Sedation and General Anesthesia in Ruminants

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Introduction

There is nothing magical about anesthesia for animals classed as Food Producing species. Generally, they will respond to anesthetic drugs in the same way as the dog or cat, and satisfactory anesthesia can be accomplished with the same drugs that are used in small animal practice, given the appropriate preparation, equipment, and time. However, confusion remains as to the "best" anesthetic technique, e.g., for a bull for penile surgery or a goat for cystotomy. In a practice situation, the major drawback to the administration of an anesthetic is cost. Often the economic value of the animal is insufficient to warrant utilization of expensive drugs or to promote acquisition of necessary equipment; anesthetic machines, surgery tables, and monitoring devices. Consequently, anesthesia becomes a question of which is the simplest, most economical, and safest technique that will allow surgery to be performed. It is difficult to recommend specific anesthetic techniques. While pitfalls can be pinpointed, precautions suggested, and pharmacological actions of drug combinations described, the practitioner must make these choices depending on the value of the animal and the availability of equipment.

This article is concerned with the most frequently encountered problems associated with sedation and/or anesthesia in ruminants and gives recommendations to reduce or eliminate the risk of these problems during subsequent surgery or surgical procedures. Further, types and effects of sedatives and general anesthetics which are used routinely are also considered.

Potential Problems

A. Regurgitation and pulmonary aspiration
B. Bloat, influencing adequacy of ventilation
C. Inadequate oxygenation in the adult bovine
D. Injury in the perioperative period

A. Regurgitation. Regurgitation of rumenal contents and subsequent pulmonary aspiration is always a potential hazard of heavy sedation or general anesthesia in the ruminant.

During rumination in the conscious animal, vagal activity produces reticular contraction forcing ingesta against the cardia while reflux into the pharynx is dependent upon an intact parasympathetic nervous system to the pharyngoesophageal sphincter and esophagus. Atropine may reduce the incidence of regurgitation by reducing reticular contractions. However, the risk of regurgitation is more influenced by the relaxing effect of anesthetic drugs on the pharyngo-esophageal and gastro-esophageal sphincters. Experimental data indicate that the pharyngo-esophageal sphincter is the most resistant barrier,[1] but clinical experience has demonstrated that some sedatives, especially xylazine,[a] and all general anesthetic drugs depress pharyngeal tone (i.e. the swallowing reflex) in varying degrees. The most important factor, therefore, becomes the degree of pressure inside the rumen. The most effective method of maintaining low rumen pressure and decreasing the incidence of regurgitation is to reduce the volume of rumenal contents. This can be accomplished by withholding food for 36 hours and water for 6-8 hours prior to the procedure. The adverse effects of withholding food for this period of time are apparently minimal in the healthy animal. Mitchell and Williams have reported that only a mild metabolic alkalosis occurred in sheep following 48 hours of starvation.[2]

Forceful regurgitation sometimes occurs on induction of general anesthesia. Typically, in a lightly anesthetized patient, this occurs during intubation of the trachea. It is probable that stimulation of the larynx causes the glottis to close and inspiration during this time results in a strong negative intra-thoracic pressure. This pressure difference causes rumenal contents to enter the esophagus and initiates peristaltic waves which move the material towards the pharynx. Esophageal contractions are easily observed and warn of impending regugitation. Alternatively, coughing, stimulated by laryngeal manipulation during intubation, also may initiate regurgitation through an acute rise in rumenal pressure. Clinical impression suggest that a lower incidence of regurgitation occurs if *surgical* anesthesia is induced in the ruminant before endotracheal intubation is performed. Regurgitation while an endotracheal tube is in

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[a] Xylazine, Bayer

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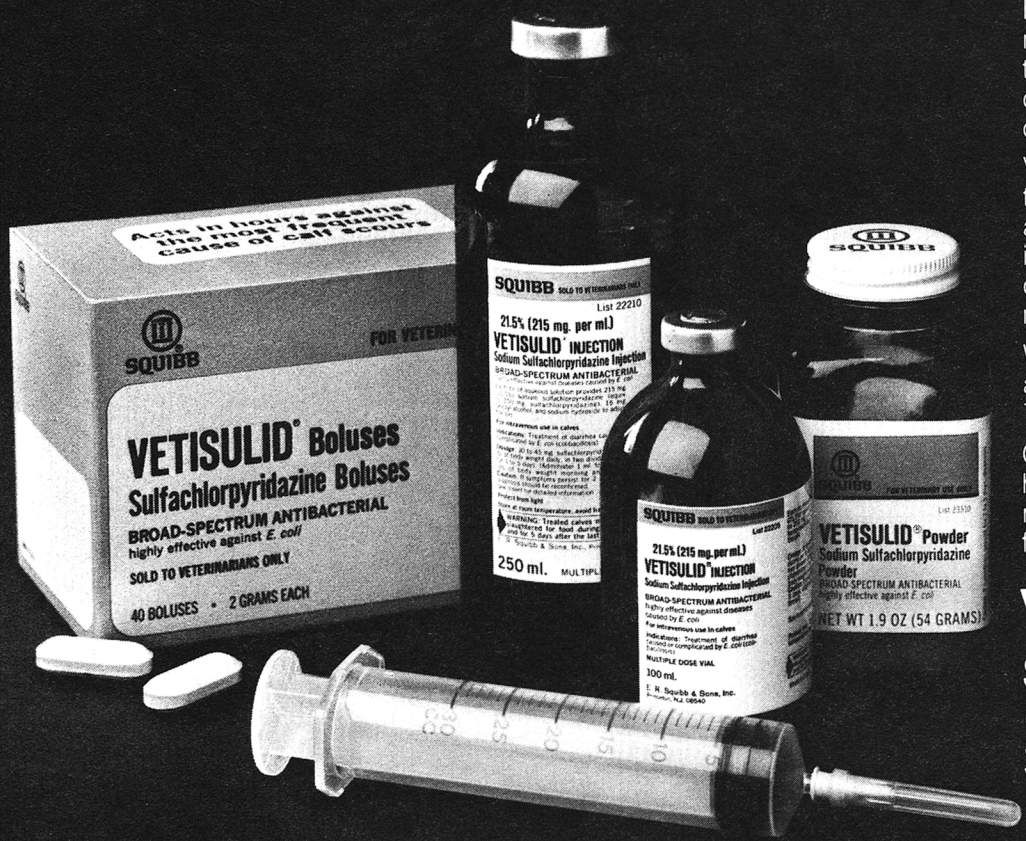

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place is of little concern provided that the pharynx is cleared and drained and the nasal cavity flushed prior to extubation.

Recommendations: To prevent or reduce regurgitation and pulmonary aspiration, management of the ruminant under heavy sedation or general anesthesia must include 1) prior withholding of food for 36 hours and water for 6-8 hours, 2) endotracheal intubation even though anesthesia is maintained with injectable agents, 3) positioning the head with the nostrils lower than the larynx to allow free drainage of saliva and regurgitated fluid, and 4) avoid moving the animal once it is anesthetized. Regurgitation and aspiration occurring in the anesthetized adult bovine as a result of rolling it over leaves the veterinarian liable for negligence.[3]

B. Bloat and Ventilation. The decrease in intestinal motility which results from atropine administration, sedation, or general anesthesia permits gas from bacterial fermentation to accumulate. If food has not been withheld, distension of the rumen will be evident within one hour. The increased pressure of the rumen on the diaphragm severely interferes with ventilation. The magnitude of this problem is illustrated in Figure 1 which depicts a three-month-old 100 kg Holstein calf which had been anesthetized for one hour with only halothane in 100% oxygen. The animal had not been starved. Analysis of an arterial blood sample at this time showed a pH 7.14, pCO_2 75 mmHg and pO_2 86 mmHg. Normal values are pH 7.40, pCO_2 40 mmHg and pO_2 500-600 mmHg. Thus the animal had a severe respiratory acidosis and the oxygen level, although adequate, was dramatically below the value normally expected on 100% oxygen. This degree of ventilatory embarrassment may have resulted in death of the animal due to hypoxia if it had been breathing air (21% oxygen).

Recommendations: To prevent or reduce the incidence of bloat and impaired ventilation, food should be withheld for 36 hours.

Treatment: It is important to prevent bloat occurring since passage of a stomach tube rarely achieves successful decompression due to blockage of the tube with ingesta.

C. Inadequate oxygenation in the adult bovine. Inadequate ventilation may result from respiratory depression induced by anesthetic drugs and from restricted diaphragmatic movement by bloat. In addition, in the adult bovine inadequate oxygenation may be produced by *ventilation-perfusion mismatch.* The width of the thorax produces a considerable gravity effect on cardiac output, causing a greater proportion of the blood to be delivered to the ventral lung (Figure 2). Pressure of the abdominal contents on the diaphragm and restriction of inflation of the adjacent lung is greatest in the bottom half of the animal. Consequently, poorly oxygenated blood from the ventral lung mixes with well oxygenated blood from the upper lung but the disparity in volumes results in a lower than normal systemic oxygen value and increased carbon dioxide retention. A more detailed discussion of the ventilation-perfusion mismatch has recently been presented by Soma.[4]

Recommendations: To minimize ventilation-perfusion mismatch, 1) withhold food for 36 hours to reduce the weight of abdominal contents on the diaphragm, 2) maintain a good cardiac output and arterial blood pressure by avoiding large doses of sedative or tranquilizers and by maintaining a light plane of general anesthesia.

Treatment: In the absence of an anesthetic machine, oxygen can be administered by a small stomach tube passed through the ventral nasal meatus or into an endotrachael tube. Adequate oxygenation can usually be maintained in the face of moderate ventilation-perfusion mismatch by delivering 15-25 L O_2/minute into the pharynx or 10-15 L O_2/minute into the trachea.

D. Injury. Injury which might occur during induction of anesthesia as a result of an awkward fall from standing position to recumbency can be avoided by first casting the animal with ropes while muscle tone is still present. Tilting surgical tables and rotating chutes also offer ideal means of restraint.

The most frequent type of injury is forelimb lameness which is manifested upon recovery from sedation or general anesthesia. The lameness is due to radial nerve damage and/or myositis caused by ischemia during the period of recumbency. The clinical appearance of lameness due to radial nerve damage is illustrated in Figure 3. A 310 kg Holstein bull was anesthetized for one and one-half hours in right lateral recumbency for radiography with thiopental and halothane. Upon recovery, the bull was unable to extend the forelimb and had lost conscious proprioception of the foot. The limb was unable to bear weight during the following 36 hours. Damage to the radial nerve usually occurs where the nerve passes around the shoulder joint or lies in the musculo-spiral groove of the humerus. Myositis invariably involves the triceps brachii muscles but may also include the deltoideus, pectoral, or brachchiocephalicus muscles. Clinical experience indicates that a high incidence of radial nerve damage and/or myositis exists when an anesthetized animal lies for any length of time with the underneath forelimb directed caudally such that the weight of the animal is borne on the point of the shoulder. In this position the brachial blood vessels are compressed, reducing blood flow through the brachial artery and preventing venous outflow from the limb. Low systemic arterial blood pressure induced by anesthetic agents and local compression of capillaries from the weight of the animal further contribute to the reduction in tissue oxygen supply and subsequent ischemia.

Recommendation: To prevent forelimb lameness occurring in animals receiving heavy sedation or general anesthesia, 1) the lower forelimb must be pulled forwards. The upper limbs should be lifted with ropes, boxes, or straw bales to allow unimpeded blood flow through the brachial vessels. This position will relocate the center of gravity more dorsally on the thorax and relieve pressure on the triceps muscles. Air bags, inflated tire inner tubes, and foam pads can be helpful for redistributing body weight but must be combined with correct positioning. 2) Use the smallest dose

of sedative or anesthetic agent necessary to complete the procedure in order to maintain cardiac output and good perfusion pressure.

Treatment: The lameness usually resolves within a few days, but management of the animal can be difficult in the initial recovery period to avoid further injury from incoordination. Movement must be restricted to minimize the oxygen demands of the damaged tissue. When the radial nerve is damaged, the fetlock and carpus should be bandaged for protection and additionally, a Robert-Jones bandage may provide some support. In heavy animals, the opposite forelimb also requires bandaging for support. When myositis is accompanied by swelling and edema, furosemide[b] may speed resolution.

Sedatives and Anesthetic Drugs

It is no longer possible to administer a drug to an animal without considering its long term effects. Considerable emphasis has been placed on the control of antibiotic and other drug administration to animals intended for food to limit possible adverse reaction in people.[5] Drugs used to produce anesthesia should be administered with equal care as some drugs (chloral hydrate, phenothazines, xylazine, diazepam, and the barbiturates) will pass into the milk. In addition, drugs present in the meat may retain activity if the meat is only partially cooked (rare beef) or, in fact, may not be deactivated by heat. Consequently, detoxification of some drugs has been investigated in depth and the time for total excretion from the body has been determined. These drugs have been approved by the FDA for use in animals intended for human consumption and generally the manufacturer includes information with the product concerning the appropriate waiting time before slaughter. There are, however, a number of drugs and drug combinations commonly used in ruminants about which this information is not available.

This article will continue by discussing some commonly used anesthetic drugs in ruminants and combine information on pharmacological actions with recommendation for administration.

Chloral Hydrate. In 1875 Humbert first used chloral hydrate in horses and it is still used successfully for sedation or basal narcosis in both horses and cattle. The chief advantage is its ability to produce good sedation with a low risk of sudden movement. In addition, the drug is relatively inexpensive.

Chloral hydrate is reduced in the blood and liver to trichlorethanol, which is responsible for the sedation. This compound is slow to cross the blood brain barrier and therefore full sedative activity is not achieved for a minimum of five minutes. There is less risk of over-dosage if chloral hydrate is infused slowly intravenously over several minutes rather than given as a bolus injection. Slow infusion is more easily performed with a 7.5% solution. Chloral hydrate is irritating to tissues and will cause sloughing if it leaks into perivascular tissues. A cow will require 4-7 G/100kg if she has received no previous medication and depending upon her physical status and the desired effect. The duration of effective sedation from a single administration is 30-40 minutes. Investigations in man have demonstrated that chloral hydrate is metabolized primarily to trichlorethanol which is subsequently conjugated with glucuronic acid and excreted in the urine and in bile. Distribution of chloral hydrate includes passage into milk and the fetus.[6] Metabolites of chloral hydrate continue to accumulate in the body for at least two days.

The greatest danger from chloral hydrate lies in its effect on the cardiovascular system. Large doses of chloral hydrate causing recumbency and basal narcosis produce severe myocardial depression, hypotention, and respiratory depression. These effects are especially severe in the patient with pre-existing depression or hypovolemia, such as often accompanies abomasal torsion or displacement. Ventilation and blood pressure are little affected at low doses of chloral hydrate in the healthy animal.

The *phenothiazine derivatives* used in veterinary medicine are many and widely used, (e.g. promazine,[c] acetylpromazine,[d] trifluprom azine,[e] diethylisobutrazine[f]). A few are licensed for use in ruminants. The phenothiazine derivatives are useful both for tranquilization and for premedication to general anesthesia. The central nervous system effects are referred to as ataractic or neuroleptic. This is a condition where spontaneous movements and complex behavior are suppressed, but spinal reflexes and unconditioned nociceptive-avoidance behaviors remain intact. The patient is disinterested in the environment but easily aroused. Additionally, although deaths have occurred from the administration of phenothiazines to depressed, hypovolemic patients, the lethal dose in healthy animals is amazingly high. Several beneficial effects are obtained from using phenothiazines for premedication: a) analgesia is potentiated and frequency of spontaneous muscle movement lowered, b) an anti-arrhythmic effect is exerted on the heart, and c) subsequent doses of anesthetic agents are reduced, thus increasing the safety margin for anesthetic overdose.

Some of the phenothiazine derivatives are available in granular form for incorporation into feed which facilitates sedation of an animal without stress of restrain or injection (promazine, diethylisobutrazine). Parenteral dosage is considerably less since intramuscular injection can increase the availability of an active drug by 4 to 10 times over oral administration. Dosage varies according to purpose and

[b] Lasix, Hoechst

[c] Sparine, Wyeth
[d] Acepromazine, Ayerst
[e] Vetame, Squibb
[f] Diguel, Jen-Sal

required effect. Acetylpromazine, although not licensed for use in animals for human consumption in the United States, is probably the most commonly used drug because of its reputed greater reliability. Tranquilization can be achieved with acetylpromazine at 0.05-0.2 mg/kg (2.5-10 mg/100lb) IM or 0.05 mg/kg (maximum 25 mg) IV. The low dosage is recommended for preanesthetic medication. **Phenothiazines must not be used concurrently with organophosphate treatment and a minimum of one week should be allowed to elapse following use of organophosphates before the animal is anesthetized.** It is reported that milk taken within 10 hours after intravenous injection or within 24 hours of intramuscular injection must not be used for food. Also, sheep intended for human consumption must not be slaughtered for at least 3 days and cattle for at least 2 days.

The phenothiazines cause systemic arterial hypotension through direct depression of the central nervous system and the myocardium and peripheral vasodilation by alpha-adrenergic blockade: The degree of depression is dependent on dose and on dose of concurrently used anesthetic drugs.

Xylazine was first described by Sanger in 1968 and its use in cattle and horses was reported by Hall in 1969. Presently, xylazine is extensively used in cattle in Europe and became licensed for use in cattle in Canada in 1979. In the United States the drug is not yet approved for use in animals intended for human consumption. Xylazine is extremely useful in large animal practice because it produces excellent patient sedation and good muscle relaxation.

Xylazine is rapidly absored following intramuscular injection and produces good sedation within ten minutes. Onset of sedation occurs within one minute following intravenous injection. An important species difference exists in sensitivity to xylazine. The ruminant requires one-tenth of the dose needed to sedate the pig or horse. Xylazine 0.05 mg/kg (0.25 ml/1000 lb) given intramuscularly will usually produce light sedation in the bovine and higher dosages of 0.1-0.2 mg/kg (0.5-1.0 ml/1000 lb) IM will produce heavy sedation and recumbency. Pharyngeal and laryngeal reflexes are depressed or abolished at this level and care must be taken to prevent aspiration pneumonia. Endotracheal intubation is easily accomplished under 0.2 mg/kg xylazine which facilitates transfer to inhalation anesthesia without the addition of barbiturate or ketamine. Similar effect can be obtained with this dose in mature goats (0.1 ml/100 lb). Kids and sheep are satisfactorily sedated with the much lower dose. (Use of Small Animal rompun 20 mg/ml avoids overdose.) Unexpected deaths have been encountered in sheep following the use of xylazine. In many cases, death was associated with patient debilitation, hypovolemia and consequently decreased tolerance of anesthetic drugs. Since xylazine has been documented to cause marked cardiovascular changes, it could easily precipitate circulatory collapse. Xylazine is metabolized by the liver and the majority excreted in the urine. Experimental studies in which xylazine 0.33 mg/kg was administered intramuscularly to cattle demonstrated that residues in milk were reduced to 0.01 ppm at 60 hours after injection and that at 72 hours the total residue in all tissues was less than 0.1 ppm.[7]

Xylazine administration results in a bradycardia and approximately a 30% fall in cardiac output. Second degree heart block lasting about 10 minutes has been reported in the horse and dog, and in one out of 3 calves in one investigation.[8] The heart block can be detected by auscultation and if the xylazine has been given as a premedicant to general anesthesia it is advisable to wait until normal cardiac rhythm is restored before additional anesthetic drugs are injected. Blood pressure is maintained within acceptable limits due to intense peripheral vasoconstriction. Unfortunately the vasoconstriction results in blanched mucous membranes which eliminate their use as a monitoring aid to evaluation of tissue oxygenation. Heavy sedation produced by xylazine administration causes some respiratory depression unassociated with recumbency. In one investigation in which eleven cows (food and water previously withheld for 12 hours) received xylazine 0.3 mg/kg IM, the arterial pO_2 fell by 25% and the pCO_2 increased by 18% when the animals were in lateral recumbency.[9] These changes were slightly less when the cows were supine. No adverse changes in pO_2 and pCO_2 values were demonstrated when the same animals were cast, unsedated, in the supine position. In another study the effects of lateral recumbency and milk xylazine sedation (0.05 mg/kg IM) were evaluated in non-fasted sheep.[10] A fall in PaO_2 was measured when both non-sedated and sedated sheep were placed in lateral recumbency. No change in $PaCo_2$ was obtained. This information indicates that low doses of xylazine are not respiratory depressant but that considerable ventilation-perfusion mismatch will occur with recumbency related to the full gastrointestinal tract.

Rapid onset of hyperglycemia after xylazine injection in cattle has been reported with a 200% increase in plasma glucose and a 400% increase in hepatic glucose production.[11] [12] Xylazine also produces a marked increase in urine production, possibly in response to the hyperglycemia. A six to eight fold increase in urine production has been described in adult cows receiving 0.1-0.2 mg/kg xylazine intramuscularly.[13] Clinical observation of sheep and goats receiving xylazine suggests a similar effect in these species. Careful consideration should be given, therefore, before the use of xylazine in animals with urethral obstruction.

Administration of xylazine results in rumenal atony and bloat within a short time. The period of decreased gastrointestinal motility may well be responsible for the self-limiting diarrhea seen 12 to 24 hours following xylazine administration.

General anesthesia can be induced and maintained in ruminants with either barbiturates, ketamine or the inhalant anesthetic agents. However, the safety and course of anesthesia can be altered by the addition of tranquilizers, sedatives, narcotics or muscle relaxant drugs.

Barbiturates. The thiobarbiturates, thiopental[g] and thiamylal,[h] are used widely in veterinary practice because they are predictable and, in practiced hands, safe to use. Also, induction of anesthesia is rapid and atraumatic. Slightly more thiopental than thiamylal is required to produce anesthesia but the method of administration and the signs of anesthesia are identical. Use of pentobarbitol[i] has largely been discontinued due to unacceptably long recovery period. An exception to this general rule is the sheep, in which the rate of metabolism of pentobarbital is approximately three times that in other species. Pentobarbital produces a convenient duration of action without an unduly prolonged recovery in the sheep.

Anesthesia in sheep, goats and calves (up to 150 kg/300 lb) can be produced by intravenous administration of thiopental (10-20 mg/kg; 2.5% solution 1-2 ml/5 lb or 5% solution 10-20 mls/100 lbs) or thiamylal (6-12 mg/kg). The low dose is given as a bolus and additional drug injected in increments to achieve the desired effect. Prior sedation will reduce these dosages. The adult bovine can be anesthetized with thiopental (1 G/100 kg., 1 G/200 lb) or thiamylal (1 G/150 kg, 1 G/300 lb) with an initial maximum dose of 5 G and 3 G respectively. Less barbiturate can be used with less cardiopulmonary depression if glyceryl guaiacolate[j] (GG) is employed. Two grams of either thiopental or thiamylal are added to each liter of 5% GG and the mixture given intravenously to effect. In the unsedated animal approximately 2 ml/kg up to 500 kg (1 liter/1000 lb) bodyweight will be needed. The amount required for animals over 500 kg, especially bulls, is often much less (one-third to one-half). Muscle relaxation will become apparent at half this dose and the animal will become recumbent. Administration is continued until full immobilization is achieved. Duration of action is about 20 minutes, but additional solution can be given to prolong immobilization.

Awakening from an anesthetic dose of a thiobarbiturate is due mainly to redistribution of the drug from the blood and brain into well perfused organs and muscle. Metabolism by the liver partially contributes to the initial reduction in plasma thiobarbiturate levels. The rapid metabolism allows a very short waiting time before slaughter, even as short as 24-48 hours. Awakening form pentobarbital, in contrast, is due primarily to hepatic metabolism while the effect of redistribution is less significant. The liver enzyme in the fetus and neonate have activities between 25% and 100% of those found in adult animals. Metabolism of barbiturates does not reach the adult levels for up to 8 weeks and, clinically this is manifested in the young animal as a slow return to mobility after the anesthesia. Frequently poor appetite and lethargy last several days after anesthesia. As a rule of thumb, barbiturates should not be used in animals less than two months of age and, preferable, not until 3 months in calves. Anesthesia can be produced instead by sedation and local anesthetic, dissociative, or inhalation agents.

Myocardial contractility is reduced following administration of barbiturates for anesthesia. There is a corresponding fall in cardiac output but peripheral vascular tone is increased. Central respiratory centers are directly depressed resulting in an elevation of arterial carbon dioxide levels. Tidal volume is decreased while respiratory rate may be increased.

Low doses of barbiturates have been used for immobilization during cesarian section but depression is usually observed in the neonates. Injection of a short acting barbiturate into maternal blood result in rapid placental diffusion and a concentration in fetal blood equivalent to that of the dam. One study utilizing pregnant ewes demonstrated that the normal breathing movements of the fetal lamb were arrested within 2-3 minutes of injection of pentobarbitol (4 mg/kg) IV to the ewe.[14] Further, the effect lasted 25-30 minutes. Anesthesia is better achieved by local analgesia with or without sedation, extremely low doses of ketamine or halothane anesthesia. General anesthesia for cesarian section in the cow is not often practiced but barbiturates alone are to be avoided and use made of thiobarbiturate-glyceryl guaiacolate combination or ketamine if inhalation anesthesia is not available.

Glyceryl guaiacolate (GG) is not an anesthetic agent, but produces muscle relaxation and is a useful adjunct to anesthesia in the adult bovine. The drug acts centrally by depressing polysynaptic impulses in the spinal cord. A slight reduction in blood pressure is produced but the degree of ventilatory depression is dose related. Respiratory rate tends to increase as tidal volume is decreased. Recovery from GG involves metabolism and the metabolites are excreted by the kidney. GG crosses the placenta, but appear to be metabolized adequately by the neonate and has proven useful for fetal manipulation at parturition. GG produces some hemolysis unless a 5% solution is used. Solution exceeding 7.5% is irritant to tissues if injected perivascularly.

Ketamine hydrochloride produces dissociative anesthesia which includes sedation, immobility, amnesia, and marked analgesia. Although ketamine is used for anesthesia for all veterinary patients it is licensed only for use in cats and primates. The main advantage of ketamine is that it is simple to administer. A single intramuscular injection technique is very attractive in circumstances of limited assistance and limited equipment for restraint.

Ketamine is supplied as an acidic solution and is therefore incompatible in the same syringe with many other drugs. Several drug combinations are used to produce anesthesia but there are few published investigations. Use of xylazine 0.22 mg/kg (0.1 mg/lb) and ketamine 11 mg/kg (5 mg/lb) both given intramuscularly 10 minutes apart to goats has been reported.[15] Anesthesia was induced for 40-45 minutes with excellent muscle relaxation and conditions satisfactory for abdominal procedures. Endotracheal intubation was

[g] Pentothal, Abbott; Dipentol, Diamond

[h] Surital, Parke-Davis; Biotal, Bio-Ceutic

[i] Pentobarbitol USP, Nembutal, Abbott; Diabutal, Diamond.

[j] Gecolate, Summitt-Hill; Glycodes, Burns-Biotech

recommended. Clinical experience at the University of Missouri has been with a lower dose of xylazine (0.1 mg/kg IM) (0.05 mg/lb) with ketamine (10 mg/kg IM) in both goats and calves. Duration of surgical anesthesia with this combination is approximately 40 minutes.

There have been verbal reports and one published report[16] on the use of xylazine 0.1 mg/kg and ketamine 2 mg/kg IV in heifers and cows for immobilization to allow midline approach for cesarian section. In some cases this is combined with infiltration of lidocaine at the operation site.

Ketamine administered alone increases cardiac output and arterial blood pressure. These circulatory changes are attributed to increased sympathetic activity. A variety of tranquilizers or sedatives have been used in combination with ketamine and the final effects are dependent on the drug combination used and the relative and absolute dosages. The effect of ketamine anesthesia on ventilation is variable. Generally, there is minimal depression. Apnea occurs occasionally following xylazine/ketamine administration and in some animals which have required artificial ventilation, spontaneous ventilation has not resumed for 40 minutes. Additionally the pharyngeal and laryngeal reflexes are variable depressed or abolished and intubation is advisable to avoid aspiration.

Side effects such as seizures or excitement, such as occur with ketamine anesthesia in the dog or horse, are rarely a problem in the ruminant. A significant disadvantage of ketamine is the increased cost over alternative drugs.

The *inhalation agents,* halothane[k] and methoxyflurane[l] produce excellent anesthesia in the ruminant. Ideal surgical conditions are produced and a rapid recovery from anesthesia is achieved. Nitrous oxide is avoided in the ruminant (except as an aid to mask induction) because it rapidly passes from the blood into gas pockets in the rumen and produces progressive and marked distension. Anesthesia can be induced by administration of the anesthetic through a face mask, with or without prior sedation, or following barbiturate or ketamine induction. Ruminants should be intubated to avoid aspiration pneumonia. A small animal anesthetic machine can be used to administer the anesthetic to small ruminants up to 140 kg (300 lb) bodyweight using the same vaporizer settings for maintenance of anesthesia as would be used for a large canine patient. Anesthesia should be maintained in as light a plane as possible since increasing the anesthetic dosage will produce a gradual decrease in cardiovascular function. Mucous membrane color, capillary refill time, pulse rate and strength, respiratory rate and depth should be continually evaluated. The position of the eyeball provides an additional guide in the patient under inhalation agents (exception is ketamine induction) and surgical anesthesia usually corresponds to an eyeball which is rotated downwards (Figure 4). In all species a centrally fixed eyeball with absence of a palpebral reflex should be considered as an indication that the plane of anesthesia is too deep. The corneal reflex is of no use in determining depth of anesthesia since it should be active throughout anesthesia and indeed may be present for a short time after a cardiac arrest.

The lungs and kidneys are major excretory pathways of the volatile anesthetics and their metabolites. Information concerning metabolism of these agents in ruminants is limited but up to 25% of an inhaled dose of halothane is metabolized in some animals and significant elevation of serum bromide, a metabolite of halothane, has been measured in dogs nine days after anesthesia with halothane.[17] Similarly, a considerable part of an inhaled dose of methoxyflurane is metabolized (exceeding 44% in persons) and statistically significant levels of inorganic fluoride, a metabolite of methoxyflurane, have been documented in the serum of dogs six days after anesthesia.[18] The rate of biodegradation of these anesthetics is influenced by other factors, e.g., concomitant use of other drugs, renal function, physical status. No specific waiting time has been recommended before slaughter.

[k] Halothane USP, Halocarbon; Fluothane, Ayerst.
[l] Metofane, Pitman-Moore

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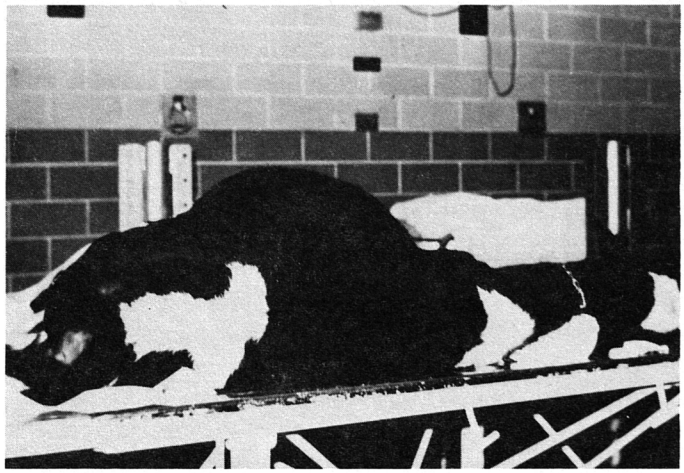

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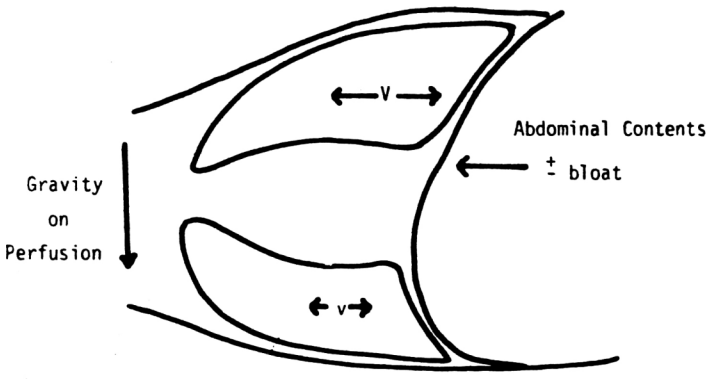

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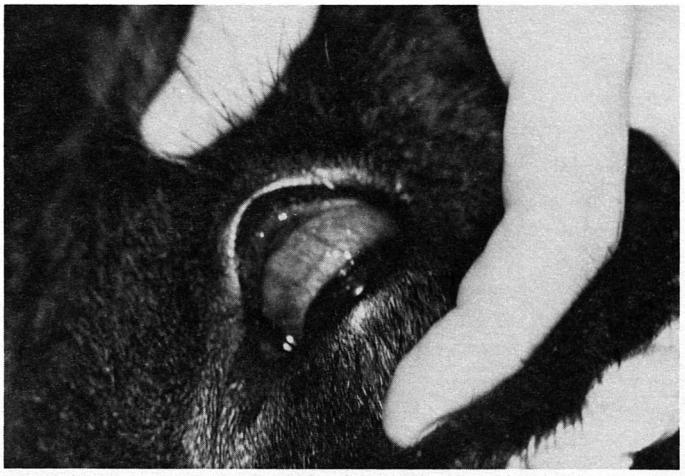

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Figure 1—*Potential Problems with Anesthesia in Ruminants: Bloat.*

Figure 2—*Potential Problems with Anesthesia in Ruminants: Inadequate Ventilation and Poor Oxygenation.*

Figure 3—*Potential Problems with Anesthesia in Ruminants: Injury.*

Figure 4—*Ruminant in Surgical Anesthesia with Inhalation Anesthetic: Eyeball Rotated Ventrally, Weak Palpebral Reflex.*

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