Key Points:
• Patient cooperation and systemic analgesia decay over time with bolus injectable anesthesia techniques.
• The large initial bolus dose used to provide extended duration increases the likelihood of adverse side effects.
• Anesthetic infusion techniques provide a more stable plane of anesthesia.

Many diagnostic and therapeutic procedures in food animal practice can be accomplished with physical and/or chemical restraint techniques. Anesthesia should be considered for procedures that require an extended period of immobility or high level of analgesia. Certain aspects of anesthesia place the patient at greater risk than chemical restraint techniques. Knowledge and vigilance reduce the additional risks associated with anesthesia.

The choice of injectable (commonly referred to as field anesthesia) or inhalation maintenance (commonly referred to as general anesthesia) will depend on several factors, most prominent being the equipment available and the experience of personnel involved. Injectable anesthesia has been traditionally considered proper only for shorter procedures, though its role is expanding in equine referral hospitals. When proper care is exercised, injectable anesthesia is safe and can be used effectively in both field and clinical settings (1).

Injectable anesthesia has been traditionally associated with intravenous or intramuscular bolus administration of drugs. The level of patient cooperation and systemic analgesia decays over time when these methods are used, requiring a higher initial level of effect to achieve the desired duration. The risk of adverse side effects such as cardiorespiratory depression is greater during the initial stages of the anesthetic period when bolus administration techniques are used. Constant rate infusion (CRI) techniques such as Double Drip or Ruminant Triple Drip are safer injectable anesthesia methods. Induction is more gradual with Double Drip or Ruminant Triple Drip. Continuous delivery also provides a more stable plane of anesthesia. The use of stock solutions with adjustments in delivery rate made to accommodate variations in patient size and/or alter the level of effect make CRI techniques easier to employ.

Methods for Controlling IV Infusion Rate

Infusion Pumps
An infusion pump is the preferred method for controlling the delivery of IV solutions containing potent drug mixtures. An infusion pump ensures medically accurate delivery of intended volume per unit time (typically ml/hr). Infusion pumps are equipped with audible alarms that sound when delivery is impeded, typically due to an occluded line or catheter. Direct observation is required to detect delivery problems with all of the other methods discussed. The digital readout provided by most infusion pumps (delivery rate, volume infused, and volume to be infused), make adjustments and documentation easier. In situations where an infusion pump is not available, there are alternative methods that can be used to control delivery. It is important that the clinician understand the limitations of the devices to minimize patient risk.
Dial-A-Flo

An IV flow control device such as a Dial-A-Flo (LifeShield Regulator IV Extension Set, Dial-A-Flo with Option-Lok, list # 11742-48, Hospira, numerous manufacturers produce similar devices) provides a more consistent flow rate than a solution administration set. Using a Dial-A-Flo type device to control CRI delivery adds approximately $7 to cost. The Dial-A-Flo has "settings" (ml/hr) of OFF, 20, 30, 40, 50, 60, 70, 80, 100, 125, 165, 210, 250, and OPEN, but intermediate delivery rates (e.g. not indicated on dial) can be set to accommodate patient size.

Dial-A-Flo type devices are designed to work within a certain specified height differential (solution container to patient catheter). They seem to provide steady delivery outside of this range, but rate may vary from setting. Delivery rate should be verified initially and periodically evaluated when using a Dial-A-Flo type device. Periodic inspection is also required to detect occlusive problems in delivery system.

In patients over 100 kg the base maintenance delivery rate of Double Drip and Ruminant Triple Drip exceeds the capability of the Dial-A-Flow device.

Solution Administration Set

Using a solution administration set is the most cost effective and readily available method of controlling the delivery rate of an IV infusion. Drip rate (drops/min.) is converted to ml/min. and ml/hr by applying the conversion factor for the solution administration set used (typically 10, 15, or 60 drops/ml). Counting the number of drops per 10 seconds provides a more accurate assessment of the drip rate. Accuracy decreases as the infusion rate decreases.

Setting the initial drip rate and any subsequent adjustments generally take more time when compared to an electronic infusion pump or a Dial-A-Flo type device. Slow drip rates take even more time to set or adjust. Infusion rate set using a solution administration set can change over time, requiring greater vigilance. Any change in the distance between the IV container (or more accurately the level of fluid within) and the patient catheter alters the flow rate. "Cold creep", the outward pressure exerted by the tubing as it resists deformation, can push roller style clamps open slightly increasing flow over time. "Crimping" of tubing under pressure from adjustment clamp does not resolve immediately. As it slowly resolves flow increases beyond the level intended when the clamp was loosened.

Anesthetic CRI Techniques

Double Drip

When used correctly Double Drip is the most benign method of anesthetic induction and injectable maintenance for ruminant patients. Double Drip is the most commonly used method for inducing anesthesia to be maintained with inhalants in small ruminants. A CRI of Double Drip can also be used to provide a stable plane of injectable anesthesia in ruminant patients.

Double Drip is created by adding ketamine (1 mg/ml) to 5% guaifenesin. Because Double Drip does not contain xylazine, the level of analgesia provided is somewhat lower when compared with Ruminant Triple Drip. The absence of xylazine's cardiovascular depressant effects makes Double Drip a better choice for injectable maintenance in compromised patients. Butorphanol (0.05-0.1 mg/kg IV or IM in smaller ruminants, 0.02-0.05 mg/kg IV or IM in larger ruminants) or morphine (0.05-0.1 mg/kg IV or IM) can be administered to augment the level of analgesia when Double Drip is used to maintain anesthesia. Onset time for butorphanol and
 morphine is slow (peak effect is approximately 10 minutes post-IV and 20 minutes post-IM administration).

Anesthetic induction of small ruminants is achieved by slowly infusing Double Drip to effect. A syringe should be used to administer Double Drip in very small patients to reduce the risk of overdosing because this combination has a somewhat slow onset. Muscle relaxation and sedation typically produce a graceful transition to recumbency well before the patient is anesthetized. Anesthetic induction generally requires administration of 1.7 to 2.2 ml/kg. Anesthesia can be maintained by continuous infusion of Double Drip at a rate of 2.6 ml/kg/hr. Both ketamine and tiletamine draw on sympathetic nervous system reserve to augment cardiac output and blood pressure. This effect helps counter their direct negative inotropic and vasodilatory effects, as well as the negative cardiovascular effects produced by any alpha2-adrenergic agonists administered. Cardiovascular function in normal healthy patients anesthetized with ketamine-based protocols is good to excellent. I cannot emphasize enough the need for caution in dosing these seemingly safe drugs in compromised patients in which sympathetic reserve may be severely limited. Recovery quality is typically good.

In larger ruminants Double Drip is often used to soften up the patient (sedate and centralize cardiac output) prior to administering the anesthetic induction bolus. Double Drip is slowly infused until the early signs of sedation and muscle relaxation become evident. At that point a combination of ketamine (1.5-2.0 mg/kg IV) and diazepam (0.06-0.1 mg/kg IV) is administered. Disconnecting the Double Drip once the Ket-Val is flushed in frees a pair of hands to help guide the patient as it goes down. Depending on how much Double Drip was delivered recumbency occurs 15-45 seconds following Ket-Val administration. This approach provides a more rapid and predictable drop, improving patient control and safety of personnel involved in the induction process. Anesthesia can be maintained with continued infusion of Double Drip.

Ruminant Triple Drip (GKX-Ru)

Ruminant Triple Drip is most commonly used to maintain a stable plane of injectable anesthesia, though it can also be used as an induction method. This technique is not appropriate for patients with conditions that might be adversely impacted by large doses of xylazine. Ruminant Triple Drip is created by adding ketamine (1 mg/ml) and xylazine (0.1 mg/ml) to 5% guaifenesin (2,3). Equine Triple Drip has a much higher concentration of xylazine (0.5 mg/ml).

Anesthetic induction of smaller ruminants is achieved by slowly infusing Ruminant Triple Drip to effect. A syringe should be used to administer Ruminant Triple Drip in very small patients to reduce the risk of overdosing because this combination has a somewhat slow onset. Muscle relaxation and sedation typically produce a graceful transition to recumbency well before patient is anesthetized. Anesthetic induction generally requires administration of 1.1 to 1.7 ml/kg. Anesthesia can be maintained by continuous infusion of Ruminant Triple Drip at a rate of 2.6 ml/kg/hr with minimal risk in normal healthy patients. Double Drip eliminates the cardiovascular depressant effects of xylazine making it a better choice for induction or maintenance of injectable anesthesia. Xylazine is cleared more slowly than ketamine. The length of post-procedure recumbency and the risk of cardiorespiratory depression increase with the duration of Ruminant Triple Drip administration. Xylazine sedation can be reversed to speed the recovery process once the patient is awake. Recovery quality is typically good.
Larger ruminants should be managed as described in the Double Drip section. Ruminant Triple Drip can be substituted for the Double Drip, if desired.

References
(1) Abrahamsen, EJ; Ruminant Field Anesthesia. Vet Clin Food Animal 2008; 24(3):429-441