Clinical comparison of xylazine and medetomidine for premedication of horses

Kazuto Yamashita, DVM, PhD; William W. Muir III, DVM, PhD, DACVA, DACVECC; Sae Tsubakishita, DVM; Eric Abrahamsen, DVM, MSc, DACVA; Phillip Lerch, DVM, MSc; John A. E. Hubbell, DVM, MSc, DACVA; Richard M. Bednarski, DVM, MSc, DACVA; Roman T. Skarda, DMV, PhD, DACVA; Yasuharu Izumisawa, DVM, PhD; Tadao Kotani, DVM, PhD

EQUINE

Objective—To compare the analgesic and cardiopulmonary effects of medetomidine and xylazine when used for premedication of horses undergoing general anesthesia.

Design—Randomized clinical trial.

Animals—40 horses.

Procedure—Twenty horses were premedicated with medetomidine (10 µg/kg [4.5 µg/lb], IM) and the other 20 were premedicated with xylazine (2 mg/kg [0.9 mg/kg], IM). Horses were then anesthetized with a combination of guaifenesin and ketamine; anesthesia was maintained with halothane. Additional doses of medetomidine or xylazine were given if horses were not sufficiently sedated at the time of anesthetic induction. After induction of anesthesia, sodium pentothal was administered as necessary to prevent limb movements. Hypotension was treated with dobutamine; hypoventilation and hypoxemia were treated with intermittent positive-pressure ventilation. The quality of anesthetic induction, maintenance, and recovery and the quality of the transition to inhalation anesthesia were scored.

Results—Scores for the quality of the transition to inhalation anesthesia were significantly higher for horses premedicated with medetomidine than for horses premedicated with xylazine. However, other scores, recovery times, and numbers of attempts needed to achieve sternal recumbency and to stand were not significantly different between groups.

Conclusions and Clinical Relevance—Results suggest that medetomidine is suitable for premedication of horses undergoing general anesthesia. Analgesic and cardiopulmonary effects of medetomidine were similar to those of xylazine, except that the transition to inhalation anesthesia was smoother when horses were premedicated with medetomidine, rather than xylazine. (*J Am Vet Med Assoc* 2002;221:1144–1149)

In horses, administration of α_2-adrenoceptor agonists results in sedation, analgesia, and muscular relaxation.[1-3] For instance, xylazine and detomidine are commonly used to control abdominal pain or provide sedation and analgesia in horses undergoing diagnostic or surgical procedures.[1-3] These drugs have been administered IV, IM, subarachnoidally, and epidurally, and the optimal route and dose depends on the physical status of the horse, the procedure being performed, and the degree of analgesia and sedation required.[1-3] Medetomidine has also been reported to be an effective analgesic and sedative in horses.[4-6]

Medetomidine is a synthetic α_2-adrenoceptor agonist that has higher α_2-adrenoceptor selectivity than do xylazine and detomidine and produces potent sedative effects at smaller doses than xylazine and detomidine in horses.[4-7] Doses of medetomidine ranging from 5 to 7 µg/kg (2.3 to 3.2 µg/lb), IV, are sufficient to cause deep sedation with severe ataxia, and doses > 10 µg/kg (4.5 µg/lb), IV, may result in recumbency.[1,4,6] Compared with xylazine at a dose of 1 mg/kg (0.45 mg/lb), IV, equipotent sedative doses of medetomidine and detomidine range from 5 to 10 µg/kg, IV, and from 20 to 40 µg/kg (9.1 and 18.2 µg/lb), IV, respectively.[4-6] At these doses, the sedative and ataxic effects of detomidine are longer lasting than those of xylazine and medetomidine.[6] Xylazine induces a similar degree of sedation with less ataxia than medetomidine but has a shorter duration of action.[4,6]

Sedation and cardiovascular depression caused by medetomidine, detomidine, and xylazine are dose-dependent[1-6,8,9] and last the longest in horses treated with detomidine.[9] Sedation is coupled in all species with marked cardiovascular changes, including decreases in heart rate and cardiac output and an initial increase followed by a decrease in arterial blood pressure.[1-3] Equipotent doses of medetomidine (4 µg/kg [1.8 µg/lb], IV) and xylazine (0.4 mg/kg [0.18 mg/lb], IV) induce similar cardiopulmonary changes in adult horses.[10] Compared with detomidine, however, medetomidine reportedly causes more profound analgesia but less severe cardiorespiratory alterations,[6,11] suggesting a potential advantage to the use of medetomidine in horses.

The sedative effects of medetomidine, combined with its short duration of action compared with that of detomidine, and excellent analgesic and muscle relaxant properties suggest that it may be useful clinically for premedication of horses prior to general anesthesia. The purpose of the study reported here was to compare the analgesic and cardiopulmonary effects of medetomidine and xylazine when used for premedication of horses undergoing general anesthesia.

From the Department of Veterinary Surgery 1, School of Veterinary Medicine, Rakuno Gakuen University, Ebetsu, Hokkaido 069-8501, Japan (Yamashita, Izumisawa, Kotani), and the Department of Veterinary Clinical Sciences, College of Veterinary Medicine, The Ohio State University, Columbus, OH 43210 (Muir, Tsubakishita, Abrahamsen, Lerch, Hubbell, Bednarski, Skarda).

The authors thank Carl O'Brien, Tirina Miller, and Drs. Warren L. Beard, Alicia L. Bertone, Lisa Kidd, James Robertson, David A. Wilkie, and Michelle Willis for technical assistance.

Address correspondence to Dr. Yamashita.

Materials and Methods

Forty horses (18 geldings, 13 mares, and 9 stallions) admitted to The Ohio State University Veterinary Teaching Hospital for elective surgical procedures were used in the study. All horses were considered to be free from clinically important cardiovascular and respiratory tract diseases on the basis of results of a physical examination, electrocardiography, a CBC, and measurement of fibrinogen concentration. Mean ± SD weight was 488 ± 84 kg (1,074 ± 185 lb; range, 364 to 670 kg [801 to 1,474 lb]); mean ± SD age was 5.3 ± 4.5 years (range, 1 to 18 years). Food, but not water, was withheld from the horses for a minimum of 8 hours before anesthesia.

Horses were randomly assigned to receive medetomidine[a] (10 µg/kg [4.5 µg/lb], IM; 20 horses) or xylazine[b] (2.0 mg/kg [0.9 mg/lb], IM; 20 horses) 1 hour before induction of anesthesia. Following administration of medetomidine or xylazine, a 14-gauge, 13.3-cm catheter was inserted percutaneously into the left jugular vein for infusion of anesthetic agents and a balanced electrolyte solution. Hair was clipped, and the surgical site was aseptically prepared in the horse's stall after the horse developed signs of moderate sedation (neck carriage in a position below the horizontal plane). The horse was then moved into an anesthetic induction stall, positioned against a wall, and restrained with a swinging door and breast rope. Horses that did not appear to be moderately sedate at the time of induction of anesthesia were given an additional dose of medetomidine (4 µg/kg [1.8 µg/lb], IV) or xylazine (0.4 mg/kg [0.18 mg/lb], IV). When horses appeared to be moderately sedate, a 5% guaifenesin solution[c] was infused through the jugular vein catheter until horses developed signs of marked ataxia (leaning on the swinging door and breast control rope). Recumbency was induced by bolus administration of ketamine[d] (2.2 mg/kg [1.0 mg/lb], IV). Quality of induction was scored as poor, fair, satisfactory, good, or excellent **(Appendix).**

Once horses were laterally recumbent, an endotracheal tube was placed, and horses were positioned on a padded surgery table. Ten of the 20 horses in each group were positioned in lateral recumbency, and the other 10 were positioned in dorsal recumbency. Anesthesia was maintained with halothane[e] in oxygen delivered with an agent-specific vaporizer[f] and a circle breathing system.[g] The oxygen flow meter was initially set at 10 L/min, and the halothane vaporizer was initially set at 3%. Delivered concentration of halothane was reduced as necessary to maintain a light plane of surgical anesthesia (palpebral reflexes maintained and absence of spontaneous limb movement). Ventilation was controlled by means of **intermittent positive-pressure ventilation (IPPV)** when hypoventilation (Pa_{CO_2} > 60 mm Hg) was documented by means of arterial blood gas analysis. The frequency of ventilation was set at 6 breaths/min, tidal volume was set at 14 mL/kg, and the **inspiration-to-expiration time (I:E)** ratio was set to < 1:3.5. The quality of the transition to inhalation anesthesia was scored as poor, fair, good, or excellent (Appendix). Additional injectable anesthetic drugs administered to deepen the plane of anesthesia during the first 20 minutes after induction were recorded.

Small incremental doses of sodium pentothal[h] (0.5 mg/kg [0.23 mg/lb], IV) were administered according to the preference of the anesthetist to control or prevent spontaneous movement. The quality of anesthetic maintenance was scored as poor, fair, good, or excellent (Appendix).

Heart rate and rhythm were recorded during anesthesia and displayed on an oscilloscope.[i] Measurement of systemic arterial blood pressure was facilitated by cannulation of the dorsal metatarsal artery or a branch of the facial artery after induction of anesthesia. **Mean systemic arterial blood pressure (MABP)** was obtained by use of a pressure transducer and oscilloscope. Dobutamine[j] was administered by slow IV infusion (0.5 to 1.0 µg/kg/min [0.23 to 0.45 µg/lb/min]) to horses with a MABP < 60 mm Hg. Dobutamine administration was discontinued when MABP was > 75 mm Hg. As soon as arterial cannulation was completed, an arterial blood sample was anaerobically obtained, and Pa_{O_2} and Pa_{CO_2} were measured with a blood gas analyzer.[k] Additional arterial blood gas samples were collected and analyzed approximately 20 minutes after IPPV was initiated or whenever hypoventilation was suspected in horses that were breathing spontaneously. In all horses, lactated Ringer's solution was administered IV at a rate of 10 mL/kg/h during anesthesia.

Recovery was considered to begin when halothane administration ceased. The endotracheal tube was removed when the horse regained a swallowing reflex. Times to extubation, the first movement of the head or limbs, sternal recumbency without returning to lateral recumbency, and standing without returning to recumbency were recorded. Numbers of attempts needed to achieve sternal recumbency and to stand were also recorded. The quality of recovery was scored as unable to stand, poor, fair, satisfactory, good, or excellent (Appendix). A single individual assigned timing of events during recovery and scores for quality of anesthesia.

The vaporizer setting required to maintain surgical anesthesia and cardiorespiratory responses (heart rate, MABP, respiratory rate) were recorded every 20 minutes from the time of anesthetic induction to the beginning of recovery. These data were evaluated with 2-way repeated-measures ANOVA. Scores for quality of anesthesia, recovery times, and numbers of attempts needed to achieve sternal recumbency and to stand were compared between groups with Mann-Whitney *U* tests. Differences were considered to be significant when P was < 0.05.

Results

Of the 20 horses premedicated with medetomidine, 7 were female, 4 were sexually intact males, and 9 were castrated males. Mean ± SD age was 5.3 ± 5.4 years; mean body weight was 475 ± 83 kg (1,045 ± 183 lb). There were 10 Standardbreds, 4 Quarter Horses, 3 Thoroughbreds, 1 Arabian, and 2 horses of other breeds. Types of surgery included arthroscopy (n = 9), laryngoplasty and sacculectomy (5), removal of the second or fourth metacarpal or metatarsal bone or a sequestrum (2), soft tissue surgery (2), tooth extraction (1), and ophthalmic surgery (1).

Of the 20 horses premedicated with xylazine, 6 were female, 5 were sexually intact males, and 9 were castrated males. Mean ± SD age was 5.1 ± 3.3 years; mean body weight was 501 ± 86 kg (1,102 ± 189 lb). There were 5 Standardbreds, 5 Thoroughbreds, 4 Quarter Horses, 2 Appaloosas, 1 Arabian, and 3 horses of other breeds. Types of surgery included laryngoplasty and sacculectomy (n = 7), arthroscopy (6), removal of the second or fourth metacarpal or metatarsal bone or a sequestrum (2), soft tissue surgery (2), tooth extraction (2), and ophthalmic surgery (1).

All horses became moderately sedate, as demonstrated by lowering of the head and neck to a position below the horizontal plane, within 20 minutes after IM drug administration. Nineteen of the 20 (95%) horses given xylazine and 15 of the 20 (75%) horses given medetomidine required IV administration of additional drug for adequate sedation in the induction stall. Time from IM drug administration to movement into the induction stall was significantly (P = 0.032) longer

for horses given medetomidine (mean ± SD, 66 ± 16 minutes) than for horses given xylazine (52 ± 20 minutes). All horses receiving an additional dose of the premedication IV had signs of moderate sedation within 5 minutes after IV drug administration. All horses had signs of moderate sedation before administration of 5% guaifenesin, and dose of guaifenesin for horses given medetomidine (mean ± SD, 49.9 ± 8.1 mg/kg [22.7 ± 3.7 mg/lb]) was not significantly different from the dose for horses given xylazine (48.9 ± 7.0 mg/kg [22.2 ± 3.2 mg/lb]).

In each group, scores for quality of anesthesia, recovery times, and numbers of attempts needed to achieve sternal recumbency and to stand were not significantly different between horses positioned in dorsal recumbency and horses positioned in lateral recumbency.

Quality of induction was considered excellent for all 20 of the horses premedicated with medetomidine and for 19 of the 20 horses premedicated with xylazine. In the remaining horse premedicated with xylazine, quality of induction was considered good. All horses collapsed smoothly and quietly in the induction stall within 2 minutes after the injection of ketamine.

The transition to inhalation anesthesia was considered excellent or good in 18 (90%) horses premedicated with medetomidine and 11 (55%) horses premedicated with xylazine. In the remaining horses, the transition to inhalation anesthesia was considered fair. One (5%) horse premedicated with medetomidine and 6 (30%) horses premedicated with xylazine received sodium pentothal (500 or 750 mg, IV) because of a light plane of anesthesia before connection to the anesthesia machine. One (5%) horse premedicated with medetomidine and 3 (15%) horses premedicated with xylazine required administration of sodium pentothal (350 to 500 mg, IV) during the first 20 minutes after connection to the anesthesia machine to control limb movements. Scores for the transition to inhalation anesthesia were significantly better for horses premedicated with medetomidine than for horses premedicated with xylazine **(Table 1)**.

Maintenance of anesthesia was considered excellent or good in 10 (50%) horses premedicated with medetomidine and 9 (45%) horses premedicated with xylazine, fair in 8 (40%) horses premedicated with medetomidine and 6 (30%) horses premedicated with xylazine, and poor in 2 (10%) horses premedicated with medetomidine and 5 (25%) horses premedicated with xylazine. The vaporizer setting was 2%, and the oxygen flow rate ranged from 4 to 5 L/min during maintenance of anesthesia in both groups. The total dose of sodium pentothal administered during anesthesia ranged from 250 to 1,500 mg for horses premedicated with medetomidine and from 250 to 2,500 mg for horses premedicated with xylazine. Scores for maintenance of anesthesia were not significantly different between groups (Table 1).

Heart rate, respiratory rate, MABP, and vaporizer dial setting during anesthesia were not significantly different between groups **(Fig 1)**. Dobutamine was administered to improve arterial blood pressure in 8 (40%) horses premedicated with medetomidine and 12 (60%) horses premedicated with xylazine. Mean ± SD total dose of dobutamine was 11.4 ± 7.4 µg/kg (5.2 ± 3.4 µg/lb) for horses premedicated with medetomidine and 12.9 ± 9.7 µg/kg (5.9 ± 4.4 µg/lb) for horses premedicated with xylazine. Mean ± SD Pa_{O_2} and Pa_{CO_2} during the transition to inhalation anesthesia were 326.1 ± 148.3 mm Hg and 59.6 ± 9.1 mm Hg for horses premedicated with medetomidine and 306.6 ± 102.5 mm Hg and 57.8 ± 7.8 mm Hg for horses premedicated with xylazine. Hypoventilation, hypercapnia, or hypoxemia requiring IPPV developed in 10 (50%) horses premedicated with medetomidine and 9 (45%) horses premedicated with xylazine. Intermittent positive-pressure ventilation was started 28.8 ± 14.9 minutes after induction of anesthesia in horses premed-

Table 1—Quality of anesthesia, recovery times, and numbers of attempts needed to achieve sternal recumbency and to stand in horses premedicated with medetomidine or xylazine (n = 20/group) prior to anesthesia with guaifenesin, ketamine, and halothane

Variable	Premedicant		*P* value
	Medetomidine	Xylazine	
Duration of anesthesia (min)	81 (50–115)	66 (45–143)	0.354
Quality of anesthesia scores*			
Induction	4 (4)	4 (3–4)	0.317
Transition	3 (1–3)	3 (1–3)	0.014
Maintenance	2 (0–3)	1 (0–3)	0.479
Recovery	4 (3–5)	4 (3–5)	0.102
Recovery times (min)†			
Extubation	18 (4–35)	14 (4–35)	0.195
First movement	25 (3–42)	17 (8–42)	0.109
Sternal recumbency	30 (12–42)	25 (9–49)	0.201
Standing	33 (12–44)	27 (9–49)	0.196
Number of attempts needed			
Sternal recumbency	1 (1–2)	1 (1–7)	0.896
Standing	1 (1–2)	1 (1–2)	1.000

Data are given as median (range).
**See* Appendix for scoring criteria. †Times were recorded from the time administration of halothane was discontinued.

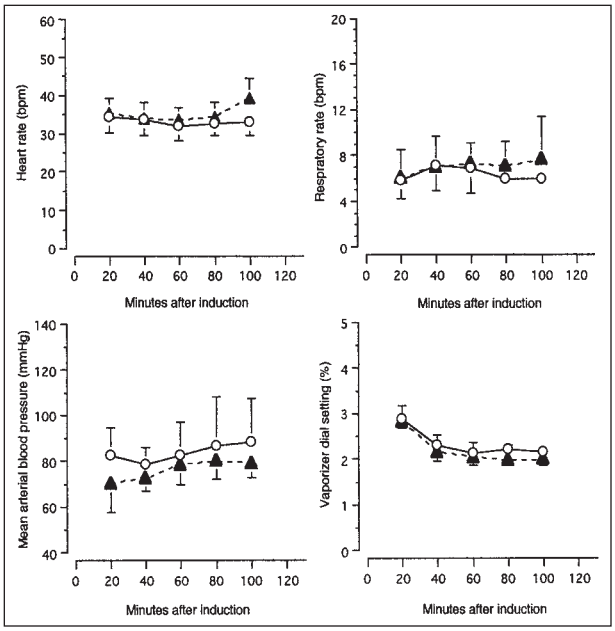

Figure 1—Mean heart rate, mean arterial blood pressure, respiratory rate, and halothane vaporizer dial setting in horses (n = 20/group) premedicated with medetomidine (open circles) or xylazine (closed triangles) prior to anesthesia with guaifenesin, ketamine, and halothane. Error bars represent SD.

icated with medetomidine and 25.3 ± 9.4 minutes after induction of anesthesia in horses premedicated with xylazine. In these horses, mean ± SD Pa_{O_2} and Pa_{CO_2} after institution of IPPV were 417.9 ± 187.0 mm Hg and 44.3 ± 3.3 mm Hg in horses premedicated with medetomidine and 380.8 ± 98.1 mm Hg and 46.3 ± 4.2 mm Hg in horses premedicated with xylazine.

Mean duration of anesthesia, mean time from induction of anesthesia to skin incision, and mean times from discontinuation of halothane administration to extubation, first movement, sternal recumbency, and standing were not significantly different between groups (Table 1). Mean ± SD duration of anesthesia was 81 ± 19 minutes (range, 50 to 115 minutes) in horses premedicated with medetomidine group and 79 ± 28 minutes (range, 45 to 143 minutes) in horses premedicated with xylazine.

The quality of recovery from anesthesia was considered excellent or good in 15 (75%) horses premedicated with medetomidine and 11 (55%) horses premedicated with xylazine. Quality of recovery from anesthesia was considered satisfactory in the remaining horses, and scores for quality of recovery were not significantly different between groups (Table 1). Mean numbers of attempts to achieve sternal recumbency and to stand were also not significantly different between groups.

Discussion

Results of the present study suggest that medetomidine is suitable for premedication of horses undergoing general anesthesia. Both drugs provided sufficient sedation for induction of anesthesia. The quality of transition to inhalation anesthesia was significantly better in horses premedicated with medetomidine than in horses premedicated with xylazine. However, scores for maintenance of and recovery from anesthesia and recovery times were not significantly different between groups.

The dose of xylazine used in the present study is commonly recommended for sedation of horses prior to induction of general anesthesia.[1,2] The dose of medetomidine was selected on the basis of results of studies[4,6] that found that this dose was equipotent, in terms of sedative effects, to a dose of 1 mg of xylazine/kg. Intravenous administration of low doses of medetomidine (4 µg/kg) and xylazine (0.4 mg/kg) induced comparable levels of ataxia and sedation and similar cardiopulmonary changes in horses.[10] To our knowledge, however, there is no information regarding the sedative effects of IM administration of xylazine, compared with IM administration of medetomidine in horses. Intravenous administration of medetomidine at a dose of 10 µg/kg produces marked ataxia[4-6] and may induce recumbency, whereas IV administration at a dose of 5 µg/kg produces moderate sedation, but less sedation than IV administration of xylazine at a dose of 1 mg/kg.[4,6] Intravenous administration of these drugs at these dosages reportedly resulted in similar durations of sedative and cardiovascular effects and ataxia.[4,6,9] In horses, doses of xylazine and detomidine administered IM that are twice the doses administered IV induce approximately the same effects.[1] Therefore, we selected an IM dose of medetomidine of 10 µg/kg (approximately twice the IV dose) and compared it with a dose of xylazine of 2 mg/kg, IM. These two doses induced similar degrees of sedation in the present study.

Time to induction of anesthesia in horses premedicated with medetomidine was longer than time to induction of anesthesia in horses premedicated with xylazine in the present study. This was unexpected and depended on the time required for preparation of the horses and availability of the surgery room, surgeon, and anesthesiologist. A high percentage of horses in both groups required additional IV administration of medetomidine or xylazine before induction of anesthesia, suggesting that the degree of sedation 1 hour after IM administration of medetomidine (10 µg/kg) or xylazine (2 mg/kg) may not be adequate to induce anesthesia. More horses premedicated with xylazine required additional IV administration, despite a shorter time from IM administration of xylazine to induction, indicating that medetomidine induced longer-lasting effects than xylazine when administered IM. The half-life of medetomidine following IV administration[12] (51.3 minutes) in horses is similar to that of xylazine[13] (50 minutes). However, medetomidine is reported to induce longer-lasting effects than xylazine when equipotent doses are administered IV.[4,6,9,10]

Intravenous administration of medetomidine at a dose of 4 µg/kg and xylazine at a dose of 0.4 mg/kg is reported to produce mild (head only slightly lowered) to moderate sedation 5 to 10 minutes after drug administration.[10] Horses in the present study had evidence of moderate sedation (head lowered below the horizontal plane) within 5 minutes after IV drug administration. Thus, IV administration of medetomidine and xylazine after IM administration induced cumulative sedative effects. The dose of guaifenesin required to induce ataxia was similar for the 2 groups in the present study, and induction of anesthesia with a combination of medetomidine, guaifenesin, and ketamine was similar to that obtained with a combination of xylazine, guaifenesin, and ketamine.

Several horses in this study required IV administration of sodium pentothal during the first 20 minutes after anesthetic induction, although there was no surgical stimulation. The relatively high blood-gas partition coefficient of halothane means that it may take a longer time to reach surgical anesthesia with this anesthetic, compared with other inhalant anesthetics.[14] However, scores for the quality of transition to inhalation anesthesia were significantly better for horses premedicated with medetomidine than for horses premedicated with xylazine. In dogs, medetomidine reduces the minimum alveolar concentrations of inhalant anesthetics more than xylazine does.[15] The difference in the quality of the transition to inhalation anesthesia between horses premedicated with medetomidine and horses premedicated with xylazine was thought to be indicative of the degree of analgesic and hypnotic effects produced by medetomidine, compared with xylazine. These qualities may make medetomidine a more suitable premedication than xylazine in horses undergoing general anesthesia.

α_2-Adrenoceptor agonists decrease heart rate and

cardiac output, increase the incidence of second-degree atrioventricular block, and cause transient hypertension followed by hypotension.[1-6,8-10,16] These hemodynamic effects are apparently well tolerated without long-term consequences in horses, but can potentially contribute to deterioration of cardiovascular function in horses with poor cardiac function, horses in shock, and horses that are receiving additional cardiovascular depressant drugs such as general anesthetics.[1-3] Guaifenesin is a centrally acting skeletal muscle relaxant that induces mild sedation and comparatively minimal cardiopulmonary depression in horses.[2,17] Ketamine results in dissociative anesthesia and comparatively minimal cardiopulmonary effects.[1,2] The combination of xylazine, guaifenesin, and ketamine results in a safe induction to general anesthesia and stable cardiopulmonary function in horses.[2,18] Halothane causes dose-related depression of cardiovascular function in horses, as well as in other species.[1,2,14] Horses premedicated with xylazine and anesthetized with guaifenesin and ketamine demonstrate mild hypotension and respiratory depression during maintenance of anesthesia with halothane.[18-20] In this study, incidences of hypotension and respiratory depression were similar in horses premedicated with medetomidine and xylazine. Dobutamine effectively corrected the decrease in arterial blood pressure, and IPPV effectively corrected respiratory depression. Our data suggest that cardiopulmonary depression induced by a combination of medetomidine, guaifenesin, ketamine, and halothane is comparable to that induced by the combination of xylazine, guaifenesin, ketamine, and halothane.

Medetomidine induces somewhat longer-lasting effects than xylazine in horses.[4,6,9,10] However, we did not record delayed recovery times in horses premedicated with medetomidine. It is thought that the effects of medetomidine may be short enough not to induce delayed recovery when horses are anesthetized for longer than 1 hour. The quality of recovery from medetomidine-guaifenesin-ketamine-halothane anesthesia was similar to that for xylazine-guaifenesin-ketamine-halothane anesthesia in the present study and to that reported for acepromazine-detomidine-ketamine-halothane anesthesia and romifidine-ketamine-halothane anesthesia.[18,20-22] Recovery times for horses in the present study were longer than those reported for horses anesthetized with a combination of romifidine, ketamine, and halothane but shorter than those reported for horses anesthetized with a combination of acepromazine, detomidine, ketamine, and halothane.[18,20-22]

[a]Domitor, Pfizer Animal Health, Exton, Pa.
[b]Tranquived Injection, Vedco Inc, St Joseph, Mo.
[c]Guaifenesin, Phoenix Scientific for Butler, Columbus, Ohio.
[d]Ketaset/Vetalar, Fort Dodge Laboratories Inc, Fort Dodge, Iowa.
[e]Halothane, Halocarbon Laboratories, River Edge, NJ.
[f]Fluotec Mark III, Matrix Medical Inc, Orchard Park, NJ.
[g]Mallard Medical, Redding, Calif.
[h]Pentothal, Abbott Laboratories, North Chicago, Ill.
[i]Passport, Datascope Corp, Paramus, NJ.
[j]Dobutamine injection, Bedford Laboratories, Bedford, Ohio.
[k]IRMA, Diametrics Medical, St Paul, Minn.

Appendix

Criteria for scoring the quality of anesthetic induction, maintenance, and recovery and the quality of the transition to inhalation anesthesia in horses

Score	Criteria
Anesthetic induction	
0 (Poor)	Ataxia and paddling; danger to horse and handler
1 (Fair)	Purposeful paddling with or without attempts to regain feet
2 (Satisfactory)	Ataxia with or without paddling
3 (Good)	Horse takes 1 or 2 steps before falling to ground; no paddling
4 (Excellent)	Horse sinks smoothly to ground
Transition to inhalation anesthesia	
0 (Poor)	Multiple incremental doses of additional drug needed
1 (Fair)	One or 2 doses of additional drug needed during first 20 minutes
2 (Good)	Appeared to be in light plane of anesthesia; responded to increase in vaporizer setting
3 (Excellent)	Smooth transition; initial increase in vaporizer setting not required
Anesthetic maintenance	
0 (Poor)	Multiple incremental doses of drug IV required to maintain surgical plane of anesthesia
1 (Fair)	One or 2 doses of additional drug required after first 20 minutes
2 (Good)	Appeared to be in light plane of anesthesia; responded to increase in vaporizer setting and oxygen flow rate
3 (Excellent)	Smooth anesthetic period; depth of anesthesia responded to increase or decrease in vaporizer setting
Anesthetic recovery	
0 (Unable to stand)	Horse cannot stand for > 2 hours after multiple attempts to stand; excitement is evident; injury or high risk of injury
1 (Poor)	Multiple attempts to stand; excitement is evident; high risk of injury
2 (Fair)	Multiple attempts to stand; substantial ataxia
3 (Satisfactory)	Stands after 1 to 3 attempts; prolonged ataxia but no excitement
4 (Good)	Stands after 1 or 2 attempts; mild, short-lived ataxia
5 (Excellent)	Stands after first attempt; no ataxia

References

1. Hall LW, Clarke KW, Trim CM. Anaesthesia of the horse. In: *Veterinary anaesthesia*. 10th ed. London: WB Saunders Co, 2001; 247–313.

2. Hubbell JE. Anesthesia and immobilization of specific species. Horses. In: Thurmon JC, Tranquilli WJ, Benson GJ, eds. *Lumb & Jones' veterinary anesthesia*. 3rd ed. Baltimore: The Williams & Wilkins Co, 1996;599–609.

3. England GC, Clarke KW. Alpha 2 adrenoceptor agonists in the horse—a review. *Br Vet J* 1996;152:641–657.

4. Bryant CE, England GC, Clarke KW. Comparison of the sedative effects of medetomidine and xylazine in horses. *Vet Rec* 1991;129:421–423.

5. Hobo S, Aida H, Yoshida K. Assessment of the sedative effect of medetomidine and determination of its optimal dose in Thoroughbred horses. *J Vet Med Sci* 1995;57:507–510.

6. Yamashita K, Kishihara K, Haramaki S, et al. Comparison of the sedative effects of medetomidine, detomidine, and xylazine in horses. *J Jpn Vet Med Assoc* 1999;52:498–503.

7. Virtanen R, Savola JM, Saano V, et al. Characterization of the selectivity, specificity and potency of medetomidine as an α_2-adrenoceptor agonist. *Eur J Phamacol* 1988;150:9–14.

8. Bryant CE, Clarke KW, Thompson J. Cardiopulmonary effects of medetomidine in sheep and in ponies. *Res Vet Sci* 1996;60:267–271.

9. Yamashita K, Tsubakishita S, Futaoka S, et al. Cardiovascular effects of medetomidine, detomidine and xylazine in horses. *J Vet Med Sci* 2000;62:1025–1032.

10. Bueno AC, Cornick-Seahorn J, Seahorn TL, et al. Cardiopulmonary and sedative effects of intravenous administration of low doses of medetomidine and xylazine to adult horses. *Am J Vet Res* 1999;60:1371–1376.

11. Kamerling S, Keowen M, Bagwell C, et al. Pharmacological profile of medetomidine in the equine. *Acta Vet Scand* 1991; 87(suppl):161–162.

12. Bettschart-Wolfensberger R, Clarke KW, Vainio O, et al. Pharmacokinetics of medetomidine in ponies and elaboration of a medetomidine infusion regime which provides a constant level of sedation. *Res Vet Sci* 1999;67:41–46.

13. Gracia-Villar R, Toutain PL, Alvinerie M, et al. The pharmacokinetics of xylazine hydrochloride: an interspecific study. *J Vet Pharmacol Ther* 1981;4:87–92.

14. Steffey EP. Inhalation anesthetics and gases. In: Muir WW, Hubbell JAE, eds. *Equine anesthesia. Monitoring and emergency therapy*. St Louis: Mosby Year Book Inc, 1991;352–379.

15. Redondo JI, Gomez-Villamandos RJ, Santisteban JM, et al. Romifidine, medetomidine or xylazine before propofol-halothane-N_2O anesthesia in dogs. *Can J Vet Res* 1999;63:31–36.

16. Wagner AE, Muir WW III, Hinchcliff KW, et al. Cardiovascular effects of xylazine and detomidine in horses. *Am J Vet Res* 1991;52:651–657.

17. Tavernor WD. The influence of guaiacol glyceryl ether on cardiovascular and respiratory function in the horse. *Res Vet Sci* 1970;11:91–93.

18. Muir WW, Skarda RT, Sheehan W. Evaluation of xylazine, guaifenesin, and ketamine hydrochloride for restraint in horses. *Am J Vet Res* 1978;39:1274–1278.

19. Donaldson LL. Retrospective assessment of dobutamine therapy for hypotension in anesthetized horses. *Vet Surg* 1988;17: 53–57.

20. Donaldson LL, Dunlop GS, Holland MS, et al. The recovery of horses from inhalant anesthesia: a comparison of halothane and isoflurane. *Vet Surg* 2000;29:92–101.

21. Bennett RC, Taylor PM, Brearley JC, et al. Comparison of detomidine/ketamine and guaifenesin/thiopentone for induction of anesthesia in horses maintained with halothane. *Vet Rec* 1998;142:541–545.

22. Diamond MJ, Young LE, Bartram DH, et al. Clinical evaluation of romifidine/ketamine/halothane anaesthesia in horses. *Vet Rec* 1993;132:572–575.