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Field Anesthesia in the Equine

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Equine field practice commonly requires short- to medium-term anesthesia being induced in horses for either minor surgical or diagnostic procedures or for urgent medical care in emergency situations. Performing a general anesthetic in the field further increases the risk associated with equine anesthesia which already is high when compared with small animal or human anesthesia, even under best of hospital conditions. For this reason, cases for field anesthesia should be carefully selected and appropriate anesthesia protocols chosen by taking into account the peculiar setting of the location, the physical condition of the patient, and the specific circumstances of the surgical, diagnostic, or other procedures planned. This review provides an overview of the anesthetic techniques suitable for field anesthesia. First, the approach to the equine patient under field as compared with hospital conditions is addressed, followed by a detailed discussion of common field anesthetic protocols reported for use in adult horses and in foals. Finally, anesthetic protocols suitable for horses suffering injuries during or immediately after maximum exercise are addressed.

KEYWORDS field anesthesia, horse, total intravenous anesthesia, dissociative anesthesia, barbiturate anesthesia

To prove useful for application under field conditions, an anesthetic protocol must possess distinct qualities. Ideally, the anesthetic technique chosen should result in a horse quietly achieving recumbency and quickly reaching a surgical plane of anesthesia, minimizing the time spent in a nonphysiological recumbency. At the same time, it is crucial that the occurrence of a surgical plane of anesthesia is predictable and its duration consistent, thus minimizing the risk for abrupt or untimely arousal. Muscle relaxation must be adequate as to aid in assessing the depth of anesthesia and providing a visually appealing anesthetic besides facilitating surgery. All anesthetic agents used in a field anesthetic protocol should impair hemodynamic and respiratory function as little as possible to minimize any cardiopulmonary insult, not the least because recumbency itself will pose some stress on both the circulatory and pulmonary system. In the best of circumstances, anesthetic agents are administered via a single injection, producing a duration of anesthesia adequate for short surgical procedures (eg, castration, minor orthopedic, or soft tissue procedures) with the option to expand the duration of anesthesia by administration of supplemental doses or by continuous infusion.[1-3] Recovery from anesthesia should occur gradually and allow the horse to smoothly regain standing position.

Performing general anesthesia under field conditions will always further increase the already high risk associated with anesthesia in the horse,[4] and thus may be less safe than when being performed under hospital conditions.[5] For this reason, much attention must be paid to the anesthetic management of the patient, even if short and simple surgical procedures are performed.[5] Thorough planning and preparation is key shall the anesthetic protocol chosen be appropriate and the anesthesia time being kept to a minimum. This will include a complete physical examination and maybe basic blood work (complete blood cell count, complete or abbreviated biochemical panel), and take into account not only the type and invasiveness of the surgical procedure but also the time required to perform it, as well as potential intra- or postoperative complications. Likewise, weather conditions at the time of surgery must be considered and precautions taken to protect the horse from heat, rain (snow), or cold exposure. Should a scale not be available, the weight of the horse can be estimated by means of experience or better by taking some physical measurements that are then entered into a classical formula to yield a fairly accurate weight estimate (Table 1). Appropriate equipment and drugs necessary to facilitate induction and maintenance of general anesthesia (Tables 2 and 3) as well as treatment of anesthesia-related complications (Table 5) should be available at the site of the field anesthetic procedure.

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Table 1 Formula for Estimating Body Weight in Horses

$$\text{Body weight (lb)} = \frac{\text{Heart girth (in)}^2 \times \text{length (in)}}{241}$$

$$\text{Body weight (kg)} = \frac{\text{Heart girth (cm)}^2 \times \text{length (cm)}}{8717}$$

Even if the anticipated surgery is minor and may last for only a brief period, the fact that the horse is placed under general anesthesia requires that it is adequately monitored during this time. Sophisticated monitoring is not necessary, but respiration must be observed and the pulse should be palpated regularly so that potentially life-threatening complications (eg, airway obstruction, apnea, hypotension, arrhythmias) are detected early enough to allow appropriate intervention. A portable pulse oximeter may serve as a very valuable noninvasive monitor in the field. In a horse breathing environmental air, pulse oximetry provides relevant information not only regarding the adequacy of arterial blood oxygenation and the state of the peripheral circulation but also pulse rate and rhythm. An intravenous (IV) catheter should always be placed in the upside jugular vein for administration of irritant solutions but also to facilitate repetitive or continuous administration of anesthetic drugs required to maintain a stable plane of anesthesia, for IV fluids, and for emergency drugs should complications arise. Ideally, whenever an animal is given a general anesthetic, some means of resuscitation should be readily available, particularly to treat apnea, hypotension, and cardiac arrhythmias. It is relatively simple to bring along an endotracheal tube and a small oxygen cylinder (size E) plus demand valve (JDM-5042-C Equine Demand Valve®; JD Medical Inc., Phoenix, AZ). Two endotracheal tubes, one with 20-mm and one with 24-mm inner diameter, are sufficient as they will fit the vast majority of horses. Even a large horse can be ventilated by this means for 10 to 20 minutes, which is long enough to maintain the patient adequately ventilated until spontaneous respiration resumes following anesthetic-induced apnea or hypoventilation.[6,7]

Table 2 Equipment Commonly Used for Field Anesthesia in the Horse

Placing an IV catheter
Scrub material and disinfectant for catheterization site
IV catheter
IV fluids and infusion set
Induction
Induction drugs
Pressure bag for guaifenesin infusion
Endotracheal tubes of appropriate size
Mouth gag/speculum
Syringe to inflate endotracheal tube cuff
Maintenance
Ropes and hubbles
Entotracheal tube
E cylinder-type O_2 tank
Demand valve
Drugs for maintenance
Pulse oximeter if available

Table 3 Drugs Commonly Used for Field Anesthesia in the Horse and Treatment of Potential Complications

- Acepromazine
- Atropine/Glycopyrrolate
- Atipamezol
- Detomidine
- Diazepam
- Dobutamine
- Ephedrine
- Epinephrine
- Flumazenil
- Guaifenesin
- Ketamine
- Midazolam
- Phenylephrine
- Propofol
- Romifidine
- Thiopental
- Xylazine
- Yohimbine

A suitable site for field anesthesia must be chosen. In good weather, a well-covered flat grass field or lawn is ideal, after removal of bricks, gravel, and other. Alternatively, an all-weather indoor or outdoor arena may be used. This provides good grip for the horse but dusty conditions for surgery. Most horses can also safely be anesthetized in a large strong box with smooth walls and deep bedding.

In the field, the most common, safe, and predictable technique to induce anesthesia in adult horses is through the administration of IV agents. Moreover, under field conditions, IV maintenance of general anesthesia is usually the method of choice, as it can be performed without the facilities at hand in equine hospitals, such as induction stalls, transport systems, padded recovery rooms, and skilled assisting personnel, and without the need of bulky equipment necessary when administering inhalant anesthesia to horses. Hence, total intravenous anesthesia (TIVA) is the preferred and most suitable anesthesia technique for field procedures.[6,7]

Animal Support During Induction Phase

The majority of induction techniques used in the field as well as in the hospital environment employ a combination of sedative drugs with dissociative agents (eg, ketamine, tiletamine in Telazol® or Zoletil®) or, but less commonly, with hypnotic/anesthetic agents (eg, thiopental, propofol).[1] Either combination may be supplemented with centrally acting muscle relaxants such us guaifenesin or benzodiazepine agents (ie, diazepam, midazolam).[1] Knowing the manner in which a horse becomes recumbent after anesthetic drug injection is very important to meaningfully assist the animal when it loses consciousness in a field environment. Dissociative anesthetic agents are not inducing loss of consciousness within a single brain circulation time, and therefore, where sedation

with an α_2-adrenoceptor agonist has preceded the IV injection of ketamine, an adult horse may take as long as 3 minutes to become recumbent.[2,3] As a result, achieving recumbency is a much more gradual process with the horse often taking a step or two sideways or backwards before slowly sitting back on its haunches and sinking into sternal recumbency.[2,8] It then rolls gently over on its side and may make one or two quite vigorous limb movements before becoming still.[2,3] Once laterally recumbent, the animal settles much more quickly and the onset of unconsciousness is more rapid when no attempt is made to forcibly restrain the head; whereas, if this is done, the horse may even try to rise and can be very difficult to restrain.[2,5] The free fall method is the simplest technique usually applied in the field. One person holds the horse's head as it becomes recumbent. If the horse leans back as anesthesia takes hold, the handler pulls the head down, which steadies the fall and prevents the horse going over backwards. With the previously described type of induction that typically occurs following injection of dissociative agents, this is less necessary, and the handler simply has to steady the head.[2,3] In contrast to induction with dissociative agents, following injection of thiopental, the horse tends to lean backwards and lifts its head, which must be restrained to prevent it from losing its balance. Usually with restraint, the horse sinks gently to the ground. Premedication with α_2-adrenoceptor agonists decreases cardiac output in a dose-dependent fashion, and the onset of unconsciousness is delayed for 40 to 120 seconds after thiopental injection.[2,8] The horse may make paddling or galloping movements when it first becomes recumbent; these movements disappear within 10 to 20 seconds as unconsciousness deepens.[2,7]

Dissociative Drug-Based Induction of Field Anesthesia

Dissociative anesthetics include phencyclidine, ketamine, and tiletamine. This group of anesthetics are unique in their effects on the central nervous system (CNS) in that they cause a functional and electrophysiological dissociation (disconnection) of thalamo-neocortical areas from limbic and other subcortical structures in the brain, rather than a generalized depression of all brain areas. As a result of this selective suppression of the thalamo-neocortical projection system, consciousness is lost, whereas neuronal activity in other brain centers such as the limbic system, including the hippocampus, is maintained. Dissociative anesthesia is typically accompanied by catalepsy (catatonia), a state of extreme motionlessness despite increased skeletal muscle tone. The eyes often remain open, sometimes with slow nystagmus, during surgical anesthesia. Protective reflexes, such as coughing, swallowing, and corneal and pedal reflexes, are maintained or even hyperactive. Skeletal muscle movements may occur independently of surgical stimulation. These responses can

Table 4 Common Sedative and Anesthetic Drug Combinations for Field Anesthesia in Horses (Dosages of different combinations are reported in the text)

PREMEDICATION

Acepromazine
α_2 adrenoceptor agonists
Acepromazine + α_2 adrenoceptor agonists

INDUCTION

Ketamine	Thiopental
Ketamine	Thiopental
Guaifenesin + ketamine	Guaifenesin + thiopental
Benzodiazepines + ketamine	
Guaifenesin + benzodiazepine + ketamine	

MAINTENANCE FOR SHORT PROCEDURES (up to 30 min)

0.5–1 mg/kg thiopental IV	0.5–1 mg/kg thiopental IV up to a total dose of thiopental of 10 mg/kg
Half of the induction dose of xylazine/ketamine combination	
Only half of induction dose of ketamine in combinations with detomidine or romifidine	

MAINTENANCE FOR MEDIUM DURATION PROCEDURES (30–90 min)

Total intravenous anesthesia (TIVA) techniques in horses*

Drug combination	Concentration (mg/mL)	Infusion rate (mL/kg · hr)
Xylazine	1	1–3 or to effect
Guaifenesin	100	
Ketamine	2	
Detomidine	0.02	1–3 or to effect
Guaifenesin	100	
Ketamine	2	
Medetomidine	0.02	1–3 or to effect
Guaifenesin	100	
Ketamine	2	

*Adopted from Muir.[41]

Table 5 Possible Complications During Field Anesthesia in the Horse and How to Treat Them

Complication	Action
Respiratory depression/arrest	Controlled ventilation
	Cuffed endotracheal tube
	Demand valve
	Oxygen tank
Hypoxemia	Increase fraction of the inspired oxygen
	Nasal oxygen administration
	Mechanical ventilation via demand valve
Cardiovascular depression, bradycardia, arrhythmias	Emergency drugs
Corneal ulcer	Assure eyelid of down eye is closed
	Eye lubrication
	Smooth surface under dependent eye
Nerve paralysis	Facial nerve
	Pad metal clips and rings on halter
	Radial nerve
	Pull down front leg forward
	Place thick pad or inner tubing under dependent shoulder
Myopathy	Adequate padding for procedure lasting in excess of 30 min

be minimized by addition of an adjunctive agent for muscle relaxation, such as an α_2-adrenoceptor agonist and a benzodiazepine.[2] Alternatively, guaifenesin (5-10%) can be used as central muscle relaxant; however, it must be administered by rapid infusion. Only ketamine and tiletamine have become popular for producing short-term chemical restraint and induction to inhalant anesthesia in horses.[2,3]

Ketamine

Following the publication in 1977 by Muir and coworkers[9] of a paper describing the use of a new technique for short-term anesthesia in the horse, a new era of safe anesthesia in the horse began. This study described a technique utilizing an α_2-adrenoceptor agonist, xylazine, and the dissociative agent, ketamine, to produce short-term intravenous anesthesia. Since then, the popularity of this technique grew and the safety of field anesthesia in the equine increased dramatically.

Ketamine, following premedication with an α_2-adrenoceptor agonist (xylazine, detomidine, or romifidine) produces good to excellent induction of anesthesia, followed by a rapid but usually very quiet recovery.[10-12] Lateral recumbency is achieved in 1 to 3 minutes after ketamine injection, anesthesia continues to deepen for 1 to 2 minutes after the horse becomes recumbent, and even when eye movements cease, relaxation of the jaw muscles is not always very good and it may be necessary to spread the mouth wide open for the passage of an endotracheal tube.[2] Relaxation can be improved by IV administration of a benzodiazepine agent (diazepam or midazolam at the same dose: 0.05-0.1 mg/kg) immediately after the ketamine injection, although this tends to deepen anesthesia and cause further respiratory depression, which is why it should be used with caution under field conditions when mechanical ventilation is not readily available.[13-15] Lowering the dose of the α_2-adrenoceptor agonist can reduce the respiratory depression. Classical signs used to determine the stage of anesthesia are not recognizable in patients during ketamine anesthesia; nystagmus and tear formation may be observed, and thus in the field, when arterial blood pressure (ABP) measurements are not available, the decision as to whether the horse arrived at an appropriate depth of anesthesia is best made based on the presence or absence of responses to surgical stimulation.[2,3,6] When no other anesthetic is given, depending on the degree of surgical stimulation, horses first raise their heads 10 to 30 minutes after ketamine injection, roll into sternal recumbency some minutes later, and stand 5 to 6 minutes thereafter.[2,6] Termination of surgical anesthesia is very abrupt, but recovery is remarkably free from excitement and horses usually stand at the first attempt. Once standing, there is very little evidence of ataxia. The very abrupt end of surgical anesthesia when no other agents are given can lead to difficulties. However, the method described appears to be a very safe way of producing short periods of anesthesia. Cardiovascular parameters are well maintained, and respiration is usually adequate. Ketamine may also be used with other premedication agents or in other combinations[2,10]; however, acepromazine premedication alone is inadequate before ketamine induction. Many dose schedules utilizing guaifenesin together with α_2-adrenoceptor agonists and ketamine have been recommended.[2,16]

α_2-Adrenoceptor Agonist: Xylazine (0.3-1.0 mg/kg), Detomidine (5-20 μg/kg), or Romifidine (80-100 μg/kg) and Ketamine (2 mg/kg)[9,12,17]

The α_2-adrenoceptor agonist is given IV and must be allowed to take full effect (5 minutes). Ketamine is then given as a single bolus injection, and the horse is restrained quietly but firmly. It is essential that the horse is not disturbed by noise or sudden movement at this stage or induction may become violent. The horse should be kept with its head straight in front of the body and not allowed to move around. However, the handler should not push against the horse as it will tend to push against the restraint and come forward as it lies down. With firm but tactful restraint, the horse should buckle at the knees, thereafter sink back into sternal and then into lateral recumbency in a slow and controlled manner. Relaxation may be slow to develop, and the horse should be allowed to settle for at least 30 seconds after it has gone into lateral recumbency. Anesthesia can be maintained for a short period with incremental doses of various induction agents, and such

techniques are commonly used for diagnostic procedures under field conditions. Recovery is generally smooth.

α_2-Adrenoceptor Agonist: Xylazine (0.3-0.8 mg/kg), Detomidine (5-10 μg/kg) or Romifidine (50-80 μg/kg) and Diazepam (0.05-0.1 mg/kg) or Midazolam (0.05-0.1 mg/kg) and Ketamine (2 mg/kg)[13-15]

This technique has become popular because, without the benzodiazepine component, anesthesia and relaxation are sometimes inadequate and recovery abrupt. Addition of a benzodiazepine appears to improve muscle relaxation, particularly in a horse that was unsettled before induction or in a disturbing environment, and prolongs anesthesia. The technique can be used with or without acepromazine (0.02 mg/kg) premedication. The α_2-adrenoceptor agonist is given and allowed to take effect (5 minutes). The benzodiazepine is given immediately before, together with, or immediately after the ketamine injection. The horse must be held still after the benzodiazepine/ketamine combination has been given as there may be a brief period of ataxia before the horse becomes unconscious. The horse normally sinks smoothly into sternal and then lateral recumbency, and relaxation develops more rapidly than when an α_2-adrenoceptor agonist/ketamine combination is used alone. Anesthesia can be maintained for short procedures with incremental doses of various induction agents.

Guaifenesin (50-100 mg/kg) and Ketamine (2 mg/kg)[18]

In healthy horses, this technique is best used after acepromazine premedication (0.03 mg/kg). Guaifenesin in infused rapidly until the horse becomes ataxic. Ketamine is then injected IV as a bolus and the animal sinks into sternal and then lateral recumbency. This technique may not produce anesthesia deep enough for even minor surgical procedures, although it is usually adequate for induction before transition to volatile agents for maintenance. In healthy horses, it is better used in conjunction with an α_2-adrenoceptor agonist or a benzodiazepine or both.

α_2-Adrenoceptor Agonist: Xylazine (0.3-0.5 mg/kg), Detomidine (3-7 μg/kg) or Romifidine (30-50 μg/kg) and Guaifenesin (25-50 mg/kg) and Ketamine (2 mg/kg)[16]

This combination can be used with or without acepromazine (0.02 mg/kg) premedication. The α_2-adrenoceptor agonist is given IV and allowed to take effect; then guaifenesin is infused as above and ketamine given as a bolus when the horse has become mildly ataxic. The α_2-adrenoceptor agonist induces some ataxia, allowing the dose of guaifenesin to be reduced, but it is more difficult to judge the degree of ataxia. This technique leads to smoother, more controlled induction of anesthesia than guaifenesin/ketamine alone. Anesthesia is best extended by short additional periods with further doses of ketamine (0.2 mg/kg) and guaifenesin (5 mg/kg).

Guaifenesin (25-50 mg/kg) and Diazepam (0.05-0.1 mg/kg) or Midazolam (0.05-0.1 mg/kg) and Ketamine (2 mg/kg)[13]

This can be used with or without acepromazine (0.02 mg/kg) premedication. In restless horses, it is best used with acepromazine so that the horse relaxes during the infusion. Guaifenesin is infused until the horse is only slightly ataxic; lower doses are required than when guaifenesin is used alone together with ketamine or thiopental. The benzodiazepine is then given as a single bolus injection, either immediately before or simultaneously with ketamine. Induction is usually smooth and calm, but the horse must be prevented from walking immediately after injection of the benzodiazepine/ketamine combination as otherwise a brief period of severe ataxia and excitement may be seen. Anesthesia is best prolonged for short additional periods with further doses of ketamine (0.2 mg/kg) and guaifenesin (5 mg/kg).

α_2-Adrenoceptor Agonist: Xylazine (0.3-0.5 mg/kg), Detomidine (3-5 μg/kg) or Romifidine (20-40 μg/kg) and Guaifenesin (25-50 mg/kg) and Diazepam (0.05-0.1 mg/kg) or Midazolam (0.05-0.1 mg/kg) and Ketamine (2 mg/kg)[13]

This drug combination is used routinely by some clinicians as they find the combined effect of all four components produces the most controlled induction in horses. Prolongation for short periods is best performed with additional administration of ketamine (0.2 mg/kg) and guaifenesin (5 mg/kg).

Tiletamine[19-21]

The basic pharmacology of tiletamine is similar to ketamine, but the drug has a three times longer duration of action and greater analgesic effect than does ketamine. Catalepsy occurs in all species, even when tiletamine is given at moderate doses. Therefore, it is combined with zolazepam, a benzodiazepine derivative that exhibits strong anticonvulsive and muscle relaxant actions, and has a plasma half-life either matching or exceeding that of tiletamine in most species. As a result, increased muscle tone, body rigidity, and convulsive movements produced by tiletamine alone are absent or at least significantly reduced when coadministered with zolazepam. A lyophilized mixture of the two compounds is traded under the brand name Telazol® or Zoletil®, which contain equal amounts of both agents in dry powder form (250 mg of each per vial) that can be made up to concentrated solutions (up to 100 mg/mL). In the horse, the combination has always been used in conjunction with an α_2-adrenoceptor agonist. This combination is used after premedication with either xylazine (0.5-0.7 mg/kg) or detomidine (5-15 μg/kg). Although it produces reasonably safe short-term anesthesia of somewhat longer duration than that seen after xylazine/ketamine/diazepam, it offers very little other advantages.

Barbiturate-Based Induction of Field Anesthesia

Thiopental

Thiopental is a hypnotic/anesthetic agent that has been used in equine anesthesia for many years and is the only thiobarbiturate currently available for use in horses in North America. The dose required to induce anesthesia in the horse depends on the amount of sedation present. As recovery from an induction dose of thiopental or a dissociative anesthetic depends on redistribution rather than elimination, reduction in the dose leads to a faster and better recovery.[2,22] Following premedication with acepromazine given at least 30 minutes before anesthesia, administration of thiopental is a satisfac-

tory induction technique. The horse becomes unconscious and recumbent within 25 to 30 seconds of drug injection, and anesthesia lasts for an adequate time, enabling performance of a short procedure such as a castration. If no maintenance agents are given, the horse regains its feet in approximately 30 to 40 minutes, and although there may be some ataxia, recovery is usually calm.[2,22] Thiopental depresses respiratory function and decreases blood pressure, but the effect is short lived and of little consequences in a healthy horse.[2] However, those effects are enhanced in the presence of endotoxemia. Because of its high pH, the solution of thiopental is highly irritant and must not be given perivascularly, which is why placement of an IV catheter is highly desirable. The dose of thiopental is critical; underdosage through underestimation of weight may lead to excitement during induction, and for this reason it used to be common practice to follow the injection of thiopental with a small dose of succinylcholine, but this agent is now used rarely.[2] The use of IV α_2-adrenoceptor agonists (xylazine, detomidine, romifidine) just before anesthetic induction reduces the dose of thiopental required in a dose-dependent manner (5.5 mg/kg), and also increases the therapeutic index of the drug, ie, it is rare for a lower dose to cause excitement.[2,23] Anesthesia of this combination lasts for 15 to 20 minutes (sufficient to enable castration) and, if no further drugs are used, the horse will regain its feet after 30 to 40 minutes.[2,23] Premedication with acepromazine before giving xylazine or detomidine does not appear to reduce the dose of thiopental subsequently required for anesthetic induction.[2] Recovery to standing occurs also in 30 to 40 minutes, and with less ataxia than when higher doses of thiopental are employed.[2]

Thiopental can be also given in conjunction with guaifenesin: after premedication with acepromazine, and/or α_2-adrenoceptor agonist, guaifenesin is infused intravenously until the horse shows pronounced ataxia. An IV bolus dose of about 5 mg/kg of thiopental then produces recumbency and apparent unconsciousness. Panic due to muscle weakness may be seen if guaifenesin is infused without prior administration of sufficient sedative.[6,7] It is also possible to combine guaifenesin and thiopental solutions for intravenous infusion to produce recumbency, but there is much less control over anesthesia when this is done and profound respiratory depression can result. Recovery from these agents alone occurs in 30 to 40 minutes, but there may be some residual muscle weakness if high doses of guaifenesin are used.[6,7]

Acepromazine (0.03-0.05 mg/kg) and Thiopental (10 mg/kg)[2]

Acepromazine is given IV at least 15 to 20 minutes (or 45 minutes if IM) before thiopental. Thiopental is given as a single bolus injection. The horse tends to pull back and falls down rapidly within 30 seconds. With good control on the head, it can be encouraged to go into sternal and then lateral recumbency.

Guaifenesin (25-100 mg/kg) and Thiopental (5-6 mg/kg)[2,22]

This technique is best used after acepromazine (0.03 mg/kg) or a low dose of α_2-adrenoceptor agonist (xylazine 0.5 mg/kg or detomidine 5-10 μg/kg or romifidine 40 μg/kg) for premedication. Guaifenesin is infused rapidly until the horse becomes ataxic. The degree of ataxia reached depends on the amount of support given to the horse. If the horse is well supported by handlers, 75-100 mg/kg can be given before induction of anesthesia with thiopental has to commence. If the horse is less well supported, up to 50 mg/kg is given. The horse should be well restrained during infusion so that it does not panic when ataxia develops. Thiopental is then injected as an IV bolus, and the horse normally sinks first quietly into sternal and then lateral recumbency. Induction of anesthesia may also be performed with 2.5 g thiopental added to a bottle of 10% guaifenesin and this infused until the horse goes down. It is more difficult to judge when the horse will become recumbent, and the procedure tends to be less well controlled in inexperienced hands. Anesthesia can be maintained for a short period with incremental doses of guaifenesin and thiopental. It is preferable that the total dose does not exceed 100 mg/kg of guaifenesin and 10 mg/kg of thiopental or the horse's recovery will be prolonged and ataxic. Higher doses of guaifenesin lead to more severe ataxia and increase the risk of recovery complications.

α_2-Adrenoceptor Agonist: Xylazine (0.5-1 mg/kg), Detomidine (10-20 μg/kg) or Romifidine (50-80 μg/kg) and Thiopental (5-6 mg/kg)[2,22,23]

This technique can be used with or without acepromazine (0.03 mg/kg) premedication. The α_2-adrenoceptor agonist is given IV and allowed to take effect (5 minutes). Thiopental is given as a slow single injection, and the horse is restrained quietly but firmly. It usually sinks down first into sternal and then lateral recumbency in a slow, controlled manner, taking considerably longer (1-2 minutes) than after acepromazine only. The horse takes time to relax and may paddle the legs gently. This should be allowed to subside over the next 30 to 60 seconds. Anesthesia can be prolonged with incremental doses of thiopental, but the total dose should not exceed 11 mg/kg. Induction of anesthesia with lower doses of an α_2-adrenoceptor agonist followed by 7 to 8 mg/kg of thiopental also works well. Induction is faster and slightly more predictable.

Propofol

Propofol is an anesthetic agent characterized by a rapid onset of action and a short duration. Nolan and coworkers[24] described for the first time the use of propofol for induction and maintenance of general anesthesia in ponies. Since then, it has been evaluated for use in foals and adult horses. The quality of induction after propofol (8 mg/kg) administration is reported to be variable, ie, either of good or poor quality.[25] The administration of xylazine (0.5-1 mg/kg IV) or detomidine (0.015-0.030 mg/kg IV) seems to not improve significantly the induction quality with propofol (3-5 mg/kg IV).[26] However, with the addition of guaifenesin (75 mg/kg IV) in the induction protocol, induction was rated as good to excellent.[27] Recovery quality was good with all protocols.[26,27] In the authors' opinion, further clinical trials are needed to find the propofol-based protocol that allows to combine the unique pharmacokinetic profile of propofol with an assurance of safety in a field condition.

Maintenance of Field Anesthesia

Total intravenous anesthesia (TIVA) has been defined as a technique that utilizes IV-administered drugs to produce and maintain unconsciousness, analgesia, and muscle relaxation without concurrent use of inhalant agents and may consist of a single bolus, repeated bolus, or continuous infusion of intravenous drugs.[28] Under field conditions, TIVA has been used for many years, and still today it represents the most common anesthetic technique used for surgical procedures in the field. Currently, drugs which are rapidly metabolized and eliminated are being introduced, and TIVA can be used for more prolonged procedures as recovery from anesthesia produced or maintained by some of the more recently introduced agents and combinations does not last longer than after anesthesia with volatile agents.[2,6,7] Techniques suitable for TIVA can be considered in three categories: those suitable for short procedures (up to 30 minutes), those suitable for more prolonged use (up to 1.5-2 hours), and those which could be extended almost indefinitely should the surgical procedure demand it.[2,6,7] The last category will not be considered in this overview because it does not apply to surgeries performed under field conditions.

TIVA for Short Procedures

The intravenous induction techniques described above provide adequate anesthesia for procedures lasting 10 to 15 minutes. If no additional agents are given, recovery from ketamine-based induction techniques occurs within 20 to 25 minutes and is usually very smooth and controlled. However, recovery can be abrupt, and sometimes the horse can awaken during surgery with little warning so it is essential that a rapid means to deepen anesthesia is available. The duration of surgical anesthesia can be increased and the risk of inadvertent movements be reduced by supplementing a TIVA technique with local or regional anesthesia. This is particularly suitable for highly painful surgical procedures such as a castration. The α_2-adrenoceptor agonist utilized before ketamine does not necessarily influence quality and duration of anesthesia, or speed and quality of recovery.[10] With thiopental-based methods, recovery is generally slower (30-40 minutes), and some residual hind limb weakness may remain, causing the horse to make more than one attempt to rise. Nevertheless, with appropriate premedication, rising is usually calm. Although the horse can still move in response to a surgical stimulus, this is easy to anticipate and therefore abrupt awakenings seen with ketamine do not usually occur.[6,7] Small doses (0.5-1.0 mg/kg) of thiopental may be given to extend anesthesia, which has been induced with either thiopental or ketamine.[7] The major advantage of thiopental is that it acts much more rapidly and is ideal to bring an waking animal quickly back under control. However, overdose may cause apnea and, as the drug is cumulative, speed and quality of recovery depend on the total dose administered. Thus, if initial anesthetic induction was with ketamine, more increments may be given than is possible following induction using thiopental. A total dose of 10 mg/kg still results in a calm recovery within an acceptable time; higher total doses may be safe but will lengthen recovery.[7] Anesthesia induced with α_2-adrenoceptor agonist/ketamine combinations may be prolonged with additional doses of ketamine, but there is a danger of undesirable excitatory effects unless the α_2-adrenoceptor agonist-induced sedation is still adequate.[2,7] In clinical practice, incremental doses of half of the original dose of both xylazine and ketamine are given as required. There will be a delay before these agents will be effective (1-3 minutes). The xylazine/ketamine combination can be extended to give medium-term anesthesia by administration of half the initial dose of both xylazine and ketamine at approximately 20-minute intervals.[7] Infusions of a combination of the two drugs have been used to provide approximately 90 minutes of anesthesia.[7] With the detomidine/ketamine combination, only a further dose of ketamine (1 mg/kg) is required initially to extend the duration, although if ketamine increments are to be given more than 30 minutes after anesthetic induction, it is probably advisable also to administer a small dose of detomidine (2-5 μg/kg).[7]

TIVA for Medium Duration Procedures

Prolongation of anesthesia beyond 30 minutes is usually achieved by administering a combination of an α_2-adrenoceptor agonist with ketamine and guaifenesin.[29-32] Neither of these drugs have an ideal pharmacokinetic profile to provide long-term anesthesia, hence they cannot be used for anesthesia in excess of 90 minutes. Xylazine and detomidine have adequately rapid kinetics, but residual guaifenesin will cause muscle weakness in recovery, thus drug protocols in which the dose of this central muscle relaxant is reduced are preferred. If benzodiazepines are used, they must be antagonized with flumazenil (Romazicon®) at the end of surgery, causing an important increase in costs for the procedure.[7] Theoretically, ketamine is not cumulative (due to its rapid metabolism), but if used by infusion for periods of more than 90 minutes, prolonged and poor quality recoveries with apparently hallucinatory effects have been seen.[7] The "triple-drip" was first used by Green and coworkers,[29] who used a mixture of xylazine/guaifenesin/ketamine for maintenance of general anesthesia. This technique and modifications of it using different α_2-adrenoceptor agonists are now widely used for surgical procedures of up to 90 minutes duration (Table 4).[30-32] Anesthetic induction should preferably avoid guaifenesin to reduce the total dose of this long-acting agent being administered.[7] Triple-drip solution is usually titrated to effect based on responses to the surgical procedure. However, it is important not to confuse an accelerated breathing pattern, which commonly occurs as a result of slowly developing mild to moderate hypoxemia (unless supplemental oxygen is administered) as a sign of awakening. If misinterpreted as evidence of a too light plane of anesthesia, increasing the triple-drip solution rate in this situation would further aggravate impairment of respiratory function. The triple combination of an α_2-adrenoceptor agonist with ketamine and guaifenesin causes usually little respiratory depression for the first half hour, but for procedures lasting in excess of 30 to 45 minutes, the horse should breathe an oxygen-enriched gas mixture and be intubated.[7] Recovery from prolonged infusion of this mixture is usually not rapid but calm. The α_2-adrenoceptor agonist blocks insulin release and causes hyperglycemia and diuresis, with copious volumes of urine being produced,[7] which is of concern when surgery takes place under open air in hot weather conditions,

unless sufficient volumes of IV crystalloid solutions are simultaneously administered.

Systemic and Local/Regional Analgesia

Options to improve analgesia in horses during surgery include nonsteroidal antiinflammatory drugs (NSAIDs), opioids, and techniques of local analgesia.[32] Various NSAIDs have been used in horses for many years and may provide adequate postoperative analgesia. Usually they are given IV before anesthesia so that they can be effective during surgery and the recovery period.[32-35] Phenylbutazone (5-20 mg/kg IV), flunixin meglumine (0.2-1.1 mg/kg IV), ketoprofen (1.1-2.2 mg/kg IV), and carprofen (0.5-1.1 mg/kg IV) are popular NSAIDs which produce their analgesic effects mainly by inhibiting cyclooxygenase-1 (COX-1) activity.[32,34] Both pure μ and mixed agonist/antagonist opioids (eg, butorphanol 0.02-0.04 mg/kg IV)[32] are used in horses. They produce little sedation when used alone, but in combination with small doses of sedatives they provide chemical restraint and some analgesia.[32] Respiratory depression is rarely a problem in horses when the drugs are used at clinical doses. In a recent study, butorphanol, as compared with morphine, improved the quality of induction, maintenance, and recovery from general anesthesia in combination with romifidine and ketamine in ponies undergoing castration under field conditions.[36] But in this study, it was impossible to determine whether the superior conditions provided by romifidine and butorphanol were the result of better sedation or greater analgesia.[36] The use of local or regional anesthetic/analgesic techniques often applied in field conditions to improve intraoperative analgesia but also to prolong the recumbency time reducing the nociceptive stimulus. Those techniques are recommended in all surgical procedure in which a local or regional technique is feasible. Nerve blocks in the limbs, epidural block, and site infiltration (eg, block of the spermatic funicle) are techniques that can easily be applied under field condition and produce a significant improvement of the anesthetic management.[37] The use of local anesthetics usually assures both a motor and sensitive block, whereas the use of opioids (especially μ_2 agonists) induces analgesia only.

Anesthesia of Foals Under Field Conditions

A number of minor procedures can be performed in sedated foals; foals lie down more readily than adults, and sedation may often induce recumbency. Premedication has definite advantages (analgesia, sedation, decreased dose of other agents, etc.), but administration of any drug to a young foal must be done with knowledge of its physiology and in light of a foal's temperament and health status. Although xylazine may be used and sometimes be necessary to calm the patient, it has such a pronounced effect on heart rate and cardiac output in foals, that its use before anesthesia is generally reserved for fractious or older foals.[6,38] The dose is reduced in comparison to the adult and in a month-old foal a dose of 0.5 mg/kg IV will usually provide substantial sedation.[6] In neonatal foals, diazepam or midazolam (0.05-0.1 mg/kg) provides tranquilization and good muscle relaxation and may be used alone or in combination with a low dose of an opioid, such as morphine (0.03-0.06 mg/kg) or butorphanol (0.05-0.1 mg/kg).[6,38,39] The effects of opioid drugs on respiratory function and gastrointestinal motility are unknown in the neonatal foal. The drugs do seem to cause sedation when used in combination with benzodiazepines and may provide analgesia. Ketamine (2 mg/kg) or propofol (2 mg/kg) have been successfully used following sedation with either xylazine or diazepam.[6,38] Cardiovascular function is thought to be adequately maintained with either combination, but cost and familiarity generally favor the use of ketamine. Recovery does not appear to be prolonged in the young healthy patient after a single dose of these injectable drugs.[6,38] It is better to avoid barbiturates in very young foals as recovery may be prolonged and respiratory depression more pronounced.[38] Foals of 2 to 3 months of age respond to barbiturates more like adults.[38] Propofol has been used for anesthetic maintenance in foals, but most commonly it is the inhalation anesthetics that are used in young patients as their effect is terminated via exhalation.[6,38] Single doses of systemic analgesics may be used, but information regarding the effects of infusions of drugs, such as lidocaine, that are now commonly used in the adult is limited.[38] Due to limitations in administration of systemic analgesics, regional analgesic techniques are suggested when appropriate for a procedure (eg, epidural for repair of a scrotal or inguinal hernia, intraarticular local anesthetic/morphine after lavage of a septic joint).[38]

General Anesthesia for Transport and/or Veterinary Care of Horses Injured During Exercise

Providing emergency care to horses that are injured during exercise is problematic. Horses that are injured are often exhausted, stressed, excited, and painful and may be physically challenged (eg, they may not be bearing weight on one or more limbs).[40] Exertion increases metabolic rate and is associated with marked changes in cardiovascular and respiratory function that return to preexercise values only at various rates during the recuperative period following exercise.[40] Injury may prolong the recuperative period because injured horses may not be able to undergo an active cool-down period because of the risk of further injury.[40] With the addition of stressors such as pain and physical impairment, injured horses may be difficult to control, posing further risks to themselves and their handlers. An additional confounding condition is that injuries usually occur at locations remote from facilities fully equipped for provision of anesthesia. This condition necessitated the development and characterization of anesthetic regimes of sufficient duration to allow safe transportation of injured and exhausted horses to appropriate veterinary medical facilities. Effective sedation can be produced by administering commonly used sedatives and tranquillizers at twice the commonly accepted clinical doses.[36] Detomidine and combination of xylazine and acepromazine produce effective sedation when administered intravenously 1 minute after maximal exercise.[40] The production of sedation and analgesia is sufficient to allow safe handling of in-

jured horses in most situations, but on occasion, more severe, unstable injuries occur. The induction of general anesthesia to horses injured while exercising could provide complete immobilization and analgesia, reducing the potential for exacerbation of the injury and improving safety for the horse and its handlers, thus facilitating emergency care.[40]

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