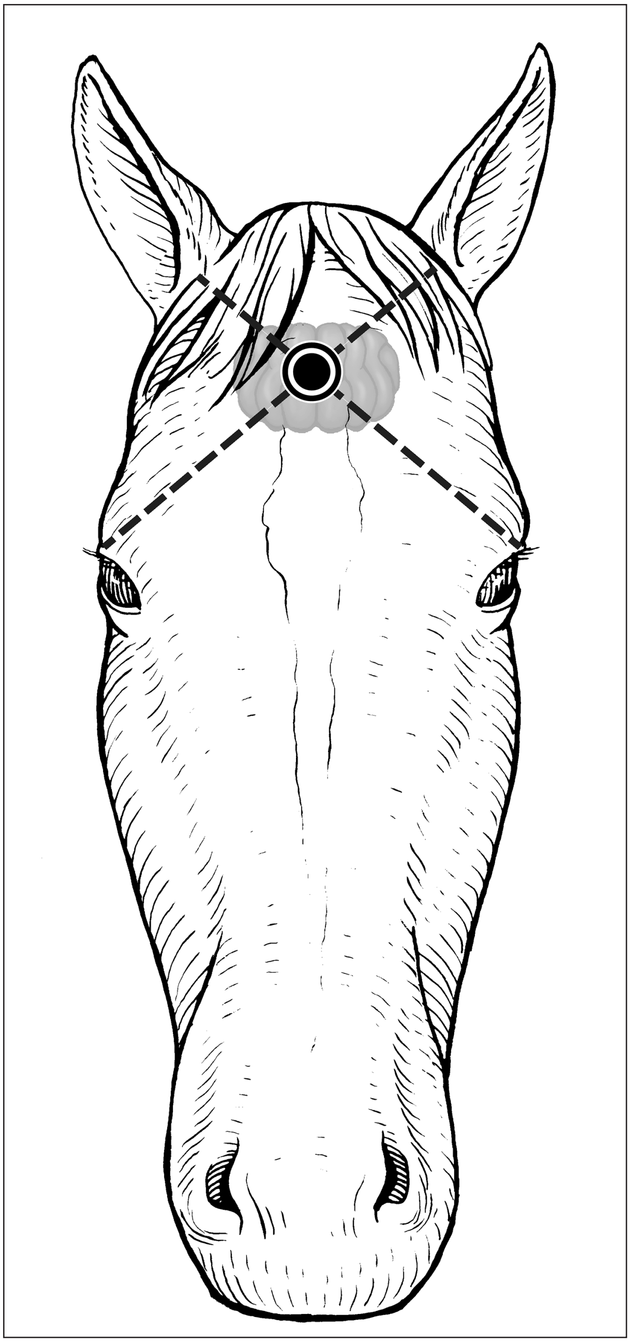
spinal canal. The temporal site is slightly anterior and below the ear.

The correct anatomic site for application of gunshot and penetrating captive bolt for equids is illustrated in **Figure 10**.[91] The site for entry of the projectile is described as being on the intersection of two diagonal lines, each running from the outer corner of the eye to the base of the opposite ear.

T2.2 Electric

Electric stunning for humane slaughter causes immediate loss of consciousness.[59,92] Alternating current has been used to euthanize dogs, cattle, sheep, goats, swine, chickens, foxes, mink, and fish.[55,76,80,92–101] 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.[102] For stunning poultry, the current reaching the brain must be adequate to produce an epileptic seizure but less than that required for cardiac fibrillation leading to death.[103] In poultry, epileptic activity in the brain may require less current than that required for cardiac fibrillation and death.[103] In mammals, reliable induction of an epileptic seizure may require a greater amount of current than that required for induction of cardiac arrest.[104] If killing is not performed quickly, then consciousness is regained.[105]

T2.2.1 Principles

Ohm's law involves current, potential difference (ie, resistance), and frequency. Current, or what flows

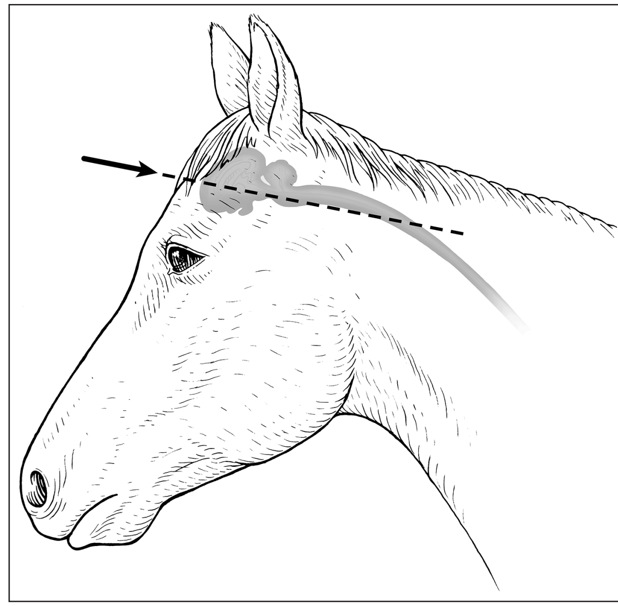


Figure 10—Anatomic site for the application of gunshot or penetrating captive bolt for equids. The point of entry of the projectile should be at the intersection of two imaginary lines, each drawn from the outside corner of the eye to the center of the base of the opposite ear. (Adapted with permission from Shearer JK, Nicoletti P. Anatomical landmarks. Available at: www.vetmed.iastate.edu/vdpam/extension/dairy/programs/humane-euthanasia/anatomical-landmarks. Accessed Jun 24, 2011.)

through a wire, is measured in terms of amps (A). Current is proportional to the potential difference across two points. Voltage (V) is a measure of that difference in electric potential between two 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 market-weight pigs,[41,106,107] 1.00 A for sheep,[55] and 1.25 A for cattle.[106] Amperage must be maintained for at least 1 second. Insufficient amperage can cause an animal to be paralyzed without losing insensibility.[107] Electronic equipment designed to provide constant amperage, which sets the amperage and allows voltage to vary according to animal resistance, may prevent amperage spiking.[107,108] 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.[e] Unconsciousness is most effectively induced at a frequency of 50 cycles (50 Hz).[98,109] 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.[f] In fact, 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.[110] In other studies,[98,107,111] frequencies of 2,000 to 3,000 Hz failed to induce unconsciousness. Grandin[107] recommends that higher frequencies only be used when they are passed through at least two electrodes to the head. Frequenices 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.[110] Eight hundred hertz applied to the head with 50 Hz applied to the body is also acceptable.[112]

Proper electric stunning must not be confused with electric immobilization that paralyzes an animal without inducing unconsciousness.[113] Immobilization without unconsciousness is highly aversive and must not be used.[114,115] Electrocution induces death by cardiac fibrillation, which causes cerebral hypoxia.[99–101] 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.

T2.2.2 Methods

Three methods are used to perform electric stunning: the head-only reversible method; the one-step head-to-body cardiac arrest method; and the two-step method consisting of a current applied only to the head, followed by a current applied to the body, which stops the heart.[116] The head-only method does not cause cardiac arrest and will result in a return to consciousness in 15 to 30 seconds.[59,117] In the head-only method, animals should be bled within 15 seconds.[117] Tongs must be placed so that the current goes only 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 (**Figure 11**).

The one-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 (**Figure 12**).[59,116] Wotton and Gregory[118] suggest that the induction of cardiac arrest provides a major animal welfare advantage because it promotes the start of death. Use of the head-to-body (or –chest, -back) method has been shown to be highly effective in inducing irreversible unconsciousness in over 98% of pigs evaluated.[g] Pork plants using V-shaped conveyor restrainers have achieved > 99% correct electrode placement when the one-step head-to-body cardiac arrest method is used.[119] Grandin[108] recommends when the one-step method is used that the first 1-second treatment should be at least 1.25 A at 50 to 60 Hz. One electrode must be placed on the head, and the other electrode can be placed on any part of the body (except for sensitive areas such as the eye, ear, or rectum). The first electrode must not be placed on the neck or the back of the neck because the current will bypass the brain and cause instant pain.

The two-step method (**Figure 13**) 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.[120]

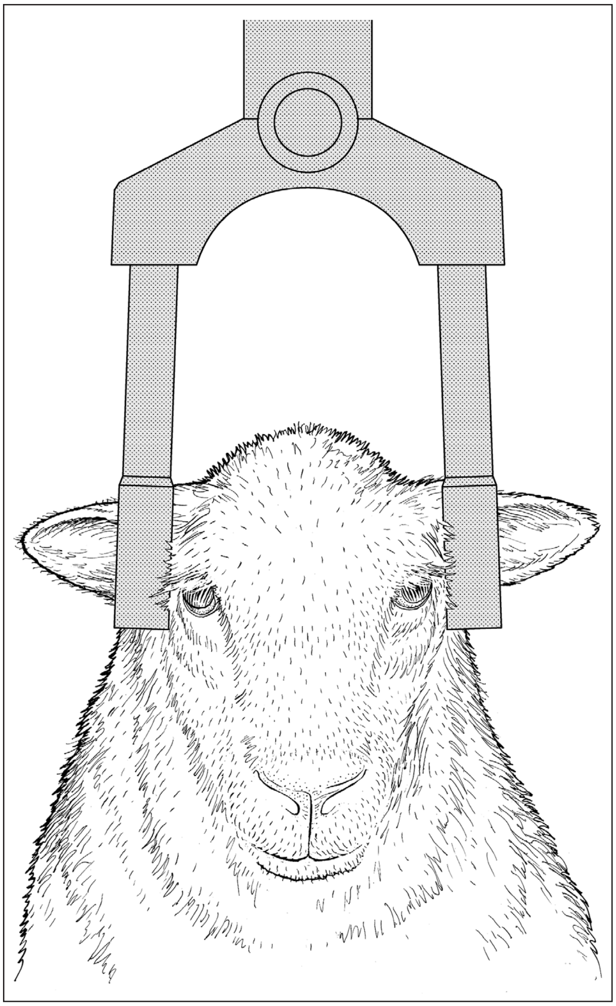


Figure 11—Proper electrode placement for the head-only electric stun method.

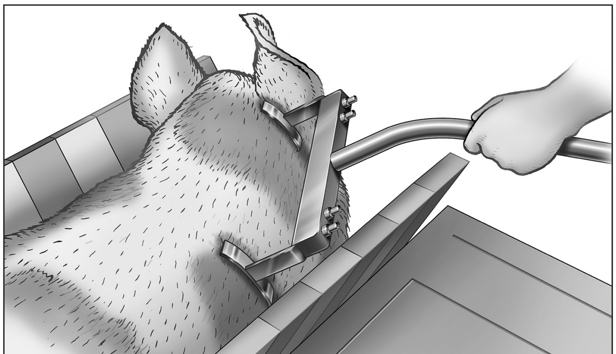


Figure 12—Proper electrode placement for the one-step (head-to-body) electric stun method, where the current is passed simultaneously through both the brain and the heart. The head electrode may be placed on the forehead or immediately behind the ear (as shown).

T2.2.3 Signs of effective stunning

Unconsciousness occurs when electricity inhibits impulses from both the reticular activating and the somatosensory systems of the brain.[121] Signs of effective seizure induction include extension of the legs, opisthotonus, and downward rotation of the eyeballs as

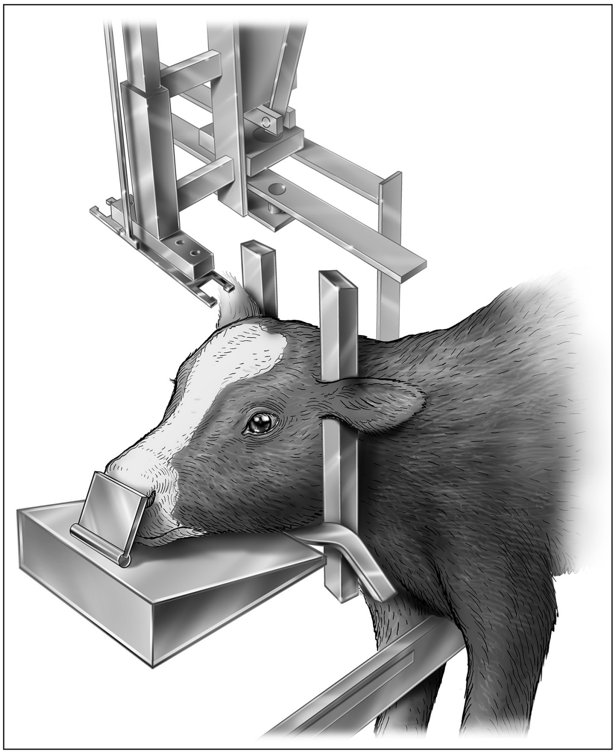


Figure 13—Proper electrode placement for the two-step electric stun method. First a current is passed from the nose plate to stanchion bars on the neck, causing unconsciousness. This is followed by the application of a second current from the neck stanchion to the brisket electrode, causing death via cardiac arrest.

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.[59,106]

On a more practical level, signs of effective stunning have been described.[34] 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. Sheep heads may not hang directly straight down because of anatomic differences, but pig and 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.

T2.2.4 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. 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 two-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.[114,115] For both humane and safety reasons, the use of household electric cords is not acceptable.

<u>Meat quality</u>

The head-only method has both animal welfare and meat-quality issues.[g] Negative meat effects include decreased tenderness, increased drip-loss (water-binding capacity; synersis leading to water puddling), and pale muscle color due to more intense muscular contractions compared with either one-step or two-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.

<u>Cattle</u>

A two-step electric stun method must be used with grown cattle[107,122] 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.[123] Because grown cattle are so large, the head must be properly restrained before affixing electrodes firmly to the head. A frequency of 50 to 60 Hz should be used for the stun[107] if head-only stunning is used. A 3-second application of 1.15 A at 50 cycles applied between the nose and the neck is effective to induce epileptiform activity in the brain.[124]

<u>Pigs and small ruminants</u>

In the interest of animal welfare, electric stunning of sheep should be done with an amperage of at least 1.0 A (160 V), and in pigs, a minimum of 1.25 A should be used for 100-kg (220-lb) animals.[106,125] In the United States, market-weight pigs are much heavier, and more amperage may be required to reliabily induce unconsciousness in these animals. Pigs weighing 130 kg (287 lb) live weight require 1.8 to 2.0 A.[126] More recent research has shown that amperage is the most important electric parameter,[127] but the use of a single electric parameter such as amperage is not sufficient to guarantee effective stunning.[128] Plant operators should also evaluate the animals for signs of a grand mal seizure using the methods described by Grandin.[34]

The time between stunning and bleeding is critical when head-only stunning is used. Animals should be bled within 15 seconds.[59,129] When cardiac arrest is induced, the animals should be bled within 60 seconds. Most large commercial plants use head-to-body stunning where the current is passed simultaneously through both the brain and the heart.[34,116] In small plants, Grandin[119] has observed problems with animals returning to consciousness after head-only stunning because of slow hoisting procedures. To prevent return to consciousness, a second current should be applied to the body immediately after initial head stunning to stop the heart.[120] Proper restraint is critical to allow the correct placement of the electrodes. Electrodes should be cleaned daily and properly maintained.

Improper electric stunning of sheep and 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 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 but sheep will remain silent.[34] 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.[130] Electric stunners work best when they are equipped with an automatic timer.

Poultry

Electric stunning is the most universally accepted and used method for stunning prior to slaughter for poultry.[103] The most widely used method for electrostunning poultry is the electric water-bath stunning method (**Figure 14**), which involves the direct contact of the bird's head in an electrified water bath. Birds are shackled and, while suspended upside down, pass through a water bath. Each bird is immediately stunned for a period that lasts between 30 and 60 seconds.[131]

Efficacy of the water-bath system is influenced by the species, number, and size of the birds passing through the water bath because with increasing size and number of birds in the bath at one time the resistance increases and because parallel paths of current arise with increasing numbers of birds. Variable resistance can result in insufficient current to produce immediate unconsciousness. Constant-current stunners may alleviate this problem.[132]

Smaller commercial facilities may use a handheld stunner for electrically stunning birds. When this method is used, birds must be properly restrained and held. 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.

Welfare issues for electric stunning of poultry exist. Birds must be handled carefully, as the shackling procedure may be distressful and painful.[133] If wing flapping occurs immediately prior to the entrance of the water-bath stunner, preshocks from the stunner can occur.[134] Breast rubs, low lighting, and a smooth transition into the stunner can reduce the frequency of wing flapping. 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. If handheld stunners are used, then appropriate placement of the electrodes between the ears and eyes is essential. 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[135]:

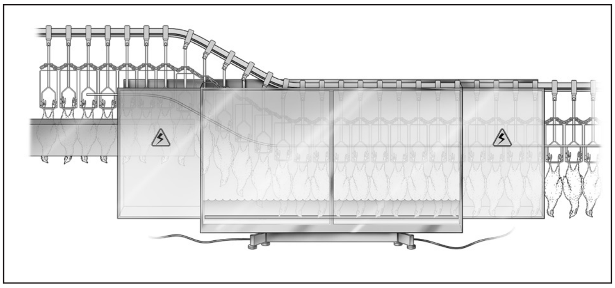


Figure 14—In electrical water-bath stunning, birds are shackled, and while suspended upside down, the bird's head comes into direct contact with an electrified water bath.

United States model—Contrary to the European model, electrical stunning in the United States involves pulsed direct current with low current (25 to 45 mA/bird),[103] low voltage (10 to 25 V),[103,136,137] and high frequency (approx 500 Hz).[103,136,137] 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.[103] 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.[121]

Behavioral reactions

Efficacy of the stunning in US slaughter plants has been determined by assessing corneal and comb reflexes.[121] 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.[121] One study[138] 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).[138] The best results for this combination occurred in male birds at the highest voltage settings (phase one, 15 V; phase two, 60 V).[137] Under these conditions, only 22% of the birds had corneal reflexes, 18% had spontaneous blinking, and < 10% had wing flapping.[138]

Physiologic reactions

One study[138] 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 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.[h] These investigators found the EEG recording of the brain activity to be very similar to that seen with the European model of electrical stunning.[h]

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,[138,139] further research is needed to evaluate the effectiveness and humaneness of electrical stunning with low voltage settings in 1- and 2-phase stunning systems.

CONCLUSIONS

The biological variability of birds makes it difficult to construct recommendations for optimal parameters for electrical stunning of poultry at slaughter. Inadequate electrical variables can result in a return to consciousness before birds enter the neck slitter. However, use of electrical frequencies that are too high results in an increase in blood spotting,[131] leading to larger amounts of carcass waste and an overall increase in the number of birds needed to yield the same amount of end product.

T2.2.5 Detection of problems

Failure to cause immediate unconsciousness is highly stressful and may be painful. Humans experience pain when electroconvulsive shock therapy fails.[140] 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.[118,119]Another cause of failure that has been noted in cattle and pigs is dehydration of the animal prior to stunning.[116] 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.[121] 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.[99] 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.[123,124] For the one-step (head-to-body) method, the head electrode may be placed on the forehead or immediately behind the ear. The head electrode should never be placed on the neck because the brain will be bypassed.[119] 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 position that is effective is head to back.[116] When the two-step procedure is used, placement of the body electrode behind the forelimb is effective.[120] 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).[141]

Grandin[119]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.[119] When the electrodes are applied to the temporal fossae of a sheep's head, they can be stunned multiple times with no increase in either heart rate or glucose secretion.[142] This indicates that the sheep does not remember being repeatedly shocked.

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 why good bleeding technique is essential.[119] 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.[120] There are definite problems with electric stunning if pigs squeal or cattle moo or bellow when the electrodes are applied.[34] 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 cattle or pigs vocalize during electrode application.[89,119]

Proper equipment maintenance is essential. At a minimum, electrodes should be cleaned once daily and regularly maintained.[107] Old, worn, or rusted equipment should be replaced on a regular schedule.

T2.2.6 Corrective action for 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. When a one-step head-to-body method is used, the seizure may be masked. Often a very weak tonic and clonic movement is still visible.[34] 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.
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. For sheep, cattle, and other animals with wool or hair, a small stream of water should be applied either through the electrode or right beside it to wet the application area.
5. Make sure animals are not dehydrated. Dehydrated animals are more difficult to render unconscious with electricity.
6. Use a bleeding knife and techniques that will produce a stream of blood at least 2.5 cm wide in pigs. A copious blood stream helps prevent problems with return to consciousness.[119]

7. 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 two 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.
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 firmly press the electrode against the animal. Firm contact is essential for an effective stun.[130]
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 that will prevent electricity from flowing from a single electrode to ground. The electricity should only flow between the two 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 kept covered during plant wash down.
15. 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. A head holding device is usually not required for pigs or sheep.
16. Employee training is essential.

T2.3 Other Physical Methods

T2.3.1 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 and rabbits.[137] 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 on 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.[143]

Decapitation without prior stunning is rarely used in poultry slaughter plants.[121] Decapitation is also a method that is sometimes used for home slaughter of poultry.[137] Early studies[144–146] 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[147–150] 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 vertebrae 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.[150]

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 one blow. Animals 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.[143]

T2.3.2 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,[151] therefore the Panel has opted to provide guidance.

For poultry, the legs of the bird should be grasped (or wings if grasped at the base) and the neck stretched by pulling on the head while applying a ventrodorsal rotational force to the skull. Crushing of cervical vertebrae and spinal cord is not acceptable unless the bird is first rendered unconscious. Personnel should be trained on anesthetized or dead animals to demonstrate proficiency.

Data suggest that electrical activity in the brain persists for 13 seconds following cervical dislocation in rats,[148] and unlike decapitation, rapid exsanguination does not contribute to loss of consciousness.[149,150] For some classes of poultry, there is evidence that cervical dislocation may not cause immediate unconsciousness.[145,152–154]

Cervical dislocation is a method that may induce rapid loss of consciousness,[148,155] 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 loss of consciousness is rapidly induced.

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 or anesthetized prior to cervical dislocation. When performed on poultry, cervical dislocation must result in luxation of the cervical vertebrae without primary crushing of the vertebrae and spinal cord. In some classes of poultry, there is evidence that cervical dislocation may not cause immediate unconsciousness.[145,152–154] In these cases, other physical methods such as blunt force trauma or decapitation may be more humane[156] and should be employed when available or practicable.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.

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Appendix

Signs of a properly stunned animal by stunning method.

Animal and method	Head	Tongue	Back	Eyes	Limbs	Vocalization	Respiration	Tail	Response to pain
Cattle									
Captive bolt	Must appear dead, hang straight and floppy	Straight and limp	Hanging straight, no righting reflex	No natural blinking. Wide open, blank stare, no response to touch; nystagmus absent	Uncoordinated kicking of hind legs acceptable, no righting reflex present	None	Rhythmic breathing (ribs moving in and out at least twice) is absent. Agonal gasping not acceptable.	Relaxes shortly after being on the rail	A pinch or pinprick may be applied to nose only and no response should be observed.
Electric	Must appear dead, hang straight and floppy	Straight and limp	Hanging straight, no righting reflex	Eyes may vibrate (nystagmus), but no natural blinking	Uncoordinated kicking of hind legs acceptable, no righting reflex present	None	Agonal gasping like a fish out of water normal. Rhythmic breathing (ribs moving in and out at least twice) is absent.	Relaxes shortly after being on the rail	A pinch or pinprick may be applied to nose only and no response should be observed.
Pigs									
CO_2	Must appear dead, hang straight and floppy	Straight and limp	Hanging straight, no righting reflex	No natural blinking	Uncoordinated kicking of hind legs acceptable, no righting reflex present	None	Agonal gasping like a fish out of water normal. Rhythmic breathing (ribs moving in and out at least twice) is absent.	Relaxes shortly after being on the rail	A pinch or pinprick may be applied to nose only and no response should be observed.
Electric	Must appear dead, hang straight and floppy	Straight and limp	Hanging straight, no righting reflex	Eyes may vibrate (nystagmus), but no natural blinking	Uncoordinated kicking of hind legs acceptable, no righting reflex present	None	Agonal gasping like a fish out of water normal. Rhythmic breathing (ribs moving in and out at least twice) is absent.	Relaxes shortly after being on the rail	A pinch or pinprick may be applied to nose only and no response should be observed.
Captive bolt	Must appear dead, hang straight and floppy	Straight and limp	Hanging straight, no righting reflex	No natural blinking. Wide open, blank stare, no response to touch; nystagmus absent	Uncoordinated kicking of hind legs acceptable, no righting reflex present	None	Rhythmic breathing (ribs moving in and out at least twice) is absent. Agonal gasping not acceptable.	Relaxes shortly after being on the rail	A pinch or pinprick may be applied to nose only and no response should be observed.
Sheep									
Electric	Must appear dead, neck hangs on angle with limp and floppy head	Straight and limp	Owing to anatomic differences in sheep, back may not hang completely straight; no righting reflex	Eyes may vibrate (nystagmus), but no natural blinking	Uncoordinated kicking of hind legs acceptable, no righting reflex present	None	Agonal gasping like a fish out of water normal. Rhythmic breathing (ribs moving in and out at least twice) is absent.	Relaxes shortly after being on the rail	A pinch or pinprick may be applied to nose only and no response should be observed.

Unique Species Issues

U1 Additional Considerations: Bovine

U1.1 Bulls

Large bulls, water buffalos, or American bison 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 creates serious safety concerns. 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 balance for effective positioning over the proper anatomic site. 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.[1] However, use of the poll position for penetrating captive bolt stunning is prone to problems associated with 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).[1]

U1.2 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 such as cancer eye, 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.

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[2] 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 five 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 safe product for the human food supply). Four animals were described as having clinical signs consistent with reversible stunning, and one demonstrated signs consistent with consciousness 20 minutes after being stunned with the captive bolt.[2] 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[3] reports that the best packing plants are able to achieve a successful first shot stun on average 97% to 98% of the time. In an earlier study by Grandin[4] involving 21 packing plants, 17 successfully rendered all cattle insensible before they were hoisted onto the bleeding rail, whereas four plants had cattle showing evidence of a return to sensibility that required restunning. Of 692 bulls and cull cows, eight (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.[4] A UK study[a] found that 1.7% of 628 cull cows were stunned poorly.

U1.3 Nonambulatory Cattle

On the basis of nonfed cattle reports[5–7] 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.[8] Furthermore, this study reported that < 1% of the nonambulatory cases developed during the transit process. Nearly all developed the nonambulatory condition on the farm of origin. A survey[9] 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. Severe emaciation and weakness are factors that makes cows more likely to become nonambulatory. There are a few medical reasons why the downer cow condition is more common in dairy cattle, but 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. In fact, one study[10] identified the three major causes of downer cow problems in dairy cattle as hypocalcemia (19%), calving-related injuries (22%), and injuries from slipping and falling (15%).[10] The primary cause of the downer cow syndrome in beef cattle is calving paralysis.[11]

Estimates are that about 5% of dairy cattle in the United States have hypocalcemia annually. The majority of cases (75%) occur within 24 hours of calving, 12% of cases within 24 to 48 hours of calving, and only about 6% of cases at calving.[12] However, when hypocalcemia occurs prior to, or in association with, calving, it can be an important contributor to dystocia and may result in calving paralysis and associated complications. Hypocalcemia is rare in beef cattle, but may occur in conditions where severe dietary mineral imbalances are present. The incidence of milk fever is low in sheep, but may approach incidence rates similar to dairy cattle in dairy goats with high milk yield.[12]

Calving paralysis is a common cause of recumbency in cattle. It is usually the consequence of attempts to deliver a large calf relative to the pelvic size of the cow. Paralysis results from damage to branches of the ischiadic (sciatic) and obturator nerves, which are vulnerable to compression at calving by virtue of their position within the birth canal.[13]

Traumatic injuries may be the primary cause of recumbency, or they may occur as a secondary consequence of a cow that is down and struggling to rise. Examples of such lesions would include sacroiliac (hip) luxation, coxofemoral luxation (uni- or bilateral), pelvic or other fractures, and rupture of the gastrocnemius tendon. These injuries also occur as a consequence of slips and falls. Injuries of the upper leg and pelvis increased significantly in cows during the summer months in a southeastern dairy as a result of wet concrete flooring conditions.[14]

U1.3.1 Downer cow syndrome

Cows 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 is compartment syndrome.[13]

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.[15] Similarly, a survey[10] 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[16] suggests that good nursing care may have the single greatest effect on improving the prognosis for nonambulatory cattle.

U1.3.2 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.[7]

U1.4 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.

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 does not permit the calf freedom to turn around as one of the major breaches of animal welfare in veal production.

Neonatal 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 people 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 arrive at the plant with varying degrees of hypoglycemia 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:

> If an animal is down at a terminal market (e.g., slaughterhouse or packing plant)
>
> Animals that are down should be euthanatized immediately and not taken to slaughter. However, if swine are down, and are not in extreme distress or do not have an obviously irreversible condition, they may be allowed up to 2 hours to recover. Acceptable interventions to assist in this recovery include rest, cooling, or other treatments that do not create drug residue concerns.

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.

U1.5 Fetal Effects

A 2002 report[17] suggested that world demand for fetal calf serum was 500,000 L/y and growing, a need that would require the harvest of at least 1,000,000 fetuses/y. To serve this need and safeguard fetal welfare, it is important to understand what happens to the fetus when its dam is slaughtered.

Behavioral and EEG evidence to date indicates that mammalian fetuses are insentient and unconscious throughout the first 75% to 80% of gestation.[18] 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 eight 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.[18]

These observations indicate that the fetus does not suffer as if drowning in amniotic fluid when the dam is slaughtered, nor is it likely to experience conscious pain associated with other types of invasive procedures 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 animals are killed by physical methods that include exsanguination, delaying removal of the fetus from the uterus for a minimum of 5 minutes after hemorrhaging has ceased generally assures a substantial amount of anoxia-induced damage to the cerebral cortex that will normally prevent progression toward a return to consciousness.[19] If there is any doubt as to the fetus's level of consciousness, it should be euthanized immediately by captive bolt and adjunctive methods as appropriate.

U2 Additional Considerations: Swine

U2.1 Nonambulatory Swine

Lameness disorders that interfere with locomotion and contribute to nonambulatory conditions in pigs include foot disorders (foot rot, overgrown claws, and torn dewclaws), leg injuries, leg weakness (epiphysiolyis, apophysiolysis, osteochondritis, and arthrosis), osteomalacia, fractures, arthritis, and various neurologic disorders. Although many of these conditions may not 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.[20]

Foot problems are reportedly one of the single most important causes of lameness in sows.[21,22] Slatted concrete floors contribute to 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 where sows are kept on nonabrasive floors such as plastic or steel slats.[20] Foot rot and claw lesions (erosions, white line disease abscesses, and vertical wall cracks) are common disorders as well, with occurrence rates as high as 64% in slaughter-weight pigs.[23]

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.[24] 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 manifested by the carrying of 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.[25]

In addition to these causes, there are neurologic disorders affecting the spinal cord and brain. An early study by Vaughan[25] 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, vertebral body, or adjacent paravertebral tissues. Causes in adult animals are believed to be associated with 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 market-weight pigs (dead and nonambulatory) is approximately 1%.[26,b] In a study[27] 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. 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, pigs that were nonambulatory at the plant were divided into two 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.[27]

U2.1.1 Preventing nonambulatory swine

Lameness disorders involving the foot and leg are complicated. There is no one solution to correcting or preventing these conditions. But, floors are a major consideration in the prevention of foot and leg problems. Pigs housed on slatted floors had an injury rate of 44% compared with 28% of pigs housed on solid floors.[28] Concrete floors caused more foot and leg problems than did softer earthen floors or deep straw-bedded surfaces, and perforated floors contributed to an increase in injuries.[29] In farrowing stalls, plastic and steel slats caused more lameness than did solid floors.[29] Flooring surfaces should provide good 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 wear of the sole.

Softer flooring conditions are also believed to be beneficial for decreasing the incidence of osteochondritis. Even more important to the prevention of leg weakness caused by osteochondritis is to avoid overfeeding of gilts during the growing period. In one study,[24] gilts fed ad libitum were culled earlier and at a higher rate as a consequence of leg weakness, compared with gilts fed on a controlled feeding schedule. Research[30] also demonstrates that pigs need exercise to increase muscular strength and to develop proper agility on differing flooring systems.

Other factors 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%.[31] Fortunately, the Halothane gene has been bred out of many swine herds. It is not now a major cause of losses in the United States.[32] High doses of the β-agonist ractopamine may contribute to downers and make pigs more difficult to handle.[33] It may also cause hoof cracking.[34] 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.[35–37] Producers should walk their pens during finishing to get pigs acclimated to people walking through them. This will make handling and loading easier.[38] Fatigued nonambulatory pigs may be reduced because the pigs will be less likely to become agitated during truck loading or during handling at the plant.

U3 Handling and Slaughter of Rabbits

U3.1 Handling Procedures for Rabbits

In the United States, rabbits are not covered by the HMSA, and federal inspection of rabbit meat is voluntary, although individual states may have rabbit-specific inspection requirements.[39] There are few USDA-inspected plants in the United States that process rabbits, and most of the available information on rabbit processing comes from Europe, where commercial rabbit processing is more common. For interstate commerce, rabbits not voluntarily inspected at slaughter by the USDA are under the regulatory oversight of the FDA.

Rabbits are prey animals that retain behavioral patterns similar to their wild counterparts,[40] and the harvesting, transport, and handling of rabbits prior to slaughter are stressful.[41] 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.[42] Other biomarkers of stress in rabbits include elevations in serum glucose, serum triglycerides, serum aspartate aminotransferase, alanine aminotransferase, glutamyltransferase, lactate dehydrogenase, creatinine kinase, and myocardial creatinine kinase, as well as decreases in serum tetraiodothyronine.[43] Elevations of these values have been reported in rabbits during transport and lairage.[44]

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.[43] 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 and handling, disruption of the social group, changes in social structure, separation or 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.[45]

Critical points during transport are waiting time at the farm before loading, loading, ventilation and temperature during transport, loading stops, unloading, duration of lairage, and environmental conditions during lairage.[45] Although some research[46] has suggested that transport conditions are more important than the time of the journey, other studies[47] have shown decreased welfare and carcass quality in rabbits experiencing prolonged transport to slaughter. Ideal temperatures for rabbit transport are between 50° and 68°F (10° and 20°C), and temperatures above 95°F (35°C) or humidity below 55% are detrimental to rabbit welfare.[44] It is important to remember that when transport 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.[41] Crates for transport and lairage should have solid floors to prevent urine and feces transfer from higher crates.[41] Multifloor cage stands can adversely affect welfare if rabbits are left in them for long periods of time.[45]

Providing adequate ventilation, preventing exposure to extreme temperatures, providing food and water for prolonged lairage, and avoiding long delays between loading and transport or arrival and stunning are important factors in maintaining rabbit welfare in the preslaughter period.[45] Extended lairage times should be avoided, and water should be provided when delays between arrival and slaughter are expected; this not only is good for animal welfare but reduces live weight and carcass losses.[45] Lairage areas should be protected from the elements to minimize exposure to temperature extremes.

Commercial processing of rabbits in the United States is generally performed in plants designed to process poultry.[48] Rabbits should be stunned prior to shackling; shackling and hanging of conscious rabbits should be avoided. Shackling has been shown to be painful and distressful to poultry,[49,50] and without research to show differently, it must be assumed that it is also painful and distressing to conscious rabbits. Although one paper[51] on halal slaughter of rabbits suggests that shackling of rabbits by one leg and simultaneously performing deep throat cuts did not result in signs of rabbit distress, there are questions about those authors' methodology. The primary criterion used to determine distress was the presence of vocalization in the rabbits; however, the throat cuts severed the tracheas of these rabbits, thereby making vocalization impossible. The authors indicate that other potential signs of distress and sensibility, such as movement of mouth or eye reflexes, were not recorded.

Successful stunning is characterized by cessation of respiration, excessive salivation, and increased motor activity consisting in the (eg. immediate onset of tonic spasm followed by weak to heavy clonic spasms).[52,53] Not all animals develop convulsive muscle activity, and cessation of rhythmic breathing is considered a more reliable indicator of a successful stun,[52] although some consider lack of corneal reflex as the best measure of insensibility in rabbits.[54]

Maria et al[55] studied five methods of electrostunning for commercial rabbits (n > 50) using variable voltages and frequencies. Voltages < 19 V were not recommended. 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.[56] Anil et al[52] recommend a minimum current of 140 mA by application of 100 V to obtain adequate stunning. The European Food Safety Authority[57] recommends that 400 mA be used in head-only stunning devices. 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.[52]

Captive bolt apparatus designed for waterfowl can be used on rabbits.[53] 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.[53] This is achieved by placing the captive bolt slightly paramedian on the front as close to the ears as possible (**Figure 15**). It is essential to stabilize the head to prevent misses.

Following electric or captive bolt stunning, rabbits are immediately shackled and exsanguinated. Rabbits must be killed within 35 seconds of electric stunning or they may recover consciousness.[45] 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.[45,54] Bleeding time is reported to be 10 to 12 seconds[57] to 2 to 3 minutes.[41]

Decapitation is not commonly employed in the commercial slaughter of rabbits, but is sometimes used for on-the-farm slaughter.[58] Operator competence is required to perform decapitation in a humane fashion. The operator must be familiar with the technique and

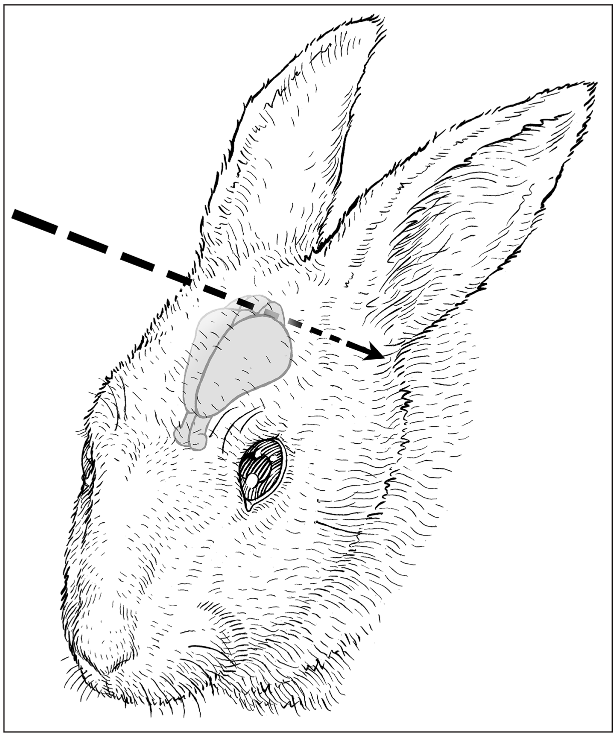

Figure 15—Recommended placement for captive bolt slaughter of rabbits.

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 properly; they must be sharp enough to sever the entire head without need for more than one blow. Rabbits must be restrained to prevent them from moving away from the blade.

Cervical dislocation is also used for on-the-farm slaughter of rabbits.[59] When performed by well-trained individuals on appropriate animals, the method appears to be humane. However, there are few scientific studies available to confirm this observation.

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.[60,61]

Data suggest that electric activity in the brain persists for 13 seconds following cervical dislocation in rats,[62] and unlike decapitation, rapid exsanguination does not contribute to loss of consciousness.[63,64]

Cervical dislocation is a method that may induce rapid loss of consciousness,[62,65] 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 loss of consciousness is rapidly induced.

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 or anesthetized prior to cervical dislocation. For rabbits, the large muscle mass in the cervical region makes manual cervical dislocation physically more difficult.[66]

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.

U4 Slaughter of Food Fish Intended for Human Consumption

U4.1 General Considerations

In the United States, fish are not covered by the HMSA. In addition, these Guidelines do not address fishing or wild-caught aquatic animals for recreational purposes. Euthanasia and depopulation of fish can be found in separate AVMA documents devoted to those topics. *Slaughter* is used primarily to describe the humane killing 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 thought that finfish, amphibians, reptiles, and invertebrates lacked the anatomic structures necessary to perceive pain as we understand it in birds and mammals. However, recent evidence indicates finfish possess components of nociceptive processing systems similar to those found in terrestrial vertebrates,[62–64,67–79] though debate continues on the basis of questions of the impact of quantitative differences in numbers of specific components such as unmyelinated C fibers in major nerve bundles. Studies indicating that finfish responses to pain represent simple reflexes[80] have been refuted by studies demonstrating forebrain and midbrain electric activity in response to stimulation that differs with type of nociceptor stimulation.[81,82]

While there is ongoing debate about finfishes', amphibians', reptiles', and invertebrate animals' ability to feel pain or otherwise experience compromised welfare, the AVMA's POE assumed a conservative and humane approach to the care of any creature is warranted, justifiable, and expected by society, and the POHS will support 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 physiology and anatomy is acquired.

U4.2 Preparation and Environment for Food Fish Slaughter

This section will consider fish welfare implications during harvesting when fish are removed from their growth or production habitat and are transported to slaughter. If possible, withholding food for 12 to 24 hours prior to slaughter will reduce regurgitation, defecation, and nitrogenous waste production. The environment should be as quiet and nonstimulatory as possible, and light intensity should be reduced if possible, but with adequate lighting for personnel.

Water quality should be similar to that of the environment from which the finfish originated, or optimized for that species and situation, for the duration of killing. If of acceptable quality for finfish health, water in which they have been housed or captured should be used. Water quality should be monitored including parameters such as oxygen, pH, CO_2, salinity, ammonia, and temperature and optimized for the species of fish in question. Any necessary changes should be done gradually to allow the fish to adjust. Supplemental aeration and temperature control may be used when necessary. The addition of salt (2 to 8 g/L) to the water can also decrease stress in freshwater fish during holding periods.[83] Handling and crowding, as well as time out of water, should be minimized as much as possible to control and minimize physiologic stress to fish. 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, or other changes that would compromise the integrity of the materials used.

U4.3 Methods of Slaughter for Food Fish

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 finfish into the food chain, either by rendering, as fish meal, or by distribution for directly consumed product.[84] Carbon dioxide is a drug of low regulatory priority[85] that avoids unacceptable residues, but it is not an FDA-approved method for killing aquatic animals used for food. 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, properly maintained, by trained personnel who are regularly monitored for proficiency.

Carbon dioxide

Immersion in CO_2-saturated water causes narcosis and loss of consciousness after several minutes.[72,86] This method is most often used as the first step of a two-step process with another method such as exsanguination. Some species may exhibit hyperactivity prior to loss of consciousness.[87,88] Purity and concentration of CO_2 are important for effectiveness. Only CO_2 from a source that allows for careful regulation of concentration, such as from cylinders, is acceptable. Care must be taken when using CO_2 to prevent exposure to personnel (ie, slaughter must be conducted in well-ventilated areas).

Captive bolt
(most commonly nonpenetrating; one step)

This is a method usually applied to large finfish species.[89] The nonpenetrating captive bolt gun has either a wide mushroom-shaped head or a flat head that does not penetrate the brain. In general, regular nonpenetrating captive bolt guns only stun animals. Correct positioning is critical for effective stunning (**Figure 16**).

Gunshot

This technique is primarily used with large fish such as tuna. 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 (refer to the section Techniques—Physical Methods—Concussive—Gunshot for further safety information).

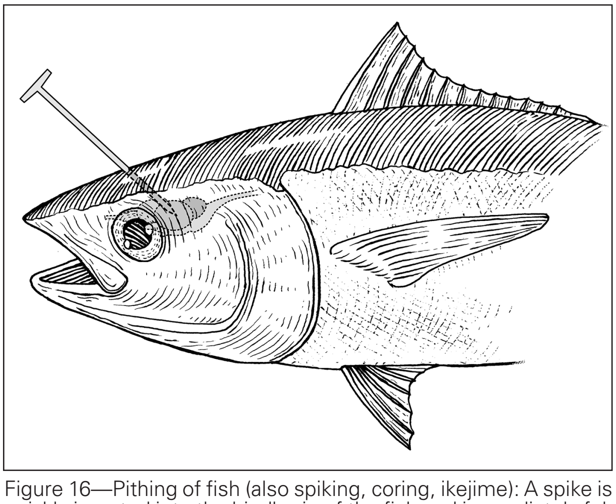

Figure 16—Pithing of fish (also spiking, coring, ikejime): A spike is quickly inserted into the hindbrain of the fish and immediately followed by physical disruption of brain tissue by rotary movement of the spike. This causes immediate brain death.

Pithing

This method is similar to spiking, coring, or ikejime. 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 one-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 two main ikejime methods (Figure 16): from the side of the head or through the gill cover. The first method is used for most medium-sized fish where a sharp spike is driven into the brain from the right side of the head. The position of spiking is diagonal and about 2 cm behind the eye. Smaller fish can be spiked through the gill opening with a sharp knife. This will both spike and bleed the fish. The aim of both methods is to destroy the hind brain of the fish, which is the part of the brain controlling movement.[c] Operators using this method should be trained in the proper location and timing of the pithing process to ensure minimal stress and rapid brain death for the fish.

Manually applied blunt force trauma
(cranial concussion) followed by secondary kill step

Manually applied blunt force trauma (a rapid, accurately placed blow of sufficient energy to the cranium with an appropriate-sized club) 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 finfish's size, species, and anatomy and the characteristics of the blow (including its accuracy, speed, and club mass) will determine the efficacy of manually applied blunt force trauma. 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[90] (**Figure 17**).

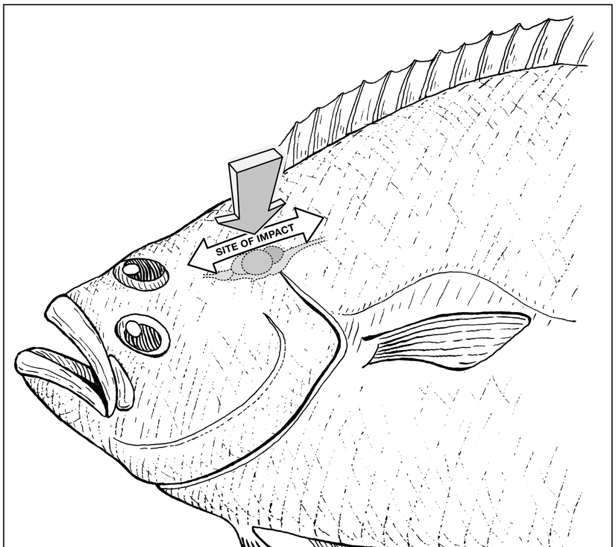

Figure 17—Recommended placement for percussive stunning of fish.

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 Automated systems require training for operators on a regular basis and a preventative maintenance program to ensure the proper functioning of the equipment.

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 O_2 concentrations. Pithing helps ensure rapid loss of brain function and death for those species.[89]

Cervical transection using a knife or other sharp instrument inserted caudal to the skull to sever the spinal cord and cervical vertebrae, followed by secondary kill step

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

Electrocution

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). Operators using this method should be sufficiently trained in the level of electric current appropriate to be used for the species of fish in question as well as in safety measures for themselves (**Table 3**).

Exsanguination as a secondary kill step

Gill arches are cut to cause bleeding of the fish and ultimately death. Exanguination without prior stunning should be avoided, as fish may struggle intensely[99] with vigorous head shakes and tail flaps.[100]

Rapid chilling (hypothermic shock; one step or two step)

This method of killing is not appropriate for temperate-, cool-, or cold-water tolerant finfish or other species that can survive at 4°C (39°F) and below, nor is it currently acceptable for medium- to large-bodied finfish because of surface-to-volume considerations. Fish display vigorous movement upon chilling; 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[101]; however, more recent literature shows that this is likely due to rapid depletion of energy stores as a result of struggling during capture.

U4.4 Conclusions

Food fish slaughter techniques are very diverse, and fish species vary in their response to different methods[102] such as sensitivity to oxygen deprivation[103] or tolerance for low temperatures. Therefore, slaughter techniques should be continually researched and determined specifically for the food fish species in question.

U5 Handling and Slaughter of Ratites

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).

Regardless of the slaughter facility used, care should be taken to avoid standing in front ratites during handling or catching. They can kick forward, and 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 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,[104] and trimming can negatively affect their balance making the birds prone to slipping in wet conditions.[105]

When slaughter-stage ratites are worked with, highly stressed and aggressive birds should be caught first to prevent agitation within the rest of the group. Handlers can capture individual ostriches by using a shepherd's crook or by catching the beak in one hand and pulling the bird's head down and in the direction the handler wishes the bird to move. Another option for moving an individual bird is described in the Ostrich Business Chamber's Code of Conduct[106]:

> A minimum of three handlers is needed to restrain an adult bird to avoid injuries to both the ostrich and handlers. A handler must be positioned at each side of the ostrich holding the wings. One of these handlers

Table 3—Electrical parameters recommended for different species of fish.

Species	Waveform	Frequency (Hz)	Electric field strength (V/cm)	Electric current density (A/dm2)	Duration (s)
Atlantic salmon[91]	sine	50–80	0.25–0.5	Insufficient data	10
Rainbow trout[92]	sine	50	Insufficient data	8.3	5
Carp[93]	sine	50	25.7	0.73	5
African catfish[94]	sine	50	18.8	1.5	5
Sea bass[95]	sine	50	1	5	1
Halibut[96]	sine	50	1	Insufficient data	10
Nile tilapia[97]	sine	50	12.5	1	1
Eel (2 steps)[98]	sine	50	13	0.7	1
	sine	50	3.3	0.17	300

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 backwards to the tail from where the ostrich can be steered.

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.[107] Lifting the tail up and holding the head down make it more difficult for ratites to forward kick and injure personnel.

For lairage, it is important that all pens be round, hexagonal, or octagonal in shape. This prevents the birds from crowding into the corners of the pens and injuring one another. Additionally, side walls should be 1.7 to 2.0 m high to prevent birds from seeing distractions outside the pen.[108] Walls should also be constructed to handle the force of birds running or pushing against them.[108] It should also be noted that while ratites are flightless birds, they can jump over low fences.[108] It is important to avoid startling the birds, as they will attempt to flee and will injure themselves and each other.[108] Any unexpected behavior by personnel may startle the birds and result in rapid evasive behavior. Low light levels and minimal noise in lairage may help birds remain quiet and calm.[108] It is best to avoid mixing birds from different farms, as they can be become aggressive toward one another. Water should always be freely available to the birds during lairage. Grooved cement floors can cause birds to slip, and metal grids placed on top of cement can dissuade birds from settling and lying down. A floor system that is suitable for ratites is metal mesh (1- to 1.5-cm sided square holes) raised above a concrete floor.[108]

There are no universally agreed-upon stunning methods for ratites. A large number of ostriches are slaughtered annually in South Africa, and electric head-only stunning performed with handheld tongs is the most commonly used method. The recommended electric stunning parameters for ostriches in South Africa are a current of 0.4 to 0.6 A at 90 to 110 V for a duration of 4 to 6 seconds.[106] Glatz recommends stunning emus using 120 V at 1.2 A for 10 seconds and ostriches using 120 V at 1.2 A for 15 seconds.[107] An electric stunning current > 0.4 A at 50 Hz alternating current used in head-only application prevented recovery in 90% of ostriches when they were bled within 60 seconds.[109] The return of rhythmic breathing movements indicates the first stages of recovery in birds following an electric stun.[110] Effective stunning can be presumed when epileptiform activity is seen (ie, rigidity with flexed legs [tonic phase] followed by kicking of varied intensity [clonic phase]).[106] The CFIA Manual of Procedures[111] includes recommendations for electric stunning (**Figure 18; Table 4**).

Chapter 7 of the Food and Agriculture Organization of the United Nations Guidelines for Humane Handling, Transport and Slaughter of Livestock[112] recommends 1.5 to 2 A and 90 V for 10 to 15 seconds for electric stunning of ostriches.

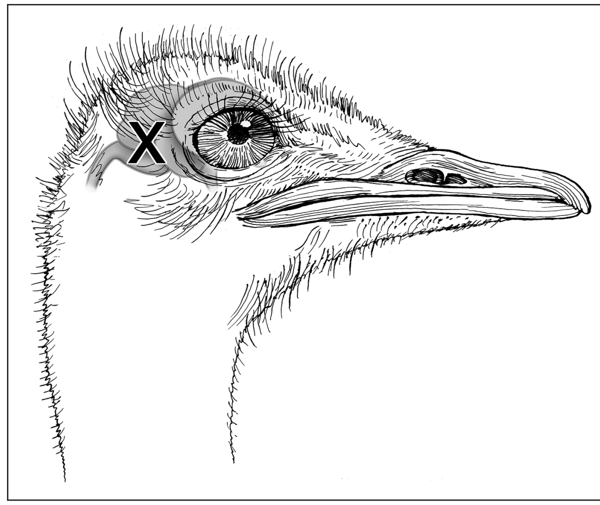

Figure 18—The tongs should be placed on both sides of the head behind the eyes and just over the outer ear openings. "X" indicates where the electrodes should be applied to each side of the animal's head.

Table 4—Canadian Food Inspection Agency recommended parameters for electrical stunning of ratites. (Adapted from CFIA. Meat and poultry products: manual of procedures. Chapter 12, annex A—species-specific guidelines—red meat species: ratites. Available at: www.inspection.gc.ca/english/fssa/meavia/man/ch12/annexa7e.shtml. Accessed Sep 13, 2012. Reprinted with permission.)

Birds	Amperage	Volts	Frequency	Seconds
Ostriches, rheas, and emus (not hooded)	0.12–0.4	230–300	50–60	4–6
Ostriches, rheas, and emus (hooded)	0.4	230–300	50–60	4–6

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. Some commercial ratite slaughter plants now use a new restraining and stunning mechanism that completely encompasses the bird in a padded clamp holder that restrains the legs and body at strategic points. The head of the bird is placed into a box where the electric current is applied. While the bird is being electrically stunned, the box rotates 180° so that toe clamps can be applied without any danger to the stunning operators. The box is then opened, and the bird is hoisted and conveyed for exsanguination.[108]

An air-powered captive needle pistol can also produce an effective stun in birds.[113,114] When a captive needle pistol is used, the needles should be applied at the intersection of two imaginary lines drawn from the ear on one side of the head to the inner corner of the eye on the other side.[113,114] In a report to the American Ostrich Association, the Texas Agricultural Extension Service noted the use of a Schermer captive bolt stun-

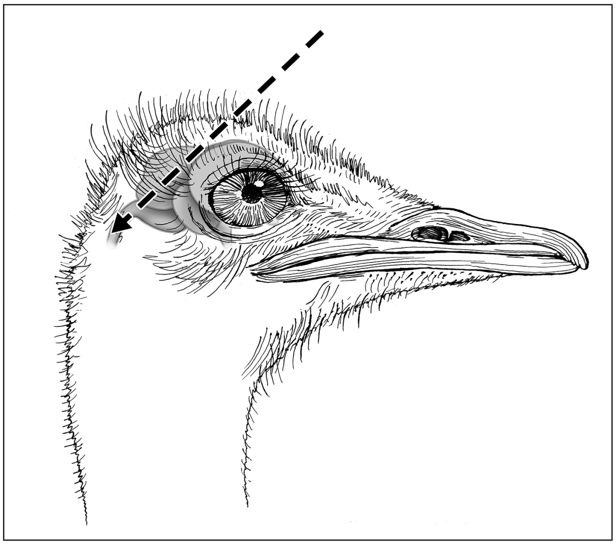

Figure 19—Arrow indicates the direction that the stunning device should be pointed and the entry point at the top of the animal's head.

ner for the birds.[115] The CFIA Manual of Procedures[111] 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 19)**.

The Ostrich Business Chamber also finds captive bolt stunning to be acceptable.[106] However, Chapter 7 of the Food and Agriculture Organization of the United Nations Guidelines for Humane Handling, Transport and Slaughter of Livestock states that a captive bolt gun is not suitable for stunning ostriches, as "[t]heir brain is small and lobulated, and the bolt does not produce proper concussion."[112]

Birds should be bled immediately after stunning (within 60 seconds[105]) with a complete ventral neck cut that severs both carotid arteries and both jugular veins or thoracic sticking. The CFIA recommends that the birds are bled out via 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. Anecdotally there is better and faster bleed out when both the neck cut and thoracic stick are performed.

U6 Handling and Slaughter of Alligators

In the United States, alligators are not covered by the HMSA and are classified as seafood for federal meat inspection purposes.[116] A small fraction of alligators are 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.[117,118] Most farmed alligators are slaughtered on farm prior to either processing on-site or shipment to processing facilities. This minimizes damage to hides that might occur during mass shipment of live animals.

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. 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[76] of the efficacy of analgesics to minimize the impact of noxious stimuli on these species. Consequently, slaughter techniques that result in rapid loss of consciousness and minimize pain and distress[76] should be strived for, even where it is difficult to determine that these criteria have been met.

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.[119] 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.

Alligators possess unique anatomic and physiologic traits that can make the assurance of quick and humane death difficult. Reptiles have 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[120]; some reptiles may remain conscious up to an hour following decapitation. Studies of varying physical methods of euthanasia of American alligators indicated that penetrating captive bolt, nonpenetrating captive bolt, and pithing reduced brain wave activity to levels equivalent to or below those of anesthetized alligators; these methods were considered to be appropriate methods for euthanasia.[d] In contrast, severance of the spinal cord alone resulted in brain wave activity that did not significantly differ from awake animals; for this reason, spinal cord severance alone (as occurs during decapitation) was considered an inappropriate euthanasia 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 ft 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.[120]

Proper placement of captive bolts or gunshots is imperative to ensuring a rapid and humane death in alligators. The brain of the alligator is relatively small and is located immediately behind 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 orbit 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 approach is likely to only sever the spinal cord without destroying the brain and is therefore not appropriate. **Figure 20** illustrates the appropriate sites for captive bolt or gunshot placement and for spinal cord severance or decapitation.

For purposes of humane slaughter, the following methods are considered acceptable provided that they

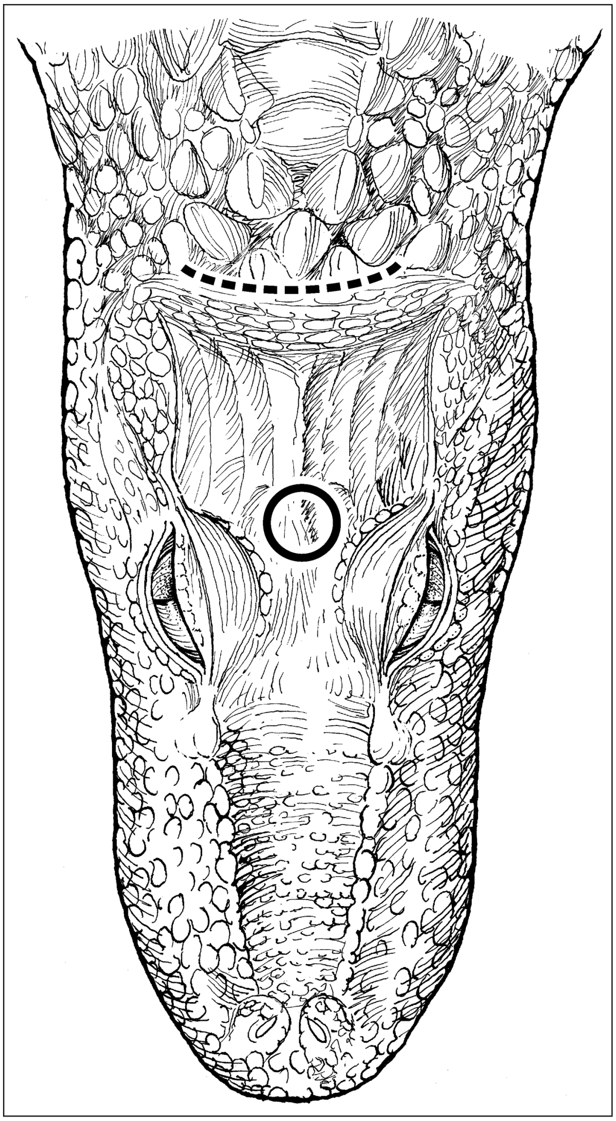

Figure 20—Recommended placement for captive bolt or gunshot of alligator.

are performed with proper equipment that is properly maintained by trained personnel who are regularly monitored for proficiency: 1) 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. 2) Gunshot delivered to the brain may be used providing 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. 3) Decapitation or spinal cord severance is acceptable only if immediately followed by pithing to ensure destruction of brain tissue. The following killing methods are considered unacceptable for slaughter of alligators: cervical dislocation, exsanguination, hypothermia, hyperthermia, suffocation, and drowning.

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Design of Facilities and Slaughter Process for Religious Slaughter

R1 Handling Procedures at Slaughter Plants for Hoofstock

R1.1–R1.5 Steps 1 Through 5

Refer to the chapter Design of Facilities and Slaughter Process for information on arrival at the plant, unloading, receiving, lairage, and handling. The procedures for these steps are the same regardless of whether the animals will be slaughtered via conventional or religious methods.

R1.6 Step 6—Restraint

There are various methods used to restrain and position the animal for religious slaughter. In the United States, there is an exemption from the HMSA[1] 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. When an animal is slaughtered 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, the HMSA specifically declares such slaughter and handling in connection with such slaughter to be humane. 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. Unloading animals from transport vehicles, lairage, driving the animals to the restraint point, and insuring that the animal is unconscious with no corneal reflex before invasive dressing procedures begin are under FSIS jurisdiction, the same as conventional slaughter.

R1.6.1 Detection of problems

From an animal welfare standpoint, there are three issues that occur during religious slaughter, which uses a neck cut to create unconsciousness. 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, 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.[2] In one study,[3] 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[4] showed that cattle vocalized less in an upright restraint compared to rotating boxes. The OIE 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 United Kingdom, Canada, Western Europe, and many other countries. Fortunately most mid- to large-size religious slaughter plants in the United States have stopped this practice because of concerns for both animal welfare and worker safety. One study[5] found that conversion of a system that used shackling and hoisting to a conveyor restrainer reduced worker injuries.

Upright restraint is less stressful for both mammals and poultry, compared with being suspended upside down.[2,6,7] Sheep were less willing to move through a single-file chute after having been subjected to inverted restraint, compared with being put into a restraint device in an upright position.[8] In two different plants where cattle were suspended by one back leg, the percentage of cattle that vocalized varied from 30% to 100%.[a] Increased percentages of cattle that vocalize (mooing or bellowing) during restraint are associated with increased cortisol levels.[3] In one study,[9] 99% of the cattle vocalizations during handling and restraint were associated with an obvious aversive event such as the use of electric prods or excessive pressure from a restraint device. In cattle, vocalization scoring is routinely used to monitor handling and restraint stress,[10,11] and no more than 5% vocalization (3% for nonreligious animal slaughter) is acceptable according to the North American Meat Institute standards.[10] The difference in the percentages for acceptability relates to the differences in handling between the two procedures. 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.[12] 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 one or more limbs, shackling by one or more limbs and dragging, trip floor boxes that are designed to make animals fall, and leg-clamping boxes. Even though suspension is stressful for conscious poultry, such as chickens and turkeys, it is used in a vast majority of all US poultry plants for both conventional and religious slaughter; with attention to handling details and proper equipment, the stress can at least be minimized.

R1.6.2 Corrective action for problems with restraint

For the religious slaughter of cattle, restraint devices are available that hold the animal either in an upright position (**Figure 21**) or inverted onto their backs. Smaller ruminants, such as sheep or goats, can be held in an upright position by people or placed in a simple restraint device.[2] Large heavy animals, such as cattle or 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

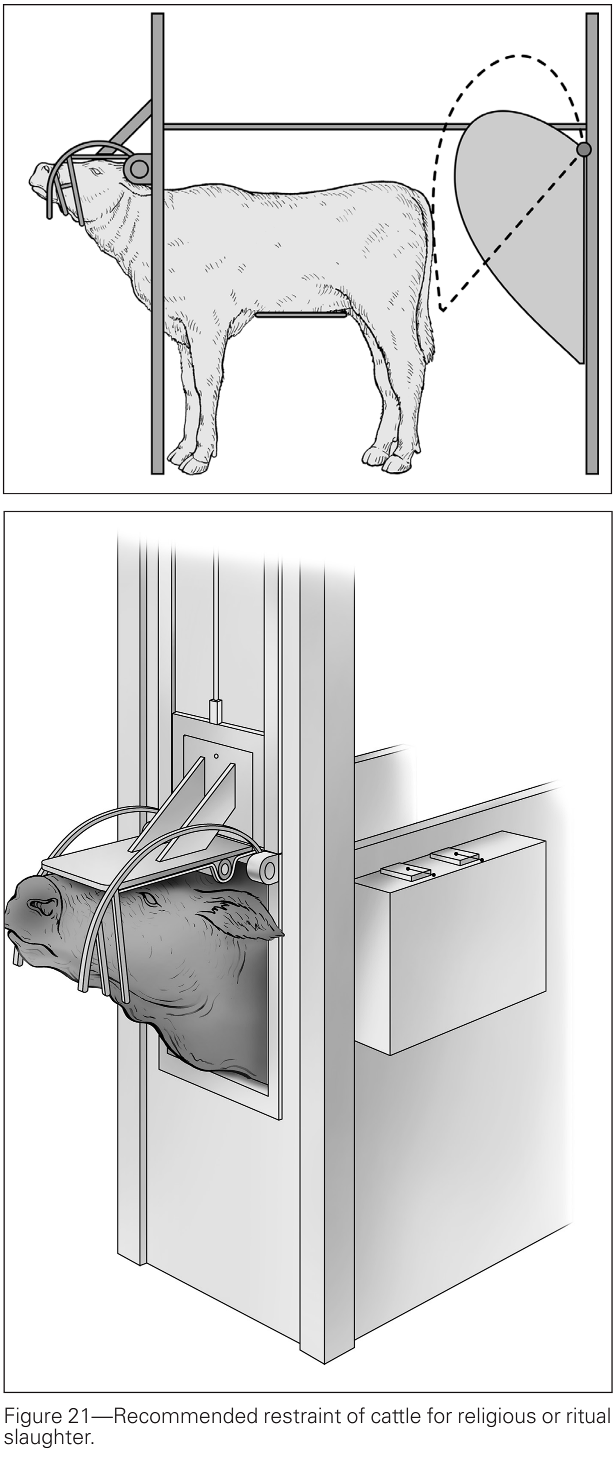

Figure 21—Recommended restraint of cattle for religious or ritual slaughter.

religious slaughter are operated poorly or have design problems, such as excessive pressure applied to the animal, 25% to 32% of the cattle vocalize.[9,13] In one study,[14] 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%.[11,15,16] 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.[3]

Information on the correct operation and design of upright restraint devices for religious slaughter can be found in reports by Grandin,[17,18] Grandin and Regenstein,[19] and Giger et al.[20] 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. Upright or sideways (lying on the side) restraint may be less aversive than full inversion. Hutson[8] 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.[21]

It is important to minimize the time that an animal is held firmly by a head restraint. Head restraint using a mechanized device that tightly holds the head is more aversive than body restraint.[17] 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.[17] 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. When Velarde et al[22] 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.[17] The percentage of cattle vocalizing (mooing or bellowing) either while in a restraint device or while entering it should be 5% or less.[11,16] Restraint devices should not cause animals to struggle or vocalize.[23] For poultry, stress during shackling can be reduced by subdued lighting. Wing flapping can be reduced by installing vertical pieces of conveyor belting with a smooth surface for the breasts of the shackled birds to rub on. A possible future method to reduce bird stress while in shackles is the incorporation of a moving horizontal conveyor that supports the bird's body.[24] A Dutch poultry plant recently installed a system where each shackled chicken has its body supported in a plastic holder.[25] In both large and small plants, where possible chickens can be held by a person in an upright position for the throat cut and then placed immediately either in a bleeding cone or on the shackle.

R1.7 Step 7—Performing the Throat Cut

There are three basic ways that religious slaughter is performed: 1) preslaughter stunning before the throat cut with either a captive bolt or electric stunning, 2) immediate postcut stunning with a nonpenetrating 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.[26] For halal slaughter, electric head-only stunning is used in many large cattle and sheep plants in New Zealand, Australia, and the United Kingdom. Head-only electric stunning is acceptable to many Muslim religious authorities because it is fully reversible and induces temporary unconsciousness (refer to the section Techniques—Physical Methods—Electric). 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 or birds 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,[a] 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 with the rear body electrode removed worked well because the design of the handle facilitated positioning of the stunner on the sheep's head. In poultry a very light reversible electric water-bath stun is done. The preceeding 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.[27] 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.

R1.7.1 Detection of problems

The greatest welfare concerns may occur during traditional religious hand slaughter. There are two 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.[28,29] 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 a whetstone. Before and after each animal is cut, the knife is checked for nicks that could cause pain.[28,29] Any nick in the knife makes the animal nonkosher, so there is a strong incentive to keep the knife razor sharp and nick free.

R1.7.2 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 long caused pain comparable to dehorning.[30,31] 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 whetstone. 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.[18] One of the rules of kosher slaughter is that the incision must remain open during the cut.[28,29] When the wound is allowed to close back over the knife, cattle will violently struggle.[19] 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.[18,19] In calves, there has been a similar observation.[32] Grandin[18] reports that people invading the animal's flight zone by getting near to the animal's face caused a bigger reaction. An eartag punch has also caused a bigger reaction than a good kosher cut.[19] Most chickens slaughtered by shechita exhibited no physical response to the cut, and they lost the ability to stand and eye reflexes at 12 to 15 seconds.[33]

R1.7.3 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. Before invasive dressing begins, all signs of brainstem function such as the corneal reflex must be abolished by bleeding. 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.[34,35] In cattle, when the carotid arteries are severed, the brain can still receive blood from the vertebral arteries.[34,35] After the cut, sheep will become unconscious and lose posture 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.[36–42] In these studies,[36–42] time to onset of unconsciousness was measured by either EEG or loss of the ability to stand (LOP). Allowing the wound to close up after a transverse halal throat cut with a 20-cm-long knife may delay onset of unconsciousness. Electroencephalographic measurements on sheep indicated consciousness could last 60 seconds.[43] In a study[44] where a rotating box was used to invert veal calves onto their backs, unconsciousness was measured by EEG. It occurred at an average of 80 seconds. In sheep, unconsciousness as measured by time to eye rotation was 15 seconds.[45]

There is a large amount of biological variability, and a few cattle, calves, or sheep have extended periods of sensibility (> 4 minutes[42,46]). If the animals can stand and walk they are definitely conscious. In sheep the corneal reflexes, which are a brainstem reflex, may be present for up to 65 seconds after the cut.[45] In veal calves, corneal reflexes were still present at 135 ± 57 seconds after the throat cut.[44] The methods section of Lambooij et al[44] did not describe the type of knife. However, that study was done in a slaughter plant that performed halal slaughter. 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.[47] Corneal reflexes occur during a state of surgical anesthesia[48] or when visual potentials and SEPs are abolished.[49] 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 of the ends of the severed arteries (false aneurysms).[50] This problem does not occur in sheep.

R1.7.4 Aspiration of blood

Another welfare concern is aspiration of blood into the trachea and lungs after the cut.[51] In one study,[52] when cattle were held in a well-designed upright restraint, 36% (for kosher) and 69% (for halal) aspirated blood. In 31% of these nonstunned cattle, blood had been aspirated into the bronchi. It is likely that in a rotating box where the animal is held on its back, aspiration of blood will be higher.[b]

R1.7.5 Corrective action for problems

To reduce 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.[23] It is also essential that the knife be extremely sharp, and the use of a whetstone 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 detect sharp knives with nicks.

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[46,53] 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.[46,53] 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 must be absent. Even though an animal showing only a corneal reflex is unconsciousness, 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 conduct both conventional slaughter and religious slaughter.

R2 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.[17,18]
2. Conduct collapse-time scoring. When the best methods are employed, 90% of the cattle will collapse and lose the ability to stand within 30 seconds.[c] Researchers in Europe reported a similar result when they used a well-designed upright restraint device.[54] 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 must not be confused with the corneal reflex. To evaluate natural blinking (menace reflex), a hand is waved within 4 inches (10 cm) of the eye without touching it. A natural blink occurs if the eye does a full cycle of closing and then reopening. Omit scoring of time to unconsciousness if pre- or postcut stunning is used.
3. The vocalization score should be 5% or less for cattle.[10,11] Score on a per-animal basis, as a silent animal or a 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. 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 LOP.
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 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.[55] Score prod use using 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.
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 one or more limbs, shackling and dragging by one or more limbs, trip floor boxes that are de-

signed 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.

R3 Auditing Religious Slaughter to Improve Animal Welfare for Both Kosher and Halal Slaughter of Chickens, Turkeys, and Other Poultry

1. If stunning is used, audit and monitor the percentage of birds that are effectively stunned using the same criteria as for conventional slaughter.
2. Score the performance of shacklers for faults such as one-legged shackling using the same criteria as for conventional slaughter.
3. 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.
4. Score the percentage of birds that wing flap after restraint. In a well-designed shackle line with a breast rub conveyor, the percentage of flapping birds should be very low.

R4 The Importance of Measurement

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 roll-back or the absence of natural blinking will enable both plant personnel and religious slaughter personnel to improve their procedures.

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