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Anesthesia of ruminants

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General anesthesia is helpful for many procedures in ruminant practice, including exploratory laparotomy of the colicky calf, castration of an adult llama, or exploring a fistulous tract. Ruminants can be difficult to manage under general anesthesia and large animal anesthetic machines are required for volatile anesthesia of animals that are >150 kg body weight (BW). For these reasons, local anesthesia is often the most suitable choice for mature cattle. Calves, sheep, and goats can be readily anesthetized with small animal anesthetic equipment that is available in most mixed practices. This issue of *Large Animal Veterinary Rounds* focuses on the general anesthesia of small ruminants and camelids. Techniques for sedation and local anesthesia are reviewed and case discussions are presented to illustrate the techniques described in this article.

General preanesthetic considerations for ruminants

As with any anesthetic, the physical state of the animal – particularly its level of hydration – is an important consideration (Table 1). Calves that are presented for abdominal surgery are often dehydrated and require aggressive fluid therapy before induction. Tissue oxygenation should also be assessed. Alpha-2 agonist drugs can produce hypoxemia in healthy ruminants[1] and may lead to serious complications in animals with pre-existing hypoxemia. The animal's oxygen-carrying capacity should also be considered. Packed cell volume (PCV) should be measured prior to general anesthesia since animals with a PCV that is <25% can be at a higher risk for complications during anesthesia. Calves may be bacteremic or endotoxemic. These animals are considered high-risk patients and usually require aggressive fluid loading.

Ruminants are prone to regurgitation and ruminal tympany during general anesthesia. Calves, sheep, goats, and camelids should be fasted for 12-18 hours prior to general anesthesia and deprived of water for 8-12 hours.[2] Very young animals that are still nursing are at less risk of developing ruminal tympany and regurgitation. However, young animals are also prone to hypoglycemia with prolonged fasting. These animals can be muzzled for 1-2 hours prior to induction, to prevent nursing.

When possible, an IV catheter should be placed prior to induction. A 16-gauge catheter can be placed in the jugular vein of calves, sheep, or larger goats. The cephalic vein may be an easier target in some animals and generally, an 18-gauge catheter is the best choice for this vein. The jugular vein can be difficult to palpate in llamas and alpacas because the skin on the neck is thick and the jugular groove not prominent. Local anesthesia and incision of the skin will facilitate catheter placement. For a complete description of this technique, refer to Reibold.[3]

Monitoring and supportive care

Ruminants are prone to hypoxemia. The development of hypoxemia has been linked to xylazine administration and body position.[4] Dorsal recumbency should be avoided whenever possible, as ruminal tympany will result in thoracic compression and ventilation/perfusion mismatch. Hypoxemia is best diagnosed with a multisite pulse-oximeter probe that can be placed on the tongue

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Table 1: Preanesthetic Concerns

Physical state

- Well-hydrated
- Good tissue oxygenation
- No hypoxemia
- PCV > 25%

Preparation for induction

- Fasting (12-18 hrs for calves, sheep, goats, and camelids)
- Water restriction (8-12 hours)
- Young nursing animals (muzzled 1-2 hrs)
- Placement of IV catheter

of anesthetized ruminants. Hemoglobin saturation should be maintained above 95%. Animals under volatile anesthesia should receive oxygen as the carrier gas. Nasal administration of oxygen, at 5-10 liters/minute, will offset hypoxemia in animals anesthetized with injectable techniques.

Ruminants are prone to regurgitation and should be intubated when anesthetized with volatile anesthetics. Orotracheal intubation can be performed in calves, sheep, goats, and llamas. The preferred technique is to visualize the glottis with a laryngoscope. A stylet is placed inside the endotracheal tube, with the tip extending approximately 10 cm past the end of the endotracheal tube. It is then advanced into the trachea during adduction of the arytenoid cartilages on inspiration. The tube is then advanced over the stylet.[5] If a laryngoscope is not available, blind intubation can be attempted. In this case, the head and neck are extended and the tube is placed in the oropharynx. The larynx is manipulated and the tube advanced on inspiration.

The cardiovascular system should be monitored at least every 5 minutes throughout anesthesia. The common digital arteries can be palpated just dorsal to the dewclaws.[5] Heart rate will generally range between 80-120 beats/minute in anesthetized calves, sheep, and goats.[5] A Doppler and cuff technique can be used to obtain systolic pressure with placement over the common digital artery. The cuff is placed proximal to the carpus and its width should be approximately 40% of the underlying limb circumference. Systolic pressure should be maintained between 100-150 mm Hg. The respiratory system can be monitored by observation of chest excursions. A respiratory rate of 30-40 breaths/minute can be expected in anesthetized calves, sheep, and goats.[5] Pulse oximetry can be used to monitor the percent of hemoglobin saturation and heart rate.

Appropriate padding should be used, particularly with larger animals since they are prone to compartmental crush syndromes. Monitoring of body temperature is very important in young calves, lambs, and kids.

Pharmacological considerations for ruminant anesthesia

There are very few anesthetic drugs labeled for use in ruminants; therefore, most of the recommended protocols are off-label (Table 2).

Anesthesia in small ruminants

- Xylazine is a useful sedative and analgesic in ruminants and camelids and is labeled for use in cattle. Major side effects are ruminal tympany and hypoxemia;[5] however, fasting will decrease the incidence of ruminal tympany and supplemental inspired oxygen can offset hypoxemia. The effects of xylazine can be antagonized with tolazoline in cattle, sheep, and goats, while yohimbine can be used to antagonize its effects in sheep, goats, and camelids. One potential drawback of xylazine at higher doses is that it produces recumbency that is undesirable in cattle if standing sedation is required.
- Detomidine will produce a more reliable standing sedation in cattle. Some authors advocate the use of detomidine in the last third of gestation because there may be less risk of abortion, compared to xylazine.[5]
- Epidural xylazine is very useful in cattle because it produces sedation and analgesia.[6] It can be used alone to supplement volatile anesthesia or it can be combined with a local anesthetic to produce sedation and prolong the effects of local anesthesia.
- Diazepam is a very useful drug in small ruminants and camelids. Intravenous diazepam induces reliable sedation with minimal adverse cardiopulmonary or respiratory effects. Diazepam is probably more suitable than xylazine for young animals or those with cardiovascular compromise.
- Butorphanol can be combined with diazepam to produce neuroleptanalgesia, which may be suitable for sedation in young calves, goats, and sheep, or as a preanesthetic combination. The combination of butorphanol and diazepam will reduce volatile anesthetic requirements, resulting in less cardiopulmonary depression during anesthesia. Animals sedated with diazepam-butorphanol may be induced with volatile anesthesia through a mask.
- Intravenous ketamine also produces a reliable induction and is the induction agent of choice for animals in shock. It may also be used to decrease volatile anesthetic requirements in animals with shock.
- Anticholinergics are generally not used in ruminants since they thicken salivary secretions, contribute to ruminal tympany, and often (eg, atropine) have a very short duration of action.[5]

Maintenance of anesthesia

Volatile anesthetics are the most suitable agents for maintenance of anesthesia in small ruminants.

Table 2: Drug dosages for sedation and anesthesia in ruminants and camelids. All dosages are in mg/kg.

	Sedation	Induction of anesthesia	Maintenance of anesthesia
Calves	Diazepam 0.1-0.2, followed by, butorphanol 0.1 IV Xylazine 0.025-0.05 IV 0.1-0.2 IM	Diazepam 0.2, followed by, butorphanol 0.1, followed by, ketamine 2-4	Halothane 1-2% Isoflurane 1.5-2.5% Sevoflurane 2.5-4%
Adult Cattle	Xylazine 0.05-0.2 IM or IV Detomidine .0025-.01 IV	Xylazine 0.1 IV, followed by, ketamine 2 IV	1 liter of 5% guaifenesin + 1000 mg of ketamine. Infuse at 2-2.5 ml/kg/hr
Sheep	Xylazine 0.1-0.2 IV or IM Detomidine .0025-.01 IV Diazepam 0.1-0.2 IV, followed by, butorphanol 0.1 IV	Xylazine 0.2, followed by, ketamine 2-4 IV	Ketamine 1-2 IV as needed Halothane 1-2% Isoflurane 1.5-2.5% Sevoflurane 2.5-4%
Goats	Xylazine 0.025-0.05 IV or IM Diazepam 0.1-0.2 IV, followed by, butorphanol 0.1 IV	Xylazine 0.05 IV, followed by, ketamine 2-4 IV Diazepam 0.2 IV, combined with ketamine 2-4 IV	Ketamine 1-2 IV as needed Halothane 1-2% Isoflurane 1.5-2.5% Sevoflurane 2.5-4%
Llamas and alpacas	Xylazine 0.25-0.5 IV 0.5-0.75 IM Xylazine 0.5-0.75 IM, combined with, butorphanol 0.05-0.1 IM	Xylazine 0.25-0.5 IV, followed by, ketamine 2-4 IV Diazepam 0.2 IV **or** midazolam 0.1 IV combined with ketamine 2-4 IV	Ketamine 1-2 IV as needed Halothane 1-2% Isoflurane 1.5-2.5% Sevoflurane 2.5-4%

- Isoflurane and halothane are the most economical choices.
- Sevoflurane is an option, but is probably cost-prohibitive at the current time.
- Isoflurane is the preferred choice in very young animals and in those with cardiovascular compromise.

Anesthesia in large ruminants

Large ruminants (>150 kg) require a large animal anesthetic machine for volatile anesthesia. For practical reasons, most procedures are performed under local anesthesia. On rare occasions, however, general anesthesia may be required. Short-term anesthesia can be produced in adult cattle with xylazine as a preanesthetic, ketamine for induction, and a mixture of guaifenasin and ketamine for maintenance. This technique is described below.

Postoperative pain control

There are several drugs available to produce postoperative pain control. Nonsteroidal anti-inflammatory drugs (NSAIDS, eg, flunixin or ketaprofen) can be used to provide several hours of postoperative analgesia.[7] Butorphanol will provide 2-3 hours of postoperative analgesia, and epidural morphine may provide 12-24 hours of postoperative analgesia.

Anesthesia of calves

Calves can be anesthetized with general anesthetics or a combination of deep sedation and local anesthesia. Young calves (<3 months old) have an immature cardiovascular system; as such, they are very dependant on heart rate to maintain cardiac output. It is best to avoid xylazine in very young calves since it will lower heart rate and decrease cardiac output. If xylazine is used, it should be at a low dose or administered epidurally. Young calves are also prone to hypoglycemia and hypothermia; therefore, blood glucose and body temperature should be closely monitored. Diazepam-butorphanol is a suitable sedative or preanesthetic mixture. Neonatal calves can be mask-induced; older calves can be induced with intravenous ketamine. Calves older than 3 months may be more difficult to physically restrain. Xylazine can be used at a dose of

0.1-0.2 mg/kg IM or 0.1 mg/kg IV to facilitate restraint. This can be followed by diazepam-ketamine (Table 2) for induction. Maintenance of anesthesia can be achieved with isoflurane or halothane.

Case 1

A 2-month-old calf presents with a large umbilical abscess. The calf is slightly febrile, but is bright and alert. A decision is made to resect the abscess and explore the abdomen.

How should this case be managed?

The first issue is to make sure that the calf is adequately hydrated prior to surgery. A good physical examination should be performed and the packed cell volume and total protein measured. If the animal is dehydrated, its fluid deficit should be replaced with a balanced electrolyte solution prior to induction. If the animal is easy to handle, a jugular catheter should be placed prior to induction. IV diazepam can be administered at a dose of 0.2 mg/kg. Once the calf is sedated, IV butorphanol is administered at a dose of 0.1 mg/kg. The calf will generally become recumbent after this combination. At this point, the calf can be mask-induced with isoflurane or halothane or 2-4 mg/kg of IV ketamine can be administered. The calf should be intubated and maintained with the volatile agent. Ideally, blood pressure, heart rate, body temperature, and percent hemoglobin concentration should be monitored.

An alternate approach would be to use deep sedation and local anesthesia. Diazepam and butorphanol are administered at the above dose. A mixture of 0.05 mg/kg of xylazine and 1 ml/5 kg of lidocaine is administered into the epidural space of the spinal canal, in the space between the last sacral and first coccygeal vertebrae. The calf is restrained in dorsal recumbency and oxygen is supplied via a nasal catheter or a mask. If supplemental sedation is required, the calf can receive additional diazepam and butorphanol at 50% of the above dose, or 0.025 mg/kg of xylazine. Alternatively, a sleep dose of isoflurane (0.6-0.8%) or halothane (0.4-0.6%) may be administered by mask.

A potent nonsteroidal anti-inflammatory drug (NSAID) may be used, in addition to the above, for postoperative pain control. The NSAID can be administered immediately following extubation.

Anesthesia of mature cattle

Anesthesia in mature bovids is a higher risk than in calves. All of the preanesthetic concerns should be addressed. In the absence of a large animal anesthetic machine, IV anesthesia can be used for short procedures. It is important to ensure that the animal is adequately padded and that the procedure is limited to ≤ 1 hour.

Case 2

A 2-year-old Holstein cow is presented with a chronic draining tract on the medial aspect of the metatarsus. The cow is difficult to handle. Xylazine is tried alone, at a dose of 0.2 mg/kg IV, but fails to provide adequate sedation when the tract is probed. The cow needs to be anesthetized for radiographs and exploration of the draining tract.

If the cow has recovered from the previous dose of xylazine, and the procedure is short and minimally invasive, it may be possible to induce recumbency with 0.2 mg/kg of xylazine administered intravenously into the tail vein. Once the cow is recumbent, 2 mg/kg of IV ketamine is administered. This can be repeated at a dose of 1 mg/kg as needed (generally every 10-15 minutes). If complete anesthesia is required, the cow is induced as above and maintained with a mixture of 5% guaifenasin and ketamine (Table 2). Ideally, the cow should be intubated if this mixture is used. Supplemental oxygen can be administered at a flow of 8-10 liters/minute via the endotracheal tube or at a flow of 10-15 liters/minute via a nasal catheter.

Following radiographs and exploration, it is determined that a sequestrum is present that should be removed. The cow responds each time the area is probed. The above anesthetic protocol is generally adequate for soft tissue procedures, but will not be adequate for orthopedic procedures. The simplest solution is to supplement the analgesia with a local block. In this location, an IV regional block should work well. A tourniquet is applied immediately distal to the tarsus and lidocaine is administered at a dose of 20-30 ml IV, which will provide sufficient analgesia for removal of the sequestrum.

Postoperatively the cow could receive butorphanol at a dose of 0.05 mg/kg IV or IM, plus an NSAID. Another option would be to use epidural morphine at a dose of 0.1 mg/kg. The cow should remain intubated until the animal can swallow and hold her head up. The cuff should be partially inflated when the tube is removed.

Anesthesia of sheep and goats

Sheep and goats are included together in this section, but they respond somewhat differently under anesthesia. Goats can be particularly sensitive to stress and pain, therefore, it is important to perform procedures under adequate sedation and with adequate analgesia. Goats may also be more sensitive to xylazine;[2] generally, 0.025-0.05 mg/kg of xylazine IV is used in these animals. In sheep, 0.1-0.2 mg/kg of xylazine will

induce recumbency. If light anesthesia is required, xylazine is administered at the above dose, and this is followed by ketamine at a dose of 2-4 mg/kg IV. Light anesthesia can be maintained with supplemental ketamine at a dose of 1-2 mg/kg, as needed. The animal can also be intubated and maintained on volatile anesthesia. If the animal is not intubated, supplemental inspired oxygen should be administered via a nasal catheter or mask.

In animals with cardiovascular compromise or with pulmonary disease, it is best to avoid xylazine. These animals can be induced with diazepam-ketamine, or diazepam-butorphanol-ketamine as described above, for calves.

Anesthesia of camelids

Llamas and alpacas are included in this section. A variety of techniques have been described for anesthesia of camelids.[3] Most llamas and alpacas can be anesthetized with small animal anesthetic machines. Short procedures in healthy animals can be performed with xylazine-ketamine anesthesia, with xylazine administered at a dose of 0.5 mg/kg IV, followed by ketamine at a dose of 3-4 mg/kg IV. This mixture will generally produce 30-minutes of light anesthesia. On occasion, a fractious animal is encountered and IV drug administration is difficult. These animals can be sedated with 0.5-0.75mg/kg of xylazine IM plus 0.05 mg/kg of butorphanol. Once the animal is well-sedated, the induction can be completed with 0.1 mg/kg of diazepam combined with 2-4 mg/kg of ketamine IV. Debilitated animals should not receive xylazine. Instead, anesthesia can be induced in these animals with diazepam-ketamine or midazolam-ketamine (Table 2). Butorphanol can be used to lower volatile anesthetic requirements. Crias can be mask-induced with isoflurane or sevoflurane after sedation with 0.1 mg/kg of diazepam and 0.05 mg/kg of butorphanol.

Intubation and IV catheterization can be difficult in camelids. A complete description of these techniques can be found in Riebold.[3] Anesthesia can be maintained with halothane or isoflurane. If direct blood pressure measurement is not available, indirect techniques such as Doppler and cuff or oscillometric monitoring, can be used. Hypotension can be treated with fluid loading, ephedrine (0.05-0.1 mg/kg IV), or dobutamine (2-5 µg/kg/min). Pulses can be palpated over the caudal auricular artery or the common digital arteries.[3]

Case 3

A 3-year-old llama is presented for castration. The llama has no history of illness and is well-mannered.

What is a good technique for field anesthesia?

The best agent in this situation would be xylazine-ketamine. The llama should be fasted for at least 24 hours prior to anesthesia. Xylazine is administered at a dose of 0.5 mg/kg IV. The llama will generally become recumbent in 2-3 minutes. Once recumbent, it should be restrained in sternal recumbency. Ketamine is administered at a dose of 2-4 mg/kg IV. A bale or large cushion can be placed under the abdomen to elevate the hind-end and facilitate surgery. It is common to encounter some movement during incision or emasculation. Lidocaine can be infiltrated as a line block to provide anesthesia of the scrotum, it can also be injected into the spermatic cord to prevent response on emasculation. The heart rate and pulse quality should be monitored at a minimum of 5-minute intervals. A pulse oximeter is an excellent monitor for field situations. Supplemental oxygen can be administered by nasal insufflation at a flow of 5-8 liters/min to offset hypoxemia. Once the procedure is complete, the xylazine-induced sedation should be antagonized. This is best achieved with yohimbine at a dosage of 0.1 mg/kg IV.

Conclusion

Anesthesia is an important part of veterinary practice and necessary when performing surgical procedures on animals. Anesthesia administered to ruminants should be appropriate for the size of the animal and sufficient to induce and maintain adequate anesthesia throughout the procedure. Of the agents listed, only xylazine is approved for use in cattle. Xylazine has a withdrawal time of 48 hours in milk and 72 hours from meat. All of the other agents are used extra-label in cattle and the veterinarian is responsible for determining the withdrawal time for milk and/or meat; further information can be obtained from the Canadian gFARAD.

Finally, the concerns for the practicing veterinarian include:

- carefully evaluating the physical condition of the animal pre-procedure
- preventing regurgation and ruminal tympany during the procedure
- monitoring and supportive care to assure stable intubation, respiration, blood pressure, and heart rate
- appropriate drug administration for induction and maintenance of general and local anesthesia, as well as postoperative analgesia and withdrawal time.

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Abstract of Interest

Quantification of the pain and distress responses to castration in young lambs.

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Pain and distress after castration were assessed in lambs using behavior, plasma cortisol, and mechanical nociceptive thresholds. The behavioral manifestations of pain were assessed as active pain (signs such as foot stamping, lip curling, and kicking, visible when observing the undisturbed lamb), unresponsive behaviors (how the lamb reacted when the observer entered the pen), and scrotal pain (response to scrotal palpation). Pain measurements started before the procedure and then at various intervals for the 72-hour period following castration.

Castration methods included rubber ring, combined ring and Burdizzo clamp, and surgery. Controls were handled, but not castrated. The effects of castration following local anesthetic pretreatment and castration under general anesthetic were compared to castration with no anesthetic. This gave a 4 X 3 X 3 block design (36 experimental treatments). Six lambs were allocated to each treatment for a total of 216 lambs.

In unanesthetized lambs, rubber ring castration had the greatest signs of active pain for the first 80 minutes following castration and the greatest peak in serum cortisol concentrations. Surgical castrates had the greatest scrotal pain, unresponsive pain behaviors and the largest rise in mechanical nociceptive thresholds between 3 and 8 hours post-castration. Overall, combined ring and Burdizzo clamp castration was the least painful as measured by a combination of behavior, mechanical nociceptive thresholds, and rise in serum cortisol. Local anesthesia abolished the pain responses to rubber ring, and combined ring and Burdizzo clamp castration. Local anesthesia had a tendency to reduce signs of active pain in the first hour following surgical castration, but scrotal pain scores were higher than in non-anesthetized lambs from 1 to 48 hours following the procedure. General anesthesia did not reduce the responses to rubber ring (mainly signs of active pain in the first hour following application of the ring) or surgical castration (signs of scrotal pain were more severe in the 1 to 8 hour period following castration). General anesthesia abolished the rise in mechanical nociceptive thresholds and markedly attenuated active pain behaviors in lambs castrated with the ring and Burdizzo clamp technique. This suggests that the clamping procedure itself rather than post-castration pain and distress is responsible for the rise in nociceptive thresholds and active pain behaviors with this method. The method of castration had a greater effect on postoperative pain than the method of intraoperative anesthesia. The least painful combination was local anesthesia of the testes and skin combined with ring and clamp castration.

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