Evaluation of xylazine and ketamine for total intravenous anesthesia in horses

Khursheed R. Mama, DVM; Ann E. Wagner, DVM, MS; Eugene P. Steffey, VMD, PhD; Cynthia Kollias-Baker, DVM, PhD; Peter W. Hellyer, DVM, MS; Anne E. Golden; Lucien F. Brevard, BS

Objective—To evaluate the use of xylazine and ketamine for total IV anesthesia in horses.

Animals—Eight horses.

Procedure—Anesthetic induction was performed on 4 occasions in each horse with xylazine (0.75 mg/kg, IV), guaifenesin (75 mg/kg, IV), and ketamine (2 mg/kg, IV). Intravenous infusions of xylazine and ketamine were then started by use of 1 of 6 treatments as follows for which 35, 90, 120, and 150 represent xylazine dosages (µg/kg/min) and X and K represent xylazine and ketamine, respectively: X35+K90 with 100% inspired oxygen (O2), X35+K120-O2, X35+K150-O2, X70+K90-O2, K150-O2, and X35+K120 with a 21% fraction of inspired oxygen (ie, air). Cardiopulmonary measurements were performed. Response to a noxious electrical stimulus was observed at 20, 40, and 60 minutes after induction. Times to achieve sternal recumbency and standing were recorded. Quality of sedation, induction, and recovery to sternal recumbency and standing were subjectively evaluated.

Results—Heart rate and cardiac index were higher for total IV anesthesia in horses. The mean arterial pressure was highest in the X35+K120-air group and lowest in the K150-O2 group (125 ± 6 vs 85 ± 8 at 20 minutes, respectively). Mean PaO2 was lowest in the X35+K120-air group. Times to sternal recumbency and standing were shortest for horses receiving K150-O2 (23 ± 6 minutes and 33 ± 8 minutes, respectively) and longest for those receiving X70+K90-O2 (58 ± 28 minutes and 69 ± 27 minutes, respectively).

Conclusions and Clinical Relevance—Infusions of xylazine and ketamine may be used with oxygen supplementation to maintain 60 minutes of anesthesia in healthy adult horses. (Am J Vet Res 2005;66:1002–1007)

Total IV anesthesia (TIVA) for horses has been reported to offer several potential advantages over inhalation anesthesia, including better maintenance of cardiovascular and respiratory function and quiet, coordinated recoveries. Traditionally, the main disadvantages of TIVA have been the potential accumulation of drugs and metabolites that might unsatisfactorily prolong recovery and the risk of hypoxemia if supplemental oxygen is not provided. However, as safer and shorter-acting injectable anesthetic drugs have been developed and technology for precise drug delivery has improved, interest in TIVA for longer procedures has increased. Xylazine and ketamine have been widely used in horses to induce anesthesia and occasionally to prolong recumbency for up to 70 minutes by use of supplemental bolus doses. Recovery from short periods of xylazine-ketamine anesthesia tends to be smooth and satisfactory. However, limited information exists on administration of xylazine and ketamine to horses by constant rate infusion. The objectives of the study reported here were to determine whether constant rate infusion of xylazine and ketamine can safely be used to maintain anesthetic-induced recumbency for up to 60 minutes in horses; whether the quality of anesthesia, recovery, and cardiopulmonary function are dependent on the dose of xylazine and ketamine administered; and whether the percentage of inspired oxygen influences the cardiopulmonary effects of constant rate infusion of xylazine and ketamine.

Materials and Methods

Animals and instrumentation—The study protocol was reviewed and approved by the Colorado State University Animal Care and Use Committee. Eight mares weighing (mean ± SD) 489 ± 49 kg and with ages of 5.6 ± 3.6 years were studied. Each horse was anesthetized 4 times with at least 1 week between anesthetic episodes. On the day of anesthesia, each horse was weighed and a resting rectal temperature, heart rate, and respiratory rate were obtained. The skin over the right jugular vein was clipped and surgically prepared. Following SC injection of 2% lidocaine at the sites, two 8-F catheter introducers were placed into the jugular vein. A 7-F, 110-cm Swan-Ganz catheter was then inserted through the caudally located introducer, connected to a calibrated (with a mercury column) pressure transducer, and advanced into the vein until its distal port was in the pulmonary artery. Another 6.5-F catheter was then inserted through the cranially located introducer and advanced until its port was in the right atrium. Correct positioning of catheter ports was verified by observation of characteristic pressures and...
pressure waveforms on an oscilloscope. The pressure transducer was then disconnected from the catheters, and the catheters were bandaged for protection during induction of anesthesia.

**Experimental protocol**—Before induction of anesthesia, a 20-mL sample of venous blood was collected into heparinized tubes for determination of baseline plasma drug concentrations. Then, each horse was sedated by administration of xylazine (0.75 mg/kg, IV), and a sedation score of 1 (poor) to 5 (excellent) was assigned by 3 nonblinded observers (KRM, AEW, and LFB). Five minutes later, anesthesia was induced with guaifenesin (75 mg/kg, IV) and ketamine (2 mg/kg, IV) behind an induction gate and the horse placed in left lateral recumbency on a 30-cm-thick foam pad. Time to lateral recumbency from time of xylazine administration was recorded, and a qualitative induction quality score of 1 (poor) to 5 (excellent) was assigned by 3 nonblinded observers (KRM, AEW, and LFB) experienced in observing anesthetic inductions in horses. Intravenous infusions of xylazine and ketamine were started immediately after induction by use of 1 of 6 preassigned treatments as follows for which the numbers 35, 90, 120, and 150 represent infusion dosages (µg/kg/min) and X and K represent xylazine and ketamine, respectively: (1) X35+K90 with 100% inspired oxygen (O2), (2) X35+K120-O2, (3) X35+K150-O2, (4) X70+K90-O2, (5) K150-O2, and (6) X35+K120 with a 21% fraction of inspired oxygen (FiO2, ie, air). Treatments were selected on the basis of prior limited experience with this technique. In this prior report of a single dose combination (X35 and K90), cardiopulmonary values were similar to those recorded for other anesthetic techniques, recovery was good to excellent, and horses moved 13 of a possible 18 times in response to noxious stimulation. In the present study, treatments were assigned by use of a computer-generated incomplete block design. Each horse received 4 of the 6 treatments separated by a minimum of 1 week; no treatment was repeated in a horse, but each treatment was repeated among horses a minimum of 5 times (ie, treatments X35+K90-O2, X35+K120-O2, K150-O2, and X35+K120-air) or a maximum of 6 times (ie, treatments X35+K150-O2 and X70+K90-O2). Separate syringe pumps were used to administer xylazine and ketamine infusions. The trachea was intubated with a 26-mm cuffed endotracheal tube with horses in lateral recumbency immediately following induction. The number of attempts required for successful intubation was recorded. For treatments 1 through 5, the endotracheal tube was connected to a large-animal circle breathing circuit supplied with 100% oxygen and free of any inhalation anesthetic agent. Horses receiving treatment 6 breathed ambient air; local barometric pressure is approximately 640 mm Hg. A catheter was then disconnected from the catheters, and the horse was allowed to recover unassisted. The horses that were spontaneously moving were not stimulated. After the final set of measurements, monitoring equipment was disconnected and horses were transported to a 12 × 12-foot padded recovery stall. The xylazine and ketamine infusions were then discontinued, and actual infusion times were recorded; the horses were allowed to recover unassisted. Horses receiving only K150-O2 were given an additional dose of xylazine (0.75 mg/kg, IV) at the time ketamine infusion was terminated. Horses in the 5 groups that received both xylazine and ketamine infusions received no additional drugs after xylazine and ketamine infusions were stopped. Quality of anesthesia induction and recovery to sternal recumbency and standing and standing were graded independently by 2 observers (1 blinded [LFB] and 1 nonblinded [KRM] to the protocol) by use of a predetermined continuous scoring system; scores ranged from 1 (poor) to 5 (excellent).11

**Determination of plasma drug concentrations**—Heparinized blood samples were centrifuged, and plasma harvested and stored at −70°C until analyzed. Ketamine, xylazine, and guaifenesin were quantitated in horse plasma by liquid chromatography–mass spectrometry after a simple protein precipitation clean-up procedure. Calibrators were prepared by adding appropriate volumes of the working standard solutions to drug-free control plasma. The range of concentrations used for plasma calibrators was 0.5 to 8 µg/mL for ketamine and xylazine and 25 to 250 µg/mL for guaifenesin. Plasma samples and calibrators were processed for analysis by mixing 0.5-mL aliquots with 0.6 mL of acetonitrile with 1M acetic acid (9:1, vol/vol) and chilling at 4°C for 1 hour, followed by centrifugation (1,580 × g) for 10 minutes and harvesting of the deproteinated supernatant. Quantitative determinations of analytes in equine serum were performed on a high-performance liquid chromatograph coupled to a quadrupole ion-trap mass spectrometer with an electrospray interface. Detection involved full-scan mass selection (MS) and fragmentation with full-scan MS/MS of the molecular ion ([M + H]+) of xylazine and guaifenesin (m/z 125, 126, 163, 180.9) was plotted; peaks at the proper retention time were integrated by use of software. The software program was used to generate calibration curves and quantitate these analytes in all samples.
Statistical analysis—For responses having 1 measurement/horse, treatments were compared by use of an incomplete block model. When the overall treatment effect was significant, adjusted treatment means (least squared means) were compared by use of pairwise t tests. Responses having measurements over time were analyzed by use of a repeated-measures ANOVA. The model included fixed effects for treatment, period, and treatment by period as well as random effects for horse and horse by treatment. An autoregressive lag 1 error structure over time was assumed but omitted when not significant. When the treatment by period interaction was significant, treatments were compared separately at each period, and periods were compared separately for each treatment. When the interaction was not significant, treatments and periods were compared, each averaging over the other. Values of P < 0.05 were considered significant.

Table 1—Mean ± SD values of variables measured to determine the quality of anesthesia and recovery in horses anesthetized with 5 combinations of xylazine-ketamine and 2 fractions of inspired oxygen (FiO2, 100% and 21%); barometric pressure, 640 mm Hg) for 60 minutes.

<table>
<thead>
<tr>
<th>Variable</th>
<th>X35+K90-O2</th>
<th>X35+K120-O2</th>
<th>X35+K150-O2</th>
<th>X70+K90-O2</th>
<th>K150-O2</th>
<th>X35+K120-air</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. (%) of horses moving*</td>
<td>3/15 (20%)</td>
<td>0/15 (0%)</td>
<td>3/18 (16%)</td>
<td>5/18 (28%)</td>
<td>12/15 (80%)</td>
<td>3/15 (20%)</td>
</tr>
<tr>
<td>Duration of infusions (min)</td>
<td>73 ± 3a</td>
<td>72 ± 2a</td>
<td>73 ± 1a</td>
<td>72 ± 1a</td>
<td>66 ± 6b</td>
<td>72 ± 1a</td>
</tr>
<tr>
<td>Time to standing (min)</td>
<td>50 ± 16a</td>
<td>51 ± 13a</td>
<td>55 ± 20a</td>
<td>69 ± 27a</td>
<td>33 ± 6b</td>
<td>46 ± 17a</td>
</tr>
<tr>
<td>Quality of recovery to standing (score)†</td>
<td>5.0 ± 0.0</td>
<td>5.0 ± 0.0</td>
<td>4.5 ± 0.7</td>
<td>5.0 ± 0.0</td>
<td>4.8 ± 0.4</td>
<td>4.5 ± 0.0</td>
</tr>
<tr>
<td>Quality of recovery to standing (score)‡</td>
<td>5.0 ± 0.0</td>
<td>4.8 ± 0.4</td>
<td>4.4 ± 0.9</td>
<td>4.8 ± 0.4</td>
<td>4.3 ± 0.8</td>
<td>4.9 ± 0.2</td>
</tr>
</tbody>
</table>

*Spontaneously or in response to electrical stimulus. †Please see text for detail on recovery scoring scale. ‡Values without a common superscript letter are significantly different (P < 0.05) across groups.

Intravenous infusions of xylazine and ketamine were administered by use of 1 of 6 treatments as follows for which the numbers 3, 5, 90, 120, and 150 represent infusion dosages (µg/kg/min) and X and K represent xylazine and ketamine, respectively: X35+K90, X35+K120, X35+K150, X70+K90, K150, and X35+K120 with a 21% fraction of inspired FiO2.

Table 2—Mean ± SD cardiovascular responses and plasma protein concentration in horses anesthetized with 5 combinations of xylazine-ketamine and 2 FiO2 (100% and 21%); barometric pressure, 640 mm Hg) for 60 minutes.

<table>
<thead>
<tr>
<th>Variable</th>
<th>X35+K90-O2</th>
<th>X35+K120-O2</th>
<th>X35+K150-O2</th>
<th>X70+K90-O2</th>
<th>K150-O2</th>
<th>X35+K120-air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate (beats/min)</td>
<td>31 ± 3a</td>
<td>28 ± 4a</td>
<td>29 ± 5a</td>
<td>27 ± 5**</td>
<td>35 ± 4**</td>
<td>30 ± 3a</td>
</tr>
<tr>
<td>Cardiac output (L/min)</td>
<td>20 ± 1.4b</td>
<td>20.9 ± 1.8b</td>
<td>19.1 ± 2.9b</td>
<td>17.7 ± 3.4b</td>
<td>29 ± 2.8b*</td>
<td>27.1 ± 4.8b</td>
</tr>
<tr>
<td>Cardiac index (mL/kg/min)</td>
<td>42.9 ± 6.1a</td>
<td>40.5 ± 1.9b</td>
<td>39.8 ± 8.2a</td>
<td>37.1 ± 9.6b</td>
<td>58.9 ± 10.8a</td>
<td>54.8 ± 7.2a</td>
</tr>
<tr>
<td>TPR (dyne/s/cm²)</td>
<td>45.0 ± 7.2a</td>
<td>41.3 ± 8.5a</td>
<td>39.9 ± 10.4a</td>
<td>41.0 ± 11b</td>
<td>68.7 ± 5.0a</td>
<td>52.8 ± 9.8b</td>
</tr>
<tr>
<td>MAP (mm Hg)</td>
<td>45.7 ± 5.8a</td>
<td>45.7 ± 9.2a</td>
<td>39.4 ± 8.4a</td>
<td>44.4 ± 9a</td>
<td>80.0 ± 17.3a</td>
<td>57.8 ± 10.5a</td>
</tr>
<tr>
<td>MMAP (mm Hg)</td>
<td>20 ± 110a</td>
<td>412 ± 111a</td>
<td>437 ± 114a***</td>
<td>504 ± 128b</td>
<td>236 ± 16b</td>
<td>377 ± 64b</td>
</tr>
<tr>
<td>MPAP (mm Hg)</td>
<td>439 ± 75a</td>
<td>487 ± 174a</td>
<td>504 ± 104a***</td>
<td>564 ± 137a</td>
<td>249 ± 31b</td>
<td>446 ± 108a</td>
</tr>
<tr>
<td>RAP (mm Hg)</td>
<td>474 ± 32a</td>
<td>476 ± 115a</td>
<td>529 ± 102a**</td>
<td>570 ± 93a</td>
<td>220 ± 60b</td>
<td>429 ± 81a</td>
</tr>
<tr>
<td>PCV (%)</td>
<td>20 ± 8a</td>
<td>29 ± 3a</td>
<td>25 ± 7**</td>
<td>30 ± 5b</td>
<td>24 ± 4**</td>
<td>29 ± 7b</td>
</tr>
<tr>
<td>Plasma protein (mg/dL)</td>
<td>15.3 ± 6.1a</td>
<td>16.4 ± 2.9a</td>
<td>14.0 ± 4.1b</td>
<td>16.0 ± 2.0a</td>
<td>10.4 ± 4.2a</td>
<td>13.6 ± 2.6a</td>
</tr>
</tbody>
</table>

*Values without a common symbol are significantly different (P < 0.05) over time within a group. **Values without a common superscript letter are significantly different (P < 0.05) across groups.

See Table 1 for remainder of key.
Results

Baseline rectal temperature and heart and respiratory rates did not differ significantly among groups and had mean ± SD values of 37.8 ± 0.3°C, 39 ± 3 beats/min, and 18 ± 2 breaths/min for the 32 trials, respectively. Similarly, there were no significant differences among groups in the quality of sedation (score, 4.4 ± 0.3) or anesthetic induction (score, 4.4 ± 0.3) or in the time (8.8 ± 0.5 minutes) to lateral recumbency from xylazine administration. Endotracheal intubation was achieved with a mean of 2.3 ± 0.6 attempts.

Mean duration of xylazine and ketamine infusions varied from 66 ± 6 minutes to 73 ± 3 minutes (Table 1). The times required to achieve sternal recumbency and standing were shortest for horses receiving K150-O2 and longest for horses receiving X70+K90-O2. Horses receiving K150-O2 were most likely to move spontaneously (4 positive responses of 15 possible) or in response to the noxious stimulus (8 positive responses of 15 possible), whereas none of the horses receiving X35+K120-O2 moved; these groups differed significantly in their response. Quality of recovery to sternal recumbency and standing was good to excellent in all groups.

Baseline drug concentrations were below the limit of detection for all drugs. Plasma guaifenesin concentrations decreased over time in all groups from 120 ± 12 µg/mL at 20 minutes to 67 ± 10 µg/mL at standing. Differences in plasma xylazine concentrations were observed among the K150-O2 (0.37 ± 0.04 µg/mL), X35 (2.15 ± 0.19 µg/mL, 4 treatment groups [ie, X35+K90-O2, X35+K120-O2, X35+K150-O2, and X35+K120-air]), and X70+K90-O2 (3.44 ± 0.20 µg/mL) treatment groups during infusion. Plasma xylazine concentrations ranged from 0.78 ± 0.29 µg/mL (K150-O2 group [ie, no xylazine]) to 1.03 ± 0.26 µg/mL (X70+K90-O2 group) at standing. Similarly, plasma ketamine concentrations during infusion varied among groups (2 groups/infusion dosage) receiving the 3 different dosages of ketamine as follows: 2.18 ± 0.15 µg/mL, 4.17 ± 0.33 µg/mL, and 5.02 ± 0.23 µg/mL in the K90 (X35+K90-O2 and X70+K90-O2), K120 (X35+K120-O2 and X35+K120-air), and K150 (X35+K150-O2 and X150+K150-O2) groups, respectively. Plasma ketamine concentrations at standing ranged from 0.36 ± 0.15 µg/mL (X35+K90-O2 and X70+K90-O2 groups) to 1.05 ± 0.13 µg/mL (X35+K150-O2 and K150-O2 groups).

The heart rate, cardiac output, and cardiac index were higher and total peripheral resistance was lower in the K150-O2 and X35+K120-air groups, compared with other groups (Tables 2 and 3). The heart rate, cardiac output, and cardiac index increased over time in the K150-O2 group. Second-degree atrioventricular block and sinus pauses were commonly seen in horses receiving xylazine via infusion. The MAP was highest in the X35+K120-air group and lowest in the K150-O2 group. Increases in MAP over time were seen in all groups. Mean values of the mean pulmonary artery pressure and right atrial pressure were lowest in the K150-O2 group. Mean Pao2 was lowest in the X35+K120-air group. Mean Pao2 in the X35+K120-air group was lower than for all other groups, except at 40 and 60 minutes when the K150-O2 group had similarly low Pao2 values. Measured FIO2 ranged from 89% to 98% in groups receiving supplemental oxygen.

Discussion

The results of this study indicate that anesthesia can be satisfactorily and safely maintained for approximately 1 hour with various infusions of xylazine and ketamine. All groups had good to excellent inductions with xylazine, guaifenesin, and ketamine and good to excellent recoveries to sternal recumbency and standing after 1 hour of xylazine and ketamine infusions. If one applied the concept of the ED30 (ie, the effective
dose at which 50% of patients respond with gross, purposeful movement to a fixed supramaximal noxious stimulus) as a method by which to assess anesthetic depth, the infusion protocol in all but the K150-O₂ group would be considered to approximate 1.2 to 1.5 minimum alveolar concentration for the inhaled anesthetic agents or a surgical plane of anesthesia (ie, 67 negative responses of 81 possible). Ketamine infusion alone did not provide satisfactory anesthesia, as evidenced by the high percentage (80%) of horses in the K150-O₂ group moving either spontaneously or in response to electrical stimulation of the buccal mucosa. A finding with potential clinical relevance was that a significant proportion of positive responses to noxious stimulation was attributed to the 1 Arabian horse in this study (11 positive responses, compared with 15 total for the 7 other horses in this study).

Hence, although ketamine is an N-methyl d-aspartate receptor antagonist and considered to have analgesic properties, ketamine infusion of 150 µg/kg/min, without concurrent xylazine administration, was apparently not sufficient to prevent response to the noxious stimulus used. Behavioral signs such as pronounced muscle twitching precluded an increase in the dosage of ketamine above 150 µg/kg/min and would have made conditions for performing surgery very unsatisfactory. The significantly faster recoveries to sternal recumbency and standing in the K150-O₂ unsatisfactory. The significantly faster recoveries to standing in the K150-O₂ group may be another indication of how lightly anesthetized those horses were. Recovery times were dependent mainly upon the dosage of xylazine infusion, which paralleled plasma concentrations; horses in the K150-O₂ group, which received only 2 bolus doses of xylazine (before induction and again at the end of ketamine infusion) rather than a xylazine infusion, had the lowest plasma xylazine concentrations and quickest recoveries, whereas those in the X70+K90-O₂ group took longest to recover and had the highest plasma xylazine concentrations upon recovery.

Except for the K150-O₂ group, the time taken to achieve standing was generally longer than that reported for similar periods of equivalent anesthesia with inhalation anesthetics, such as halothane (mean times to standing, 32,17 38,16 and 30 minutes15), isoflurane (means, 17,15 40.16 and 24 minutes15), or sevoflurane (means, 1415 and 27 minutes15). If anesthesia is maintained for longer than the 60-minute period of the current study, excessively prolonged recovery times may be a disadvantage of TIVA with xylazine and ketamine.

Previous studies15,16 of TIVA in horses or ponies have suggested that cardiopulmonary parameters are better maintained during TIVA, compared with inhalation anesthesia. Mean MAP values in the current study ranged from 85 to 149 mm Hg, which were similar to, or slightly higher than, MAP during halothane, isoflurane, or sevoflurane anesthesia.17,18,22 However, mean cardiac index values in the current study were similar to, and in some cases lower than, those reported20,21 for horses during 1.0 to 1.5 minimum alveolar concentration of isoflurane or sevoflurane anesthesia. The treatment associated with the highest cardiac index and lowest total peripheral resistance was K150-O₂, which was not surprising since all other groups received infusions of xylazine, which is known to decrease cardiac index and increase total peripheral resistance.22,23 The increase in cardiac index in the K150-O₂ group over time likely reflected decreasing xylazine concentrations (from the preinduction bolus) and the associated decrease in anesthetic depth. The right atrial pressure and mean pulmonary artery pressure tended to be lowest and decrease further over time in the K150-O₂ group and again was likely explained by the decreasing concentration of xylazine. The current study also provides a reminder that the relationship between MAP and cardiac index may vary.24-26 For example, the group with the lowest overall MAP values (K150-O₂) also had the highest overall cardiac index values. Conversely, changes in MAP over time paralleled changes in cardiac index in the X35+K120-air group.

All groups that received supplemental oxygen maintained acceptable PaO₂ values, although apparently no better than those of spontaneously breathing horses anesthetized with inhalation anesthetics in oxygen in which mean PaO₂ values range from 230 to 360 mm Hg.27-29 The PaO₂ (75.8 ± 6.8 mm Hg) in blood gas samples taken from these horses during rest in their paddock on 3 different occasions during the study was within normal ranges for horses at the study location. Therefore, matching of ventilation to perfusion in laterally recumbent horses may be no better during TIVA with xylazine and ketamine than during inhalation anesthesia. It is not clear why PaO₂ values decreased below 200 mm Hg in the X35+K120-O₂ group. As expected, horses in the X35+K120-air group were hypoxemic throughout the period of anesthesia. Although no overt problems attributable to hypoxemia were observed in that group, the elevated cardiac index in this group of horses might indicate subclinical tissue damage or an attempt to compensate for reduced oxygen delivery.22-24 Supplemental oxygen is therefore recommended during xylazine-ketamine anesthesia, especially when local barometric pressure is less than that at sea level.

All groups that received supplemental oxygen hypoventilated, but PaCO₂ values remained in a clinically acceptable range, and arterial pH values were within normal limits. Horses that did not receive supplemental oxygen did not hypoventilate, presumably because their hypoxemia was stimulating ventilation.27 Ventilation in horses in the K150-O₂ group tended to return to normal as recumbency progressed, presumably because of a lightening plane of anesthesia.

In summary, infusions of xylazine and ketamine may be used to maintain 60 minutes of anesthesia in healthy adult horses without compromising anesthetic recovery. Although cardiovascular function was better maintained with ketamine alone, the quality of recumbency would not facilitate most surgical interventions. Hypoxemia has an influence on cardiovascular parameters (eg, cardiac index and MAP) and must be considered when interpreting these values. The degree of hypoxemia during xylazine-ketamine anesthesia was similar to that observed with inhalation anesthetics and highlighted the importance of oxygen supplementation.
a. Catheter introducer system, Universal Medical, Instrument Corp, Ballston Spa, NY.

c. Cobe pressure transducer, Electricom, Denver, Colo.
d. Cook Veterinary Products Inc, Bloomington, Ind.
e. Escort II, MDE, Arleta, Calif.
f. Medex Inc, Duluth, Ga.
g. Critikon, Tampa, Fla.
h. Inovye, Becton-Dickinson, Sandy, Utah.
j. ABL 305, Radiometer Medical A/S, Copenhagen, Denmark.
k. Sorenson Research Co Inc, Salt Lake City, Utah.
l. Astro-Med Inc, West Warwick, RI.
m. Agilent 1100 GC, Agilent Technologies, San Jose, Calif.

References
