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Guidance for Veterinarians on Euthanasia Methods that Do Not Include Pentobarbital Sodium

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1. Introduction

1.1. Rationale

Due to a global shortage of pentobarbital sodium, the active ingredient used in most euthanasia products for animals, the existing Canadian supply may be impacted in mid to late 2021 through mid-2022. Health Canada's Veterinary Drugs Directorate (VDD), the Canadian Animal Health Institute (CAHI) and the Canadian Veterinary Medical Association (CVMA) are working together with manufacturers, importers and distributors to help minimize the impact of the shortage and provide information and updates to stakeholders.

The CVMA through an advisory committee has developed the current document as guidance on products, methods and protocols that can be used by veterinarians as alternatives to those that utilize pentobarbital sodium for euthanasia of animals.

1.2. Disclaimer

The use of Guidance for Veterinarians on Euthanasia Methods that do include Pentobarbital Sodium ("Guidance") for any purpose whatsoever, constitutes the user's agreement as follows:

1. The user strictly acknowledges and agrees that all content found in this Guidance has been formulated and reviewed by an advisory committee at the time that the guidelines were formulated; that the information contained therein may be modified subsequent to these guidelines being disseminated and that the information provided in the guidelines is intended as guidance and must be utilized by veterinarians in conjunction with sound clinical judgment.
2. The Canadian Veterinary Association (CVMA) and their consulted veterinarians make no representations or warranties of any kind, express or implied, regarding the completeness, accuracy, reliability, suitability or availability with respect to this Guidance or the information, products, procedures or practices contained therein for any purpose whatsoever. By utilizing this Guidance you completely release the CVMA and their consultants, agents, employees, servants, successors and assigns from any and all liability, whatsoever, arising from the said Guidance.
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4. The guidance contained herein should be thoroughly reviewed before considering its application. Further, users of the Guidance should consider any updates or modifications to the document which may be found at <https://www.canadianveterinarians.net/policy-advocacy/national-issues-resources>.
5. The CVMA does not specifically endorse any of the content of this Guidance and reiterates that the Guidance is for informational purposes only.

More detail regarding guiding principles of euthanasia can be found in the American Veterinary Medical Association (AVMA) Guidelines for the Euthanasia of Animals (2020) available at: <https://www.avma.org/sites/default/files/2020-01/2020-Euthanasia-Final-1-17-20.pdf>, and the Canadian Council on Animal Care (CCAC) Euthanasia Guide (2010) at: <https://www.ccac.ca/Documents/Standards/Guidelines/Euthanasia.pdf>.

1.3. Advisory Group Members

Dr. Bettina Bobsien	CVMA Animal Welfare Committee
Dr. Nigel Caulkett	University of Calgary, Faculty of Veterinary Medicine
Dr. Henry Ceelen	CVMA National Issues Committee
Dr. Serge Chalhoub	CVMA National Issues Committee
Dr. Daniel Pang	University of Calgary, Faculty of Veterinary Medicine
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Dr. Enid Stiles	CVMA President
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Dr. Doug Whiteside	University of Calgary, Faculty of Veterinary Medicine; Calgary Zoo

2. Companion Animal (Dogs, Cats, Small Companion Mammals*, Birds, Reptiles)

* Rodents, rabbits, ferrets

2.1. Anesthetic recommendations prior to euthanasia with potassium chloride (KCl) or T-61 for companion animals

Important considerations:

- Most companion animal veterinarians are familiar with the use of pentobarbital sodium for euthanasia. An overdose of pentobarbital has the advantage of inducing general anesthesia, followed by respiratory arrest and collapse of the cardiovascular system. The lethal dose of pentobarbital has been well established in many species. Theoretically, other anesthetic agents can be used for euthanasia but the lethal dose is less well established.
- Potassium chloride (KCl) and T-61 are useful agents for euthanasia but both agents must be administered in an anesthetized patient. An appropriate depth of general anesthesia must be confirmed by unresponsiveness to auditory or tactile stimulation (e.g., toe-pinch), absence of spontaneous palpebral reflex, and absence of swallowing or gag reflex, prior to administration of the euthanasia agent. If depth of anesthesia is insufficient, 50% of the original intravenous induction agent dose can be administered and anesthetic depth re-assessed (in the case of an animal receiving an inhalational anesthetic agent, more time with the vaporizer setting increased can be allowed).
- The recommendations that follow for inducing general anesthesia before administration of KCl or T-61 are based on intravenous doses of injectable anesthetic agents sufficient to induce a deep plane of general anesthesia. These doses represent approximately 1.5 times the dose required to induce general anesthesia in an un-premedicated animal. Animals requiring euthanasia which are already under inhalant anesthesia (isoflurane, sevoflurane) can be euthanized with KCl or T-61; typically, the plane of anesthesia is deepened by increasing the anesthetic vaporizer setting before administration of the euthanasia agent.
- Providing premedication to achieve sedation/tranquilization will smooth the anesthetic induction process and reduce anesthetic requirements. This document does not include information regarding pre-anesthetic sedation/tranquilization (premedication) prior to administration of the anesthetic as this will vary based on the individual animal, the situation, and the environment where the euthanasia is being performed.
- It is highly recommended to place an intravenous catheter prior to administration of the anesthetic agent and the euthanasia agent, to ensure that the correct dose can be reliably administered.
- It is best to choose an injectable anesthetic agent, or combination of agents, that are familiar to the practitioner. It is important to note again that the doses below are higher than should be used for routine induction of anesthesia. Respiratory arrest should be

anticipated, and cardiovascular depression may also occur with some agents therefore these doses should only be administered prior to euthanasia.

Table 1. Injectable anesthetic agents for use prior to euthanasia of dogs and cats.

Injectable Anesthetic Agent	Dogs:	Cats:
To be administered following appropriate premedication. Administer the full dose over 20—30 seconds	Intravenous dose (mg/kg), given before euthanasia with KCl or T-61	Intravenous dose (mg/kg), given before euthanasia with KCl or T-61
Propofol	6	8
Alfaxalone	4	6
Diazepam + Ketamine	0.4 Diazepam + 6 Ketamine	0.4 Diazepam + 7 Ketamine

Inhalational agents: If the patient is already being maintained with an inhalant anesthetic, adjust the vaporizer to the maximum setting for at least 2 minutes. With a rebreathing (circle) system the oxygen flow should also be adjusted to 100-200 ml/kg/min. After 2 minutes, administer the KCl or T-61 as a rapid intravenous bolus.

2.2. Anesthetic recommendations prior to euthanasia for companion exotic pets (small mammals*, birds, reptiles)

* Rodents, rabbits, ferrets

It is beyond the scope of this document to provide a listing of dose requirements for deep anesthesia in companion exotic species. In the United States, alfaxalone is indexed for use in exotic animals and information regarding anesthetic dosing in exotics can be found on the following website: <https://www.fda.gov/animal-veterinary/cvm-updates/fda-adds-alfaxan-multidose-idx-index-legally-marketed-unapproved-new-animal-drugs-minor-species>.

Numerous drug combinations have been established for the various companion exotic species. It is recommended that veterinary practitioners consult the literature or experienced colleagues should they be unfamiliar with anesthesia for exotic species.

Additional information for anesthesia of companion exotic species can be found in:

1. Divers and Stahl. 2019. Mader's Reptile and Amphibian Medicine and Surgery, 3rd edition. ISBN: 0323482538.
2. Grimm et al. 2015. Veterinary Anesthesia and Analgesia: 5th Edition of Lumb and Jones. ISBN: 1118526236.
3. Mitchell and Tully. 2009. Manual of Exotic Animal Practice. ISBN: 9781416001195.

4. Quesenberry, Mans, and Orcutt et al. 2020. Ferrets, Rabbits and Rodents: Clinical Medicine and Surgery 4th edition. ISBN: 0323484352.
5. Speer B. 2015. Current Therapy in Avian Medicine and Surgery. ISBN: 9781455746712.
6. West G, Heard D, Caulkett N. 2014. Zoo Animal and Wildlife Immobilization and Anesthesia. 2nd edition. Ames, Iowa, Blackwell publishing. ISBN: 081381183X

2.3. Euthanasia Methods for Companion Animals (Dogs, Cats, Small Mammals*, Birds, Reptiles)

* Rodents, rabbits, ferrets

Table 2. Euthanasia Methods for Companion Animals (Dogs, Cats, Small Companion Mammals*, Birds) Under General Anesthesia.

Species	Euthanasia methods for Companion Animals (Dogs, Cats, Small Mammals*, Birds) Under General Anesthesia (*Rodents, rabbits, ferrets) <i>(in all cases animals <u>must</u> be under general anesthesia before administration)</i>	
Cats, Dogs Small Companion Mammals ⁴	Potassium chloride (KCl) ^{1,2} 150 mg/kg (2 mEq/kg), IV	T-61 ³ - 0.3 ml/kg, IV
Birds ⁴	Potassium chloride (KCl) ^{1,2} 10 mEq/kg, IV	T-61 ³ - 0.3 ml/kg, IV
Reptiles ^{4,5}	Potassium chloride (KCl) ^{1,2} 10 mEq/kg, IV	T-61 ³ - 0.5 ml/kg, IV

Footnotes to Table 2

¹Animals MUST be under general anesthesia before administration of potassium chloride (KCl). Death is caused by cardiac arrest. If an ECG is available, it can be used to assist confirmation of death through visualization of ventricular fibrillation (in combination with additional methods; Note 3, below).

²Potassium chloride MUST be administered by fast intravenous injection (placement of an intravenous catheter is preferred over an “off the needle” injection to ensure completion of the injection). Muscle activity (twitching, paddling, convulsions) may occur during/shortly after injection. Due to a lack of data in these species, magnesium sulphate is not currently recommended for euthanasia of small animals.

³Animals MUST be under general anesthesia before administration of T-61. Death is caused by loss of consciousness, respiratory depression, and muscular paralysis. Carcasses should not be left accessible to potential predation.

⁴For small mammals, birds, and reptiles where intravenous access is not feasible due to a compromised patient, then intracardiac injection while under deep anesthesia is appropriate. Intraperitoneal injection is NOT recommended for potassium chloride(KCl) or T-61.

⁵As reptile brains are tolerant of extremely low oxygen levels it is possible for the brain to function for a period of time after cessation of breathing and cardiac contractions. Adjunctive methods to destroy brain function (e.g., pithing, crushing skull) are always recommended.

Important Notes to Table 2

1. For species not listed in Table 2 please consult AVMA Euthanasia Guidelines 2020.
2. If pentobarbital sodium is available, to minimize waste, do not exceed the recommended dose (unless necessary to achieve death). The use of sedatives may decrease pentobarbital requirements.
3. Regardless of euthanasia technique, time to death may be delayed. This is more likely if alpha2-adrenergic agonists (e.g., xylazine, dexmedetomidine) have been included in the sedation/anesthetic protocol or if the animal is sick. In both instances, a slower circulation will result in a longer time for the euthanasia drug(s) to take effect. However, if anesthetized, the animal is unaware (unconscious) during this period. To achieve a more rapid effect, central venous injection (jugular vein) should be considered.
4. Death must be confirmed by a combination of methods. Suggested methods include: lack of palpable pulse, respiratory arrest, absence of corneal reflex, absence of heart beat (by thoracic auscultation with a stethoscope), rigor mortis.
5. KCl saturated solution: add 340 g of salt to 1 L of warm water (at, or above, room temperature [approx. 20C]) and stir well. The final solution will be approximately 340 mg/ml. It is normal for crystals (precipitate) to be present at the bottom of the container. If no precipitate is present, continue to add salt in 50g increments until precipitate is formed.
6. Due to a lack of data in these species, magnesium sulphate is not currently recommended for euthanasia of companion animals (dogs, cats, small companion mammals*, birds, reptiles)

References (Companion Animals):

1. AVMA Guidelines for the Euthanasia of Animals: 2020 Edition. Available from: <https://www.avma.org/sites/default/files/2020-01/2020-Euthanasia-Final-1-17-20.pdf>.

3. Large Ruminants, Small Ruminants, Swine, Equidae

3.1. Summary of Euthanasia Methods that Do Not Rely on the Use of Pentobarbital (for use in animals rendered unconscious)

Table 3. Summary of Euthanasia Methods for use in Large Ruminants, Small Ruminants, Equidae, Swine rendered unconscious (see below Table for details on each species).

Species	Summary of Euthanasia methods		
	(in all cases animals <u>must</u> be UNCONSCIOUS before administration)		
Large ruminants, (cattle, bison)	Potassium chloride (KCl) ^{1,2} 150 mg/kg (2 mEq/kg), IV	T-61 ³ - 4-6 mls/ 50 kg, slow IV	Magnesium sulphate ^{2,4} (MgSO ₄) 260-800 mg/kg (see Important Notes 7,8 below)
Small ruminants (sheep, goats, llamas, alpacas)	Potassium chloride (KCl) ^{1,2} 150 mg/kg (2 mEq/kg), IV	T-61 ³ - 4-6 mls/ 50 kg, slow IV	Magnesium sulphate ^{2,4} (MgSO ₄) 260-800 mg/kg (see Important Notes 7,8 below)
Equidae (horses, donkeys, mules)	Potassium chloride (KCl) ^{1,2} 150 mg/kg (2 mEq/kg), IV	T-61 ³ - 4-6 mls/ 50 kg, slow IV	Magnesium sulphate ^{2,4} (MgSO ₄) 260-800 mg/kg (see Important Notes 7,8 below)
Swine	Potassium chloride (KCl) ^{1,2} 150 mg/kg (2 mEq/kg), IV	T-61 ³ - 4-6 mls/ 50 kg, slow IV	Magnesium sulphate ^{2,4} (MgSO ₄) 260-800 mg/kg (see Important Notes 7,8 below)

Footnotes to Table 3

¹ Animals MUST be under general anesthesia before administration of potassium chloride (KCl). Death is caused by cardiac arrest. If an ECG is available, it can be used to assist confirmation of death through visualization of ventricular fibrillation (in combination with additional methods; Note 3, below).

² Potassium chloride and magnesium sulphate MUST be administered by fast intravenous injection (placement of an intravenous catheter is preferred over an “off the needle” injection to ensure completion of the injection). Muscle activity (twitching, paddling, convulsions) may occur during/ shortly after injection.

³ Animals MUST be under general anesthesia before administration of T-61. Death is caused by loss of consciousness, respiratory depression and muscular paralysis. Muscle activity may occur during the euthanasia process. T-61 should not be used in circumstances where the carcass may be scavenged or when deadstock removal companies prohibit its use.

⁴ Animals MUST be under general anesthesia before administration of magnesium sulphate since respiratory and cardiac arrest may be preceded by muscular paralysis, with minimal central depression.

Important Notes on Table 3

1. For species not listed in Table 3 consult AVMA Euthanasia Guidelines.
2. Depth of anesthesia should be equivalent to that suitable for a surgical procedure - this includes absence of cranial (e.g., palpebral) reflexes and airway reflexes (loss of swallow response), and absence of a withdrawal response (e.g., to pinching a digit/ skin). An acceptable depth of general anesthesia can be achieved with injectable and/or inhalational anesthetic agents.
3. If pentobarbital sodium is available, to minimize waste, do not exceed the recommended dose (unless necessary to achieve death).
4. Regardless of euthanasia technique, time to death may be delayed. This is more likely if alpha2-adrenergic agonists (e.g., xylazine, dexmedetomidine) have been included in the sedation/anesthetic protocol or if the animal is sick. In both instances, a slower circulation will result in a longer time for the euthanasia drug(s) to take effect. However, if anesthetized, the animal is unaware (unconscious) during this period. To achieve a more rapid effect, central venous injection (jugular vein) should be considered.
5. Death must be confirmed by a combination of methods. Suggested methods include: lack of palpable pulse, respiratory arrest, absence of corneal reflex, absence of heartbeat (by thoracic auscultation with a stethoscope), rigor mortis.
6. KCl saturated solution: add 340 g of salt to 1 L of warm water (at, or above, room temperature [approx. 20C]) and stir well. The final solution will be approximately 340 mg/ml. It is normal for crystals (precipitate) to be present at the bottom of the container. If no precipitate is present, continue to add salt in 50g increments until precipitate is formed.
7. Magnesium sulphate (MgSO₄) saturated solution: add 800 g of salt to 1 L of warm water (at, or above, room temperature [approx. 20C]) and stir well. The final solution will be approximately 800 mg/ml. It is normal for crystals (precipitate) to be present at the bottom of the container. If no precipitate is present, continue to add salt in 50g increments until precipitate is formed.
8. The lethal dose of intravenous MgSO₄ is poorly defined in most species. If used, maintenance of general anesthesia until death is confirmed is essential. This may require a maintenance phase of anesthesia, using repeated IV boluses of injectable anesthetic or inhalational anesthesia.

3.2. Large Ruminants

Table 4. Summary of Euthanasia Methods for Large Ruminants rendered unconscious.

Species	Euthanasia methods		
	(in all cases animals <u>must</u> be UNCONSCIOUS before administration)		
Large Ruminants (cattle, buffalo)	Potassium chloride (KCl) ^{1,2} 150 mg/kg (2 mEq/kg), IV	T-61 ³ - 4-6 mls/ 50 kg, slow IV	Magnesium sulphate ^{2,4} (MgSO ₄) 260-800 mg/kg ^{5,6}

Footnotes to Table 4

¹ Animals MUST be under general anesthesia before administration of potassium chloride (KCl). Death is caused by cardiac arrest. If an ECG is available, it can be used to assist confirmation of death through visualization of ventricular fibrillation (in combination with additional methods; Note 3, below).

² Potassium chloride and magnesium sulphate MUST be administered by fast intravenous injection (placement of an intravenous catheter is preferred over an “off the needle” injection to ensure completion of the injection). Muscle activity (twitching, paddling, convulsions) may occur during/ shortly after injection.

³ Animals MUST be under general anesthesia before administration of T-61. Death is caused by loss of consciousness, respiratory depression and muscular paralysis. Muscle activity may occur during the euthanasia process. T-61 should not be used in circumstances where the carcass may be scavenged or when deadstock removal companies prohibit its use.

⁴ Animals MUST be under general anesthesia before administration of magnesium sulphate since respiratory and cardiac arrest may be preceded by muscular paralysis, with minimal central depression.

⁵ Magnesium sulphate (MgSO₄) saturated solution: add 800 g of salt to 1 L of warm water (at, or above, room temperature [approx. 20C]) and stir well. The final solution will be approximately 800 mg/ml. It is normal for crystals (precipitate) to be present at the bottom of the container. If no precipitate is present, continue to add salt in 50g increments until precipitate is formed.

⁶ The lethal dose of intravenous MgSO₄ is poorly defined in most species. If used, maintenance of general anesthesia until death is confirmed is essential. This may require a maintenance phase of anesthesia, using repeated IV boluses of injectable anesthetic or inhalational anesthesia.

The AVMA and AABP recognize and accept the following methods of euthanasia for cattle:

1. Gunshot*:

*Canada’s firearms laws and regulations apply. See <https://www.rcmp-grc.gc.ca/en/firearms>.

Calves:

- .22 caliber handgun or rifle with a solid-point bullet
- .28 or .410 shotgun

Adults:

- .22 magnum or larger caliber (.223, .243, .270, .308 or 30-06) firearms
- 12, 16, 20 gauge shotgun with number 6 or larger birdshot or slugs

For handguns or rifles: use solid point bullets to ensure adequate skull penetration.

For all guns: NEVER hold the gun directly against the animal's head when firing because it can result in explosion of the barrel or severe recoil with serious consequences for the shooter.

Target: see diagrams *AVMA Euthanasia of Animals Guidelines 2020* (page 115).

- At the intersection of two lines drawn from the lateral canthus (outer corner) of the eye to the center of the base of the opposite horn (or where the horn would be).
- The angle of the shot should be perpendicular to the front of the skull.

Suggestion: If possible under given circumstances, sedate with xylazine at a dose that results in recumbency- 10mg for calves to 300 mg for large bulls- intravenously or intramuscularly. This greatly facilitates more accurate targeting.

Protocol:

- a) If possible, restrain and sedate with xylazine
- b) Shoot
- c) When gunshot is performed properly, a secondary step is rarely required
- d) If necessary (i.e. death is not rapid), use an adjunctive step such as IV administration of a saturated solution of KCl or MgSO₄ (see Penetrating captive bolt (PCB) method for more details), exsanguination or pithing*
- e) Confirm death: (immediate and permanent cessation of rhythmic breathing; absence of vocalization, absence of eye reflexes; glazed or glassy appearance of the eyes; eyes remain open facing straight forward; absence of a heartbeat).

2. Penetrating captive bolt (PCB) with an adjunctive step:

- The captive gun MUST be placed firmly against the skull when firing.
- Accurate targeting is facilitated by effective restraint (haltered or tied) and/or sedation (xylazine at the dosages listed under Gunshot).

Important note: PCBs induce immediate unconsciousness but death is NOT always assured. Therefore, an adjunctive method such as exsanguination, pithing, or the IV injection of a saturated solution of potassium chloride or magnesium sulphate is **essential and necessary** to ensure rapid death.

Target: Same as for Gunshot

- The PCB is suitable for both calves and adults and only a penetrating captive bolt is acceptable for adults.
- A non-penetrating captive bolt (NPCB) is not suitable for adults, but is suitable for calves.

Protocol:

- a) Provide excellent restraint (halter and tied)
- b) Sedate with xylazine as per Gunshot
- c) Administer PCB
- d) Confirm PCB has been effective in rendering the animal unconscious
- e) Rapid IV administration of a saturated solution of KCl or MgSO₄.

KCl – Administer “to effect” (death)

- Prepare a saturated solution by adding 340 grams of KCl salt to one litre of warm water and stir well.
- 250 ml is usually sufficient to induce death (cardiac arrest) in a mature dairy or beef cow.

MgSO₄: Administer to effect (death)

- Add 800 grams of MgSO₄ salt to one litre of warm water and stir well.
- If a precipitate does not develop, add 50 gram increments of MgSO₄ until a precipitate forms (saturated solution).
- 250 ml is usually sufficient to induce death (cardiac arrest) in a mature dairy or beef cow.
- Death is usually slower but has been judged to be smoother than with KCl.

OR

Pithing*

f) Confirm death (immediate and permanent cessation of rhythmic breathing; absence of vocalization, absence of eye reflexes; glazed or glassy appearance of the eyes; eyes remain open facing straight forward; absence of a heartbeat).

* Pithing is an adjunctive procedure to ensure death in an animal that has been rendered unconscious by other means. In livestock, it can be performed following stunning by gunshot or by PCB, both of which provide direct entry into the cranial cavity.

It is performed by inserting a pithing rod or long narrow tool (flexible wire or polypropylene rod) through the hole created by the bullet or PCB bolt. It must be long enough to reach the brain and spinal column, and rigid, but flexible. Pithing rods are commercially available. The operator manipulates the pithing tool to substantially destroy both the brainstem and spinal cord tissue. The rod is thrust caudally through the brain, brainstem and finally spinal cord. It is then slid back and forth to cause maximum damage to the brain and upper spinal cord, a practice that is known as “fiddling”.

Muscular activity can be considerable during the procedure, but it is followed by quiescence. Pithing should not be performed in ruminants intended for food because of the risk of Bovine Spongiform Encephalopathy (BSE) contamination and spread.

“Poll” shooting or stunning is NOT recommended because of its inability to effectively ensure loss of consciousness. Poll stunning is prohibited in the European Union.

Saturated Salt Solutions (KCl and MgSO₄)

Generally speaking, MgSO₄ solutions are preferred in cattle for the following reasons:

- Depending on sedation and anesthesia, MgSO₄ solutions produce significantly less violent neuromuscular reactions (kicking, flailing, spasms, paddling, muscle twitching, head extension) than KCl solutions.

- The volume of MgSO₄ solutions necessary to cause death are often significantly lower than KCl solutions.

Concerns regarding MgSO₄ solutions in euthanasia:

- Muscular paralysis may precede respiratory and cardiac arrest.
- The lethal dose is poorly defined in most species.

References (Large Ruminants):

1. AVMA Guidelines for the Euthanasia of Animals: 2020 Edition. Available from: <https://www.avma.org/sites/default/files/2020-01/2020-Euthanasia-Final-1-17-20.pdf>.
2. AABP Guidelines for the Humane Euthanasia of Animals: 2019 Edition. Available from: <http://aabp.org/vendors/resources/EUTHANASIA-2019.pdf>.
3. NFACC Code of Practice for Beef Cattle. Available from: <https://www.nfacc.ca/codes-of-practice/beef-cattle>.
4. NFACC Code of Practice for Bison. Available from: <https://www.nfacc.ca/codes-of-practice/bison>.
5. NFACC Code of Practice for Dairy Cattle. Available from: <https://www.nfacc.ca/codes-of-practice/dairy-cattle>.
6. Iowa State University – “Exsanguination/Pithing/Intravenous Injection of KCl”. Available from: <https://vetmed.iastate.edu/vdpam/about/production-animal-medicine/dairy/dairy-extension/humane-euthanasia/humane-euthanasia/exsanguination-pithing-intravenous-injection-kci>.
7. Humane Slaughter Association – Pithing Online Guide. Available from: <https://www.hsa.org.uk/bleeding-and-pithing/pithing>.

3.3. Small Ruminants

Table 5. Summary of Euthanasia Methods for Small Ruminants rendered unconscious.

Species	Euthanasia methods (in all cases animals <u>must</u> be UNCONSCIOUS before administration)		
Small ruminants (goats, sheep)	Potassium chloride (KCl) ^{1,2} 150 mg/kg (2 mEq/kg), IV	T-61 ³ - 4-6 mls/ 50 kg slow IV	Magnesium sulphate ^{2,4} (MgSO ₄) 260-800 mg/kg ^{5,6}

Footnotes to Table 5

¹ Animals MUST be under general anesthesia before administration of potassium chloride (KCl). Death is caused by cardiac arrest. If an ECG is available, it can be used to assist confirmation of death through visualization of ventricular fibrillation (in combination with additional methods; Note 3, below).

² Potassium chloride and magnesium sulphate MUST be administered by fast intravenous injection (placement of an intravenous catheter is preferred over an “off the needle” injection to ensure completion of the injection). Muscle activity (twitching, paddling, convulsions) may occur during or shortly after injection.

³ Animals MUST be under general anesthesia before administration of T-61. Death is caused by loss of consciousness, respiratory depression and muscular paralysis. Muscle activity may occur during the euthanasia process. T-61 should not be used in circumstances where the carcass may be scavenged or when deadstock removal companies prohibit its use.

⁴ Animals MUST be under general anesthesia before administration of magnesium sulphate since respiratory and cardiac arrest may be preceded by muscular paralysis, with minimal central depression.

⁵ Magnesium sulphate (MgSO₄) saturated solution: add 800 g of salt to 1 L of warm water (at, or above, room temperature [approx. 20C]) and stir well. The final solution will be approximately 800 mg/ml. It is normal for crystals (precipitate) to be present at the bottom of the container. If no precipitate is present, continue to add salt in 50g increments until precipitate is formed.

⁶ The lethal dose of intravenous MgSO₄ is poorly defined in most species. If used, maintenance of general anesthesia until death is confirmed is essential. This may require a maintenance phase of anesthesia, using repeated IV boluses of injectable anesthetic or inhalational anesthesia.

Methods of euthanasia for small ruminants:

1. Gunshot*

*Canada’s firearms laws and regulations apply. See <https://www.rcmp-grc.gc.ca/en/firearms>.

- 0.22 LR rifle; .38 Special, .357 magnum and 9mm or equivalent handgun with solid point bullets
- shotguns
- For all guns, hold the gun 6-12 inches from the head or target.

Target: See diagram in the *AVMA Euthanasia of Animals Guidelines 2020* page 115 (for sheep) and page 116 (for goats).

- At the intersection of 2 lines, each of which is drawn from the lateral canthus of one eye to the middle of the base of the opposite ear.

Suggestion: If possible under the circumstances, sedation with xylazine at a dose that results in heavy sedation or recumbency (0.4 mg/kg I.V. or I.M.) will greatly facilitate more accurate targeting.

Protocol:

- a) Sedate with xylazine and/or restrain with a halter
- b) Shoot
- c) Confirm death (immediate and permanent cessation of rhythmic breathing; absence of vocalization, absence of eye reflexes; glazed or glassy appearance of the eyes; eyes remain open facing straight forward; absence of a heartbeat).

2. **Penetrating Captive Bolt (PCB) or non-penetrating captive bolt (NPCB) with an adjunctive step**

The use of a non-penetrating captive bolt (NPCB) is ONLY acceptable in neonates.

Important Note: PCBs and NPCBs induce immediate unconsciousness but death is not always assured. Therefore, an adjunctive method such as IV injection of a saturated solution of KCl or MgSO₄, exsanguination or pithing is essential to ensure rapid death.

The Suggestions and Targets are as per gunshot.

Protocol:

- a) Provide excellent restraint (halter and tied)
- b) Sedate with 0.4mg/kg xylazine IV or IM
- c) Administer PCB (adults) or NPCB (neonates only)
- d) Administer a KCl (150 mg/kg) or MgSO₄ (2ml/kg) solution rapidly IV to effect (100 ml usually sufficient)
- e) OR exsanguinate
- f) OR pith
- g) Confirm death (immediate and permanent cessation of rhythmic breathing; absence of vocalization, absence of eye reflexes; glazed or glassy appearance of the eyes; eyes remain open facing straight forward; absence of a heartbeat).

3. Electrocution:

- Requires specialized equipment to restrain the animal for proper placement of the electrodes that is often not available under field conditions and therefore electrocution is not considered practical for routine use.

References (Small Ruminants):

1. AVMA Guidelines for the Euthanasia of Animals: 2020 Edition. Available from: <https://www.avma.org/sites/default/files/2020-01/2020-Euthanasia-Final-1-17-20.pdf>.
2. NFACC Code of Practice. Available from: <https://www.nfacc.ca/codes-of-practice>.
3. NFACC Code of Practice for Goats. Available from :<https://www.nfacc.ca/codes-of-practice/goats>.
4. NFACC Code of Practice for Sheep. Available from: <https://www.nfacc.ca/codes-of-practice/sheep>.

3.4. Swine

Table 6. Summary of Euthanasia Methods for Swine rendered unconscious.

Species	Euthanasia methods (in all cases animals <u>must</u> be UNCONSCIOUS before administration)		
Swine	Potassium chloride (KCl) ^{1,2} 150 mg/kg (2 mEq/kg), IV	T-61 ³ - 4-6 mls/ 50 kg, slow IV	Magnesium sulphate ^{2,4} (MgSO ₄) 260-800 mg/kg _{5,6}

Footnotes to Table 6

¹ Animals MUST be under general anesthesia before administration of potassium chloride (KCl). Death is caused by cardiac arrest. If an ECG is available, it can be used to assist confirmation of death through visualization of ventricular fibrillation (in combination with additional methods; Note 3, below).

² Potassium chloride and magnesium sulphate MUST be administered by fast intravenous injection (placement of an intravenous catheter is preferred over an “off the needle” injection to ensure completion of the injection). Muscle activity (twitching, paddling, convulsions) may occur during/ shortly after injection.

³ Animals MUST be under general anesthesia before administration of T-61. Death is caused by loss of consciousness, respiratory depression and muscular paralysis. Muscle activity may occur during the euthanasia process. T-61 should not be used in circumstances where the carcass may be scavenged or when deadstock removal companies prohibit its use.

⁴ Animals MUST be under general anesthesia before administration of magnesium sulphate since respiratory and cardiac arrest may be preceded by muscular paralysis, with minimal central depression.

⁵ Magnesium sulphate (MgSO₄) : add 800 g of salt to 1 L of warm water (at, or above, room temperature [approx. 20C]) and stir well. The final solution will be approximately 800 mg/ml. It is normal for crystals (precipitate) to be present at the bottom of the container. If no precipitate is present, continue to add salt in 50g increments until precipitate is formed.

⁶ The lethal dose of intravenous MgSO₄ is poorly defined in most species. If used, maintenance of general anesthesia until death is confirmed is essential. This may require a maintenance phase of anesthesia, using repeated IV boluses of injectable anesthetic or inhalational anesthesia

Methods of euthanasia that can be used for swine include:

1. Gunshot*

*Canada’s firearms laws and regulations apply. See <https://www.rcmp-grc.gc.ca/en/firearms>.

- Commonly used to euthanize *growing* and *adult* swine.

Targets:

There are 3 possible sites or targets for gunshot: (AVMA Guidelines for the Euthanasia of Animals 2020, page 119).

- Frontal: Centre of the forehead slightly above a line drawn between the eyes
 - Direct bullet towards the spinal canal
 - requires a greater caliber firearm (.223, .243, .270, .308 or 30-06) or a 12, 16, or 20 gauge shotgun
 - a shotgun is preferred for adult pigs.

- use a solid point bullet (rifle) or solid slug (shotgun).
- b) Temporal: Slightly anterior and below the ear
- Same firearm requirements as the Frontal Approach.
- c) From behind the ear toward the opposite eye
- A .22 caliber firearm with a solid-point bullet is acceptable.

2. **Penetrating Captive Bolt (PCB) with an adjunctive step:**

- Acceptable for growing and adult swine.
- As per cattle and small ruminants, use required effective restraint of the animal because the device must be held firmly against the skull when fired.
- Pre-sedation is highly advisable to assist in accurate targeting.
- Use the frontal approach ONLY.

Important Note: PCBs induce immediate unconsciousness but death is not assured. Therefore an adjunctive method such as exsanguination, pithing or IV injection of a saturated solution of KCl or MgSO₄ is **mandatory** to ensure rapid death.

Protocol:

- a) Heavy sedation (ex: 3 ml Ketamine + 1 ml butorphanol + 1 ml xylazine per 45 kilograms body weight IM into the neck muscles)
- b) PCB – frontal approach
- c) Rapid IV or intra-cardiac administration of a saturated solution of KCl or MgSO₄ (120 ml often sufficient, but administer to effect)
 - a. OR exsanguination
 - b. OR pithing
- d) Confirm death (immediate and permanent cessation of rhythmic breathing; absence of vocalization, absence of eye reflexes; glazed or glassy appearance of the eyes; eyes remain open facing straight forward; absence of a heartbeat).

3. **Electrocution**

Acceptable for pigs from 3 days of age to 125 kg in weight.

The electrical current must pass through the brain to achieve loss of consciousness and then cross the heart to cause fibrillation and cardiac arrest.

Note: Proper training and special equipment (generally restricted to abattoirs) are essential to ensure an adequate and safe euthanasia.

4. Blunt force trauma to the head (suckling pigs only):

Acceptable for suckling pigs only

- In suckling pigs, the frontal bones are not fully developed leaving the brain susceptible to blunt, high velocity impact.
- Requires proper training and proper application of the technique.

Bottomline:

- This method should be used only if alternative methods are not available or training in other methods is sub-optimal.

Protocol:

- a) Apply blunt force trauma
- b) If necessary (death is not rapid), exsanguination should be used as an adjunctive step.

5. CO2 and other gases:

- Acceptable for all ages and sizes of pigs.
- Inhaled gas euthanasia techniques are available but not commonly used in the field except in packing plant venues, during mass depopulation events and whole barn euthanasia scenarios and therefore will not be discussed further in this document.

References (Swine):

1. AVMA Guidelines for the Euthanasia of Animals: 2020 Edition. Available from: <https://www.avma.org/sites/default/files/2020-01/2020-Euthanasia-Final-1-17-20.pdf>.
2. NFACC Code of Practice for Pigs. Available from: <https://www.nfacc.ca/codes-of-practice/pigs>.

3.5. Equidae

Table 7. Summary of Euthanasia Methods for Equidae rendered unconscious.

Species	Euthanasia methods		
	(in all cases animals <u>must</u> be UNCONSCIOUS before administration)		
Equidae (horses, donkeys, mules)	Magnesium Sulphate ^{2,4} (MgSO ₄) 260-800 mg/kg	Potassium chloride (KCl) ^{1,2} 150 mg/kg (2 mEq/kg), IV	T-61 ³ - 4-6 mls/ 50 kg, slow IV

Footnotes to Table 7

¹ Animals MUST be under general anesthesia before administration of potassium chloride (KCl). Death is caused by cardiac arrest. If an ECG is available, it can be used to assist confirmation of death through visualization of ventricular fibrillation (in combination with additional methods; Note 3, below).

² Potassium chloride and magnesium sulphate MUST be administered by fast intravenous injection (placement of an intravenous catheter is preferred over an “off the needle” injection to ensure completion of the injection). Muscle activity (twitching, paddling, convulsions) may occur during or shortly after injection.

³ Animals MUST be under general anesthesia before administration of T-61. Death is caused by loss of consciousness, respiratory depression and muscular paralysis. Muscle activity may occur during the euthanasia process. T-61 should not be used in circumstances where the carcass may be scavenged or when deadstock removal companies prohibit its use.

⁴ Animals MUST be under general anesthesia before administration of magnesium sulphate since respiratory and cardiac arrest may be preceded by muscular paralysis, with minimal central depression.

The acceptable alternative methods of euthanasia for horses endorsed by the AAEP and AVMA are:

1. Saturated Solution of Magnesium Sulphate (MgSO₄)

- Add 800 gms Magnesium sulphate (MgSO₄) to one liter of warm water (at or above room temperature (approx. 20C) and stir well. The final solution will be approximately 800 mg/ml. It is normal for crystals (precipitate) to be present at the bottom of the container. If a precipitate has not formed, add MgSO₄ in 50 gram increments until a precipitate forms.
- Keep solutions at room temperature if possible. If a precipitate forms after storage, warm the solution to remix the MgSO₄.
- Administer rapidly I.V. after a general plane of anesthesia is achieved (by syringe or via an I.V. line).

Dosage: Not well established in equids.

200-250 ml of the saturated (800 g/l) solution should be sufficient.

Always administer until death is confirmed (lack of palpable pulse; respiratory arrest; absence of a corneal reflex; absence of a heart beat (by thoracic auscultation with a stethoscope); rigor mortis.

Note: Generally, MgSO₄ solutions result in a smoother death than with KCl and without the side effects noted for KCl.

The Dose of MgSO₄ (in ml/kg) is usually less than with KCl and death occurs more slowly than with KCl.

MgSO₄ may include muscle paralysis in advance of respiratory and cardiac arrest, therefore it is essential that the patient is under a surgical plane of anesthesia.

2. Saturated solution of KCl

- Add 340 gms/liter KCl to one liter of warm to hot water. If there is no precipitate, continue to add KCl in 50 gm increments until a precipitate is present. 340-400 gm per liter is easily achievable (NOTE: one tablespoon is approximately 20 grams).
- Keep solution at room temperature if possible. If a precipitate forms during storage, warm the solution to remix the KCl.
- Administer rapidly I.V. after general anesthesia is achieved (by syringe or via an I.V. line).

Dosage: 75-80 grams of KCl (200-250 ml of a 340mg/ml solution) should be sufficient
Always administer until death is confirmed.

Note: During and following administration, some muscle movement and fasciculation may be seen. As well, agonal breaths may occur for up to 5 minutes following KCl administration. Warning witnesses of the possible sequelae is advisable prior to administration. KCl causes cardiac arrest.

Protocol for MgSO₄ and KCl euthanasia:

- a) Induce general anesthesia (recommended combination of xylazine ± butorphanol, ketamine and diazepam).
- b) Place an I.V. catheter (recommend a 14 gauge 2-3.5 inch catheter) in the jugular vein (if one is not already in place).
- c) Administer the saturated solution of KCl or MgSO₄ rapidly by an I.V. catheter (delivery by IV catheter is recommended to ensure the injection can be completed rapidly) until death is confirmed using the dosages listed above as a guide.
- d) Confirm death (immediate and permanent cessation of rhythmic breathing; absence of vocalization, absence of eye reflexes; glazed or glassy appearance of the eyes; eyes remain open facing straight forward; absence of a heartbeat).

Note: KCl and MgSO₄ residues in carcasses do not pose a hazard to scavengers or to human health when the carcass is rendered.

3. T-61

Use of T-61 must ALWAYS be preceded by general anesthesia.

T-61 should not be used in circumstances where the carcass may be scavenged or when deadstock removal companies prohibit its use.

Dosage: 4-6ml/50 kg I.V. slowly.

Protocol:

- a) Induce general anesthesia (see protocol presented above)
- b) Place an I.V. catheter (14 gauge, 2-3.5 inch) if not already in place
- c) Administer T-61 at the dosage rate provided
- d) Confirm death (immediate and permanent cessation of rhythmic breathing; absence of vocalization, absence of eye reflexes; glazed or glassy appearance of the eyes; eyes remain open facing straight forward; absence of a heartbeat).

4. Intrathecal Lidocaine

Materials required:

- 60 cc syringes
- 2% lidocaine (20mg/ml) administered at 2.6 – 4 mg/kg
- 18-20 gauge, 3.5 inch catheter or spinal needle
- Preanesthetic medications to induce general anesthesia

Protocol: (Reference: Iowa State University “Intrathecal Lidocaine Euthanasia Procedure in Equids”)

- a) Anesthetize the horse and place in lateral recumbency
- b) Locate the atlanto-occipital (A-O) joint on the dorsal midline at the level of the cranial border of the atlas (see diagram in the reference). Flex the head so that the median axis of the head is at a 90 degree angle to the cervical vertebrae’s median axis (lifting the nose so that the lateral head is parallel to the ground may be helpful)
- c) Insert the catheter or spinal needle (with the bevel facing towards the head) and aimed toward the lip commissures or lower jaw. Be careful to introduce the needle on the dorsal midline to avoid entering the A-O space but missing the subarachnoid space
- d) Advance the needle slowly through the skin, muscle, and nuchal ligament until a “popping” sensation accompanied by a decrease in resistance is felt as the subarachnoid space is entered. Spinal fluid should flow from the catheter or spinal needle
- e) Once the subarachnoid space has been entered, rapidly administer the lidocaine at 2.6 – 4 mg/kg (approximately 60-90 ml for a 1000 pound horse)
- f) Remove the catheter or spinal needle to prevent leakage of the lidocaine
- g) Confirm death (immediate and permanent cessation of rhythmic breathing; absence of vocalization, absence of eye reflexes; glazed or glassy appearance of the eyes; eyes remain open facing straight forward; absence of a heartbeat).

Important Note: The time to death is slower than with pentobarbital by several minutes (Aleman et al 2015 Journal of Veterinary Internal Medicine, 29: 1676-1682.)

5. Gunshot*

*Canada’s firearms laws and regulations apply. See <https://www.rcmp-grc.gc.ca/en/firearms>.

The following firearms and ammunition have been investigated and found effective in causing instantaneous death:

- 0.22 caliber long rifle firing a 40 grain, plated lead, solid-core or hollow point bullet (HPB)
- 9mm pistol firing a 115 grain, jacketed hollow point bullet
- .223 caliber carbine firing a 55 grain, jacketed HPB
- .45 caliber Colt pistol firing a 230 grain, jacketed HPB
- 12 gauge shotgun firing a 1 oz rifled slug
- A large variety of firearms and ammunition are effective in causing death in equines
- In all cases, sedation is highly recommended prior to gunshot (where possible)

Target: AVMA Guidelines for the Euthanasia of Animals 2020 (see diagrams on page 120) and the Canadian Equine Code of Practice Page 79-80.

The target is at the intersection of 2 diagonal lines each running from the outer corner of the eye to the inner margin of the opposite ear.

Cautions:

- Never hold the gun directly against the animal's head when firing because it can result in explosion of the barrel or severe recoil with serious consequences for the shooter.
- Ideally, the firearm should be angled so the bullet follows the angle of the neck or the spine.
- Ensure that an adequate caliber firearm is employed.

Protocol:

- a) Sedate (where possible)
- b) Shoot
- c) When gunshot is performed properly, a secondary step is rarely required
- d) If necessary, (death is not rapid), use an adjunctive step such as IV administration of KCl or MgSO₄, exsanguination, pithing, or T-61 (if deadstock removal services permit its use, and if wildlife will not have access to the carcass)
- e) Confirm death (immediate and permanent cessation of rhythmic breathing; absence of vocalization, absence of eye reflexes; glazed or glassy appearance of the eyes; eyes remain open facing straight forward; absence of a heartbeat).

6. Penetrating Captive Bolt (PCB):

Important Considerations:

- The captive bolt must be firmly placed against the skull when firing.
- The animal should be sedated (where possible).
- PCBs induce immediate unconsciousness but death is NOT always assured.

Therefore:

An adjunctive method such as the I.V. administration of saturated solutions of KCl or MgSO₄ is essential to ensure rapid death. Adjunctive methods such as exsanguinations and pithing are effective, but may be difficult for horse owners to accept.

Target: As per gunshot.

Protocol:

- a) Sedate (where possible)
- b) Administer PCB
- c) Provide an adjunctive method to ensure rapid death, as per gunshot
- d) Confirm death (immediate and permanent cessation of rhythmic breathing; absence of vocalization, absence of eye reflexes; glazed or glassy appearance of the eyes; eyes remain open facing straight forward; absence of a heartbeat).

References (Equine)

1. NFAAC Code of Practice for Care and Handling of Equines. Available from : <https://www.nfacc.ca/codes-of-practice/equine>.
2. AVMA Guidelines for the Euthanasia of Animals 2020. Available from: <https://www.avma.org/sites/default/files/2020-01/2020-Euthanasia-Final-1-17-20.pdf>.
3. AAEP Website Euthanasia Guidelines. Available from: <https://aaep.org/guidelines/euthanasia-guidelines>.
4. Iowa State University – Potassium Chloride Euthanasia Guidelines in Equids. Available from: https://aaep.org/sites/default/files/2021-03/KCl_Procedure_%20ISU.pdf.
5. Iowa State University – Intrathecal Lidocaine Euthanasia Procedure in Equids. Available from: https://aaep.org/sites/default/files/2021-03/Intraethecal_Euthanasia.pdf.
6. Lund JF, Ketover HR, Hetzel S, Waller K, Brounts SH . Computed Tomographic assessment of brain tissue disruption and skull damage in equine cadaveric heads caused by various firearm-ammunition combinations applied as potential gunshot methods for euthanasia in horse. AJVR 2021;82;1(28-38).
7. NFAAC Code of Practice for the Care and Handling of Equines (2013). Available from: <https://www.nfacc.ca/codes-of-practice/equine>.
8. Tristan Jubb. Euthanasia of Livestock using Magnesium Sulphate (2018). Available from: <https://nabsnet.com.au/wp-content/uploads/2018/06/Euthanasia-of-livestock-with-magnesium-sulphate-15Jun2018-TristanJubb.pdf>.