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Anesthetic Management of the Horse: Intravenous Anesthesia (31 Oct 2000)

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Introduction

For decades thiobarbiturates have been used to induce and maintain short term (15 - 30 minutes) general anesthesia in equids. Thiamylal is no longer commercially available, at least in the United States, but use of thiopental remains widespread. In earlier years these ultrashort acting barbiturates were the agents of choice to induce short term recumbency in tranquilized horses. Later guaifenesin and more recently xylazine (or other alpha-2 agonist type drugs) were administered in combination with or immediately prior to the intravenous injection of the thiobarbiturates to improve upon the quality of anesthetic induction and recovery. These improved techniques of general anesthesia facilitated surgical and other therapeutic procedures requiring more prolonged recumbency (e.g. 30 - 60 minutes). However, as duration of barbiturate administration increased, the duration of recovery from anesthesia became longer and the quality of recovery became more unpredictable and in some cases dangerous to the animal and associated personnel.

Today, dissociative drugs such as ketamine have largely replaced thiobarbiturates for routine equine anesthetic management. This change has improved upon the qualitative consistency of both anesthetic induction and recovery. Because the dissociative agents have undesirable central nervous system excitatory properties their use in equids requires concurrent administration of other behavior modifying drugs such as an alpha-2 agonist (e.g. xylazine). A brief review and update of specific contemporary techniques follow.

Anesthetic Induction and Maintenance - Dissociative Drug Based

Xylazine/ketamine and xylazine/guaifenesin/ketamine - the use of xylazine and ketamine for induction and short-term anesthetic maintenance in the horse has been extensively described [1-5]. Recently, investigators evaluated the behavioral and cardiopulmonary responses associated with varied dose combinations of xylazine and ketamine during anesthetic maintenance [6-8].

Response to noxious stimulation varied with drug and dose as did speed of recovery from anesthesia; quality of recovery was good to excellent in all horses. Bradydysrhythmias and relative hypoxemia were commonly recorded during xylazine/ketamine maintenance. Blood pressure recorded in horses receiving xylazine and ketamine was higher than that previously reported for inhalation anesthesia; cardiac output was similar (low) [8]. Low cardiac output in the face of good blood pressure is likely a direct result of drug actions (e.g., bradycardia, vasoconstriction). In support of this interpretation, Singh et al., showed that pretreatment with glycopyrrolate (2.5 µg/kg) minimized the negative influence (likely due to the decreased heart rate) of xylazine and ketamine on cardiac output [9]. The stimulatory influence of PaO^2 on cardiac output must also be considered. Results from a study by Mama et al., indicate that during maintenance with equipotent doses of xylazine and ketamine, cardiac output was significantly higher in horses breathing room air (likely due to sympathetic stimulation resulting from hypoxemia) as compared to those breathing 100% oxygen [6].

The addition of guaifenesin to xylazine and ketamine for short-term equine anesthetic maintenance was first described in the mid 1970's [3]. This combination of drugs provides desirable characteristics (analgesia, unconsciousness and muscle relaxation) associated with general anesthesia, and horses tend to recover well and in a predictable manner after drug administration is discontinued. Hypotension, which is

commonly observed during inhalation anesthetic maintenance, is rarely observed with xylazine/guaifenesin/ketamine maintenance when horses breathe air. These positive attributes have led to the common use of these three drugs in clinical veterinary practice both for induction of anesthesia and during maintenance of anesthesia for procedures (e.g. laceration repair, castration, etc.) lasting up to 1 hour.

Maintenance of anesthesia for greater than 1 hour with injectable anesthetic techniques is not usually recommended due to the potential for cumulative drug effects, which in turn prolong recovery from anesthesia and may negatively influence its quality. The potential for hypoxemia during recumbency maintained with this drug combination also limits its long-term use if oxygen is not supplemented (as in most circumstances of anesthesia performed in a non-hospital [i.e. field] setting) [3,5]. With widespread use of this injectable technique, it has also become apparent that due to the presence of reflex activity (e.g. blinking, swallowing), surgical conditions are not ideal for procedures involving the eye or upper airway [5]. The presence of reflex activity at a surgical plane of anesthesia can also confound evaluation of anesthetic depth and may lead to inappropriate drug dosing.

Detomidine/ketamine and detomidine/guaifenesin/ketamine - detomidine (20 µg/kg) plus ketamine (2 mg/kg) and detomidine plus guaifenesin and ketamine (varying infusion doses) have been studied for induction and maintenance of anesthesia in ponies and to a limited degree in horses [10-13]. While the concurrent administration of other drugs (e.g. acepromazine, flunixin) with potential behavioral, cardiovascular or analgesic effects may influence interpretation of the results from these studies, authors report that blood pressure and cardiac index was well maintained. When compared to halothane anesthesia during surgical castration authors report that cortisol levels increased over pre-surgical levels to a greater degree during inhalation anesthesia than during maintenance with detomidine, guaifenesin and ketamine. Surgical conditions and recovery from anesthesia were comparable for the two protocols.

Romifidine/ketamine and romifidine/guaifenesin/ketamine - the use of romifidine (100 µg/kg) and ketamine (2.2 mg/kg) prior to maintenance of anesthesia with halothane was first described in the early 90's [14]. While induction of anesthesia was rated excellent in 33 of 45 horses, swallowing, rigidity and mild muscle tremors were observed early in the recumbency period. In another study anesthesia was induced in a similar manner and then maintained with an additional intravenous bolus of both romifidine (40 µg/kg) and ketamine (1.1 mg/kg) administered approximately 18 - 20 minutes after the initial dose of ketamine [15]. A positive response (purposeful skeletal muscle movement) to a pinprick was observed at 35 minutes after the initial ketamine dose; lateral recumbency was maintained for an average of 43 minutes. Compared to pre-sedation values heart rate and arterial oxygen tensions were decreased and mean arterial pressure was increased during anesthetic induced recumbency.

McMurphy et al., compared cardiopulmonary effects of halothane and total intravenous anesthesia maintained with romifidine (82.5 µg/kg/h), ketamine (6.6 mg/kg/h) and guaifenesin (100 mg/kg/hour for 30 min, then 50 mg/kg/h) [16]. Although differences in some recorded variables (e.g. heart rate, mean arterial pressure) were observed at various time points during the study, authors concluded that except for changes in pulmonary artery pressures, there were no significant differences in recorded cardiopulmonary variables between the two anesthetic techniques.

Xylazine/diazepam/ketamine, romifidine/tiletamine-zolazepam and xylazine/climazolam/ketamine - the use of benzodiazepines in place of guaifenesin has been evaluated for anesthetic maintenance. In the early 90's Brock et al., characterized behavioral and cardiopulmonary effects associated with use of two doses of diazepam (0.05 and 0.1 mg/kg) in horses also receiving xylazine (0.3 mg/kg) and ketamine (2.0 mg/kg) for anesthetic induction [17]. Diazepam (0.1 mg/kg) was felt to be equivalent to guaifenesin (100 mg/kg) in this protocol.

The use of tiletamine (dissociative) and zolazepam (benzodiazepines) has also been evaluated in horses premedicated with romifidine [15]. The quality of anesthesia was smooth and horses remained in lateral recumbency an average of 45 minutes. In another study anesthesia was maintained for 120 minutes with climazolam (0.4 mg/kg/h) and ketamine (6 mg/kg/h) in ponies premedicated with xylazine and acepromazine [18]. Although recovery quality was not as good as that reported with previously described techniques, authors felt that the cardiopulmonary function was better maintained.

Anesthetic Induction and Maintenance - Propofol Based

Propofol is an anesthetic agent characterized as having a rapid onset and short duration of action. Due to these beneficial drug characteristics, its use in the anesthetic management of human beings and small animal patients is now routine. Anesthetic induction and maintenance with propofol in ponies was first described in the 1980's [19]. Since that time it has also been evaluated for use in foals and adult horses. As with ketamine, it has generally been used in combination with alpha-2 agonists and/or muscle relaxants.

Propofol for Anesthesia in Foals - foals anesthetized with propofol (2 mg/kg) after premedication with xylazine (1.1 mg/kg) and butorphanol (0.01 mg/kg) were recorded as having higher heart rates and lower blood pressures than foals induced with ketamine (2mg/kg) [20]. While surgical castration was performed successfully with both drug protocols, the time to sternal recumbency and standing was shorter in foals receiving propofol; mean time to standing 12.3 minutes versus 19.7 minutes. In another study anesthesia was maintained with an infusion of propofol (0.26 - 0.47 mg/kg/min) for non-invasive diagnostic procedures after induction with propofol (2mg/kg) in foals premedicated with xylazine (0.5 mg/kg) [21]. Quality of anesthetic induction, maintenance and recovery was satisfactory and foals took an average of 27 minutes to stand following discontinuation of the infusion. Heart rate and mean blood pressure ranged from 84 - 92 beats per minute and 98 - 123 mm Hg, respectively. In foals breathing room air the $PaCO^2$ ranged from 45 - 60 mm Hg and the $PaCO^2$ ranged from 65 - 103 mm Hg.

Propofol for Anesthesia in Horses (and Ponies) - recorded behavioral and cardiopulmonary characteristics associated with propofol in adult horses have varied. In otherwise unmedicated horses, the anesthetic induction quality was unpredictable and ranging from good to poor [22]. Surprisingly, behavioral characteristics were not significantly improved following premedication with xylazine (0.5 and 1.0 mg/kg), detomidine (0.015 and 0.030 mg/kg), or medetomidine (7 µg/kg) [23,24]. However, with the addition of guaifenesin to the anesthetic induction protocol, induction was rated as good to excellent [6]. Although induction quality varied and differed from previous reports indicating good inductions with propofol use in ponies and Brazilian horses [25], recovery quality was good to excellent with all protocols. Selected cardiopulmonary responses were recorded during xylazine/propofol and detomidine/propofol anesthesia [23]. Heart rate decreased after xylazine and detomidine administration and remained lower than pre-drug values during recumbency. The overall trend was toward a decrease in respiratory rate and increase in $PaCO^2$ during recumbency. The $PaCO^2$ decreased significantly from pre-drug values during recumbency induced by both xylazine/propofol and detomidine/propofol.

Similar findings (e.g. low heart rate, relative hypoxemia, etc.) were described during anesthetic maintenance with xylazine and low dose (0.15 mg/kg/min) propofol infusion [6]. Cardiac index was similar to that previously described for halothane anesthetized horses [6]. Anesthesia with high dose (0.25 mg/kg/min) propofol infusion was characterized by marked respiratory depression and absence of response to noxious stimulus. Despite the increased anesthetic depth, and likely the result of the indirect sympathomimetic effect of an increased arterial carbon dioxide tension, heart rate and cardiac index were maintained within the normal ranges described for unanesthetized horses.

Propofol/ketamine - the use of propofol and ketamine together for maintenance of anesthesia in ponies anesthetized for castration with detomidine/ketamine has also been evaluated [26]. Authors report very good operating conditions and quiet recoveries from anesthesia following an average of ketamine (0.04 mg/kg/min) and propofol (0.12 mg/kg/min).

Injectable Drugs as Part of a Balanced Technique

The purpose of a balanced anesthetic technique is to achieve all of the components of general anesthesia while minimizing the negative aspects of individual drugs on cardiopulmonary function. While this technique is commonly used in human beings and small animal patients, its use in the horse has been limited. Recent investigative work provides information that may facilitate increased clinical use of this technique in the anesthetic management of horses.

Halothane/xylazine and halothane/detomidine - alpha-2 agents are known for their sedative and analgesic properties in horses. It is therefore not unreasonable to expect that they would influence anesthetic requirements of concurrently administered drugs. Two reports with different alpha-2 agonist drugs substantiate this.

Steffey et al., report a 25 - 34% reduction in isoflurane dose requirement measured 40 to 60 minutes following xylazine (0.5 mg/kg and 1.0 mg/kg, IV) administration to horses [27].

Dunlop et al., demonstrated the halothane sparing effect of detomidine in horses [28]. Their report indicates that halothane requirements decreased to approximately 55% from control as detomidine dose (and plasma concentration) increased.

Halothane/ketamine and halothane/guaifenesin/ketamine - Muir et al., describe a reduction in halothane dose requirement and improvement in cardiovascular function with increasing plasma ketamine concentrations [29]. While these aspects of combining these two drugs are favorable, authors describe a poor and prolonged recovery from anesthesia and suggest further clinical based evaluation of this technique. In a clinical study a combination of guaifenesin and ketamine was used to reduce the dose requirement of halothane in horses presented for diagnostic evaluation and emergency surgery [30]. They report stable anesthetic conditions and predominantly good recoveries from anesthesia with this technique.

Halothane/lidocaine - another drug that has been evaluated for its effect on halothane minimum alveolar concentration (MAC) for equine patients (ponies) is lidocaine [31]. Reduction in halothane MAC correlated with increasing plasma lidocaine concentrations and ranged from 20 to 70%. Cardiopulmonary effects of this combination have not been fully evaluated.

Injectable Drugs as Modifiers of Recovery Following Inhalation Anesthesia

In the 1980's Rose et al., reported that recovery following isoflurane anesthesia in the adult horse was unpredictable and less than ideal [32]. Because of continued observations of unpredictable recoveries from inhalation anesthesia, but predictably good recoveries following especially short and intermediate duration injectable anesthesia, there is an interest in modulating recovery from inhaled agents by using injectable drugs. Clinically this is commonly manifested by administration of an alpha-2 agonist early in the recovery phase especially when using an inhaled anesthetic agent with a low blood gas solubility. The potential benefit is also supported by results of investigative efforts [33].

Preliminary data suggest that recovery from isoflurane anesthesia can also be improved upon by use of propofol in the early recovery period; recovery quality was better with fewer attempts to stand in horses that received propofol [34].

Summary

Injectable anesthetic techniques for horses have improved and we now have many more choices available to address needs in a variety of clinical circumstances. Despite these improvements however, deficiencies exist and the quest for the "ideal application" of injectable drugs for horses continues.

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