

EQUINE ANESTHESIA

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Introduction

- Higher morbidity and mortality associated with general anesthesia (1:100) in comparison to small animals (1:1000) or human (1: 200,000)
- No change of the risk ratio for the last 30 years, but the duration of surgery extended.
- Unique anatomic and physiologic characteristics presents additional challenge
- More pronounced cardiovascular depression (hypotension and reduced cardiac output) at equipotent MAC than other species such as dogs and cats
- The size, weight temperament and tendency to panic of the adult horse introduce the risk of injury to the patient and to the personnel.
- Prolonged recumbency is unnatural in the horse
- When a horse is placed in dorsal recumbency, the weight of the abdominal contents presses on the diaphragm and limits lung expansion, leading to hypoventilation. If the drugs used to produce anesthesia depress cardiovascular function, these changes will be exaggerated due to a ventilation-perfusion mismatch.

Standing chemical restraint and preanesthetic agents

- Due to higher risk associated with general anesthesia in this species, standing chemical restraint can offer safer alternative for many procedures
- Neuroleptanalgesia (neuroleptics + opioids) or sedative/opioid combination are most popular
- Produced by the concurrent administration of a sedative/tranquilizer and a narcotic analgesic (e.g. detomidine and butorphanol; acepromazine and morphine)
- Better restraint and analgesia (the combination is synergistic, not merely additive)
- Many procedures can be performed which would not be possible with the tranquilizer or sedative alone
- Dose sparing effect on both drugs
- Better cardiovascular preservation
- Can provide satisfactory working condition for minor surgery when combined with local anesthesia
- Less expense, less risk, less logistics
- This combination can also be effective as preanesthetic medication to produce reliable sedation (e.g. xylazine and butorphanol combination)
- A good preanesthetic sedation facilitate smooth induction and has anesthetic sparing effect during maintenance

Acepromazine

- Major tranquilizer
- Hypotensive
- Anti-arrhythmic
- Stallion: penile priapism
- Requires at least 20 min for good effect even after IV injection, and 30 to 45 min when given IM
- Prolonged duration
- 0.025 – 0.05 mg/kg
- Premedication dose of 0.04 mg/kg IV has minimal cardiovascular effect in healthy horses

- Respiratory rate decreases but tidal volume increases to maintain relatively normal ventilation
- Will cause hypotension (more so in old, debilitated, or hypovolemic horses) through direct myocardial depression and peripheral vasodilation
- Has been replaced mainly by alpha 2 agonists for sedation

Diazepam

- Minor tranquilizer
- Excellent muscle relaxation
- Minimal cardiopulmonary depression
- Not given alone in the horse due to panic (and excitement) mediated by ataxia
- Usually administered as part of induction agents with ketamine
- 0.02 – 0.1 mg/kg IV

Xylazine

- Has replaced acepromazine as sedative/premedicant
- Onset of action following IV injection at 2 min, reaching peak effect in 5 minutes.
- Potent hypnotic and produces a predictable sedation
- Head drops almost to ground
- Beware, horses are very sensitive to touch on the hindlimbs when sedated with xylazine, and still able to kick accurately
- Dose dependent severe cardiovascular effect: bradycardia, AV dissociation, myocardial depression (decreased cardiac output)
- Second degree atrioventricular heart block may persist for the duration of sedation.
- Initial transient hypertension lasting for 5 – 10 minutes, then prolonged hypotension lasting 30 minutes or longer
- Little effect on respiration: PaO₂ mildly fall
- Duration for sedative effect lasts about 30 minutes
- 0.5 - 1 mg/kg IV
- Horse becomes ataxic but remains standing
- Increasing dose does not increase the degree of sedation, but duration. (ceiling effect on the degree of sedation)
- Best given with butorphanol for standing chemical restraint
- An intra-arterial injection of xylazine will usually cause uncontrolled excitement, followed by collapse and thrashing or rigidity. This should be treated with an infusion of guaifenesin to produce relaxation, diazepam to control seizures, oxygen to counteract respiratory depression, fluids IV to counter hypotension.
- Other side effects
 - Hyperglycemia
 - Diuresis
 - Sweating
 - GIT motility depression
 - Depressed intestinal motility will last longer than the sedative effects of the drugs. Do not feed the horse until intestinal motility returns, otherwise the horse may become colicky
 - Platelet aggregation
 - Uterine contractions in cows. The incidence of abortion in pregnant mares has not been established. Detomidine in this regard has been regarded better alternative both in cows and mares.

Detomidine

- More popular in Europe (cheaper than xylazine)
- Duration of sedation longer acting than xylazine (twice), lasting at least 45 min
- 5 - 20 mcg/kg IV
- Similar side effects in all other aspects with xylazine
- Precautions are similar to those given for xylazine. Sedation may be inadequate if horse was excited before administration of detomidine.

Romifidine

- Available in Europe for a while and recently become available in the US market
- Less ataxia may be advantageous for head and neck procedures
- 50 – 150 mcg/kg IV
- Longer sedative effect than detomidine
- Similar in all other aspects with xylazine and detomidine

Butorphanol

- Not used alone due to excitement, so always given with sedatives as part of sedative/opioid combination
- Also, do not use morphine, oxymorphone, or etorphine alone in healthy horses. (excitement can be even more pronounced)
- However, the horse in pain, e.g. colic, usually will not become excited when these drugs are used in low doses for analgesia.
- Adequate analgesia for minor procedure
- 0.02 – 0.05 mg/kg IV
- Minimal change in HR, BP, CO when given alone.
- BP is decreased if butorphanol is administered during halothane anesthesia.

Anticholinergics

- Depress gastrointestinal motility and increase the risk of abdominal discomfort or colic, so only administer when bradycardia or vagal reflexes are a problem
- Bradycardia in anesthetized horses is arbitrarily defined as HR < 25 beats/min
- Atropine 0.002 - 0.01 mg/kg IV or glycopyrrolate 0.001 – 0.005 mg/kg IV

Drug combinations

- Precaution on combining xylazine with acepromazine because of the additive hypotensive effect
- More consistent degree of sedation and extended duration with the combination are advantageous
- Experimentally, it has been demonstrated that simultaneous administration of acepromazine (0.05 mg/kg) and xylazine (0.55 mg/kg) to healthy horses did not produce cardiovascular changes that were significantly different from those produced by xylazine alone at 1.1 mg/kg.

Preanesthetic Preparation

- No grain is to be fed 24 hours before anesthesia. No hay is to be fed 12 hours before anesthesia.
- Water is OK
- Foals scheduled for general anesthesia are usually allowed to nurse up to 1 hour before scheduled induction time
- Laboratory evaluation (minimum are PCV, TP, BUN, glucose)
- Additional tests may be warranted if sick and carries higher risks
- Review patient's medical history; check for deworming dates. Wait at least one week, preferably two, following organophosphate treatment.
- Do a physical examination to determine any abnormalities. Auscultate for cardiac dysrhythmias and murmurs, or abnormal lung sounds.
- Stabilize animal's physiology in debilitated animals (e.g. colic, ruptured bladder)
- IV catheterization in place
- A 12-14 gauge 3 – 5 inch long catheter is used for most horses.
- Pick the feet and clean the debris and dirt or cover the shoes
- Rinse the mouth with warm water prior to induction
- The mouth is washed out thoroughly using a dose syringe and water. This is done to prevent the endotracheal tube carrying food material into the trachea and lungs.



Mouth rinsing



IV catheterization



Anesthetic Induction

Critical for the safety both for the horse and the personnel, so smooth induction is essential

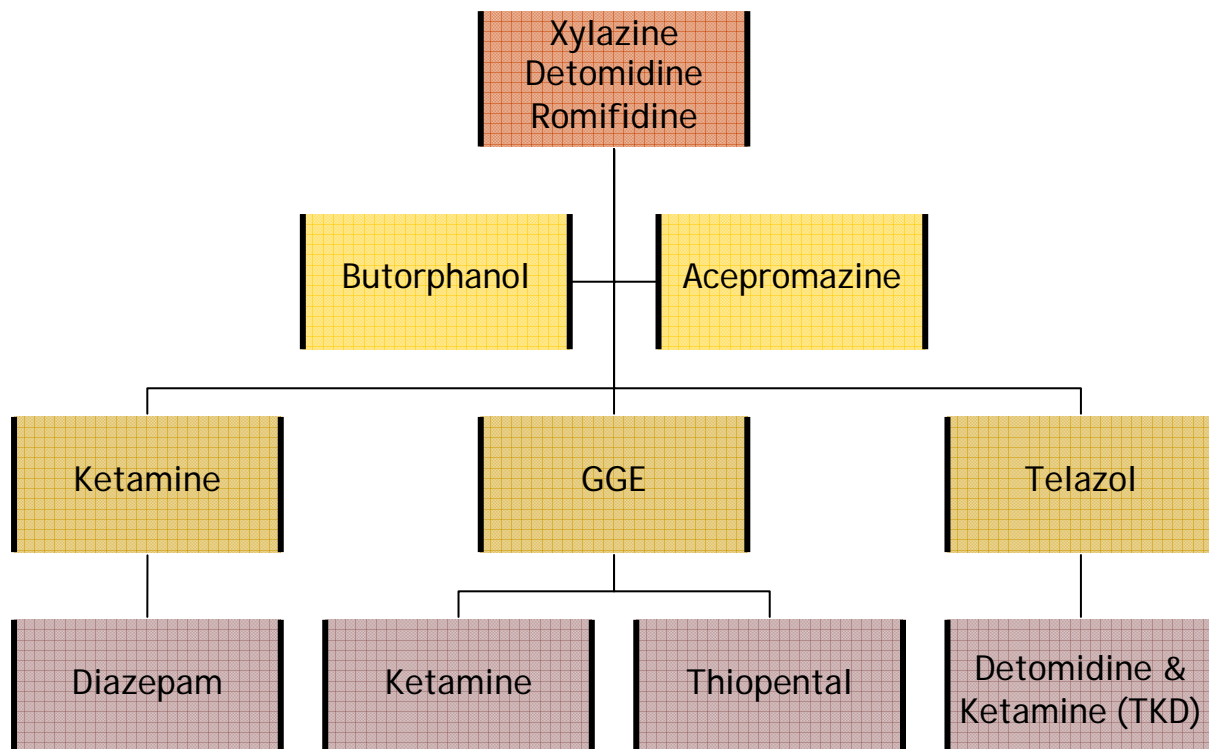
- Techniques to induce:
 - Swing door
 - Free fall
 - Hydraulic table



Most Common Anesthetic Drug Combination for Induction

- Xylazine premedication and ketamine (\pm diazepam) Induction
- Ketamine administered alone without sedative premedication to the horse causes excitement
- Ketamine is injected 3-5 min after apparent xylazine induced sedation
- Ketamine is not used by IM injection in the conscious horse because the horse may be injured during the period of incoordination occurring while the drug is taking effect
- Biologic half life of ketamine is 45 minutes in the horse, with 99% of a bolus dose eliminated in 4 hours. Recovery to consciousness is due to extensive extravascular distribution of the drug
- Induction of anesthesia occurs about 60 seconds after ketamine injection. Horse falls to the ground characteristically with the forelimbs buckling and the hindlimbs straight. The person holding the horse's head should exert steady backward pressure on the horse during loss of consciousness in an attempt to make the horse sit on its hindquarters and not fall on its nose.
- Xylazine-ketamine anesthesia is accompanied by strong muscle tone for the first 5 minutes, and usually nystagmus, a strong palpebral reflex, and pupillary dilation.
- The duration of anesthesia varies from 7 min to 20 min. Anesthesia is often short in young horses and in Thoroughbreds.
- The major advantage of this combination is that recovery is usually smooth, with less incoordination than is seen with thiobarbiturate or guaifenesin combinations. The horse is usually standing 30-40 minutes following a single administration of xylazine and ketamine.
- Glyceryl Guaicolate Ether (GGE) is another useful drug for equine anesthetic induction
- Also known as guaifenesin (US) or guaiphenesin (Europe), it is administered at 50 – 100 mg/kg IV to effect to produce sedation/muscle relaxation
- Because of its muscle relaxant effect, this drug alone is not suitable to produce sedation as the ataxic horse may panic

- When animal knuckles following adequate dose (usually 50 mg/kg), a rapid bolus dose of 0.5 mg/kg ketamine IV or 2 mg/kg thiopental sodium is administered to provide smooth anesthetic induction
- Anesthesia can then be maintained either on inhalational agent or intravenous anesthetics.
- Available in 5, 10, 15 % in commercial preparation, but concentration higher than 15 % is not recommended for use due to hemolysis.
- Can be mixed with thiopental sodium, ketamine or xylazine in the diluent
- Home-made GGE may form precipitates if left unused for prolonged period, but rewarming the diluent will resolve this, and the efficacy of the agent is not altered. This problem is not seen with commercial preparations.
- Variations (see the chart below)
 - Substitute xylazine with detomidine or romifidine
 - Add butorphanol to premed
 - Add acepromazine to premed
 - Add diazepam to induction
 - Add/substitute guaifenesin ± thiopental to induction
 - Add/substitute Telazol, detomidine to induction (TKD mixture)



Endotracheal Intubation

Relatively easy and carried out blindly

- No forcing, but rather smooth fit
- Check the cuff for leaks but maintain clean tube
- Apply KY jelly at the outside of the tip end of the ETT using a gauze sponge or paper towel. This lubrication will facilitate the intubation.
- Modified PVC mouth gas is useful to facilitate the intubation

Endotracheal tube sizes based on weight

Horse weight	70-100 kg	150-200 kg	250 kg	350 kg	450 kg
Endotracheal tube size ID	15-18 mm	18-22 mm	22-24 mm	24-26 mm	26-30 mm



Maintenance of Anesthesia

Mostly carried out using inhalants, but intravenous techniques can be used for a short anesthetic

Inhalational anesthesia

- Problems occur more frequently and in greater magnitude than during canine anesthesia
- More pronounced hypotension, hypoventilation, reduction of cardiac output
- More dramatic consequence to the operator and the patient if anesthetic plane is not well controlled
- Halothane, isoflurane, sevoflurane, desflurane recovery differ. The fasted recovery may not be the best quality

Nitrous oxide

- Analgesia from N₂O reduces inhalational anesthetic requirement therefore less cardiovascular depression.
- However, even with 50 % oxygen and 50 % nitrous oxide mixture hypoxemia is common probably due to the nitrous oxide dissolving into gaseous space such as GIT and leading to the V/Q mismatches.
- Use of this agent is not recommended in this species (exception is foals and small-sized equids)

Halothane (Fluothane®)

- Halothane has the highest metabolism, so avoid in hepatic insufficiency
- Currently it is not marketed in the US, but some equine practices still carry it in their inventory
- This agent is being largely displaced by newer agent such as sevoflurane and isoflurane as the cost of the newer agents becomes more affordable, however some equine practitioners use it other than cost reason, mainly for superior recovery quality (particularly important for orthopedic cases)
- 1 MAC halothane in horses is 0.9%, and 0.7 % in foals
- Always administered via endotracheal tube after induction of anesthesia with injectable drugs.
- Halothane decreases ventilation. RR may be normal or decreased but arterial carbon dioxide levels increase and oxygen levels decrease.
- Halothane sensitize the myocardium to circulatory catecholamines with more frequent dysrhythmias exhibited
- A lightly anesthetized (1 MAC), spontaneously breathing horse will have a 40-50% decrease in CO
- Heart rate is maintained in the normal range (28 to 44 beats/min)
- The arterial blood pressure decreases from conscious value (MAP 110) to 80 mmHg
- As anesthesia is deepened by increasing halothane concentration, CO and arterial pressure decrease further. HR usually remains constant.

Isoflurane (Aerrane®, Forane®, IsoFlo®)

- Used to be much more expensive than halothane, but the price has come down substantially for the past few years, so more frequently used
- Quicker anesthetic stabilization and more rapid recovery
- However, in some recovery from anesthesia to consciousness is too quick leading to poorer quality. Sedation with a minute dose (0.2 mg/kg) of xylazine has been recommended to provide better recovery in some orthopedic procedures.
- 1 MAC in horses is 1.3%, and 0.9% in foals
- The degree of respiratory depression is greater with isoflurane than halothane.
- As anesthesia deepens, the respiratory rate tends to increase with halothane and decrease with isoflurane.
- Controlled ventilation (IPPV) is recommended for isoflurane anesthesia
- Isoflurane, similar to halothane, induces a dose-dependent cardiovascular depression.
- Little difference in cardiovascular function has been noted between halothane and isoflurane when horses are breathing spontaneously.
- Under controlled ventilation, the cardiac output has been demonstrated to be significantly higher during isoflurane anesthesia.
- Isoflurane causes more peripheral vasodilation than halothane, which is responsible for a low arterial blood pressure, but tissue looks more bright and pinky indicating better perfusion.

Sevoflurane (Ultane®)

- Anesthetic induction, recovery, and intraoperative modulation of anesthetic depths to be notably faster than halothane and isoflurane.
- More expensive than halothane and isoflurane, but the price is getting lower.
- Sevoflurane (1 MAC = 2.3 %) is less potent than halothane or isoflurane, but more potent than desflurane
- Sevoflurane induces dose-dependent cardiovascular depression to a degree similar to that of isoflurane
- Sevoflurane and isoflurane cause greater increases in PaCO₂, decreases in pH and ventilatory response to hypercapnia than does halothane in horses. Respiratory rate is lower than with halothane, and minute ventilation decreases
- Two sevoflurane breakdown products are of potential concern because of their nephrotoxicity: Compound A and inorganic fluoride.
- No clinical studies of humans demonstrate significant changes in BUN, creatinine, or the ability to concentrate urine after sevoflurane anesthesia when compared to other inhalant anesthetics. This is true also for a study in horses
- Currently, more than 90 % of BVMTH equine cases are anesthetized with sevoflurane
- The recovery quality may suffer due to rapid emergence from anesthesia, hence sedating with 0.2 mg/kg of xylazine at the time to move to the recovery stall may help

Desflurane (Suprane®)

- Lower blood/gas partition coefficient than the inhalants mentioned above, so control of anesthetic depth is relatively quick
- Horses' recovery from desflurane anesthesia is fast (e.g. 15 min to standing after 100 minutes of anesthesia), and quality rated good to excellent
- The least potent among the volatile anesthetics in clinical use (MAC = 7.6 %)
- Cardiovascular effects of desflurane are similar with those of isoflurane
- Causes dose-dependent respiratory depression, the magnitude similar to isoflurane
- May cause airway irritation with resulting coughing, secretions and breath holding
- Expensive as sevoflurane, and requires electronically controlled vaporizer which adds to the inconvenience

Total Intra-venous Anesthesia (TIVA)

- Xylazine 1.1 mg/kg premedication and ketamine 2.2 mg/kg induction provides approximately 10 - 20 minutes of general anesthesia.
- Prolongation of xylazine-ketamine anesthesia in horses is done with 0.35 mg/kg of xylazine and 0.7 mg/kg IV of ketamine starting 12 minutes after the initial ketamine induction. This dose can be repeated each 12 minutes for additional two doses, but accumulative prolonged recovery maybe seen.
- Additional one fifth dose of induction agent provide a buying time until increased vapor setting deepens anesthetic depth in the event animal suddenly wakes up during inhalation maintenance anesthesia
- Alternatively,
 - Xylazine and ketamine added to a bottle of guaifenesin (GKX) is very popular for procedures not extending beyond 1 hour and administered as a continuous infusion.
 - In 50 g of 1 L GGE, add 500 mg of xylazine and 2000 mg of ketamine and administer 1 – 3 ml/kg/hr depending on the CNS reflexes of the animal as assessed by ocular reflex (brisk palpebral reflex, occasional nystagmus must be present), changes of breathing pattern and rate, and changes of BP, HR etc.
 - Given IV, not IM and never just for sedation
 - Any procedure which is anticipated to last longer than 1 hour should not be done with GGE-xylazine/ketamine or GGE-barbiturate anesthesia alone. Prolonged recovery for extended anesthesia
- Limitations:
- The main limitation to continued administration of intravenous anesthetics is the arterial oxygenation.
- While it is true that progressive collapse of the down lung occurs with time, thus increasing the ventilation-perfusion mismatch and decreasing arterial oxygenation, this can be an unreliable guideline. One horse can be anesthetized and breathing air for an hour or more and have acceptable levels of oxygen and carbon dioxide, whereas another horse will become hypoxemic within 10 minutes.
- IV anesthesia should not be prolonged beyond 45 minutes in an adult horse without supplying the horse with oxygen to breathe and means of ventilatory support
- Propofol: non-accumulative but very expensive
- Propofol and medetomidine combo (0.1 mg/kg/min of propofol and 3.5 mcg/kg/hr of medetomidine) provides satisfactory anesthetic plane in response to supramaximal noxious stimuli, and recovery in 4 hr + anesthesia was very smooth, rapid and complete

- Tight anesthetic depth control is harder with TIVA so abrupt awakening during anesthesia is more likely if one is not familiar with the technique (inhalant anesthetic provides advantage in this respect as by monitoring anesthetic concentration in breathing gases, one can control anesthetic depth better)

The following table lists some sample doses for injectable anesthetics in the horses

Comb. #	Premedication	Dose mg/kg	Induction agents	Dose mg/kg
1	Xylazine	1	Ketamine	2
2	Xylazine	0.7	Diazepam Ketamine	0.05 2
3	Xylazine Butorphanol	1 0.02	Ketamine	2
4	Xylazine Butorphanol	0.5 0.02	Diazepam Ketamine	0.05 2
5	Acepromazine Xylazine	0.04 0.6 to 1.1	Ketamine	2
6	Xylazine	0.6 to 1.1	Guaifenesin followed by ketamine bolus	100 (G) or "to effect" 1 (K)
7	Acepromazine or Xylazine	0.04 0.6	Guaifenesin 50 g mixed with 2 g thiopental followed by thiopental bolus	100 (G) – 4 (T) or "to effect" 2 (T)
8	Acepromazine or Xylazine ± Butorphanol	0.04 0.6 0.02	Guaifenesin 50 g mixed with 2 g thiopental followed by thiopental bolus	100 (G) – 4 (T) or "to effect" 2 (T)
9	Detomidine ± Butorphanol	0.01 0.02	Guaifenesin 50 g mixed with 2 g thiopental followed by thiopental bolus	100 (G) – 4 (T) or "to effect" 2 (T)