Anesthetic Management of Cattle

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Introduction
As in other species, sedation and anesthesia are required in cattle for surgical or diagnostic procedures. The decision to induce general anesthesia may be influenced by cattle's anatomic and physiologic characteristics. Cattle usually accept physical restraint well and that, in conjunction with local or regional anesthesia, is often sufficient to allow completion of many procedures. Other diagnostic and surgical procedures that are more complex require general anesthesia. The intent of this chapter is to review current knowledge and techniques of general anesthetic management of cattle as applied in clinical practice in the United States.

Preanesthetic Preparation
Considerations for preanesthetic preparation include fasting, assessment of hematologic and blood chemistry values, venous catheterization, and estimation of body weight. Cattle as ruminants are susceptible to complications associated with recumbency and general anesthesia; tympany, regurgitation, and aspiration pneumonia. Accordingly, it is recommended that calves be fasted 12 - 18 hours and deprived of water for 8 - 12 hours. Adult cattle should be fasted 18 - 24 hours and deprived of water for 12 - 18 hours. In nonselective cases, this is often not possible and precautions should be taken to avoid aspiration of gastric fluid and ingesta. Fasting neonates is not advisable because hypoglycemia may result. Fasting and water deprivation will decrease the incidence of tympany and regurgitation by decreasing the volume of fermentable ingesta but may also produce bradycardia in cattle [1]. Additionally, pulmonary functional residual capacity maybe better preserved in the fasted anesthetized ruminant [2]. Even with these precautions, some cattle will become tympanitic while others will regurgitate.

Hematologic and blood chemistry values should be determined and evaluated as appropriate before induction of anesthesia. Venipuncture and catheterization of the jugular vein are often performed prior to anesthesia. Catheters up to 16 gauge are appropriate for calves while adult cattle require 12 - 14 gauge catheters. Infiltration of a local anesthetic at the site of catheterization is recommended.

Anticholinergics are usually not administered to cattle prior to induction of anesthesia as they do not consistently decrease salivary secretions unless used in high doses and repeated frequently. Usual doses of atropine to prevent bradycardia in cattle (0.06 - 0.1 mg/kg IV) do not prevent salivation during anesthesia. Glycopyrrolate (0.005 - 0.01 mg/kg IM or 0.002 - 0.005 mg/kg IV) may be substituted for atropine [3].

Sedation/Restraint
The alpha-2 agonist drugs are currently most commonly used to induce tranquillization and/or sedation in cattle. Other drugs such as acepromazine, chloral hydrate, and pentobarbital have long histories of use with cattle and continue to be commercially available, however, their contemporary importance has become mostly limited to special circumstances. Diazepam can also be used in calves and other small ruminants. Readers are referred to available texts for further discussion on these older drugs [4-8]. Xylazine, detomidine, medetomidine, and romifidine are alpha-2 agonists. Of these, xylazine is presently most often used in the U.S. to provide sedation or, in higher doses, restraint (recumbency and light planes of general anesthesia) in cattle [5, 9,10]. There appears to be some variation in response to xylazine within a species. Hereford cattle have been shown to be more sensitive to xylazine than Holstein cattle [11] and anecdotal evidence indicates that Brahman cattle are the most sensitive of the breeds [7]. High environmental ambient temperature will cause a pronounced and prolonged response to xylazine in cattle [12]. Xylazine also will cause hyperglycemia and hypoinsulinemia in cattle and sheep [13-16]. Additionally, it will cause hypoxemia and hypercarbia in cattle [11,17] and can cause pulmonary edema [18]. Finally, xylazine has an oxytocin-like effect on the uterus of pregnant cattle [19] and sheep [20]. Detomidine is used to a lesser extent in the U.S. but is also effective for providing sedation and/or analgesia in cattle [8, 21]. It does not appear to have the same effect on the gravid uterus as xylazine in cattle [21] and is the drug of choice when sedation is needed in pregnant cattle. The degree of sedation or restraint produced by xylazine depends on the route of injection, dosage given, and the animal's temperament. Low doses (0.015 - 0.025 mg/kg IV or IM) will provide sedation without recumbency in cattle. Detomidine is given at 2.5 - 10.0 µg/kg IV in cattle to provide standing sedation of approximately 30 - 60 minutes.
Ketamine is given at 6 - 10 mg/kg IV in unsedated animals and will provide approximately 10 - 15 minutes of anesthesia. Contraindicated because they may displace the thiobarbiturates from plasma protein and delay recovery [32]. Thiopental dependent on metabolism and recovery will be prolonged. Concurrent use of nonsteroidal antiinflammatory drugs is anesthesia with thiopental is not recommended because saturation of tissues with thiopental causes recovery to be more potent and is no longer commercially available in North America. Its use will not be further discussed. Recovery from induction doses of thiopental is based upon redistribution of the drug from the brain to other tissues in the body. Metabolism of the agent continues for some time following recovery until final elimination occurs. Maintenance of anesthesia with thiopental is not recommended because saturation of tissues with thiopental causes recovery to be dependent on metabolism and recovery will be prolonged. Concurrent use of nonsteroidal antiinflammatory drugs is contraindicated because they may displace the thiobarbiturates from plasma protein and delay recovery [32]. Thiopental is given at 6 - 10 mg/kg IV in unsedated animals and will provide approximately 10 - 15 minutes of anesthesia. Ketamine - Ketamine is commonly used in veterinary anesthesia. It also provides mild cardiovascular stimulation and is safer than thiopental in sick animals. Following anesthetic induction doses, ketamine often does not eliminate the swallowing reflex however, tracheal intubation can be accomplished. While ketamine will induce immobilization and incomplete analgesia when given alone, addition of a sedative or tranquilizer will improve muscle relaxation and quality of anesthesia. Most commonly xylazine or diazepam is recommended, although the availability of detomidine offers another alternative. Xylazine (0.1 - 0.2 mg/kg IM) can be given followed by ketamine (10 - 15 mg/kg IM) in calves [33]. Anesthesia usually lasts about 45 minutes and can be prolonged by injection of additional ketamine at 3 - 5 mg/kg IM or 1 - 2 mg/kg IV. The longer duration of action of xylazine obviates the need for readministration of xylazine in most cases. Alternatively, xylazine (0.03 - 0.05 mg/kg IV) followed by ketamine (3 - 5 mg/kg IV) can be used to provide anesthesia of 15 - 20 minutes duration [5,9,10]. Adult cattle can be anesthetized with xylazine (0.1 - 0.2 mg/kg IV) followed by ketamine (2.0 mg/kg IV) [34]. The lower dose of xylazine is used when cattle weigh greater than 600 kg [34]. Duration of anesthesia is approximately 30 minutes; anesthesia can be prolonged for 15 minutes with additional ketamine (0.75 - 1.25 mg/kg IV). Diazepam (0.1 mg/kg IV) followed immediately by ketamine (4.5 mg/kg IV) can be used in cattle. Muscle relaxation is usually adequate for tracheal intubation although the swallowing reflex may not be completely obducted. Anesthesia usually is of 10 - 15 minutes duration following diazepam-ketamine with recumbency of up to 30 minutes [4-6,10]. Medetomidine has been combined with ketamine to provide anesthesia in calves. Because medetomidine (20 µg/kg IV) is much more potent than xylazine, very low doses of ketamine (0.5 mg/kg IV) can be used [30]. However, use of a local anesthetic at the surgical site may be required when ketamine is used at this dose [30]. Consequently, complete reversal of anesthesia can be achieved with alpha-2 antagonists without excitement occurring during recovery. Guaifenesin - Guaifenesin, a centrally acting skeletal muscle relaxant, can be used alone to induce recumbency in cattle. Addition of ketamine or thiopental to guaifenesin improves induction quality and decreases the volume required for induction and increases muscle relaxation when compared to induction with ketamine or the thiobarbiturates given alone. Typically, 5% guaifenesin solutions are used as hemolysis can occur with 10% guaifenesin solutions [35,36]. Commonly these solutions are given rapidly to effect in either tranquilized or untranquilized patients. The calculated dose is 2.0 ml/kg. The amount of ketamine added to guaifenesin varies but is commonly 1.0 - 2.0 mg/ml. The amount of

**Induction**

General anesthesia can be induced by either injectable or, especially in young calves, inhalation techniques. Available drugs include: thiobarbiturates, ketamine, guaifenesin, tiletamine-zolazepam, propofol, halothane, isoflurane, and sevoflurane [5].

**Thiopental** - The thiobarbiturates, thiopental and thiamylal, have been used extensively in veterinary anesthesia, either alone and in combination with guaifenesin to quickly induce general anesthesia. Thiamylal is similar to thiopental but more potent and is no longer commercially available in North America. Its use will not be further discussed. Recovery from induction doses of thiopental is based upon redistribution of the drug from the brain to other tissues in the body. Metabolism of the agent continues for some time following recovery until final elimination occurs. Maintenance of anesthesia with thiopental is not recommended because saturation of tissues with thiopental causes recovery to be dependent on metabolism and recovery will be prolonged. Concurrent use of nonsteroidal antiinflammatory drugs is contraindicated because they may displace the thiobarbiturates from plasma protein and delay recovery [32]. Thiopental is given at 6 - 10 mg/kg IV in unsedated animals and will provide approximately 10 - 15 minutes of anesthesia.

**Ketamine** - Ketamine is most commonly used in veterinary anesthesia. It also provides mild cardiovascular stimulation and is safer than thiopental in sick animals. Following anesthetic induction doses, ketamine often does not eliminate the swallowing reflex however, tracheal intubation can be accomplished. While ketamine will induce immobilization and incomplete analgesia when given alone, addition of a sedative or tranquilizer will improve muscle relaxation and quality of anesthesia. Most commonly xylazine or diazepam is recommended, although the availability of detomidine offers another alternative. Xylazine (0.1 - 0.2 mg/kg IM) can be given followed by ketamine (10 - 15 mg/kg IM) in calves [33]. Anesthesia usually lasts about 45 minutes and can be prolonged by injection of additional ketamine at 3 - 5 mg/kg IM or 1 - 2 mg/kg IV. The longer duration of action of xylazine obviates the need for readministration of xylazine in most cases. Alternatively, xylazine (0.03 - 0.05 mg/kg IV) followed by ketamine (3 - 5 mg/kg IV) can be used to provide anesthesia of 15 - 20 minutes duration [5,9,10]. Adult cattle can be anesthetized with xylazine (0.1 - 0.2 mg/kg IV) followed by ketamine (2.0 mg/kg IV) [34]. The lower dose of xylazine is used when cattle weigh greater than 600 kg [34]. Duration of anesthesia is approximately 30 minutes; anesthesia can be prolonged for 15 minutes with additional ketamine (0.75 - 1.25 mg/kg IV). Diazepam (0.1 mg/kg IV) followed immediately by ketamine (4.5 mg/kg IV) can be used in cattle. Muscle relaxation is usually adequate for tracheal intubation although the swallowing reflex may not be completely obducted. Anesthesia usually is of 10 - 15 minutes duration following diazepam-ketamine with recumbency of up to 30 minutes [4-6,10]. Medetomidine has been combined with ketamine to provide anesthesia in calves. Because medetomidine (20 µg/kg IV) is much more potent than xylazine, very low doses of ketamine (0.5 mg/kg IV) can be used [30]. However, use of a local anesthetic at the surgical site may be required when ketamine is used at this dose [30]. Consequently, complete reversal of anesthesia can be achieved with alpha-2 antagonists without excitement occurring during recovery.
thiobarbiturate added to guaifenesin varies but is commonly 2.0 - 4.0 mg/ml. For convenience, guaifenesin-based mixtures may be injected with large syringes rather than administered by infusion to calves. Following induction, guaifenesin-based solutions can be infused to effect to maintain anesthesia. Xylazine may also be added to ketamine-guaifenesin solutions for induction and maintenance of anesthesia in cattle [34,37]. Final concentrations are guaifenesin (50 mg/ml), ketamine (1 - 2 mg/ml), and xylazine (0.1 mg/ml). This solution is infused at 0.5 - 1 ml/kg IV for induction. Anesthesia can be maintained by infusion of the mixture at 1.5 ml/kg/hr for calves [37] and at 2 ml/kg/hr for adult cattle [34,37] although final administration rate will vary depending upon circumstances. If the procedure requires greater than 2 ml/kg of the guaifenesin-ketamine-xylazine mixture to allow completion of the surgical procedure, the amount of xylazine added should be decreased by 50% because its duration of action is longer than the other two agents. [25] Alternatively, a mixture of guaifenesin (50 mg/ml), ketamine (1 mg/ml), and xylazine (0.05 mg/ml) could be infused at 2.0 ml/kg following induction for maintenance. If anesthetic depth becomes insufficient, the infusion rate should be increased by 10 - 20%. Use of an infusion pump allows administration to be more precise and convenient. Recovery usually occurs within 30 - 45 minutes.

**Tiletamine-Zolazepam** - Tiletamine-zolazepam is a proprietary combination available for use as an anesthetic agent in cats and dogs. In many respects tiletamine-zolazepam can be considered to be similar to ketamine pre-mixed with diazepam. Tiletamine-zolazepam can be used successfully with or without xylazine in cattle. However, addition of xylazine to tiletamine-zolazepam lengthens duration of effect. Tiletamine-zolazepam has been given at 4.0 mg/kg IV to healthy untranquilized calves and found to cause minimal cardiovascular effects and provided anesthesia of 45 - 60 minutes duration [38]. Xylazine (0.1 mg/kg IM) followed immediately by tiletamine-zolazepam (4.0 mg/kg IM) produced onset of anesthesia within 3 minutes and duration of anesthesia of approximately 1 hour [39]. Calves were able to stand approximately 130 minutes following injection. Increasing xylazine to 0.2 mg/kg IM increased duration of anesthesia and recumbency and the incidence of apnea [39]. The drugs can be administered intravenously. Xylazine can be given at 0.05 mg/kg IV followed by tiletamine-zolazepam at 1.0 mg/kg IV [34].

**Propofol** - Propofol is a nonbarbiturate, nonsteroidal hypnotic agent and can be used to provide brief periods of anesthesia. Economic considerations limit the applicability of propofol as it is an expensive drug to use in adult cattle. Inhalation Agents - Anesthesia can be induced by mask in calves weighing less than 150 kg. If a commercial mask is unavailable a mask can be made by cutting the bottom out of a one gallon plastic jug or other container of appropriate size and padding the edges with cotton and tape. The mask must fit tightly around the calf's muzzle to prevent inspiration of atmospheric air and dilution of anesthetic gases. Halothane and isoflurane are agents of choice for use in cattle because they give short induction and recovery times. Sevoflurane and desflurane are also excellent choices for mask induction but their use carries considerable expense. The addition of nitrous oxide to the gas mixture hastens induction. Unless its use is contraindicated, nitrous oxide may be used as 50% of the total gas flow with one of the inhalation agents for mask induction of calves and then discontinued after intubation. It is recommended that nitrous oxide be discontinued after induction to avoid its accumulation in the rumen. Normal oxygen flow rates during induction are 3 - 6 liters/minute. Normal vaporizer settings are 3 - 5% halothane or isoflurane and 5 - 7% for sevoflurane during induction. The higher flow rates and vaporizer settings are used for bigger calves.

### Maintenance

Tracheal intubation is recommended in cattle to provide a secure airway and prevent aspiration of salivary and ruminal contents if passive regurgitation occurs. Several techniques (blindly, digital palpation, or direct laryngoscopy) can be used to accomplish intubation and the reader is referred to descriptions of those techniques. An endotracheal tube of appropriate size is inserted and manipulated into the larynx (Table 1). The technique is similar to that performed in small ruminants [4-8,40].

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<th>Body Weight (kg)</th>
<th>Endotracheal Tube Size (mm id.)</th>
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<tr>
<td>&lt; 30</td>
<td>4 - 7</td>
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<td>30 - 40</td>
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Anesthesia in cattle can be maintained with halothane, isoflurane, or sevoflurane. Economic issues often dictate which agent is used. Conventional small animal anesthetic machines can be used to anesthetize calves weighing less than 40 kg. Conventional human anesthetic machines or small animal machines with expanded soda lime canisters are adequate for animals up to about 200 kg. Oxygen flow rates of 20 ml/kg/minute during induction and 12 ml/kg/minute during maintenance with minimal flow rates of 1 L/minute are adequate. Anesthesia is usually maintained with halothane at 1.5 - 2.5% or isoflurane at 1.5 - 3% or sevoflurane at 2.5 - 4%. Because cattle have a respiratory pattern characterized by rapid respiratory rate and small tidal volume, higher vaporizer settings (e.g., halothane 2 - 3%) may be required to maintain anesthesia in spontaneously breathing patients. Vaporizer setting can be decreased if controlled ventilation is used.

**Supportive Therapy**

Supportive therapy is an important part of anesthetic practice and can exert a strong influence on recovery and patient morbidity/mortality. Supportive therapy includes patient positioning, fluid administration, mechanical ventilation, cardiovascular support, good monitoring techniques, and oxygen administration to cattle under intravenous anesthesia. These techniques are addressed more completely in other chapters and other texts [4-8,41-43]. The reader is encouraged to consult those references for additional information.

As with any species, good anesthetic techniques require monitoring to allow drug administration to meet the animal's requirements and prevent excessive insult to the cardiovascular, respiratory, central nervous, and musculoskeletal systems, thereby decreasing risk of complications. Monitoring techniques are similar to those employed in horses [4,6,44,45].

In healthy anesthetized adult cattle, heart rate is usually 70 - 90 beats/minute. Animals that have received an anticholinergic will have an increased heart rate. Normal heart rate for calves varies with age. Younger calves will have a heart rate of 90 - 130 beats/minute, decreasing as they mature. Pulse pressure can be ascertained by palpating the common digital, caudal auricular, radial, and saphenous arteries. Mucous membranes should be pink although the mucous membranes of some cattle are pigmented, making assessment difficult. Electrocardiography (ECG) is used with either standard limb leads (I, II, III) or a dipole lead for detection of cardiac rate and rhythm disturbances. Arterial pressure provides an accurate variable for assessing depth of anesthesia and can be monitored with either direct or indirect techniques. Normal arterial pressure values in anesthetized cattle are systolic pressure, 120 - 150 mmHg; diastolic pressure, 80 - 110 mmHg; and mean arterial pressure, 90 - 120 mmHg; and exceed those of standing cattle [46]. The respiratory system is evaluated by monitoring respiratory rate and tidal volume. Spontaneous breathing rates are usually 20 - 30 breaths/minute in adult cattle and usually 20 - 40 breaths/minute in calves. Awake cattle have a decreased tidal volume when compared to horses and that relationship persists during anesthesia [47]. Normal arterial blood gas values for anesthetized cattle are similar to those of anesthetized horses. Respiratory gas analysis to determine end tidal CO2 and anesthetic agent concentration can be performed to provide additional information. Care must be exercised during selection of agent analyzers. Ruminants often have detectable amounts of methane (and other gases) in their expired gas. Methane (and perhaps other gases) will be interpreted as the anesthetic agent by some infrared monitors and falsely report anesthetic concentration [48]. The central nervous system can be monitored by observation of ocular reflexes. The palpebral reflex disappears with minimal depth of anesthesia in cattle and is usually of no value during anesthesia. Dorsoventral rotation of the globe will occur as anesthetic depth changes in cattle [49]. The eyeball is normally centered between the palpebra. As anesthesia is induced the eyeball rotates ventrally, with the cornea being partially obscured by the lower eye lid. As depth of anesthesia is increased, the cornea becomes completely hidden by the lower eyelid; this sign usually indicates adequate depth of surgical anesthesia. A further increase in anesthesia is accompanied by dorsal rotation of the eyeball. Dorsal movement is complete when the cornea is centered between the palpebra; this sign indicates deep surgical anesthesia with profound muscle relaxation. During recovery eyeball rotation occurs in reverse order to that occurring during induction [49]. Nystagmus usually does not occur during anesthesia of cattle and when it does occur, can not be correlated with changes in depth of anesthesia. The corneal reflex should be present.

**Recovery**

Cattle recover well from general anesthesia and seldom experience emergence delirium or make premature attempts to stand. When an alpha-2 agonist is used as part of the anesthetic regimen, an antagonist can be used to hasten recovery [30,50,51] Exubation of cattle should not occur until the laryngeal reflex has returned and the animal begins to chew. If the patient has regurgitated the buccal cavity and pharynx should be lavaged to prevent aspiration of the material. In these instances, the endotracheal tube should be withdrawn with the cuff inflated in an attempt to remove any material that may have located in the trachea. Although cattle recover well from general anesthesia with minimal assistance, an attendant should be available.

**References**


44. Hubbell JAE. Monitoring. In: WW Muir and JAE Hubbell eds. Equine Anesthesia -- Monitoring and Emergency


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