Farm Animal Anesthesia: Cattle, Small Ruminants, Camelids, and Pigs presents practical guidance on using anesthetic and analgesic drugs to prevent pain caused by surgery or disease. This cohesive resource offers complete coverage of anesthetics and anesthetic techniques in farm animals with a focus on practical applications. Providing thorough information on pain management and residues, the book also covers specific techniques for common surgical procedures and considerations for animals with pathophysiological conditions.

The book includes chapters on preanesthetic considerations, anesthetic drugs, chemical restraint and standing sedation, injectable anesthesia, inhalant anesthesia, local techniques, specific procedures, pain management, residues, and euthanasia. Farm Animal Anesthesia is a useful guide for farm animal practitioners, veterinary students, and researchers working with these species.

Key features
- Offers complete coverage of practical uses for anesthetics and analgesics in cattle, small ruminants, camelids, and pigs
- Brings information on sedation and pain management in these species together into a single resource
- Presents difficult-to-find information on anesthetizing camelids and pigs
- Includes information on pain management and residues
- Provides a comprehensive reference for farm animal practitioners, veterinary students, and researchers

The editors
HuiChu Lin, DVM, MS, DACVAA, is a Professor of Anesthesia at the College of Veterinary Medicine at Auburn University in Auburn, Alabama, USA.

Paul Walz, DVM, MS, PhD, DACVIM, is an Associate Professor of Food Animal Medicine at the College of Veterinary Medicine at Auburn University in Auburn, Alabama, USA.

Related titles
Noordsy's Food Animal Surgery, Fifth Edition • 9781118352601
By N. Kent Ames

Turner and McIlwraith's Techniques in Farm Animal Surgery, Fourth Edition • 9781118273234
By Dean A. Hendrickson and A.N. Baird

Pain Management in Veterinary Practice • 9780813812243
Edited by Christine M. Egger, Lydia Love, and Tom Doherty

Visit www.wiley.com/wiley-blackwell
Farm Animal Anesthesia
Farm Animal Anesthesia

Cattle, Small Ruminants, Camelids, and Pigs

Edited by

HuiChu Lin, DVM, MS
Diplomate of American College of Veterinary Anesthesia and Analgesia,
Professor,
Department of Clinical Sciences,
College of Veterinary Medicine,
Auburn University, USA

Paul Walz, DVM, MS, PhD
Diplomate of American College of Veterinary Internal Medicine
Associate Professor,
Department of Pathobiology,
College of Veterinary Medicine,
Auburn University, USA

WILEY Blackwell
For the unconditional support of my father, Pin-Kuo, who passed away in 2010; my mother, Yao-Hwa; and my son, Dow, who have given me support to pursue my dream and to do what I love to do.

–HuiChu Lin

To my wife, Heather, and children, Jacob, Madison, and Kaitlyn, for their encouragement and support and to my veterinary colleagues and students, who have continually provided me inspiration.

–Paul Walz
### Contents

#### 3 Standing sedation and chemical restraint

*HuiChu Lin*

- Cattle 39
- Small ruminants and camelids 42
- Swine 48
- References 57

#### 4 Injectable anesthetics and field anesthesia

*HuiChu Lin*

- Injectable anesthetics 61
  - Ketamine 61
  - Telazol 64
  - Propofol 66
  - Guaiifenesin 68
- Field anesthesia 68
  - Cattle 68
  - Small ruminants and camelids 72
  - Swine 80
- References 87

#### 5 Inhalation anesthesia

*HuiChu Lin*

- Cattle 101
- Small ruminants and camelids 103
- Swine 104
- References 106

#### 6 Perioperative monitoring and management of complications

*HuiChu Lin*

- Perioperative monitoring 111
- Supportive fluid therapy 116
- Positioning 121
- Recovery 123
- Perioperative complications 123
  - Regurgitation and aspiration pneumonia 123
  - Airway obstruction 124
  - Ruminal tympany/bloat 125
  - Salivation 126
  - Hypoventilation 126
  - Cardiac arrhythmias 127
  - Hypotension 128
  - Hypothermia 129
  - Malignant hyperthermia 130
Postanesthetic neuromyopathy 131
Cardiovascular collapse 131
References 132

7 Local and regional anesthetic techniques 136
Misty A. Edmondson
Local anesthetics 136
Anesthesia for dehorning 137
Nasal anesthesia 137
Anesthesia of the eye 139
   Eyelid 139
   Eye and orbit 139
Anesthesia for laparotomy 141
   Proximal paravertebral nerve block 141
   Distal paravertebral nerve block 142
   Inverted-L block 142
   Line block 143
Anesthesia for reproductive procedures 144
   Caudal epidural anesthesia 144
   Continuous caudal epidural anesthesia 146
   Lumbosacral epidural anesthesia 147
   Sacral paravertebral nerve block 148
   Internal pudendal nerve block 149
   Dorsal penile nerve block 150
   Castration 151
Teat anesthesia 152
   Inverted-V block 152
   Ring block 152
   Infusion of teat cistern 152
Anesthesia of the distal limb 153
References 154

8 Anesthetic management for specific procedures 155
Benjamin Newcomer and Paul Walz
Umbilical hernias 156
Wounds, lumps, bumps, and abscesses 157
   Wound management 157
   Ocular squamous cell carcinoma 158
   Enucleation 158
   Entropion 159
   Abscess removal 159
Surgical disorders of the abdomen 159
   Laparotomy 159
   Disorders of the forestomachs 161
   Displacements and volvulus of the abomasum 162
9 Pain management for farm animals

HuiChu Lin

Local anesthetics 177
Systemic pain management 178
  Opioid analgesics 178
  Nonsteroidal anti-inflammatory drugs 183
  Alpha-2 agonists 187
  Ketamine 188
  Gabapentin 188
Drug combinations for pain management 189
  Constant rate infusion 190
Local or regional analgesia 197
  Caudal epidural analgesia 197
  Lumbosacral epidural anesthesia 198
  Intra-articular analgesia 200
References 204

10 Fluid therapy

Paul Walz

General considerations 215
Physiology of body fluids 216
Patient assessment 218
Fluid and electrolyte therapy in the perioperative period 219
  Quantity and rate of fluid administration 220
  Fluid type 221
  Method of administration 224
  Monitoring fluid administration 226
  References 227

11 Regulatory and legal considerations of anesthetics and analgesics used in food-producing animals 228
  Thomas Passler
  Alpha-2 agonists 231
  Barbiturates 233
  Benzodiazepines 233
  Dissociative anesthetics 234
  Local anesthetics 235
  Opioids 236
  Nonsteroidal anti-inflammatory drugs 238
  Phenothiazine derivatives 241
  Propofol 241
  References 243

12 Euthanasia of farm animals 248
  Thomas Passler
  Considerations prior to euthanasia 248
  The process of euthanasia 251
    Methods of euthanasia 251
    Injectable euthanasia drugs 252
    Physical methods 253
    Adjunctive and other methods of euthanasia 257
  Considerations subsequent to euthanasia 258
  References 259

Index 263
Contributing Authors

Dr. Misty A. Edmondson, DVM, MS
Diplomate of American College of Theriogenologists
Associate Professor
Department of Clinical Sciences
College of Veterinary Medicine
Auburn University, USA

Dr. Benjamin Newcomer, DVM, PhD
Diplomate of American College of Veterinary Internal Medicine,
Diplomate of American College of Veterinary Preventive Medicine
Assistant Professor
Department of Pathobiology
College of Veterinary Medicine
Auburn University, USA

Dr. Thomas Passler, DVM, PhD
Diplomate of American College of Veterinary Internal Medicine
Assistant Professor
Department of Clinical Sciences
College of Veterinary Medicine
Auburn University, USA
This book covers both the basic knowledge of commonly used anesthetics and analgesics and practical use of these drugs to prevent farm animal pain caused by surgery and/or disease processes. We hope farm animal veterinarians find this book useful and practical for the anesthetic techniques and pain management aspect of their daily practice. There are few anesthetics and analgesics approved by the Food and Drug Administration. As consumers demand healthy and safe food products, it is imperative that farm animal veterinarians and producers are aware of the regulatory and legal guidelines of extralabel use of these drugs to ensure edible animal products are free of harmful pharmaceutical residues.

My appreciation to my coeditor, Dr. Paul Walz; contributing authors, Drs. Misty Edmondson, Benjamin Newcomer, and Thomas Passler (their chapters make this book a complete book on farm animal anesthesia); illustrators, Kim Crosslin and Katlyn King, for their picture-perfect artworks; and my colleagues, Drs. Fred Caldwell, John Schumacher, and Jennifer Taintor, for reading and editing several chapters of this book.

Special thanks to my mentors, Drs. John Benson, John Thurmon, and William Tranquilli, for laying the foundation during my residency training at the University of Illinois that has benefited me throughout my career.

Most of all, I thank my colleagues in the Food Animal Section of Auburn University for being always kind and helpful; you make my job so much easier and fun.

HuiChu Lin
Chapter 1

Preanesthetic considerations

HuiChu Lin
Department of Clinical Sciences, College of Veterinary Medicine, Auburn University, USA

General anesthesia in farm animals, like cattle, sheep, goats, llamas, alpacas, and pigs, requires special attention due to the uniqueness of the anatomical and physiological characteristics as compared to dogs, cats, and horses. Camelids (llamas and alpacas) only have two forestomachs but are otherwise similar in many ways to cattle and small ruminants. Although some farm animals may cost as much as purebred companion animals, farm animal veterinarians are often faced with economic constraints and a limited number of approved drugs for use in surgical procedures requiring anesthesia. Physical restraint and local anesthetic techniques are most commonly employed to produce immobility and analgesia for these species. Ruminants generally tolerate physical restraint and recumbency well. This, along with local and/or regional anesthetic techniques, allows many minor surgical procedures to be performed in the standing position and under field conditions. General anesthesia is more frequently performed in camelids and swine for even minor surgical procedures due to their intolerance of physical restraint. It is important to remember that farm animals perceive pain no differently than other species; therefore, analgesia for prevention and easing of pain is just as important as it is for companion animals. With surgical procedures requiring general anesthesia, balanced anesthetic technique should be employed to provide narcosis, analgesia, and muscle relaxation, thereby minimizing the stress response induced by surgery and anesthesia. Most of the anesthetics and anesthetic adjuncts commonly used in farm animal practice do not have Food and Drug Administration (FDA) approval for use in ruminants, camelids, and swine [1, 2]. However, per the Animal Medicinal Drug Use Clarification Act (AMDUCA) of 1994, extralabel use of drugs is permitted when animal health is threatened or death may result if not treated [3]. While prevention of violative residues should always be considered, anesthetics are usually used for a short duration, and anesthetized animals are unlikely to be marketed immediately after surgery. Furthermore, anesthetics used today tend to have very short half-lives (t½), and they are potent enough that only low doses are required to produce general anesthesia.
The possibility of an animal carrying anesthetic residues within its edible tissues after the surgical incision has healed, which normally occurs within an average of 14 days, is extremely low. Thus, problems with anesthetic drug residues appear to be rare [4]. Nevertheless, veterinarians should consult the Food Animal Residue Avoidance Databank (FARAD) for meat and milk withdrawal intervals for extralabel use of analgesics, sedatives, and injectable anesthetics as well as for updates of drugs prohibited from extralabel use [1, 2].

Prior to anesthesia, an appropriate patient history including breed, age, sex, condition, and temperament of the patient, and a complete physical examination, are indicated. Due to economic reasons, blood work including complete blood count and chemistry profile is performed only in farm animals with significant systemic diseases and those considered to have a higher anesthetic risk. For example, animals with severe gastrointestinal (GI) abnormalities often suffer extreme dehydration with or without electrolyte alteration, which may require intervention to optimize the patient’s condition with fluid therapy prior to the induction of anesthesia [5]. In healthy animals, total plasma protein and packed cell volume are sufficient indicators of a patient’s hydration status.

Most of the sedatives and general anesthetics cause some degree of cardiovascular depression, which may not be a great concern for healthy patients. However, normal cardiovascular protective mechanisms or reflexes in response to the depressing effects of anesthetics may be obtunded in animals with compromised cardiac function or severe electrolyte imbalances as a consequence of disease conditions. Maintaining balance of concentrations of electrolytes like calcium, sodium, and potassium across the cell membranes is essential in establishing normal cell membrane potential and contractility. Disturbance of these electrolyte balances across cell membranes changes cellular resting membrane potentials and subsequent initiation and propagation of cellular depolarization and repolarization. Acidosis has been shown to cause electrolyte imbalances resulting in decreased myocardial contractility and increased response of the myocardial cells to circulating catecholamines. Therefore, anesthetic-induced cardiovascular depression combined with severe preexisting acidosis and electrolyte imbalances can lead to detrimental side effects like severe cardiac arrhythmias, bradycardia, decreased myocardial and vascular cellular contractility, reduced cardiac output, and hypotension. As a result, anesthetized animals may not be able to maintain adequate cardiac output or arterial blood pressure leading to significantly decreased peripheral tissue and muscle perfusion with subsequent development of severe adverse effects such as irreversible postanesthetic neuromyopathy [6].

Positioning

Ruminants, camelids, and swine are susceptible to complications associated with anesthesia and recumbency. Positioning of these animals, particularly adult cattle, in dorsal or lateral recumbency for surgery allows for the weight of abdominal viscera to shift ventrally and cranially, causing the diaphragm to be pushed further into the thoracic cavity, thereby reducing the functional residual capacity of the lungs (Figure 1.1). As a result, an increased ventilation/perfusion mismatch may lead to significant hypoventilation and hypoxemia during anesthesia. Furthermore, the weight of the abdominal viscera may compress great vessels such as the vena cava leading to decreased venous return, cardiac output, and
arterial blood pressures [7]. Therefore, close monitoring of cardiovascular and pulmonary functions and institution of appropriate treatments to ensure normal arterial blood pressure and adequate ventilation are important parts of perioperative anesthetic management.

**Ruminal tympany**

Ruminal tympany, bloat, regurgitation, and aspiration pneumonia are common problems associated with general anesthesia in farm animal species that should be anticipated and addressed with proper precautions. Ruminal fermentation continues even in anesthetized animals. Postprandial gas production at an average of 30 L per hour has been reported in cattle [8]. Normal, awake animals are able to relieve the gas produced by fermentation through the eructation. Sedatives and anesthetics tend to inhibit GI motility and prohibit eructation, thus allowing gas to accumulate in the rumen. The rumen of an adult large ruminant has a capacity of 115–150 L [9]. An average capacity of 15–18 L has been reported in small ruminants [10]. Bloating, especially in nonfasted animals, can occur during anesthesia and compromise the cardiopulmonary systems by increasing intra-abdominal pressure resulting in compression of the diaphragm and great vessels such as the vena cava in the abdominal cavity, thus further complicating the already compromised cardiopulmonary function resulting from abnormal positioning required by the surgery. Fasting of these animals prior to anesthesia reduces the amount of gas produced by fermentation and minimizes its detrimental effect on the cardiopulmonary systems.

**Regurgitation**

Regurgitation and aspiration of stomach content can occur in farm animal species during anesthesia, especially in nonfasted animals. The risk of regurgitation decreases significantly when water is withheld for 6–12 hours and feed is withheld for 12–24 hours prior
to anesthesia in small ruminants. Pigs are monogastrics. It has been indicated that alfalfa or any type of hay delays gastric emptying time, and vomiting with possible aspiration may occur during induction of anesthesia after a recommended fasting period of 12 hours. Thus, removal of alfalfa or other types of hay from their routine diet should be instituted 2–3 days prior to anesthesia [11].

Domestic ruminants have a large rumen that is usually full of liquid materials, and it does not empty completely even after 24–48 hours of fasting. Regurgitation can occur either during light (active regurgitation) or deep (passive regurgitation) anesthesia in ruminants and camelids in spite of preoperative fasting and withholding of water. Active regurgitation usually occurs during light anesthesia and is characterized by explosive discharge of large quantities of ruminal materials. Passive regurgitation occurs during deeper planes of anesthesia when the esophageal muscles and transmural pressure gradients relax as a result of anesthetic-induced muscle relaxation. If the airway is not protected, a large amount of ruminal materials can be aspirated into the trachea and reach the small airways. Aspiration of acidic stomach fluid causes immediate reflex airway closure and destruction of type II alveolar cells and pulmonary capillary lining cells. Consequently, pulmonary edema and hemorrhage, hypoxemia, and arterial hypotension develop due to loss of alveolar and capillary integrity leading to reflex airway closure, bronchospasm, dyspnea, hypoxemia, and cyanosis. Recovery from aspiration pneumonia depends on the pH and amount of ruminal materials aspirated [10]. Pigs tend to have very acidic stomach fluid with a pH as low as 1.5–2.5 [12], whereas the rumen pH remains within 5.5–6.5 in cattle, sheep, and goats [13] and 6.4–7.0 for C1 of camelids [14]. Thus, the greater impact of aspirating rumen contents lies in the amount of bacterial microflora and solid food materials aspirated. In pigs, the level of acidity of stomach fluid is the primary factor affecting the severity of damage to the pulmonary tissues upon aspiration. Severe consequences like reflex airway constriction, mechanical airway obstruction, and aspiration of bacteriologically active materials can still occur in the presence of a neutral pH in ruminants [10]. Animals may die before an endotracheal tube can be placed to protect the airway in extreme cases. Please refer to Chapter 7 for prevention and treatment of aspiration pneumonia.

Preoperative withholding of feed and endotracheal intubation with an adequately inflated cuff immediately following induction of anesthesia are recommended in all anesthetized farm animals.

Salivation

Ruminants normally salivate profusely during anesthesia. Total amounts of saliva secretion in conscious adult cattle and sheep have been reported to be 50 L and 6–16 L per 24 hours, respectively [15, 16]. In the past, anticholinergics like atropine were used routinely as part of the anesthetic induction regimen in an effort to prevent salivation. However, atropine only reduces the water content of the saliva [17], thus causing the saliva to become more viscous and increasing the potential of airway obstruction, particularly in neonates. If the trachea is left unprotected during anesthesia, large amounts of saliva may be aspirated.
Thus, tracheal intubation with appropriate inflation of the cuff immediately following induction should be instituted to protect the airway. For large ruminants, setting up the surgery table in a way that the head is lower and the throatlatch area is elevated relative to the mouth and thoracic inlet will help drainage and prevent pooling of the saliva and ruminal contents in the oral cavity (Figure 1.2). Placing a sandbag or rolled-up towel under the neck of a small ruminant or camelid patient to elevate the throatlatch so that the mouth opening is lower than the occiput allows saliva to escape, avoiding the potential for aspiration (Figure 1.3). This technique also helps to minimize the flow of passive regurgitation during deep anesthesia [18].

![Figure 1.2](image1.2.png)

**Figure 1.2** Lateral recumbency of an adult bovid; note the elevation of the throatlatch. (Source: Illustration by Kim Crosslin.)

![Figure 1.3](image1.3.png)

**Figure 1.3** Lateral recumbency of a small ruminant; note the elevation of the throatlatch.
Malignant hyperthermia

Malignant hyperthermia, also referred to as porcine stress syndrome, is a genetic disorder that occurs due to mutation of the ryanodine receptors (ryr-1 locus) of the calcium channels in the skeletal muscles [19–21]. The presence of abnormal ryanodine receptors allows a massive amount of calcium to be released from the cells into the sarcoplasmic reticulum resulting in generalized extensive skeletal muscle contraction. Though malignant hyperthermia has been reported in other animal species, pigs and humans seem to be the most susceptible. Certain breeds of pigs like Pietrain, Portland China, or Landrace are very susceptible to this syndrome, while Large White, Yorkshire, and Hampshire, on the other hand, are much less so [22, 23]. The clinical signs of malignant hyperthermia syndrome are manifested in a sudden and dramatic rise in body temperature and end-tidal CO₂ followed by muscle fasciculation, muscle rigidity, tachypnea, tachycardia, arrhythmias, myoglobinuria, metabolic acidosis, renal failure, and often death. The prognosis is usually poor once the episode is initiated. The triggering agents of malignant hyperthermia include stress (e.g., excitement, transportation, or preanesthetic handling), halogenated inhalation anesthetics (e.g., halothane, isoflurane, sevoflurane, and desflurane), and depolarizing neuromuscular blocking drugs (e.g., succinylcholine). Lidocaine and ketamine have been indicated as triggering agents, but there is no evidence to support this theory [24]. Halogenated inhalation anesthetics are known triggers for malignant hyperthermia, and halothane has been indicated to be the most potent trigger [25]. A report in humans demonstrated that in a total of 75 malignant hyperthermia cases, 42 were isoflurane related, 12 were sevoflurane related, 11 were halothane related, and 8 were enflurane related [26]. Further study showed that the augmentation of caffeine-induced contractures of frog sartorius muscle by isoflurane is 3 times and by enflurane is 4 times, whereas by halothane is 11 times [27]. Similarly, halothane appears to be the most potent and most frequently reported trigger of malignant hyperthermia in pigs. Isoflurane has been reported to trigger malignant hyperthermia in susceptible pigs like Pietrain or Pietrain-mixed pigs [28]. Only one incidence of isoflurane-induced malignant hyperthermia has been reported in a potbellied pig [29]. Sevoflurane-induced malignant hyperthermia also has been reported in purebred Portland China pigs [30]. Episodes of malignant hyperthermia induced by desflurane have been reported in Large White, Pietrain, and Pietrain-mixed pigs [28, 31]. There is no report of isoflurane- or sevoflurane-induced malignant hyperthermia in cattle. In 1981, McGrath et al. [32] reported that intramuscular (IM) acepromazine at 1.1 and 1.65 mg/kg reduced the incidence of malignant hyperthermia by 40% and 73%, respectively. A lower dose of 0.55 mg/kg IM was only able to delay but not prevent the onset of the episode [32]. Because of limited availability of effective drugs for treatment, minimizing the stress prior to anesthesia and avoiding using anesthetics that are known triggers are imperative in susceptible animals to prevent a malignant hyperthermia episode.

Differences in sensitivity to anesthetics

Xylazine is a potent sedative, analgesic, and muscle relaxant that is frequently used as a preanesthetic or anesthetic adjunct in farm animal species. Cattle are more sensitive to xylazine than horses, and they require only one-tenth of the dose needed in horses
to produce equipotent sedation [33]. Apparently, there are differences in the level of sensitivity to xylazine among breeds and species of these animals. It appears that Brahmins are the most sensitive, Herefords intermediate, and Holsteins are the least sensitive [34, 35]. Small ruminants are more sensitive to xylazine than cameldids, whereas goats tend to be more sensitive than sheep and llamas are more sensitive than alpacas. Administration of xylazine to pregnant ruminants in the final trimester may cause premature parturition and retention of fetal membranes [36, 37]. In pregnant dairy cows during late gestation, intravenous (IV) administration of xylazine (0.04 mg/kg) resulted in a significant increase in uterine vascular resistance (118–156%) and a decrease in uterine blood flow (25–59%), which were accompanied by a drastic decrease in O₂ delivery to the fetus (59%) [38]. Therefore, the use of xylazine during late gestation in pregnant ruminants is not recommended to avoid detrimental effects to the fetus. Fayed et al. (1989) [39] had observed pronounced and prolonged response when xylazine was administered to cattle under high ambient temperature. Interestingly, cameldids are less sensitive to xylazine than ruminants; thus, higher doses are required to produce a similar degree of sedation in ruminants. In addition, the dose requirement is higher for alpacas than llamas. Compared to other farm animal species, pigs are the least sensitive to xylazine and other α₂ agonists. These drugs when used alone in pigs are not effective in producing adequate sedation. Vomiting has been observed following the administration of xylazine to pigs with digestive disturbances [11]. In addition to α₂ agonists, pigs are also less sensitive to the pharmacologic effects of opioids [40, 41]. Benzodiazepines, for example, diazepam and midazolam, seem to produce reliable sedation in pigs even at doses that do not produce effective sedation in other species [42].

In regard to α₂ antagonists, ruminants and cameldids are more sensitive to tolazoline than other species [43, 44]. When administered intravenously alone at 1.5 mg/kg to nonsedated Holstein calves, tolazoline caused coughing, increased frequency of defecation, and a mild increase in breathing effort. At higher IV doses from 2 to 10 mg/kg, adverse effects including bright red conjunctival mucous membrane, coughing, nasal discharge, profuse salivation, labored breathing, CNS depression, signs of abdominal pain, straining, head pressing, restlessness, and severe diarrhea were observed. However, there were no long-lasting adverse effects observed in those calves [44]. Currently, lower doses of tolazoline at 0.5–1.5 mg/kg IV are recommended for use in all ruminants including cameldids. Others have suggested that IV administration of tolazoline should be avoided, except in emergency situations, to prevent adverse effects such as cardiac asystole [45].

There are concerns from potbellied pig owners and breeders regarding the statement that “injectable anesthetics should not be used in young pigs” and that “ketamine in particular should not be used in potbellied pigs of any age” [46]. These statements have never been proven or supported by controlled, scientific studies. Furthermore, the clinical experiences of this author and of most practicing veterinarians indicate otherwise.

Ruminants recover gradually but smoothly from Telazol anesthesia as a result of the slower metabolism and longer-lasting effect of zolazepam [47, 48]. Pigs, on the other hand, often experience prolonged and stormy recovery characterized by swimming and paddling with repeated attempts to right themselves when recovering from Telazol anesthesia, similar to that observed when ketamine was used alone [42, 49]. Studies have shown that tiletamine and zolazepam are both eliminated slower in pigs than in other species [49] and tiletamine apparently outlasted zolazepam in pigs [47].
Preanesthetic preparation

When possible, adult cattle should be fasted for 24–48 hours and water withheld for 24 hours before induction of anesthesia. Small ruminants, camelids, and swine should be fasted for 12–24 hours and water withheld for 8–12 hours before induction of anesthesia. Preanesthetic fasting may not completely prevent regurgitation, but it will decrease the amount of solid matter in the rumen content. Fasting also does not prevent bloating during anesthesia, but it reduces the rate of fermentation, thus reducing the amount of gas formation, the severity of bloating, and its effect on ventilation. Removal of alfalfa or other types of hay from their routine diet should be instituted 2–3 days prior to anesthesia to avoid prolonged gastric emptying time caused by this type of diet [11]. A shorter fasting period of 6–8 hours is sufficient for pigs undergoing most elective surgeries due to rapid intestinal transport times in the upper GI tract and less time required to empty the stomach [50]. Ruminants are born without a developed forestomach system and thus can be treated as monogastrics until 3 weeks of age [51]. Fasting of young ruminants less than 4 months old is not recommended because of the potential for hypoglycemia and prolonged recovery. Fasting may not be possible under emergency situations, and precautions should be taken to avoid aspiration of gastric fluid and ingesta. Prevention of regurgitation and aspiration of ruminal content can be achieved effectively by placing the animal in sternal recumbency and endotracheal intubation instituted immediately following induction. However, some practices may induce anesthesia with adult cattle already strapped to the table and in lateral recumbency. In this case, it is even more important to ensure animals are under an adequate plane of anesthesia to prevent stimulation of active regurgitation and allow immediate intubation. Regurgitation does not occur in pigs as commonly as in ruminants. However, vomiting can result from nonfasting prior to induction of anesthesia and following administration of xylazine. In general, removal of hay or alfalfa and withholding food for 12 hours and water for 6–8 hours the night before anesthesia should be sufficient for most elective surgeries [23].

In adult cattle, a 14-gauge and 2- to 3-in. needle is placed in the jugular vein for administration of IV anesthetics for induction of anesthesia and for maintenance of fluid therapy. A 14-gauge, 5¼-in. indwelling catheter can be used if postoperative IV medication or fluid therapy is needed. Cutdown of the skin at the catheterization site may be helpful to facilitate insertion of the catheter. A 16- or 18-gauge catheter is appropriate for younger animals. The technique for IV catheterization in sheep and goats is similar to that used in calves. Venipuncture can be difficult in camelids because they have thick fiber coats and neck skin and, a less-apparent jugular groove. The jugular vein lies deep to the sterno-mandibularis and brachiocephalicus muscles, ventral to the cervical vertebral transverse processes, and superficial to the carotid artery and vagosympathetic trunk within the carotid sheath for most of its length [52–56]. The jugular vein of camelids is not always visible even after occlusion of the vessels, particularly in adult males. The right internal jugular vein is the best choice for catheterization in these animals. A 14- or 16-gauge indwelling catheter is appropriate for adult camelids, and an 18-gauge catheter is suitable for younger animals. Catheters should be secured with suture or bandage. Skin cut down with a #15-scalpel blade or a sharp 14-gauge needle is helpful in passing the catheter into the vein [57]. An ear vein can be an alternative site for IV injection using a 25-gauge...
needle or butterfly catheter to deliver a small volume of chemical restraint drugs in camelids. Also, camelids have four or five jugular valves that prevent flow of venous blood into the head when they lower their head during grazing. These valves may occlude the IV catheter and prevent backflow of the blood into the catheter, giving a false impression that the catheter may not be correctly placed in the vessel.

In swine, IV injection poses a greater challenge than in other species because pigs resist restraint and they have very few superficial veins accessible for IV injection or catheterization for administration of drugs or fluid therapy. In Vietnamese potbellied pigs, IV catheterization has been even more difficult because they have small ears with small vessels and their skin is usually dark colored. In large adult pigs with proper restraint, a central dorsal ear vein can be used for IV injection and/or catheterization. An 18- or 20-gauge, 1- to 1½-in. hypodermic needle or butterfly catheter can be used for large adult pigs. A 21- or 23-gauge butterfly catheter will be suitable for smaller-sized pigs with small ears. This author prefers a butterfly catheter because it has a shorter needle and tends to stay in the vessel better than hypodermic needles, especially when the animal struggles during injection. Shorter needles are easier to hold in place and decrease the chance of perivascular injection. IM injection of anesthetics or anesthetic combinations to pigs has been shown to produce short-term anesthesia effectively. Always keep in mind that pigs have a thick subcutaneous layer of fat, and thus, to ensure the drug is deposited into the muscle, a longer needle (>1½ in. for large, mature pigs; 1 in. for piglets) should be used.

Tracheal intubation is somewhat difficult in ruminants, camelids, and pigs. Blind intubation as in horses is less likely to be successful. For large ruminants, this author’s preference is to use digital palpation to guide the endotracheal tube into the trachea immediately following induction of anesthesia with the animal in either sternal or lateral recumbency (Figure 1.4a). Another technique involves use of a stomach tube as a stylet with the aid of digital palpation to place the stomach tube in the trachea; the stomach tube then serves as a guide tube (Figure 1.4b). The endotracheal tube is threaded into the trachea and the stomach tube removed once the endotracheal tube is in place. Intubation should be performed immediately after induction. In calves, intubation is easier when placing the animal in sternal recumbency and an assistant pulls the mouth open by placing a loop of gauze around the upper jaw and a second loop around the lower jaw and tongue. An assistant should lift the head and keep the head and neck in a straight line to allow visualization of the epiglottis and the larynx. If the larynx cannot be visualized, the neck should be extended further. A long laryngoscope blade (250–350 mm) can be used to suppress the tongue base and epiglottis to enable visualization of the larynx. A guide tube or stylet (preferably a 10-French, 22-in.-long polyethylene canine urethral catheter that is three times the length of the endotracheal tube) can be used (Figure 1.5). A cuffed endotracheal tube will prevent regurgitation and aspiration of ruminal contents, and the calf should be maintained in sternal recumbency until the cuff is inflated.

Intubation is more difficult in small ruminant and camelids as compared to large ruminants and other animal species because their mouths do not open widely, the intermandibular space is narrow, and the laryngeal opening is distant to the thick base of the tongue (Figure 1.6). In camelids, the presence of glottal folds adds to the difficulty in visualizing the epiglottis. The technique used for tracheal intubation of small ruminants and camelids
Figure 1.4  (a) Intubation in an adult bovid using digital palpation technique: A, trachea; B, epiglottis; C, endotracheal tube/guide tube; and D, wedge. (b) Intubation in an adult bovid using a guide tube technique: A, trachea; B, epiglottis; C, guide tube; and D, wedge. (Source: Illustration by Kim Crosslin.)

Figure 1.5  Guide tube/stylet and laryngoscope used for endotracheal intubation for small ruminants, camelids, and pigs.
is similar to the technique used in calves. It is easier when the animal is placed in sternal recumbency immediately after induction of anesthesia. Intubation is best accomplished with the help of a guide tube/stylet and long-bladed laryngoscope (250–350 mm) as described for intubation in calves. Hyperextending the animal’s neck helps visualization of the larynx (Figure 1.7). The method makes endotracheal intubation in small ruminants and camelids much easier to achieve than with other methods. A cuffed endotracheal tube should be used to provide an adequate seal between the tube and the tracheal mucous membrane so to prevent aspiration of saliva and regurgitated ruminal contents. The animal should be maintained in sternal recumbency until the cuff is inflated. Blind intubation, similar to that used in horses, has been used for intubation in sheep and goats; however,
it may require multiple attempts in order to successfully place the endotracheal tube in the trachea. Another technique described as *stick intubation* has been used effectively at Auburn University. With the animal in lateral recumbency, a small-diameter rod made of wood or stainless steel can be used as a stylet to stiffen the endotracheal tube. One hand occludes the esophagus, and the other hand manipulates the endotracheal tube into the trachea (Figure 1.8). Care and gentle maneuvering should be used to prevent initiating laryngeal spasm and to minimize trauma to the oral mucous membrane.

Similar to small ruminants and camelids, pigs’ mouths cannot be opened wide, the epiglottis is often entrapped behind the soft palate, and the small larynx slopes downward creating a sharp angle to the tracheal opening (ventral floor fornix) (Figure 1.9). Laryngeal spasms are easily elicited by repeated attempts at tracheal intubation. Vomiting can also occur if attempting intubation while the pig is under a light plane of anesthesia, especially when the animal is not appropriately fasted prior to anesthesia. Spraying a small amount of local anesthetic to desensitize the larynx will reduce the potential for laryngeal spasm. In larger or adult pigs, tracheal intubation is easier to accomplish with the pigs placed in sternal recumbency. Using the same technique as in small ruminants and camelids, with the aid of laryngoscope and guide tube/stylet, the epiglottis and laryngeal aperture can be visualized. Be aware of the sharp angle between the larynx and tracheal opening; it is helpful to apply some pressure to the end of the endotracheal tube as it enters the larynx. This technique keeps the tip of the tube slightly elevated and enables passing the sharp angle to enter the trachea. Another helpful tip for successful endotracheal intubation in pigs is to spin the tube 180° or in a screwlike fashion and advancing it in a dorsal direction while the tube passes through the arytenoid cartilages into the trachea [58].

Figure 1.8 “Stick intubation” (blind intubation) in anesthetized goats.
It is important to understand the anatomical and physiological differences of ruminants, camelids, and pigs as compared to other species. Veterinarians should incorporate this knowledge with proper preanesthetic preparations and appropriate perioperative management to ensure successful outcome of anesthesia in these animals.

References