Recovery from desflurane anesthesia in horses with and without post-anesthetic xylazine

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Abstract

The objective of this study was to compare recovery from desflurane anesthesia in horses with or without post-anesthetic xylazine. Six adult horses were anesthetized on 2 occasions, 14 d apart using a prospective, randomized crossover design. Horses were sedated with xylazine, induced to lateral recumbency with ketamine and diazepam, and anesthesia was maintained with desflurane. One of 2 treatments was administered intravenously at the end of anesthesia: xylazine [0.2 mg/kg body weight (BW)] or an equivalent volume of saline. Recovery parameters were recorded and assessed by 2 blinded observers. A Wilcoxon signed-rank test was used to analyze recovery data. Heart rate, arterial blood pressures, and arterial blood gas data were analyzed using 2-way analysis of variance (ANOVA) for repeated measures. Values of $P < 0.05$ were considered significant. Duration of anesthesia was not different between groups. Administration of xylazine at the end of desflurane anesthesia was associated with significantly longer times to first movement, endotracheal tube removal, first attempt to achieve sternal recumbency, sternal recumbency, first attempt to stand, and standing. Number of attempts to stand and quality of recovery scores were not different between groups. Administering xylazine after desflurane anesthesia resulted in longer recovery times. Recovery scores were not significantly different between groups.

Résumé

L'objectif de la présente étude était de comparer la récupération suite à une anesthésie au desflurane chez des chevaux avec ou sans administration post-anesthésie de xylazine. Six chevaux adultes furent anesthésiés à deux occasions à 14 j d'intervalle, en utilisant un design expérimental croisé aléatoire. Les chevaux ont été soumis à une sédation à la xylazine, mis en décubitus latéral avec de la kétamine et du diazépam, et l'anesthésie maintenue avec du desflurane. Un des deux traitements suivants fut administré par voie intraveineuse à la fin de l'anesthésie : xylazine (0,2 mg/kg de poids corporel) ou un volume équivalent de saline. Les paramètres de récupération furent enregistrés et évalués à l'aveugle par deux observateurs. Le test de comparaison des données de Wilcoxon fut utilisé pour analyser les données de récupération. Le rythme cardiaque, la pression artérielle, et les données des gaz sanguins artériels furent analysés par analyse de variance (ANOVA) pour des mesures répétées. Des valeurs de $P < 0,05$ *étaient considérées comme significatives. La durée de l'anesthésie n'était pas différente entre les groupes. L'administration de xylazine à la fin de l'anesthésie au desflurane était associée à des délais significativement plus longs avant : un premier mouvement, le retrait du tube endotrachéal, un premier essai pour se mettre en décubitus sternal, le décubitus sternal, un premier essai pour se mettre debout, et se tenir debout. Le nombre d'essais pour se tenir debout et la qualité des pointages de récupération n'étaient pas différents entre les groupes. L'administration de xylazine suite à l'anesthésie au desflurane a entraîné des temps de récupération plus longs. Les pointages de récupération n'étaient pas significativement différents entre les groupes.*

(Traduit par Docteur Serge Messier)

Introduction

Anesthesia is associated with a greater risk of increased morbidity and mortality in horses than in other frequently anesthetized domestic species (1–6). Since problems during recovery from anethesia, such as fractures and myopathies, account for approximately 30% of the morbidity and mortality associated with inhalational anesthesia in the horse, it is important to carefully manage the return to standing (6). Inhalational anesthetic drugs are preferred for procedures lasting more than 60 min in the horse because they are minimally metabolized, do not accumulate over time, and are rapidly eliminated by the lungs on cessation of administration (6,7). Desflurane is associated with a more rapid return to consciousness than other available inhalational anesthetics because it has the lowest blood-gas solubility, but shortening recovery time may not result in improved recovery characteristics (8). The administration of sedatives, including xylazine, to horses before or during recovery from inhalational anesthesia has been recommended in order to postpone initial attempts to stand and to improve recovery (9–11).

The use of desflurane in the horse has been described, but the drug has not been widely adopted because of expense and the requirement for a complex, electrically heated vaporizer for safe

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administration (12). Recovery characteristics for desflurane are typical of horses recovering from inhalational anesthesia (13). Post-anesthetic administration of a combination of xylazine and propofol after 4 h of desflurane anesthesia in healthy horses resulted in improved transition from lateral recumbency to standing, but also resulted in respiratory depression (14). The effects of xylazine for post-anesthetic sedation have been studied extensively in horses anesthetized with isoflurane or sevoflurane (10,11,15,16), but have not been investigated after desflurane anesthesia. In 1 study, administration of xylazine to horses after isoflurane anesthesia resulted in a lower degree of sedation than in horses that received romifidine (11). The quality of recovery in isoflurane-anesthetized horses that received xylazine or romifidine was not different (10,11). The purpose of the study reported here was to further compare the recovery characteristics from desflurane anesthesia in horses with and without post-anesthetic sedation with xylazine. Our hypothesis was that post-anesthetic sedation with xylazine would prolong recovery times and improve recovery scores in horses anesthetized with desflurane.

Materials and methods

Animals

The study population consisted of 6 clinically healthy horses (2 Quarter horses and 4 Thoroughbreds; 4 mares and 2 geldings) anesthetized as part of a separate study on bone healing. Mean age was 12 y (range: 3 to 24 y) and mean weight was 545 kg (range: 432 to 655 kg). This study was approved by the Ohio State University Animal Care and Use Committee.

Study design

Food but not water was withheld for 12 h before the experiment. Each horse was anesthetized on 2 occasions, 14 d apart. During the first anesthetic event, osteotomy of a 4th metacarpal or metatarsal bone was carried out on each limb and 3 holes were created in the 12th rib on both sides of the thorax of each horse for a study on the use of fibroblast-mediated bone morphogenetic protein-2 therapy to accelerate bone healing (17). During the second anesthetic event, bone growth-stimulating cells were injected into each site created during the first anesthetic event. All surgeries were done by the same experienced surgeon (AB), at the same time of day (morning). Each horse received phenylbutazone (Phenylbutazone; Vedco, St. Joseph, Missouri, USA), 2 g IV, 30 min before surgery and on the first post-operative day. After recovery assessment and complete recovery from anesthesia, post-operative pain was treated intramuscularly with morphine (Morphine; Baxter Healthcare, Deerfield, Illinois, USA), 0.1 mg/kg body weight (BW).

A 14-gauge polytetrafluoroethylene catheter (Intracath; Parke Davis, Sandy, Utah, USA) was inserted in a jugular vein for the administration of anesthetic drugs and fluids. Horses were sedated with xylazine (X-Ject E; Butler Animal Health Supply, St. Joseph, Missouri, USA), 1 mg/kg BW, IV and anesthesia was induced 5 min later with ketamine (Ketaset; Fort Dodge Laboratories, Fort Dodge, Iowa, USA), 2.2 mg/kg BW, IV and diazepam (Diazepam; Hospira, Lake Forest, Illinois, USA), 0.1 mg/kg BW, IV combined in a single syringe. Horses were orotracheally intubated with a cuffed endotracheal tube (internal diameter, 26 mm) and positioned in dorsal recumbency on a foam mattress. The endotracheal tube was then connected to a large animal circle system (Mallard Medical, Redding, California, USA) that had been primed by occluding the Y piece and setting the oxygen flow rate at 8 L/min and the desflurane vaporizer (Tec 6 Vaporizer; Omeda, Madison, Wisconsin, USA) at 8% for 10 min before anesthetic induction, based on minimum alveolar concentration of desflurane in the horse (13). Horses breathed spontaneously for 15 min after connection to the circle system. Horses were mechanically ventilated (6 breaths/min and approximate tidal volume of 10 to 15 mL/kg BW as estimated from the bellows housing) beginning 15 min after induction and ventilation was adjusted to maintain the partial pressure of arterial carbon dioxide ($PaCO_2$) at between 40 and 50 mmHg. During maintenance, the oxygen flow rate was decreased to between 5 and 10 mL/kg BW per minute. Anesthetic depth was monitored based on changes in blood pressure and palpebral and corneal reflexes and the vaporizer was adjusted to maintain a surgical plane of anesthesia sufficient to prevent movement.

A facial artery was catheterized with a 20-gauge, 1 1/4-in catheter to measure arterial blood pressure and to facilitate the collection of heparinized arterial blood for blood gas analysis. Arterial blood pressures were measured using a fluid-filled catheter and pressure transducer (Edwards Life Science, Irvine, California, USA) zeroed at the level of the scapulohumeral joint. Dobutamine (Bedford Laboratories, Bedford, Ohio, USA) was administered as necessary to maintain mean arterial blood pressure at between 60 and 90 mmHg. Lactated Ringer's solution (Baxter Healthcare) was administered IV at a rate of 5 mL/kg BW per hour until just before horses were moved to the recovery stall. Heart rate, arterial blood pressures, and respiratory measurements were monitored and recorded. Arterial blood samples were collected and analyzed (IRMA; Diametrics Medical, St. Paul, Minnesota, USA and Radiometer ABL735; Radiometer America, Westlake, Ohio, USA) for determining pH and blood gas at 15 min (immediately before mechanical ventilation), 45 min after anesthetic induction, and every hour thereafter, or at the end of anesthesia. End-tidal desflurane concentration (Poet IQ2 Model 8500Q; Criticare Systems, Waukesha, Wisconsin, USA) was monitored and recorded for 9 of the 12 anesthetic events, due to equipment servicing. The instrument was calibrated before use according to manufacturer specifications. A nasopharyngeal tube (internal diameter, 12 or 14 mm) was inserted during anesthetic maintenance and remained in place until the horse was standing.

Recovery

At the end of surgery, bandages were applied around the cannon bones of all 4 limbs, the arterial catheter was removed, and the horse was disconnected from the anesthetic machine. At the time of disconnection from the anesthetic machine, 1 of 2 treatments was randomly administered IV in a blinded crossover design: 0.2 mg/kg BW of xylazine or an equivalent volume of 0.9% saline, so that the 3 horses that received xylazine in the first anesthetic event received saline in the second anesthetic event (18). The horse was transported 10 ft and hoisted from the table to a 4 × 4 m square padded recovery stall and positioned in left lateral recumbency. Ambient light and noise were minimized. One person returned to the recovery stall to

Table I. Median recovery times and quality scores

Parameter	Control	Xylazine
Duration of anesthesia (min)	165 (110 to 200)	143 (117 to 208)
Duration of surgery (min)	98 (70 to 110)	90 (60 to 95)
Time to first movement (min)	17 (13 to 29)	28 (15 to 55)[a]
Time to extubation (min)	14 (13 to 29)	27 (15 to 55)[a]
Time to first attempt to sternal recumbency (min)	23 (19 to 35)	50 (24 to 78)[a]
Time to sternal recumbency (min)	26 (21 to 35)	50 (24 to 78)[a]
Time to first attempt to stand (min)	31 (21 to 56)	51 (29 to 97)[a]
Time to standing (min)	31 (22 to 72)	51 (29 to 97)[a]
Number of attempts to stand	2 (1 to 4)	1 (1 to 2)
Recovery score	1.0 (1 to 2.5)	1.0 (0 to 3.0)

Data are presented as median (range).

[a] Significant difference ($P < 0.05$) from control group.

remove the endotracheal tube when the horse swallowed and then left the stall. Due to the nature of the bone-healing study and the potential for post-surgical fracture, head and tail ropes were attached to the nosepiece of the halter and tied to the tail, respectively as a precautionary measure. The ropes were inserted through rings on opposite walls of the recovery stall and experienced personnel allowed slack in the ropes during recovery. Personnel remained outside the recovery stall. If the horse moved, slack was taken up to prevent tangling. Tension was applied to the ropes only if personnel felt that injury might occur to the horse based on its behavior during recovery.

Duration of anesthesia was defined as the time from when the horse was connected to the anesthetic circle to when it was disconnected. Time to first movement, time to removal of the endotracheal tube, time to first attempt to sternal recumbency, time to sternal recumbency, time to first attempt to stand, and time to standing were recorded from the time the horse was disconnected from the anesthetic circle. The number of attempts to stand was recorded. Recovery was recorded with a video camera and the quality of recovery was graded based on a modified version of a quantitative recovery scoring system (7,19,20), which grades recovery on a scale of 0 to 4. Grade 0 corresponded to excellent recovery where the horse stood on the first attempt with clean effort and little/no body sway/shifting; grade 1 corresponded to good recovery where the horse stood on the first or second attempt with slight body sway/shifting once standing; grade 2 corresponded to fair recovery where the horse stood after 2 or 3 attempts with a strong effort on the last attempt and with body shifting once standing; grade 3 corresponded to poor recovery marked by several attempts to stand, marked instability once standing, and possible minor injury to the horse; and grade 4 corresponded to unacceptable recovery marked by several weak attempts to stand, falling easily or resumed recumbency, and possible major injury to the horse. Two independent observers were blinded to the treatment and assessed recovery in real time (PL) and by videotape review (RB).

Analysis of data

The kappa statistic was used to evaluate inter-observer agreement of recovery scores. Recovery scores were averaged between the 2 investigators. Non-parametric recovery results are reported as median (range). A 1-tailed paired nonparametric *t*-test (Wilcoxon signed-rank test) was used to analyze the single-variable recovery data. Heart rate, arterial blood pressures, arterial blood gas, vaporizer setting, and oxygen flow rate data are reported as mean ± standard deviation (SD) and were analyzed using 2-way analysis of variance (ANOVA) for repeated measures for main effects and interaction. A Bonferroni post test was done to identify differences within and between the 2 groups. Values of $P < 0.05$ were considered significant.

Results

Median recovery times and quality scores are presented in Table I. Anesthetic duration was 143 min for horses that received post-anesthetic xylazine sedation and 165 min in the control group, with no differences between groups. In addition, time for the first surgical procedure was 90 min and 93 min for the second procedure and was not different between procedures. Compared to saline, post-anesthetic sedation with xylazine was associated with longer times to first movement (28 and 17 min, respectively), extubation (27 and 14 min, respectively), first attempt to achieve sternal recumbency (50 and 23 min, respectively), achieving sternal recumbency (50 and 26 min, respectively), first attempt to stand (51 and 31 min, respectively), and standing (51 and 31 min, respectively). The number of attempts to stand was not different between groups. The mean recovery scores were not different between groups, and the kappa statistic was 0.66, indicating substantial inter-evaluator agreement (21,22). More horses in the sedated group (4 horses) than in the unsedated group (3 horses) stood on their first attempt and more horses in the sedated group had a recovery score of 0 (2 horses) than in the unsedated group (0 horses). No horses or personnel were injured and no myopathies or lacerations were noted for any of the horses during recovery. While ropes were applied as a precautionary measure due to the surgical procedure, tension was not applied to the ropes at any time to assist recovery.

There were no differences in cardiovascular, respiratory, blood gas parameters, desflurane vaporizer settings, or oxygen flow rates between groups (Table II). End-tidal desflurane concentrations were monitored and recorded for 9 of the 12 anesthetic events due to equipment servicing and were not statistically evaluated. Each

Table II. Cardiovascular, respiratory, and oxygen flow rates, blood gas, and desflurane variables[a]

Parameter	Group	Awake	15 min	30 min	45 min	60 min	75 min	90 min	105 min	165 min
HR	Xylazine	43 ± 6	39 ± 3	37 ± 3	37 ± 4	40 ± 8	44 ± 11	46 ± 9	47 ± 8	41 ± 1 (2)
(beats/min)	Control	38 ± 7	37 ± 5	39 ± 8	38 ± 6	41 ± 8	46 ± 11	48 ± 13	47 ± 15	39 ± 12 (3)
SABP	Xylazine	—	103 ± 8	92 ± 9	91 ± 7	97 ± 8	103 ± 13	107 ± 17	105 ± 8	80 ± 7 (2)
(mmHg)	Control	—	107 ± 19	89 ± 12	93 ± 7	99 ± 9	99 ± 6	95 ± 12	98 ± 8	100 ± 17 (3)
DABP	Xylazine	—	63 ± 5	53 ± 7	51 ± 4	58 ± 6	65 ± 12	71 ± 13	68 ± 12	53 ± 11 (2)
(mmHg)	Control	—	65 ± 12	50 ± 7	54 ± 7	59 ± 5	64 ± 6	63 ± 11	65 ± 5	67 ± 9 (3)
MABP	Xylazine	—	78 ± 6	66 ± 8	66 ± 5	72 ± 8	79 ± 13	88 ± 11	83 ± 9	62 ± 9 (2)
(mmHg)	Control	—	81 ± 15	63 ± 9	67 ± 6	73 ± 5	76 ± 6	74 ± 12	76 ± 6	79 ± 11 (3)
pH	Xylazine	—	7.28 ± 0.04	—	7.45 ± 0.04	—	—	—	7.45 ± 0.04	7.44 ± 0.06 (4)
	Control	—	7.28 ± 0.04	—	7.43 ± 0.03	—	—	—	7.45 ± 0.03	7.46 ± 0.04 (4)
PaO_2	Xylazine	—	125 ± 57	—	228 ± 136	—	—	—	213 ± 105	135 ± 140 (4)
(mmHg)	Control	—	160 ± 92	—	236 ± 170	—	—	—	220 ± 178	148 ± 129 (4)
$PaCO_2$	Xylazine	—	67.4 ± 7.7	—	42.6 ± 1.1	—	—	—	42.6 ± 2.9	42.2 ± 1.4 (4)
(mmHg)	Control	—	65.2 ± 6.5	—	44.1 ± 1.7	—	—	—	41.2 ± 2.5	40.4 ± 2.1 (4)
Vap	Xylazine	—	10.2 ± 1.0	10.5 ± 1.2	10.8 ± 2.4	10.3 ± 2.1	10.3 ±1.9	10.8 ± 1.3	11.3 ±0.8	8.5 ± 0.7 (2)
(%)	Control	—	9.8 ± 1.3	10.7 ± 1.0	10.0 ± 1.4	10.7 ± 1.5	10.5 ± 1.5	11.0 ± 0.9	11.0 ± 1.7	10.0 ± 1.7 (3)
O_2 flow	Xylazine	—	2.4 ± 0.5	2.2 ± 0.3	2.0 ± 0.2	2.0 ± 0.2	1.9 ± 0.2	1.9 ± 0.2	1.9 ± 0.2	1.9 ± 0.2 (2)
(L/min)	Control	—	2.3 ± 0.4	3.7 ± 2.4	2.7 ± 1.2	2.4 ± 1.3	2.3 ± 1.1	2.3 ± 1.1	2.3 ± 1.1	1.8 ± 0 (3)
EtDES	Xylazine	—	8.4 ± 1.1 (5)	8.2 ± 1.0 (5)	8.6 ± 1.1 (5)	8.9 ± 1.1 (5)	8.9 ± 0.9 (5)	9.2 ± 0.5 (5)	9.6 ± 0.5 (5)	10.5 ± 0 (1)
(%)	Control	—	7.9 ± 1.4 (4)	8.3 ± 1.0 (4)	8.8 ± 0.9 (4)	9.0 ± 1.0 (4)	9.3 ± 0.7 (4)	9.6 ± 0.6 (4)	10.0 ± 0.7 (4)	12.8 ± 0 (1)

Data are presented as mean ± standard deviation.

HR — heart rate; SABP — systolic arterial blood pressure; DABP — diastolic arterial blood pressure; MABP — mean arterial blood pressure; PaO_2 — partial pressure of arterial oxygen; $PaCO_2$ — partial pressure of arterial carbon dioxide; Vap — vaporizer setting; EtDES — end-tidal desflurane concentration.

[a] Six horses were used, except where number of horses is in parentheses (for time point 165 min and EtDES concentrations).

Data for EtDES and time point 165 minutes are presented, but not analyzed due to insufficient numbers.

horse required dobutamine during each anesthetic event. The dose of dobutamine ranged from 0.0625 to 1 mcg/kg BW per min and was varied to maintain a mean arterial blood pressure of 60 to 90 mmHg.

Discussion

In this study, post-anesthetic sedation with xylazine after desflurane anesthesia delayed times to first movement, extubation, first attempt to achieve sternal recumbency, achievement of sternal recumbency, first attempt to stand, and standing.

One-third of the mortalities associated with equine anesthesia are due to recovery-related events (1–5). Ideal recoveries occur when a calm, comfortable horse stands on its first attempt in a coordinated manner. A number of pharmacologic strategies have been developed to produce ideal recoveries including reduction of inhalational anesthetic requirement during the maintenance phase of anesthesia using intraoperative infusions (7,23), use of rapidly eliminated drugs (20), sedation in the recovery period (10,11,15,16,24), and post-anesthetic intravenous anesthesia (19), but no technique has produced a consistently ideal recovery. Recovery from desflurane anesthesia in this study was not consistently graded as excellent regardless of post-anesthetic sedation with xylazine. A previous study reported that recovery after desflurane anesthesia was of short duration with a rapid return to consciousness and with subjective recovery scores ranging from fair to excellent, the quality of which was affected by anesthetic dose and duration (13). Desflurane has a lower blood-gas partition coefficient than other commonly used inhalational anesthetics and therefore has the potential to improve recovery due to its rapid elimination, which reduces residual effects compared to inhalational anesthetics with greater blood gas partition coefficients (25). Recovery from anesthesia may be influenced by several factors including individual variability in demeanor, the presence of hypotension during anesthesia, the type of surgical procedure, duration of anesthesia, external stimuli, and use of sedatives (11,13,18,26). Regardless of whether it received xylazine or not, 1 horse remained recumbent longer than all other horses in both treatment groups.

The effects of xylazine on recovery quality in horses anesthetized with isoflurane or sevoflurane have been extensively investigated. Matthews et al (16) determined that recoveries from sevoflurane and sevoflurane with post-anesthetic xylazine were superior to recoveries in horses anesthetized with isoflurane. In another study, post-anesthetic xylazine administration was associated with better recovery scores in isoflurane-anesthetized horses than with post-anesthetic xylazine/ketamine or acepromazine, but the authors did not evaluate recoveries without post-anesthetic sedation (15). Two recent studies evaluated recoveries in isoflurane-anesthetized horses that received either xylazine or romifidine (10,24). One study reported no difference in recovery scores (10), while another study reported superior recoveries with romifidine (25). Santos et al (11) reported longer recovery times and improved recovery scores in isoflurane-anesthetized horses that received post-anesthetic xylazine, detomidine, or romifidine compared with no sedation. In our study, recovery times were longer with xylazine administration post-anesthesia, but overall recovery score was not different between the 2 groups. This may have been due to the differences in blood gas solubility and shorter recovery times in desflurane-anesthetized horses compared with isoflurane-anesthetized horses. It is possible that desflurane was eliminated so rapidly at the end of anesthesia that the additional time afforded by xylazine to allow further decreases in inhalant concentration was of no apparent benefit, with horses transitioning successfully from lateral recumbency to standing regardless of whether or not they were sedated. Horses that received xylazine tended to have better recovery scores in our study. Although this was not statistically different, it is also possible that our results might have been different if a larger number of horses had been studied. Further evaluation of recoveries of desflurane-anesthetized horses that receive post-anesthetic alpha-2 agonists is warranted.

Although the cardiovascular effects of desflurane were not the focus of this study, cardiovascular parameters were monitored and were not different between groups. Cardiovascular and respiratory effects of desflurane are similar to those of other volatile inhalational anesthetics in horses (13,25,27). In dogs, desflurane has been associated with an increase in systemic vascular resistance compared to isoflurane (27,28). In humans, induction with and increasing desflurane concentration during maintenance of anesthesia have been associated with a "sympathetic storm" characterized by an increase in heart rate and arterial blood pressure (29). Increases in desflurane concentration in humans result in greater increases in sympathetic tone, greater activity of the renin-angiotensin system, and higher plasma levels of arginine vasopressin compared to isoflurane (30). A surge in heart rate occurred in 2 horses during desflurane anesthesia. Tachycardia occurred in 1 horse during the first 15 min of anesthesia when the end-tidal desflurane concentration was steadily rising. The heart rate in this horse increased from 34 to 52 beats/min. In another horse, heart rate increased from 39 to 86 beats/min 1.5 h after induction and mean arterial blood pressure also increased from 70 to 132 mmHg, with no apparent change in anesthetic depth or surgical stimulation. The heart rate and the mean arterial blood pressure slowly decreased over the next 15 min in this horse and did not increase again. This may indicate that the "sympathetic storm" phenomenon described in humans also occurs in horses (30). Further studies measuring catecholamines are needed to confirm this.

Horses were positioned in dorsal recumbency and breathed spontaneously for the first 15 min after induction. At 15 min, $PaCO_2$ was increased in all horses indicating hypoventilation, which was corrected by mechanical ventilation. Concentrations of partial pressure of arterial oxygen (PaO_2) increased in 5 of the 6 horses during both anesthetic events, and pH and $PaCO_2$ had normalized in all horses within 30 min of initiating ventilation. These data are consistent with previous observations that desflurane, like other inhalational anesthetics, produces dose-dependent respiratory depression (25).

Limitations of the study presented here are the relatively small number of horses, a lack of standardization of the surgical stimulus between the first and second anesthetic events, and the application of ropes in the recovery stall. This study was carried out in conjunction with another study on bone healing, which dictated the number of horses used. Inclusion of additional horses may have increased our ability to detect differences in recovery quality. For the study on bone healing, horses were anesthetized first for osteotomies and bone drilling. During the second anesthetic event, bone growth-stimulating cells were injected into these sites. Although the surgical stimulus was thus different between the 2 events, surgical times were

not different. The order of sedation was randomized to minimize the effects of the surgical stimulus between groups and there was no difference in anesthesia time, vaporizer setting, or fresh gas flow rates between the 2 groups. Ropes were applied to the horses' heads and tails in recovery due to the potential for fracture after osteotomies. Our results may have been different if we had not applied these ropes. Recovery assistants ensured that the ropes posed no risk of entanglement to the horses by allowing enough slack in each rope so that, even though the ropes were attached, they were not used to assist recovery in any of the horses. Tension would have been applied only in the event of injury, or the likelihood of injury, to the horse that would have been the equivalent of a grade 4 on the recovery scoring system.

Results of the study reported here indicate that xylazine sedation after desflurane anesthesia resulted in longer recovery times, but there was no difference in overall quantitative recovery scores in our model with surgery. There is considerable variation in temperament and behavior among horses during recovery from anesthesia and recovery characteristics are likely influenced by multiple factors, including post-anesthetic sedation.

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