RUMINANT & SWINE ANESTHESIA

Lyon Lee DVM PhD DACVA

Ruminant Anesthesia

Introduction

- Ruminants are not good subjects for general anesthesia.
- The danger of regurgitation and inhalation of ingesta is much greater in these species compared to other common domestic species.
- Fortunately, their docile temperament allows majority of surgical procedures to be carried out by local anesthesia (± sedation) without much difficulty, and many techniques are available (see local anesthesia lecture)
- However, some procedures, with economic justifications, are better performed under general anesthesia, and with certain precautions, general anesthesia can be carried out safely without complications

Figure 1 A Longhorn under general anesthesia for umbilical mass removal

- Adult cattle carries greater risk of developing myopathies and neuropathies following prolonged recumbency, so good positioning and protective padding must be ensured
- Following recumbency esophageal opening is submerged in ruminal contents, normal eructation can not occur, and gas accumulates. The degree of bloat depends on the amount of fermentation and on the length of time that gas is allowed to accumulate

- Gross distension of the rumen becomes a hazard if anesthesia or recumbency is prolonged and regurgitation can follow from this
- In addition, the weight of the abdominal viscera and their contents prevents the diaphragm from moving freely on inspiration and ventilation becomes shallow, rapid and inefficient for gas exchange within the lungs.
- In unfortunate circumstances, the aspirated regurgitatants obstruct the airway, cause asphyxia, and bring the patient to death within 24 hours of developing the complication.
- The danger of regurgitation can be minimized by:
  - Starvation prior to anesthesia
  - Water deprivation prior to anesthesia
  - In lateral recumbency, elevating the neck to avoid easy regurgitation and positioning the head sloped down to facilitate drainage of saliva (large amount produced) and other intraoral materials.
  - Passing down a stomach tube so as to allow drainage of ruminal materials (and also accumulated gas) during the recumbency
  - Cleansing solid materials in the mouth at the end of anesthesia, and leaving the ET tube with the cuff inflated until the animal is in sternal recumbency, is swallowing and is able to withdraw its tongue into the mouth
- Important consideration is the use of anesthetics to those animals for human consumption. Most anesthetic drugs are not approved for use in food animal species and these drugs are administered on extra-label use basis. If animals were to be shipped to market, and a residue is found, an individual who administered the drug can be prosecuted. Additional information on the withdrawal time for anesthetics in food animals can be obtained at FARAD Digest: Extralabel use of tranquilizers and general anesthetics (JAVMA, Vol. 211, No. 3, 302-304)

Preanesthetic preparation

- Calves and small ruminants should be starved of food for 12 hours and of water for 8 hours
- Adult cattle should be starved of food for 12-24 hours and of water for 12-24 hours
- Large mature bulls should be starved of food for 24-36 hours and of water for 24-36 hours
- Fasting neonates are not recommended due to potential for hypoglycemia
- Laboratory evaluation can provide useful prescreening information about the general health status of the patient and where possible must be carried out prior to anesthesia
- Do a physical examination to determine any abnormalities. Auscultate for cardiac dysrhythmias and murmurs, or abnormal lung sounds.
- Stabilize animal's physiology in debilitated animals (e.g. gastrointestinal disorder, dystocia)
- IV catheterization placement
  - The common site of venous catheterization both for large and small ruminants is jugular vein
  - In camelids, two sites are recommended; 3-4 cm dorsal to angle of ventral border of mandible, and cranial to the ventral process of 5^{th} cervical vertebra, for easier access to the jugular vein
  - Other veins for venous catheter placement include the auricular vein and the coccygeal vein
  - For jugular catheterization 12-14 G for large ruminants, and 16 – 18 G for camelids and small ruminants are suitable

Preanesthetic agents

- A good preanesthetic sedation facilitates smooth induction and has anesthetic sparing effect during maintenance
- There are a few choices available
- Sedative/opioid combination (neuroleptanalgesia) is most popular (e.g. xylazine and butorphanol; acepromazine and morphine), and provides better restraint and analgesia (the combination is synergistic, not merely additive) as preanesthetic medication

Acepromazine

- Provides mild sedation
- Anti-arrhythmic
- Bull: penile priapism
- Requires at least 20 min for good effect even after IV injection, and 30 to 45 min when given IM
- Prolonged duration
- 0.025 – 0.05 mg/kg IV
- Premedication dose of 0.04 mg/kg IV has minimal cardiovascular effect in healthy cattle
- It is recommended that IV injection not given in the coccygeal vein because of accidental coccygeal arterial administration and subsequent sloughing of the tail distal to the injection site
- Will cause hypotension (more so in old, debilitated, or hypovolemic animals) through direct myocardial depression and peripheral vasodilation
- Has been replaced mainly by alpha 2 agonists for sedation

Diazepam/Midazolam

- Minor tranquillizer
- Excellent muscle relaxation
- Minimal cardiopulmonary depression
- In small ruminants they can be used as premedicants, but in large ruminants they are usually administered as induction agent (e.g. combined with ketamine)
- 0.02 – 0.1 mg/kg IV

Xylazine

- A potent hypnotic which provides deep sedation and popular as premedicant
- Onset of action following IV injection at 2 min, reaching peak effect in 5 minutes.
- Dose dependent severe cardiovascular effect: bradycardia AV dissociation, myocardial depression (decreased cardiac output)
- May cause hypoxemia and hypercapnia and pulmonary edema (this is most notable/ predictable in small ruminants, particularly in the sheep)
- 0.01 – 0.1 mg/kg IV (1/10th of equine dose) in cattle
- 0.1 mg/kg IV provides sedation without recumbency but 0.2 -0.3 mg/kg IV provides recumbency in llamas
- 0.1 mg/kg IV will induce recumbency and light plane of anesthesia for an hour in cattle but recumbency may be induced even at a lower dose
- Some variation of sensitivity
  - Herefords have been shown to be more sensitive than Holstein, and Brahmans seems most sensitive
- Other side effects
  - Hyperglycemia
  - Diuresis
  - Sweating
  - GIT motility depression
  - Platelet aggregation
  - Uterine contractions in cows. Detomidine in this regard has been regarded better alternative both in cows and mares.
- Reversal is carried out by using Tolazoline (or by other alpha 2 antagonists such as yohimbine or atipamezole) if indicated(e.g. for expedient recovery)

Detomidine

- More popular in Europe (cheaper than xylazine)
- In contrast to xylazine, the dose is similar to those used in horses 2.5 - 10 mcg/kg IV
- Duration of sedation lasts 30-60 mins
- 40 mcg/kg IV will produce profound sedation and recumbency
- The pharmacologic effects of detomidine in cattle are very similar to those of xylazine in that it causes bradycardia, hyperglycemia, and increased urine production.
- Similar side effects in all other aspects with xylazine
- Precautions are similar to those given for xylazine.
- Less ecbolic than xyalzine in cattle

Romifidine

- Has been used in Europe for a while but only recently became available in the US
- 50 mcg/kg IV has been shown to produce recumbency in the sheep
- Longer sedative effect than xylazine or detomidine
- Similar in all other aspects with xylazine and detomidine

Medetomidine

- Primarily used for sedating small animals (dogs and cats)
- 30 mcg/kg IM has been given to produce recumbency in calves and 10 mcg/kg IV to produce recumbency in the sheep
- Sedation lasts approximately for one hour

Butorphanol

- Does not provide sedation in a predictable manner, and may induce behavioral alteration such as restless and bellowing
- 0.02 – 0.05 mg/kg IV may provide sedation in cattle that are sick.
- The quality of sedation is improved when combined with xylazine (or other sedatives), along with improved analgesia
- Minimal change in HR, BP, CO when given alone
- Can be detected in the milk up to 36 hours

Anticholinergics

- Use of atropine or glycopyrrolate may decrease volume of saliva secretion while making it more viscous, making more difficult for the tracheal cilia to clear aspirated saliva
- Ruminants have high level of atropinase, requiring more frequent and higher dosing of atropine
- Depression of gastrointestinal motility may induce abdominal discomfort or colic
- Anticholinergics are not routinely administered as part of preanesthetic medication in large or small ruminants, but can be given in the event of bradycardia
- Camelids are prone to vagal arrhythmias during intubation, and use of anticholinergics is recommended; atropine 0.01-0.02 mg/kg IV, glycopyrrolate 2-5 mcg/kg IV

Drug combinations

- More consistent degree of sedation can be obtained by sedative/opioids combination
- Common combination is use of xylazine 0.02 mg/kg IV with butorphanol 0.02 mg/kg IV, which produces a peak sedative effect within 5 minutes

Anesthetic Induction

Ketamine

- Ketamine alone will not cause seizure in cattle but the quality of induction is poor
- Ketamine is associated with increased muscle rigidity and excessive salivation
- Ketamine is better used in combination with other sedatives (most commonly with benzodiazepines or alpha 2 agonists)
- Ketamine may cause increased heart rate, cardiac output, and blood pressure

Ketamine-Xylazine

- Xylazine is given to adult cattle either IM at 0.1 – 0.2 mg/kg or IV at 0.05-0.1 mg/kg to produce deep sedation often recumbency. Butorphanol 0.1-0.2 mg/kg IV can be included in this combination for better analgesia and muscle relaxation.
- Ketamine is then given IV in doses of 2 mg/kg to induce anesthesia
- Often, ET intubation can be performed soon after the xylazine injection and before ketamine is given and whenever possible this should be done, as ketamine appears to produce copious salivation or an inability to swallow the normal saliva volume
- Hypoxia due to hypoventilation during the use of this combination has also been reported. For this reason, supplemental oxygen is recommended.

Ketamine-Diazepam

- This combination will produce less cardiovascular depression than xylazine-ketamine
- This combination is used for induction in xylazine premedicated animals in the dose of diazepam 0.1 mg/kg and ketamine 2 mg/kg given IV bolus inducing anesthesia in 60 seconds
- In calves and small ruminants 0.25 mg/kg of diazepam and 5 mg/kg ketamine can be combined and injected IV as a bolus or titrated to effect. Butorphanol 0.1-0.2 mg/kg IV can be included in this combination for better analgesia and muscle relaxation. This regimen provides approximately 15 minute of anesthesia

Tiletamine and Zolazepam (Telazol)

- Pre-formulated preparation – similar to ketamine-diazepam combination in many respects
- As it comes in powder form, other injectable anesthetics, sedatives or narcotics can be added to increase the potency of final constituent and ketamine and xylazine have been used successfully for this purpose
- Telazol 4mg/kg and xylazine 0.1 mg/kg combination produces anesthesia within minutes with analgesia lasting for 70 minutes in calves
- IV administration of Telazol to sheep at a dose of 12-24 mg/kg provides 40 minutes of general anesthesia sufficient for surgery, but was associated with cardiopulmonary depression and prolonged recovery. It may be more appropriate to administer a smaller initial dose (2-4 mg/kg IV) and administer additional Telazol as needed to prolong anesthesia.

Guaifenesin

- Guaifenesin is a centrally acting muscle relaxant causing minimal cardiopulmonary depression.
- It is not recommended as a sole agent because it produces little if any analgesia.
- When used in combination with a thiobarbiturate or ketamine, induction quality is improved and a lower volume of these anesthetic agents is required.
- Triple-Drip (Guaifenesin / Ketamine / Xylazine or GKX)
  - To mix triple-drip solution combine one liter 5% guaifensin (50 mg/ml, final concentration) with 100 mg of xylazine (0.1 mg/ml, final concentration) and 1 gram of ketamine (1 mg/ml, final concentration)
  - Loading dose 0.5 -2 ml/kg is given as an IV drip “to effect” for intubation and then continue on a slow drip until the isoflurane has fully taken effect (usually 5-10 minutes).
  - Alternatively, following xylazine-ketamine induction, guaifenesin-ketamine combination (there is no need to add xylazine as half life of xylazine is longer than ketamine in cattle) can be administered intermittently or CRI at the rate of 0.5 - 2 ml/kg/hr

Thiopental

- The ultra-short acting thiobarbiturate, thiopental, provides approximately 10-15 minutes of anesthesia when used alone.
- Recovery is through redistribution of the agent from the brain into the other tissues
- Maintenance of anesthesia through continuing use of thiopental is not recommended due to accumulative effect and resultant prolonged recovery
- Maintenance of anesthesia for longer periods of time can be accomplished through the use of inhalation anesthesia.
- 6-10 mg/kg in unpremedicated animals provides 10-15 minute of recumbency
- Thiopental (2 g) can be combined with guaifenesin (50 g) and can be administered at 100 mg/kg guaifenesin-4 mg/kg thiopental titrated to effect
- Pentobarbital, a short acting barbiturate was a commonly used injectable anesthetic agent in ruminants but is largely replaced by contemporary induction agents.

Propofol

- Propofol can be used in small ruminants or in calves for the induction and maintenance of general anesthesia. It provides rapid induction and is very rapidly eliminated from the plasma. 5-6 mg/kg IV produces 4-9 minutes of anesthesia
- Maintenance of anesthesia can be achieved using a constant rate of infusion.
- Expense is the primary limiting factor (along with impractically large volume for rapid administration) for use of this agent in large ruminants

Inhalation Agents (Isoflurane, Halothane, Sevoflurane, or desflurane)

- In small ruminants and calves general anesthesia can be induced by administering isoflurane, halothane, sevoflurane, or desflurane with a facemask
- For faster induction and less exposure to anesthetic gases, these agents can also be administered through nasotracheal intubation
- It is preferable to use non-rebreathing circuits for quicker induction and then switched to the circle rebreathing systems

Table1 Sample doses for injectable anesthetics in the cattle

Comb. #	Premedication	Dose mg/kg	Induction agents	Dose mg/kg
1	Xylazine	0.1	Ketamine	2
2	Xylazine	0.05	Diazepam Ketamine	0.05 2
3	Xylazine Butorphanol	0.05 0.02	Ketamine	2
4	Xylazine Butorphanol	0.03 0.02	Diazepam Ketamine	0.05 2
5	Xylazine ± Butorphanol	0.05-0.1 0.02	Guaifenesin followed by ketamine bolus	100 (G) or "to effect" 1 (K)
6	Xylazine ± Butorphanol	0.05-0.1 0.02	Guaifenesin 50 g mixed with 2 g thiopental followed by thiopental bolus	100 (G) – 4 (T) or "to effect" 2 (T)
7	Xylazine ± Butorphanol	0.05-0.1 0.02	Guaifenesin 50 g mixed with 1 g ketamine and 100 mg xylazine followed by ketamine bolus	100 (G) 2 (K) 0.2(X) "to effect" 1
8	Detomidine ± Butorphanol	0.01 0.02	Guaifenesin 50 g mixed with 2 g thiopental followed by thiopental bolus	100 (G) – 4 (T) or "to effect" 2 (T)

Endotracheal intubation

- Tracheal intubation with a cuffed endotracheal tube provides a patent (secure) airway and prevents aspiration of saliva and ruminal contents if regurgitation occurs.
- Following sternal recumbency, a mouth gag is placed to widen the animal's oral oprening
- In adult cattle, a tracheal guide tube is passed down through blind digital palpation and ET tube is placed over the guide
- In sheep, goats, calves, and llamas, visualization of airway is limited due to narrow opening of the mouth. Use of customized long laryngeal blade and stylet can be very useful to facilitate the intubation.

Figure 2 An ET tube is being introduced over the polyethylene urinary catheter pre-placed into the trachea

- The laryngeal spasm is not uncommon in small ruminants and llamas to tactile stimulation. Topical desensitization of the larynx with use of lidocaine can be helpful to limit this.
- Nasotracheal intubation can be an alternative in difficulty of orotracheal intubation
- Following intubation, correct placement can be confirmed by feeling air coming out of the ET tube in synchrony of movement of the chest. If available, reading of CO_2 by a capnogrpahy is a useful method to confirm the correct position of the tube

Figure 3 A cuff is being inflated immediately following intubation to protect the airway

Table 2 Endotracheal tube sizes based on weight

Body weight (kg)	<30	30-40	60-100	100-200	200-300	300-400	400-600	>600
Endotracheal tube size (mm)	4-10	8-12	10-14	12-16	14-20	16-22	22-26	26-30

Maintenance

Inhalation anesthesia is the method of choice for maintaining anesthesia for prolonged procedure. Intravenous techniques can be used for a short anesthetic procedure.

Inhalational anesthesia

- Halothane, isoflurane, sevoflurane, and desflurane are available,
- Because of economic implications, halothane used to be the most widely used inhalant but it is no longer marketed, and isoflurane has become the most commonly used inhalant.
- Problems associated with inhalation anesthesia occur more frequently and in greater magnitude than in small animals, with more pronounced hypotension, hypoventilation, and reduction of cardiac output
- More dramatic consequence to the operation is likely if anesthetic plane is not well controlled

Nitrous oxide

- Analgesia from N_2O reduces inhalational anesthetic requirement therefore less cardiovascular depression.
- However, even with 50 % oxygen and 50 % nitrous oxide mixture hypoxemia is common probably due to the nitrous oxide dissolving into gaseous space such as GIT and leading to the V/Q mismatches (the magnitude of this abnormality increases with body size and duration of recumbency).
- Use of this agent is not recommended in this species

Halothane (Fluothane®)

- 1 MAC halothane in cattle is 0.8 %
- Vapor setting is at 5% (2.5-4 % in small ruminants) at induction with oxygen flow at 20 ml/kg/min and is reduced between 1-3 % during the maintenance with oxygen flow at 10 ml/kg/min
- Always administered via endotracheal tube after induction of anesthesia with injectable drugs.
- As anesthesia is deepened by increasing halothane concentration, CO and arterial pressure decrease further. HR usually remains constant.

Isoflurane (Aerrane®, Forane®, IsoFlo®)

- Used to be much more expensive than halothane, but the price has come down substantially for the past few years, so more frequently used
- Quicker anesthetic stabilization and more rapid recovery
- 1 MAC in cattle is 1.3%
- Vapor setting is at 5% (3-4 % in small ruminants) at induction with oxygen flow at 20 ml/kg/min and is reduced between 1.5-3 % during the maintenance with oxygen flow at 10 ml/kg/min
- Isoflurane, similar to halothane, induces a dose-dependent cardiovascular depression.

- Isoflurane causes more peripheral vasodilation than halothane, which is responsible for a low arterial blood pressure, but tissue looks more bright and pinky indicating better perfusion.
- Isoflurane is less prone to cause arrhythmia compared to halothane

Sevoflurane (Ultane®)

- Anesthetic induction, recovery, and intraoperative modulation of anesthetic depths to be notably faster than halothane and isoflurane.
- More expensive than halothane and isoflurane, but it is getting cheaper.
- Sevoflurane (1 MAC = 2.3 %) is less potent than halothane or isoflurane, but more potent than desflurane
- Sevoflurane induces dose-dependent cardiovascular depression to a degree similar to that of isoflurane

Desflurane (Suprane®)

- Lower blood/gas partition coefficient than the inhalants mentioned above, so control of anesthetic depth is relatively quick
- The least potent among the volatile anesthetics in clinical use (MAC = ~8 %)
- Cardiovascular effects of desflurane are similar with those of isoflurane
- Expensive as sevoflurane, and requires electronically controlled vaporizer which adds to the inconvenience

Total Intra-venous Anesthesia (TIVA)

- The triple drip as described above (combination of xylazine, ketamine, and guaifenesin) can be used to induce anesthesia with a single bolus dose, and then to maintain anesthesia using constant rate infusion
- If xylazine and ketamine is used for induction, then, guaifenesin can be combined just with ketamine (double drip) for maintenance (ketamine has a shorter half life than xylazine in cattle)
- These combinations are associated with minimal cardiopulmonary depression. However, there are two main limitations to continued administration of intravenous anesthetics; the arterial oxygenation and prolonged recovery.
- IV anesthesia should not be prolonged beyond 45 minutes in an adult cattle without supplying with oxygen to breathe and means of ventilatory support
- Propofol is non-accumulative, so can be used for prolonged procedure, but very expensive
- Tight anesthetic depth control is harder with TIVA so abrupt awakening during anesthesia is more likely if one is not familiar with the technique (inhalant anesthetic provides advantage in this respect as by monitoring anesthetic concentration in breathing gases, one can control anesthetic depth better)

Monitoring

- Anesthetic monitoring is important to maintain a proper plane of anesthesia and to prevent excessive insult to the cardiovascular, respiratory, and central nervous systems.
- Anesthetic depth can be measured by observation of the following signs: physical movement or jaw chewing in response to stimulation, eye position and degree of muscle tone, and presence or absence of palpebral reflexes etc. There are some differences in the eye position in the ruminants. The eye rotates ventrally as anesthesia deepens rather than rotating rostroventrally and only the sclera is seen (see figure 4); it then rotates centrally during deep anesthesia.

Figure 4 Checking eyeball position to assess anesthetic depth

- Variables used to monitor the cardiovascular system include heart rate, pulse pressure, mucous membrane color, and capillary refill time.
- Direct blood pressure measurement can provide continuous hemodynamic status of the animal and can be easily accomplished through catheterizing the auricular artery.
- The ECG is useful to monitor cardiac dysrhythmias.
- The respiratory system is evaluated by monitoring respiratory rate and volume.
- It can be estimated by observing the emptying of the rebreathing bag of the anesthetic machine during respiratory cycles.
- Pulse oximetry and/or arterial blood gas analysis provide information of ventilatory efficiency
- Ocular reflexes are used to monitor the central nervous system. The palpebral reflex is lost at light planes of anesthesia in ruminants, so it is of little value during anesthesia of these species.
- Ophthalmic ointment should be applied to the eyes during anesthesia to prevent corneal injury.
- Body temperature is an important parameter to monitor during anesthesia. Loss body heat of for anesthetized animals (especially small ruminants) often requires supplemental heat sources to maintain adequate body temperature (100-103˚F).

Perioperative pain management

- Assessment of pain in ruminants can be difficult because of their stoic nature.
- Behavioral changes associated with pain include decreased appetite, sluggishness, indifference to the surrounding, and avoiding human contacts.
- Changes of body temperature, respiratory rate, heart rate, and blood pressure can also be used to assess pain. These signs, however, are not always reliable indicators of pain.
- Due to the difficulty of accurately determining pain levels in ruminants, the routine use of analgesic therapy prior to and following painful or surgical procedures is recommended.
- Several types of drugs have been used to provide analgesia in ruminants including opioids, $\alpha 2$-adrenergic agonists, local anesthetics, and nonsteroidal anti-inflammatory drugs (NSAID's).
- Significant variations exist in regards to duration of action and quality of analgesia provided by these agents.

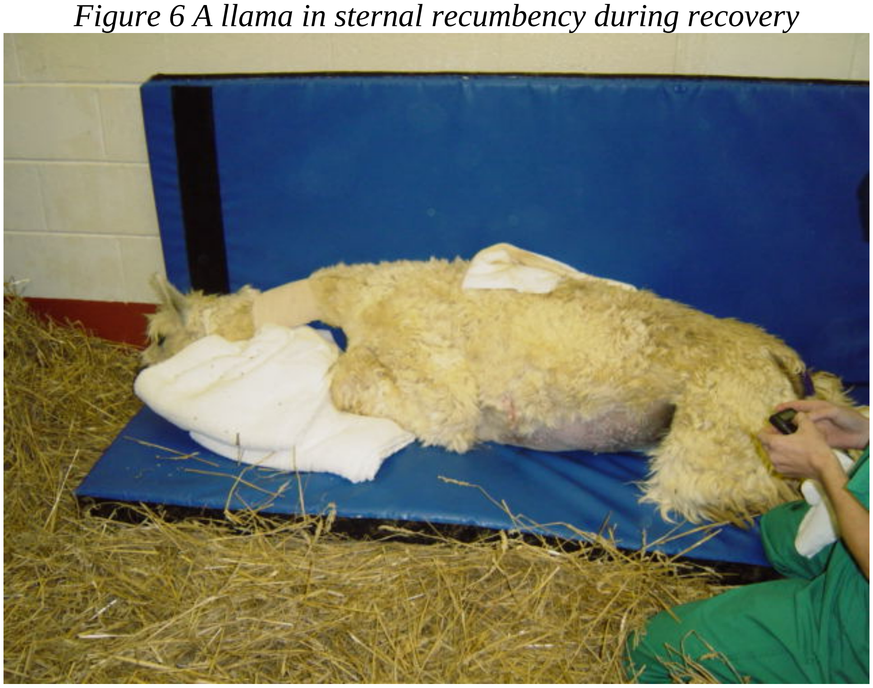
Recovery

- Ruminants seldom attempt to stand up and remain in sternal recumbency until able to stand
- Position in sternal recumbency with a pad placed under the mandible with the mouth end below the level of the larynx to drain saliva/regurgitants and prevent aspiration

Figure 5 Sternal recumbency with the head lowered during recovery

- Regurgitation in ruminants is always a possibility and therefore the ET tube cuff must remain in place as inflated

Figure 6 A llama in sternal recumbency during recovery



- If animal does not show sign of getting light for longer than 20 minutes, reversal can be considered. Tolazoline 0.2 – 1.0 mg/kg can be given titrated to effect IV
- Extubation can be attempted with return of strong swallowing reflex and muscle tone
- Close observation should be continued to avoid the animal returning to sleep and potential danger of developing aspiration until the animal is on its feet

Introduction

- Pigs range in size from small newborns to adult boars weighing about 350 kg, and methods of restraint and for administration of anesthesia must be varied accordingly
- Although pigs are easily trained, handled and restrained, some pigs can be extremely difficult to control
- In general pigs are good subject for general anesthesia. They do not become violently excited, despite loud squeals they produce, and it does not seem to increase the epinephrine release induced dysrhythmias, and the recovery is usually calm.

Figure 7 Pigs may resent human handling and it may present difficulty in effective premedicating

Drug administration

- Intravenous injections are best made into one of the auricular veins in the external aspect of the ear-flap
- The ear vein is not suitable for injecting large volumes of fluids, and surgical cut-down of jugular vein may be necessary
- Cephalic vein can be used although direct visualization is difficult due to skin thickness, but most experienced handlers do well with blind attempts
- For intramuscular injection of drugs neck muscles are usually used. In large pigs (or pot-bellied pig), long needle must be used to have the injected drug to reach into muscle tissue. Rear limb may be preferred injection site in large pigs (or pot-bellied pig) to avoid injecting drugs into the deep fat in the neck

Anesthetic induction

- Just as in other domestic species balanced anesthetic technique is the most common approach
- Combination of alpha 2 agonists with dissociatives IM, IV
  - Xylzine-Ketamine, Medetomidine-Ketamine
  - Much less sensitive to alpha 2 agonists than other species
- Combination of benzodiazepines with disscoiatives IM, IV
  - Ketamine-Midazolam, Ketamine-Diazepam
- Telazol (± Ketamine and Xylazine; Ketamine and Medetomidine) IM, IV
- Thiopental, Propofol IV etc.
- Opioids such as butorphanol or morphine can be added to the above combination to enhance the degree of CNS depression and analgesia, and to spare maintenance agent requirements.

Endotracheal intubation

- Intubation is not easy in the pig.
- The shape and size of the head and mouth make the use of a laryngoscope difficult
- Laryngeal spasm is easily provoked so that intubation must be carried out under deep general anesthesia or with the aid of muscle relaxant or local anesthetic spray
- The size of ET tube when compared to those used in dogs of similar weight is unexpectedly smaller (e.g. 6 mm ID for a 25 kg pig)
- Introduction of the tube may be made easier by using stylet. Malleable metal stylet or plastic urinary catheter can be used
- Laryngoscopes made for man can be suitable for small pigs, but Rowson laryngoscope may be needed for large pigs to expose the larynx to view
- The rima glottis is extremely small and the larynx is set at an angle to the trachea, causing difficulty in passing the ET tube beyond the cricoid ring.
- The induced pig is usually placed in dorsal recumbency with the head and neck extended. The shape of larynx is unique in the pig so that flexing the neck will facilitate when the tube's progress arrested with re-angled tube end.
- When resistance to the advancement of the ET tube is met, the tube is rotated to 180 degree which should effectively introduce the tube beyond the ventral floor of the larynx and allow successful completion of the intubation

Anesthetic maintenance

- Just as in the other domestic species maintenance of anesthesia for prolonged duration is best done with inhalation anesthesia
- Isoflurane, halothane, sevoflurane and desflurane all can be used, although halothane is the least desirable due to malignant hyperthermia.
- In farms, procedures such as C-section can probably be best performed under epidural or regional anesthesia.

Porcine malignant hyperthermia

- Some strains and breeds suffer from a biochemical myopathy which manifests itself during general anesthesia
- Termed 'porcine malignant hyperthermia', this is characterized by development of muscle rigidity, tachypnea, tachycardia, a severe sustained rise of body temperature, hyperkalemia, respiratory acidosis and metabolic acidosis.
- Common breeds affected by this syndrome include heavy muscled show pigs such as Poland-China, Pietrain, Landrace, Large White, Hampshire. Some breeds are less susceptible and include Duroc breed.
- Dantrolene sodium, a skeletal muscle relaxant, given orally in doses of 2 to 5 mg/kg 6 to 8 hours before the induction of anesthesia, may prevent the onset of the syndrome in susceptible pigs and IV in doses of 2 to 10 mg/kg, has proved of some use in treating the established condition

Recovery

- During recovery it is important to keep the pig in warm environment as due to their lack of body hair they are prone to develop hypothermia if left in cold surrounding
- Adequate post-operative pain relief should be provided by opioids, NSAIDs or local anesthetics
- Close observation to the upper airway obstruction must be ensured and any problem attended appropriately.

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