MEETING ABSTRACTS

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SMALL ANIMALS

Echocardiographic evaluation of the cardiac performance in dogs sedated with high and low dose romifidine with and without glycopyrrolate

MD Sinclair, M O'Grady, WN McDonell*
University of Guelph, Guelph, Ontario, Canada

The purpose of this study was to investigate the cardiopulmonary response, with quantitative M-mode echocardiography, of glycopyrrolate (G, 10 μg kg^{-1} IM) as a pretreatment (p) or administered concurrently (c) with romifidine (RO) SQ in dogs.

Healthy adult dogs (3M, 3F) 18.5–25 kg (mean ±SD, 23 ± 2.4) were utilized in a randomized cross over design. All dogs were conditioned to lie in lateral recumbency with manual restraint. Doppler measurement of systolic blood pressure (SBP), with inflatable cuffs 40% of leg circumference, was performed simultaneously with echocardiographic measurements. Baseline measurements were recorded and one of the treatments was administered: T1, 0.5 mL saline (S)(p) + RO (40 μg kg^{-1}); T2, G(p) + RO (40 μg kg^{-1}); T3, S(p) + RO (120 μg kg^{-1}); T4, G(p) + RO (120 μg kg^{-1}); T5, S(p) + G(c) + RO (120 μg kg^{-1}). Measurements were repeated 15 minutes after G(p) or S(p); RO or G(c) were administered 20 minutes after G(p) or S(p), and further measurements were taken at 10, 20, 30, 60, and 90 minutes after RO. Dimensions of the left ventricle (LVID), interventricular septum (IVS), and left ventricular free wall (LVFW) were obtained in systole (S) and diastole (D). Heart rate (HR) and amplitude of motion (Amp) of the IVS and LVFW were also measured. From these, measures of wall stress (SBPxLVID-S)/([4LVFW-S](1 + [LVFW-S/LVID-S])) and fractional shortening (FS) of the left ventricle (LVID-D − LVID-S)/(LVID-D) were obtained. Data were analyzed by a two-way ANOVA, with an LSD posthoc test and 95% confidence level.

Echocardiographic indices of cardiac performance (LVID-D, LVID-S, FS, AMP-LVFW) and HR were decreased in all RO sedated dogs ($p < 0.001$). The magnitude of change in cardiac indices was minimal with low dose RO. At most, but not all, times high dose RO produced significantly more alteration in cardiac indices, i.e. T1 *versus* T3 and T2 *versus* T4 ($p < 0.02$). G significantly increased HR ($p < 0.0001$), but, cardiac indices were not improved. Comparisons between T1 *versus* T2, and T3 *versus* T4 demonstrated significant differences in Amp-LVFW ($p < 0.007$), LVID-D ($p < 0.007$), LVID-S ($p < 0.002$) and FS ($p < 0.0004$) between 10 and 90 minutes. Wall stress (WS) showed a significant treatment effect ($p < 0.0001$) with a dramatic increase in G(c) or G(p) groups. Comparisons between T1 *versus* T2 and T3 *versus* T4 were significant from 10 to 90 minutes ($p < 0.0001$).

In conclusion, RO caused a reduction in cardiac performance, which was most dramatic with high dose RO. G(p) or G(c) did not improve indices of cardiac performance despite an increase in HR. G may actually worsen cardiovascular function with an increase in myocardial oxygen demand as suggested by the increase in WS.

Morphine or lidocaine infusion as a pre-emptive analgesic for intraocular surgery in dogs

LJ Smith,* A Shih, E Bentley, PE Miller
University of Wisconsin, Madison, Wisconsin, USA

Systemic administration of lidocaine has been shown to provide analgesia in acute and chronic pain models in rodents. Pre-emptive administration of lidocaine increases pain threshold following sciatic ligation in rats even when plasma concentrations of lidocaine are undetectable. This study investigated the postoperative analgesic effect of lidocaine administered intraoperatively to normal dogs undergoing OD phacoemulsification and lens extraction.

Twelve healthy beagle or spaniel dogs (15.5 ±1.7 kg; 2.5 ± 0.6 years) of either sex were premedicated with acepromazine (0.05 mg kg^{-1} IM), induced with propofol (4–6 mg kg^{-1} IV) and maintained on isoflurane in oxygen with IPPV. Treatment groups ($n = 4$) were: lidocaine (L), 1 mg kg^{-1} bolus followed by constant rate infusion (CRI) at 0.025 mg kg^{-1} $minute^{-1}$; morphine (M), 0.15 mg kg^{-1} bolus followed by CRI at 0.1 mg kg^{-1} h^{-1}; and saline (S), 0.05 mL kg^{-1} bolus followed by CRI at 0.075 mL kg^{-1} h^{-1}. Drug concentrations were adjusted such that equal volumes kg^{-1} were delivered regardless of treatment. HR, direct mean pressure (MAP), and end-tidal isoflurane concentration (ET_{ISO}) were recorded every 5 minutes following drug bolus. Fifteen minutes following drug bolus, atracurium

(0.2 mg kg^{-1} IV) was administered and lens extraction surgery was begun. Beginning at extubation ($t = 0$), dogs were monitored for pain using a standardized subjective pain-scoring system by a blinded observer at $t = 0$, 0.5, 1, 2, 3, 4, 6, 8, 16 and 24 hours. If dogs exhibited mild–moderate discomfort, morphine (1.0 mg kg^{-1} IM) was given and 'time to treatment failure' recorded. Incidence of treatment failure was analyzed using Fisher's Exact test; time to treatment failure was analyzed using a Wilcoxon Rank Sum test. Differences between treatments and effects of treatment over time for HR, MAP, and ET_{ISO} were analyzed using a repeated-measures ANOVA.

Incidence of treatment failure was 100% in the S group, and was significantly lower in the M and L groups (50%). Time to treatment failure (mean ±SD hours) was significantly lower in the S group (0.25 ± 0.14; $p = 0.03$) than in the M (1.0 ± 0.25) or L (1.75 ± 1.25) groups. There was no significant difference between treatments in HR, MAP or ET_{ISO} at any time point.

Results of this study suggest that lidocaine infusion provides pre-emptive analgesia comparable to low dose morphine infusion, without adverse effects on HR or MAP, in healthy dogs. Further investigation into postoperative analgesic effects of systemic lidocaine with a larger number of dogs is warranted based on results of this pilot study.

Comparison of surface and subdermal electrodes for monitoring bispectral index in anesthetized dogs

SA Greene,* GJ Benson,* WJ Tranquilli*
University of Illinois, Urbana, Illinois, USA

Bispectral index (BIS) is a value derived from the EEG used to assess central nervous system depression. In a previous report, canine BIS values using adhesive surface electrodes were inversely related to sevoflurane (SEVO) minimum alveolar concentration (MAC)-multiples. However, use of subdermal needle electrodes would allow more practical measurement of BIS in animals. The purpose of this study was to compare canine BIS values obtained using both surface and subdermal electrodes.

SEVO MAC was determined in eight English pointer dogs (four males, four females; mean ±SD age and weight of 3.9 ± 2.2 years and 20.7 ± 4.1 kg, respectively). One week later, BIS was determined at 0.8, 1.0, 1.5, and 2.0 MAC multiples using both electrode sets applied in randomized order. Ventilation was controlled and atracurium (0.2 mg kg^{-1} followed by 6 μg kg^{-1} $minute^{-1}$ IV) was administered to eliminate EMG artifact from the EEG. BIS was determined using an A-2000 monitor connected to a computer for data collection at 5-second intervals. After a 15-minute equilibration period at each MAC multiple, BIS data were collected for 5 minutes and median BIS values calculated. Heart rate, direct mean arterial blood pressure (MAP), esophageal temperature, and arterial blood gases were measured at each BIS collection period. End-tidal CO_2 and percentage [SEVO] were continuously monitored using an infrared gas analyzer. Median BIS values were analyzed by simple linear regression and other variables were analyzed using one-way analysis of variance ($p < 0.05$).

Mean ±SD SEVO MAC was 2.1 ±0.3%. Mean ±SD BIS values at 0.8, 1.0, 1.5 and 2.0 X MAC were 77 ± 3, 73 ± 5, 57 ± 7 and 53 ± 7, respectively, for surface electrodes and 80 ± 6, 72 ± 7, 56 ± 4 and 50 ± 5, respectively, for subdermal electrodes. At 2X MAC, BIS could not be determined in six dogs due to burst suppression. The regression equation comparing electrodes was: BIS (subdermal) $= -5.5 +$ [1.1 X BIS (surface)]; $R^2 = 0.846$. Of the other measured variables, only mean MAP was significantly different among MAC-multiples.

We conclude that use of subdermal needle electrodes for measurement of BIS in anesthetized dogs is a reliable and practical alternative to use of adhesive surface electrodes.

Lithium chloride dilution as a new method of cardiac output determination in the dog: effect of lithium chloride dosage on serum lithium concentration

DJ Mason, M O'Grady, JP Woods, W McDonell*
University of Guelph, Guelph, Ontario, Canada

We have previously demonstrated excellent agreement in the dog between thermodilution (TD) and lithium chloride dilution (LCD) as measures of CO, with an intraclass correlation of 0.989. LCD results in an accumulation of lithium (Li) in the body, which results in background interference for subsequent determinations. The manufacturer of the LCD sensor has calculated a theoretical upper serum Li value of 0.2 mmol L^{-1}, above which interference may become significant. The purpose of this study was: (1) to determine the relationship between the dose of lithium chloride (LiCl) administered and the background serum Li level; and (2) to examine the relationship between background serum Li levels and the degree of agreement for CO measured by LCD and TD.

Ten healthy mixed breed mature dogs were studied, seven female and three male, with a mean body weight of 36.2 kg (range 30.5–45.4 kg). Each dog was premedicated with butorphanol (0.4 mg kg^{-1} IM), induced with thiopental (15–20 mg kg^{-1} IV), and maintained with 1.5% inspired halothane (except when depth was increased as outlined below) using a circle system and a fresh gas flow rate of 50 mL kg^{-1} $minute^{-1}$. The dogs were instrumented with a central venous catheter, a Swan-Ganz pulmonary arterial catheter, a femoral venous balloon catheter, and a peripheral arterial catheter. Four levels of CO were induced in each dog. Ranging from the highest to lowest level of CO, these were induced by: dobutamine infusion, routine anesthesia, a deep plane of anesthesia, and preload reduction with balloon inflation in the caudal vena cava, respectively. A data collection set, measured at each level of CO, consisted of three determinations of CO by TD interspersed with two

pairs of LCD. Anesthetic stability for each CO level was assessed before and after each CO determination.

Cumulative dosages of 0.08 ± 0.03 and 0.17 ± 0.03 mmol kg^{-1} lithium chloride produced serum Li concentrations of 0.2 and 0.4 mmol L^{-1}, respectively. There was a tendency for the difference between CO measured by LCD and TD to gradually increase as background serum Li concentration increased. At a background Li concentration of 0.2 mmol L^{-1} and 0.4 mmol L^{-1}, mean difference between CO measured by LCD and TD was 0.25 L $minute^{-1}$ and 0.55 L $minute^{-1}$, respectively.

It was concluded that it is possible to predict the background serum Li concentration knowing the animal's weight and the total cumulative administered LiCl dose. A higher level of agreement between CO measured by LCD and TD occurred at lower background serum Li levels.

The systemic and regional hemodynamic effects of dopamine, dobutamine, dopexamine and 5% dextrose in sevoflurane anesthetized dogs

YH Lee, JC Thurmon, GJ Benson, WT Tranquilli, S Crotchik
University of Illinois, Urbana, Illinois, USA

This study examined the influence of dopamine (DA), dobutamine (DB), dopexamine (DX) and 5% dextrose (5Dx) on microcirculation in the kidney and muscle, and on their relations to other cardiopulmonary changes in dogs.

Six English Pointers (two male, four female, 23 ± 6 kg, 2 ± 1 years) were mask-induced and maintained with sevoflurane anesthesia at 2.6% end tidal concentration under controlled ventilation in left lateral recumbency. Cardiopulmonary variables measured include direct blood pressures, cardiac output (CO) by thermodilution technique, heart rate (HR), blood gases, and end tidal gases. During one hour of anesthetic stabilization time, a laser Doppler flowmeter was incorporated to monitor dynamic changes in intrarenocortical blood flow (IRBF) and intramuscular blood flow (IMBF), utilizing fine stainless optical fibers embedded within the cortex of the right kidney guided by ultrasonography and the right biceps femoris, respectively. First measurement of variables (baseline: BL) was taken prior to drug infusion followed by subsequent measurements at 15-minute intervals for a further 2 hours. On separate occasions, DA, DB and DX diluted in 5Dx were infused at 2, 4, 8, 16 µg kg^{-1} $minute^{-1}$, and the equivalent volume of 5Dx, for the control group, at 12.5, 25, 50, 100 mL h^{-1} was infused, each dose lasting for 15 minutes. The order of each drug administration was random, with a minimum of 1 week's rest between drugs. Data collected during and following infusions were compared with BL, using ANOVA for repeated measures followed by Dunnet's post-test where applicable ($p < 0.05$). Data from 5Dx were compared with those from DA, DB and DX at equivalent time points by ANOVA for repeated measures followed by Bonferroni's post-test where applicable ($p < 0.05$).

DA, DB and DX all increased IMBF in dose dependent manner, up 250% higher than BL, with all being statistically significant at the highest infusion rate. Among groups significance occurred only in DA compared to 5Dx value at 16 µg kg^{-1} $minute^{-1}$. IRBF increase was less distinctive than IMBF, being 150% higher than BL in DA and DB, and 120% in DX, even at the highest infusion rate. 5Dx did not increase IRBF, all values being lower than BL. HR changed little following DA and 5Dx but increased, with increased infusion rates, up to 165 ± 27 from 116 ± 10 (DB) and up to 138 ± 9 from 105 ± 16 beats $minute^{-1}$ (DX). DA significantly increased mean arterial blood pressure (MAP) up to 116 ± 26 from 67 ± 14 mm Hg (BL). In contrast, DX significantly decreased MAP, down to 42 ± 8 from 62 ± 9 mm Hg (BL). Slight changes of MAP were seen at all time points in DB and 5Dx. CO increased significantly, in a dose related manner in all treatment groups, reaching the maximum of 9.2 ± 3.4 from 3 ± 1 L $minute^{-1}$ (BL) in DB.

All drugs demonstrated potential benefit in improving regional and systemic hemodynamics. Whilst DA was more effective in raising MAP, IRBF and IMBF; DX was effective in improving CO, IRBF and IMBF despite a marked decrease in MAP. This study presents that microcirculatory changes tend to follow those of CO but are less dependent on vascular driving force.

Comparison of isoflurane and sevoflurane chamber induction and recovery in cats

JCH Ko,* RE Mandsager,* ME Payton, EE Maszle, HD Moore, EM Salomn
Oklahoma State University, Stillwater, Oklahoma, USA

The speed, quality of chamber induction and recovery quality using either isoflurane or sevoflurane were evaluated.

Ten 1-year-old cats, six males and four females, weighing 3.5–5 kg were used in this randomized block crossover study. Seven days were allowed between treatments. Each cat was placed into a 38 litre induction chamber and the vaporizer was turned to either 5% isoflurane (I), 5% sevoflurane (S5) or 8% sevoflurane (S8) and delivered with 5 L $minute^{-1}$ oxygen via a hose directly connected to the fresh gas outlet of an anesthetic machine. Once the cat assumed lateral recumbency it was taken out of the chamber and placed on a face mask and continued at the same anesthetic vaporizer setting and oxygen flow rate until endotracheal intubation was possible. Following intubation, the cat was connected to a Bain circuit with end-tidal inhalant anesthetic concentration (measured with a catheter placed at the thoracic inlet via endotracheal tube) maintained at 1.5 MAC of either isoflurane or sevoflurane for 8 minutes. During this time ear cleaning, nail clipping and venous blood sampling were performed, and then the cat was recovered. Heart rate, respiratory rate, SpO_2, ECG and noninvasive blood pressure were

recorded prior to induction, at face mask application, immediately following intubation, and at 5 minutes of 1.5 MAC inhalant concentration. Induction and recovery were videotaped and their quality was rated by three individuals who were blinded to treatments. All cardiorespiratory data were analyzed using ANOVA for repeated measures, and all other data were analyzed using ANOVA. Alpha value was set at 0.05. Least significant difference was used if significance was detected.

Time from induction to onset of excitement was not significantly different between treatment groups. Duration of excitement was also not significantly different (I: 54 ± 23, S5: 83 ± 22, and S8: 49 ± 23 seconds). Time from induction to lateral recumbency was significantly longer with S5 (398 ± 19 *versus* I: 281 ± 21 and S8: 275 ± 21 seconds). Time from onset of mask induction to intubation, from termination of inhalant to extubation, and extubation to sternal and walking, and induction and recovery scores were not significantly different among treatment groups. Cardiorespiratory values were not significantly different among treatment groups at each time interval and all were within acceptable ranges. Blood glucose, but not PCV,TP, K, Ca, Cl, albumin, BUN, and creatinine, significantly increased after inhalant anesthetic induction (89 ± 7 mg dL^{-1}) when compared to preinduction values (70 ± 4).

We concluded that the use of sevoflurane with either 5% or 8% vaporizer dial setting did not provide significant advantages over isoflurane for chamber induction in healthy cats.

Effect of acupuncture on electroencephalographic responses to noxious stimuli in halothane-anesthetized dogs

SA Moriyasu,[1] SA Greene,*[2] MP Moore[1]
[1]*Washington State University, Pullman, Washington; and* [2]*University of Illinois, Urbana, Illinois, USA*

Quantitative electroencephalography (QEEG) of anesthetized dogs has been used to humanely measure morphine's attenuation of CNS responses to noxious stimuli (STIM). The purpose of this study was to similarly determine the effect of acupuncture on responses to STIM as characterized by changes in QEEG.

Six mixed-breed dogs were studied; mean ±SD weight and age of 32.8 ± 7.3 kg and 5 ± 0.8 years, respectively. Dogs were mask-induced with halothane (HAL) in oxygen and maintained at 1.7% end-tidal HAL concentration with controlled ventilation. Three treatments, each with and without electrical STIM, were studied in the following order: HAL alone, HAL with low frequency (1.4 Hz) electroacupuncture (LFA), and HAL with high frequency (150 Hz) electroacupuncture (HFA). Alternating current electroacupuncture was performed using needles placed in two acupuncture points on each pelvic limb (Stomach 36 and Spleen 6). Ten minutes of QEEG was collected using a Neurometric Analyzer both prior to and 2 minutes after STIM. STIM was twice the electric current needed to elicit a maximal amplitude compound motor unit action potential (10 $second^{-1}$ for 15 seconds) using a constant-voltage stimulator applied proximal to the tarsus. Absolute power of the EEG was analyzed by repeated measures ANOVA on ranks followed by the Student-Newman-Keuls' test when indicated by significant F-values ($p < 0.05$).

STIM in HAL-anesthetized dogs was associated with significant decreases in δ and α frequencies of the EEG at 14 of 21 electrode sites. During LFA, significant decreases in δ alone were observed at only four of 21 sites following STIM. During HFA, significant decreases in δ, α, and β frequencies were observed at only six of 21 sites following STIM. Heart rate, arterial blood pressure, and end-tidal CO_2 tension were unchanged throughout the study.

We conclude that both LFA and HFA attenuate the QEEG response to STIM during 1.7% HAL anesthesia suggesting electroacupuncture-induced alteration in CNS pain processing.

Postoperative analgesia in dogs receiving epidural morphine and medetomidine

C Pacharinsak, SA Greene,* RD Keegan,* P Kalivas
Washington State University, Pullman, Washington, USA

Analgesia was assessed in 12 dogs (seven males, five females; mean ±SEM age = 79.1 ± 8.9 months and weight = 38.2 ± 2.2 kg) undergoing repair of a ruptured cranial cruciate ligament. All dogs were given acepromazine (0.05 mg kg^{-1} IM) and atropine (0.04 mg kg^{-1} IM), induced with propofol and maintained with isoflurane in oxygen. Prior to surgery, dogs randomly received either preservative-free morphine (0.1 mg kg^{-1}) or morphine (0.1 mg kg^{-1}) with medetomidine (MEDET), 5 μg kg^{-1}, via lumbosacral epidural injection. Total volume of epidural injection was 0.2 mL kg^{-1}. Respiratory character and rate, heart rate, body temperature and video of each dog were recorded prior to premedication (PREMED) and at 4, 8, 12, 18 and 24 hours after epidural injection. Plasma morphine concentration ([MOR]) of blood sampled from the cephalic vein was determined at the above times and at 0.5, 1, 2, and 3 hours after epidural injection. Numerical rating scale (NRS) pain scores, posture, vocalization, and facial expression were evaluated from review of video by three blinded observers. NRS scores ranged from 0 to 10 with 0 = no pain and 10 = intense pain. Data were analyzed by repeated measures ANOVA ($p < 0.05$).

Induction doses of propofol and time from epidural injection to extubation were similar for both groups: 4.1 ± 0.5 mg kg^{-1} and 3.2 ± 0.3 hours for dogs receiving morphine and 4.8 ± 0.7 mg kg^{-1} and 3.8 ± 0.2 hours for dogs receiving morphine with MEDET. The pooled mean ±SEM NRS score for the morphine group (1.5 ± 0.1) was significantly higher than that of the morphine/MEDET group (1.1 ± 0.1). Mean NRS scores were significantly increased at

three and four hours (2.1 ±0.6 and 1.8 ± 0.3, respectively) compared to PREMED values (0.5 ± 0.1) only in the morphine group. Compared to PREMED values, mean [MOR] for the morphine/MEDET group was significantly increased at 0.5, 1, 12, 18, and 24 hours (range of means ±SEM = 4.7 ± 2.0–7.7 ± 2.8 ng mL^{-1}). Mean [MOR] was not significantly different between treatments or over time within the morphine group. No significant differences were determined between groups for other measured variables.

In conclusion, epidurally administered morphine combined with MEDET was associated with analgesic benefits compared to morphine alone. Peak plasma [MOR] may occur >24 hours after epidural morphine/MEDET injection.

Skin burns associated with use of the Quatrode ECG electrode during MRI utilizing accessory coils

J Bailey,* M Wilhelm
Pet Imaging Center, Englewood, Colorado, USA

Profound sedation or general anesthesia are mandatory for veterinary magnetic resonance imaging (MRI) and necessitate careful monitoring. However, electrically conductive monitoring cables create a hazard to the patient. Burns resulting from current induced in ECG electrodes and cables by the oscillating radiofrequency (RF) field of the MR unit have been the most frequently reported complication. Use of shielded cables, telemetry, fiberoptics and silver/silver chloride coated plastic or carbon electrodes have minimized this risk. Proper ECG management includes assurance of intact cable insulation; avoidance of loops in the cable; minimization of cable contact with other cables, the patient's skin or the wall of the magnet; prevention of patient contact with the wall of the magnet; minimization of RF power (< 1 W kg^{-1}); removal of all unnecessary wires; monitoring of cable heating; avoidance of the examination field with ECG components; and minimization of electrode/skin impedance. Despite proper ECG management we have observed four cases of ECG electrode burns. The purpose of this publication is to describe our experience with MRI related ECG burns. Three dogs (8.7 ± 0.9 year; 32.7 ± 2.9 kg) and one cat (20 year; 2.4 kg) were anesthetized, placed in the bore of the MR unit (1.0 tesla) and monitored with an MR compatible system (Omni-Trak 3150, Invivo Research) utilizing the Quatrode electrode patch. The first patient (T/L spine coil; 2 hours scan) developed a first degree burn in association with the left arm electrode. The monitor manufacturer was contacted, and a new ECG cable and new lot number of patches were implemented. The second patient (volume neck coil; 2 hours scan) developed a first degree burn in association with the left arm electrode. The manufacturer performed a facilities evaluation and concluded proper procedure was followed. An alternative ECG cable (high impedance, shielded; specifically for accessory coils) was employed. The third patient (extremity coil; 2 hours scan) developed a first degree burn in association with the right arm electrode. The manufacturer performed a second facilities evaluation and again concluded compliance with proper procedure. The fourth patient (T/L spine coil; 1.25 hours scan) developed a first degree burn in association with the right arm and left leg electrodes. A mutual decision was made with the manufacturer to replace the Quatrode electrode. No additional burns have been observed in over 500 subsequent cases to date. All burns were treated by cold compress and triple antibiotic ointment. No additional therapy was necessary. There are a vast array of MR imaging techniques providing ample opportunity for untested circumstances that may lead to monitoring equipment mishaps. Additional caution is advised when using MR accessory coils.

Disposition of buprenorphine, morphine and meperidine in the cat

SA Robertson,*[1] PM Taylor,[2] MJ Dixon,[2] JW Sear,[2] M Ruprah,[2] C Waters[2]
[1]University of Florida, Gainesville, Florida, USA; and [2]University of Cambridge, Cambridge, UK

There is a lack of specific information on the pharmacokinetics of opioids in cats. As a result, dosing intervals for cats are extrapolated from other species despite evidence that they may handle drugs uniquely. The aim of this study was to perform kinetic analysis from measured plasma concentrations of buprenorphine [B], morphine [M], and meperidine [ME].

Healthy adult cats (five females, 1 male, 2–11 years, 2.9–7.2 kg) received B (10 μg kg^{-1} IV, IM), M (0.2 mg kg^{-1} IV, IM) and ME (5 mg kg^{-1} IM only) in a randomized order, with a minimum of 7 days between treatments. IM injections were made in the epaxial muscles. Blood was withdrawn from preplaced jugular catheters before and at 1, 2, 4, 6, 10, 15, 30, 45 and 60 minutes, and at 2, 4, 6, 8, 12 and 24 hours after drug dosing. Plasma was separated by centrifugation and stored at −20 °C until assayed. Plasma B was measured using an iodine labelled RIA; M was assayed by HPLC, and ME by gas chromatography. Concentration-time data were analyzed using a noncompartmental method.

Compared to IV administration, bioavailability (F) after IM was 100% for B, and 26–124% for M. Cmax (ng mL^{-1}, median and range) was B: 8.7 (3.6–11.8), M: 120 (45–218) and ME: 110 (86–142). Tmax (minutes, median and range) was B: 3 (2–15), M: 15 (1–45), ME: 10 (5–120). B, M, and ME $T_{1/2\beta}$ (mean ±SD) were 380 ± 131, 94 ± 8, and 216 ± 123 minutes, respectively. Plasma clearance rate (mL kg^{-1} $minute^{-1}$) was 23.6 ± 12.6 for B, 13.9 ± 4 for M, and 20.8 ± 10.6 for ME. V_{SS} (L kg^{-1}) was 8.9 ± 5.9 for B, 1.7 ± 0.8 for M, and 5.2 ± 2.1 for ME. Several of the derived pharmacokinetic variables in this study are different from those published for dogs. This study suggests that dosing schedules for opioids in cats should be based on species-specific data.

The effect of buprenorphine, morphine and saline on thermal thresholds in cats

SA Robertson,*[1] PM Taylor,[2] MJ Dixon,[2] JW Sear,[2] M Ruprah,[2] C Waters[2]
[1]*University of Florida, Gainesville, Florida, USA; and* [2]*University of Cambridge, Cambridge, UK*

In order to compare analgesic drugs, pain must be produced in a controlled fashion and the response must be measurable. Thermal nociceptive threshold devices have been used in several species, but there is little information on their use to assess opioid induced analgesia in cats. The aim of this study was to measure thermal thresholds in cats following administration of buprenorphine (B), morphine (M) and saline (S).

Six healthy adult cats (five females, one male, 2–11 years, 2.9–7.2 kg) received three treatments in a randomized crossover design. The investigator was blinded to the treatments, which were as follows: B (10 μg kg^{-1} IM), M (0.2 mg kg^{-1} IM) and S (0.3 mL IM). All injections were made in the epaxial muscles. An electrical element produced thermal stimulation at a rate of 0.8 °C $second^{-1}$, which was measured by an adjacent temperature sensor. Both were embedded in conductive epoxy and attached to the shaved thorax by an elastic and Velcro band that the cats were accustomed to wearing. The sensor output was read on a digital voltmeter. The end-point was a distinct skin twitch at which time the hold button on the voltmeter was pressed. A safety cutoff was set at 70 °C. Reproducibility of results in untreated cats has been previously reported. Measurements were made before, and at 5, 30, 45, 60 minutes and 2, 4, 6, 12 and 24 hours after IM injection. Data were analyzed by two-way analysis of variance for repeated measures.

There was no significant change in thermal threshold after S. Following B; the thermal threshold was significantly ($p < 0.05$) increased at 2 and 6 hours (5.6 and 5.8%), respectively. Four hours after M administration, the thermal threshold was increased by 11.4% ($p < 0.05$).

This study shows that significant increases in thermal thresholds are slow to develop after IM injection of B or M in cats.

Pharmacokinetics of the transdermal fentanyl patch in a feline ovariohysterectomy model

CM Egger,* LE Glerum, SW Allen, M Haag
University of Georgia, Athens, Georgia, USA

This prospective laboratory trial investigated the pharmacokinetics of transdermal fentanyl patches (TFP) in cats undergoing anesthesia and ovariohysterectomy (OHE).

Twenty-four female, purpose-bred cats (weight 3.0 ± 1.3 kg) were randomly assigned to three groups (G1, G2, and G3; 8/group), and later re-assigned to groups 4 and 5 (G4 and G5; 12/group). Group 1 received a 25-μg h^{-1} patch, G2 received the patch and anesthesia, G3 received anesthesia only, G4 received the patch, anesthesia, and an OHE, and G5 received anesthesia and an OHE. Pharmacokinetics were investigated in G1, G2 and G4. A concurrent study evaluated analgesia and behavior in all groups of cats (G1-G5). Cats were anesthetized with acepromazine, atropine, ketamine and halothane. Patches were applied 12 hours prior to anesthesia and remained in place for 72 hours. Plasma was sampled via a previously placed venous catheter and fentanyl concentrations (PFC) were measured over an 81-hour period in G1, G2 and G4. Samples were taken at: 2, 4, 6, 8, 12, 13.5, 15, 17, 25, 37, 49, 61 and 73 hours (times are from patch placement) and at 74, 75, 77, 81 hours (after patch removal at 72 hours).

Time (hours) to first detectable PFC was 3.5 ± 1.4 (G1), 3.8 ± 1.7 (G2), and 6.0 ± 3.5 (G4). Time (hours) to PFC > 1 ng mL^{-1} was 7.3 ± 2.6 (G1), 7.5 ± 5.4 (G2), and 8.4 ± 3.3 (G4). Time (hours) to peak PFC was 14.0 ± 1.9 (G1), 19.0 ± 5.0 (G2), and 20.5 ± 10.0 (G4). Mean PFC (ng mL^{-1}) from 8 hours after patch placement until patch removal was 3.4 ± 1.4 (G1), 3.0 ± 1.0 (G2), and 2.2 ± 1.0 (G4). The apparent elimination half-life (hours) was 4.6 ± 2.2 (G1), 7.2 ± 6.6 (G2), and 5.6 ± 3.1 (G4). The total area under the curve from 0 to infinity (ng h^{-1} mL^{-1}) was 222.3 ± 92.1 (G1), 204.0 ± 45.5 (G2), and 157.1 ± 54.0 (G4). There was no significant difference between groups for any of these parameters. There was a high degree of individual variability in PFC in all groups. Cats achieve significant PFC by approximately 8 hours and levels declined rapidly after patch removal. Anesthesia and surgery did not significantly alter PFC achieved. No serious side-effects were noted and the patches were well tolerated.

RUMINANTS

Behavioral changes and pharmacokinetics of butorphanol in goats following intravenous and intramuscular administration

GL Carroll,* DM Boothe, SM Hartsfield,* MK Waller, S Geller
Texas A & M University, College Station, Texas, USA

The purpose of this study was to evaluate disposition of butorphanol (BUT) in goats after intravenous (IV) and intramuscular (IM) administration and to relate behavioral changes with plasma concentrations of BUT.

Each of six healthy 3-year-old neutered goats (one male, five females) (46.5 ± 0.5 kg) were given BUT (0.1 mg kg^{-1}, IV or IM) using a randomized crossover design with a one week wash out period. Plasma BUT concentrations were determined for 14 hours after drug administration (IV: 0, 2, 5, 10, 15, 30, 45, 60, 90, 120, 180, 240, 360, 480, 600, 720 and 840 minutes; IM: 0, 5, 10, 15, 30, 45, 60, 90, 120, 150, 180, 240, 360, 480, 720 and 840 minutes). Pharmacokinetic values were calculated using a computerized model. Behavior was scored subjectively (3 = fractious; 2 = fidgety; 1 = quiet with heightened alertness; 0 = normal) at 0, 15, 30, 60, 120 and 240 minutes after butorphanol administration.

Estimated peak plasma concentration of BUT after IM administration was 54.98 ± 14.60 ng mL^{-1}; time to maximum concentration was 16.2 ± 5.2 minutes; bioavailability was 82 ± 41%. Volume of distribution at steady state after IV BUT was 1.27 ± 0.73 L kg^{-1}; systemic clearance was 9.6 ± 2.4 mL kg^{-1} $minute^{-1}$. Elimination half-life after IV BUT was 112.4 ± 89.4 minutes and after IM administration was 165.1 ± 115.9 minutes. Plasma BUT concentrations were greater than 10 ng mL^{-1} for 240 minutes. Behavioral scores for goats at 15 and 30 minutes were significantly different from baseline and 240 minutes after IM BUT. With IV BUT, baseline behavioral scores were different from those at 15 minutes; those at 15 minutes were different from scores at 120 and 240 minutes. Both time and plasma BUT concentration predicted behavior. Every 15 minutes that passed lowered the behavior score by 13% after IV BUT, and by 10% after IM BUT; each ng increase in plasma concentration increased the behavior score by 4% after IV BUT and by 7% after IM BUT. Behavioral scores had returned to baseline by 120 minutes after IV BUT and by 240 minutes after IM BUT. The dose of BUT that we use clinically to treat postoperative pain in goats results in an acceptable half-life for ease of dosing; plasma concentrations meet or exceed target plasma concentration (10 ng mL^{-1}) for 4 hours.

Behavioral changes occur after IV and IM BUT in goats without pain. Further investigation is needed to validate the efficacy of BUT as an analgesic in goats.

The effect of tiletamine-zolazepam on isoflurane minimum alveolar concentration in goats

T Doherty,* B Rohrbach, H Schultz, L Ross, D Geiser
University of Tennessee, Knoxville, Tennessee, USA

This study examined the effect of tiletamine-zolazepam (TZ) on the isoflurane (ISO) MAC in goats.

Six adult wethers (37 ± 13 kg) were used in the study. Anesthesia was induced with ISO delivered via a face mask. Goats were intubated and ventilated to normocapnia. ISO was carried in oxygen (3 L $minute^{-1}$). End-tidal (ET) gases were measured using a calibrated infrared gas analyzer (Criticare 1100). Samples were drawn from the distal end of the endotracheal tube. Each goat was studied on six occasions, at weekly intervals, using a Latin Square design, and at each study period, received one of the following intravenous treatments in random order (TZ 0.55, 1.1, 2.2, 4.4, or 8.8 mg kg^{-1}, or saline). MAC was determined by clamping a claw for 60 seconds or until purposeful movement occurred. MAC was defined as the mean ISO concentrations at which movement did and did not occur. Body temperature was maintained in the normal range (100.8–102.3° F) using a heating pad. One hour was allowed before the baseline MAC (MAC1) was determined in duplicate. Following this, a treatment was administered and a single determination of MAC was performed (MAC2). End tidal ISO concentration was held constant for 20 minutes prior to each testing. Data were analyzed, using a mixed-model ANOVA, to determine the effect of treatment on the difference in MAC (MAC1-MAC2), and the percentage change in MAC. Differences in MAC were fitted as dependent variables, and treatment and time as independent variables. Goats were included as a random variable in the model.

The mean MAC1, of all groups, was 1.3 ± 0.18%. Saline did not affect MAC. For all doses of TZ, the difference in MAC was significant ($p < 0.0001$). The mean percentage decrease ($p < 0.0001$) was 29% (0.55 mg kg^{-1}), 43% (1.1 mg kg^{-1}), 51% (2.2 mg kg^{-1}), 65% (4.4 mg kg^{-1}) and 77% (8.8 mg kg^{-1}). The percentage difference in MAC was not affected by the order of treatment or the time taken (78 ± 21 minutes) to determine MAC2.

The study indicates that, in goats, TZ decreases ISO MAC in a dose-dependent fashion.

Intraarticular lidocaine and bupivacaine in sheep undergoing stifle arthrotomy

HL Shafford, CH Mallinckrodt, AS Turner, PW Hellyer*
Colorado State University, Fort Collins, Colorado, USA

Intraarticular (IA) administration of local anesthetics is a safe and effective means of providing site-specific analgesia. The purpose of this study was to evaluate the effect of IA lidocaine and bupivacaine on postoperative pain in 16 adult Rambouillet cross ewes weighing 70.0 ± 1.6 kg (mean ±SD) undergoing stifle arthrotomy (eight sheep/day).

Twenty-four hours prior to surgery each sheep received phenylbutazone (1 g PO) and transdermal fentanyl equivalent to 15 mg or 150 μg h^{-1}. Phenylbutazone (1 g PO, every 24 hours) was administered the morning of surgery and for 3 days thereafter. Sheep were randomly assigned to one of two treatment groups. The lidocaine/bupivacaine group (L/B, $n = 8$) received perioperative IA lidocaine and bupivacaine, while the control group ($n = 8$) received no IA injections. The L/B group received lidocaine (40 mg) after aseptic preparation of the stifle approximately 5 minutes prior to surgical incision. A lateral arthrotomy of the left stifle was performed on all sheep with the purpose of creating a full thickness articular cartilage defect. Bupivacaine (10 mg) was administered IA in the L/B group following closure of the arthrotomy site. Two observers blinded to treatment assessed sheep for total pain score using a numeric ranking scale that included: comfort, movement, flock behavior, feeding behavior and respiratory rate. The first observation ($t = 0$) was obtained the evening of surgery (2–7 hours postop) when all sheep had recovered from anesthesia and were transported to their paddock. Sheep were observed for approximately 15 minutes every 12 hours for 72 hours. Data were analyzed using a likelihood-based repeated measures analysis. Between group differences were assessed using both the original scale data and rank transformed data.

L/B sheep had significantly lower total pain scores at $t = 0$ than control sheep ($p < 0.05$). Observers did not influence differences between treatments in total pain score. No significant differences in pain scores were noted at all subsequent time periods. Our findings support the use of IA lidocaine and bupivacaine as a simple, effective, yet inexpensive postoperative analgesic protocol for joint surgery in sheep.

Cardiovascular effects of butorphanol in sevoflurane-anesthetized calves

RD Keegan,* RA Valdez, SA Greene,* DK Knowles
Washington State University, Pullman, Washington, USA

The purpose of this study was to determine the suitability of mask induction using sevoflurane and the cardiovascular effects of butorphanol (B) in five healthy Holstein calves 7–9 weeks of age weighing 64 ± 10.7 kg and anesthetized with sevoflurane (SEVO). Anesthesia was induced by face mask administration of 8% SEVO in O_2 using an O_2 flow rate of 5 L minute^{-1}. Following induction of anesthesia, the animals were intubated and maintained on 3.7 ± 0.04% SEVO for 30 minutes to facilitate instrumentation. Ventilation was controlled to maintain normocapnia ($PaCO_2$ = 35–45 mm Hg, 4.7–6 kPa). After instrumentation was completed, baseline values (BASE) were recorded and B (0.2 mg kg^{-1} IV) was administered. The following parameters were recorded at BASE and at 5, 10, 15, 30, and 45 minutes following administration of B: direct systolic (SAP), diastolic (DAP), and mean (MAP) arterial blood pressures, cardiac output (CO), mean pulmonary artery pressure, central venous pressure, heart rate (HR), and pulmonary arterial temperature. Cardiac index, systemic (SVR), and pulmonary vascular resistance were calculated using standard formulas. In addition, samples for blood gas analysis were collected at baseline, 15 minutes, and 45 minutes. Differences from baseline values were determined using one-way ANOVA for repeated measures with post hoc differences between means identified using Bonferroni's method ($p < 0.05$).

Induction of anesthesia using SEVO was rapid and smooth; the mean time from beginning SEVO to intubation was 229 ± 22 seconds. Administration of B was associated with statistically significant decreases in HR (88 beats minute^{-1} to 74 beats minute^{-1}), SAP (97 mm Hg to 82 mm Hg), MAP (76 mm Hg to 65 mm Hg), and DAP (70 mm Hg to 49 mm Hg), while CO did not change. Although SVR decreased following injection of B, the difference was not statistically significant.

We conclude that: (1) SEVO is acceptable for mask induction of calves, and (2) administration of BUT (0.2 mg kg^{-1} IV) to calves anesthetized with 3.7% SEVO is associated with decreases in HR and arterial blood pressure.

Plasma colloid osmotic pressure after blood volume repletion with Oxyglobin, hetastarch, or whole blood in pregnant sheep

LP Posner, PF Moon,* SP Bliss, RD Gleed,* HN Erb
Cornell University, Ithaca, New York, USA

In preliminary measurements, Oxyglobin and hetastarch had colloidal osmotic pressures of 35 and 31 mm Hg, respectively, while ovine plasma ($n = 17$) had an osmotic pressure of 20 (16, 24) mm Hg, median (minimum, maximum). We hypothesized that Oxyglobin administration after hemorrhage would increase maternal plasma colloidal osmotic pressure (COP) more than hetastarch and that both would draw water from the fetus across an osmotic gradient.

Seventeen unmedicated, pregnant (~132 days gestation), Rambouillet ewes [55 (46, 63) kg] aged 1–2 years, chronically instrumented with catheters in maternal carotid and fetal femoral arteries, had 19 (14, 25) mL kg^{-1}, blood removed over 1 hour. The induced hypovolemia was then treated with either the removed volume of autologous blood ($n = 6$), 20 mL kg^{-1} Oxyglobin ($n = 5$), or 20 mL kg^{-1} hetastarch ($n = 6$) given IV over 30 minutes. The plasma COP of intermittent blood samples was measured using a colloid osmometer. Maternal COP was 20 (16, 24) and 15 (11, 19) mm Hg before and after hemorrhage, respectively. Significance of the differences between Oxyglobin and the other treatment groups was tested using Kruskal–Wallis nonparametric one-way ANOVA.

We detected no difference between groups in the volume of blood removed. Immediately after volume repletion, maternal COP of the Oxyglobin treated group was 22 (21, 25) mm Hg. This was significantly greater ($p < 0.05$) than the corresponding COP values after blood, 17 (16, 22) or hetastarch, 20 (17, 21) mm Hg. Greater maternal COP after Oxyglobin persisted until at least 120 minutes after volume repletion. Fetal COP after hemorrhage was 16 (12, 19) mm Hg and at 120 minutes after repletion was 16 (11, 18) mm Hg. Fetal COP was virtually unchanged by any of the volume repletion treatments.

We conclude that Oxyglobin is a more potent colloid than either whole blood or hetastarch. We found no evidence that either Oxyglobin or hetastarch induce transplacental movement of water from the fetal to the maternal circulation.

Fetal oxygen content is restored with Oxyglobin resuscitation after maternal hemorrhage

PF Moon,* SP Bliss, LP Posner, HN Erb, PW Nathanielsz
Cornell University, Ithaca, New York, USA

Red cell substitutes are used to treat hypovolemia but their effects on the fetus have never been evaluated.

Fifteen chronically instrumented, adult, Suffolk-cross ewes (56 kg, median weight) and their fetuses were studied at 132-day gestational age (term = 147 days). Ewes were bled 20 mL kg^{-1} over 1 hour, randomized to receive 20 mL kg^{-1} IV over 30 minutes of a red cell substitute (Oxyglobin, OXY,

$n = 5$), hetastarch (HTS, $n = 5$), or autologous blood (CTL, $n = 5$), and then monitored for 2 additional hours. Signed-rank tests compared within groups (overall $p = 0.10$) and rank-sum tests compared OXY to CTL and HTS (overall $p = 0.05$), each with Bonferroni corrections.

Hemorrhage resulted in maternal hypotension (from a mean blood pressure of 98 mm Hg to 48 mm Hg, median) and decreased arterial oxygen content (from 12.2 mL dL^{-1} to 11.1 mL dL^{-1}) and fetal hypoxemia (from a PaO_2 of 20 to 15.9 mm Hg, 2.7–2.1 kPa), mixed acidosis (from a standard base excess of 3.4 mmol L^{-1} to −1.0 mmol L^{-1} and an increase in $PaCO_2$ tension from 51 to 57 mm Hg, 6.8–7.6 kPa) and decreased arterial oxygen content (from 8.1 mL dL^{-1} to 3.9 mL dL^{-1}). Resuscitation restored blood pressure in all ewes and arterial oxygen content in only CTL and OXY ewes. Fetal oxygen content immediately returned to baseline with CTL (7.1 mL dL^{-1}) and OXY (8.0 mL dL^{-1}) but was never restored with HTS (4.7 mL dL^{-1}). At 60 minutes after resuscitation, fetal oxygen content was higher with OXY (8.3 mL dL^{-1}) than with HTS (4.7 mL dL^{-1}). In all groups, fetal metabolic acidosis persisted. The concentration of free hemoglobin in fetal plasma did not change with OXY.

In conclusion, restoration of maternal blood volume and pressure does not necessarily imply restoration of fetal oxygen content. Fetal oxygen content was restored only with blood or Oxyglobin. This effect was due to re-establishment of maternal oxygen content and not due to placental transfer of Oxyglobin.

HORSES

Nitric oxide production in normal, endotoxemic and critically ill colic horses

JL Jones,* TJ Doherty,* BW Rohrbach
University of Tennessee, Knoxville, Tennessee, USA

Total serum nitrate/nitrite concentration (SNN in μM L^{-1}), an indirect measure of nitric oxide (NO), has been reported to be increased during critical illness in people and dogs. The relationship of NO to critical illness in horses is unknown. The purpose of this study was to quantify and compare SNN in normal, endotoxin treated, and horses with naturally acquired colic requiring surgical intervention.

Sixteen healthy adult mares were randomly administered either endotoxin (E.coli 055 B5, 0.2 μg kg^{-1} in 1 L 0.9% NaCl; Group 1; ENDO, $n = 8$) or 1 L 0.9% NaCl (Group 2: SAL, $n = 8$) IV over 15 minutes. Clinical symptoms of colic were evident within 45 minutes post infusion in ENDO horses. Group 3 were horses with naturally occurring colic requiring emergency surgical intervention (COLIC, $n = 17$). Jugular venous samples were collected for SNN analysis prior to infusion ($t = 0$ hours) and 4 hours postinfusion ($t = 4$ hours) in ENDO and SAL and prior to anesthetic induction in COLIC horses. SNN is reported as median values in μM L^{-1}. Data were log transformed if necessary to fit a normal distribution. Analysis of variance was used to compare SNN among groups. Significance was based on a p-value of < 0.05.

COLIC had significantly higher SNN (12.78 μM L^{-1}) as compared to ENDO (3.6 μM L^{-1}) and SAL (5.7 μM L^{-1}). SNN was increased significantly at $t = 4$ hours as compared to $t = 0$ hours in both ENDO and SAL with no significant difference between groups at $t = 0$ or in the magnitude of change from $t = 0$.

We conclude that SNN was significantly increased in horses with surgical colic as compared to endotoxin and saline treated horses. A higher dose of endotoxin may be needed in an equine model to induce NO response. NO production in horses may relate to the severity and duration of critical illness.

Effect of breathing a heliox gas mixture on cardiopulmonary function in horses anesthetized immediately following exercise

RD Keegan,* SA Greene,* EA Taylor, RH Sides, WM Bayly
Washington State University, Pullman, Washington, USA

The purpose of this study was to determine the cardiopulmonary effects of breathing a heliox (60% He: 40% O_2) carrier gas mixture in horses anesthetized immediately following treadmill exercise.

Using a randomized crossover design, six healthy, Thoroughbred horses (five males, one female) weighing 517 ± 36.9 kg were instrumented to enable measurement of heart rate (HR), systolic (SAP), mean (MAP) and diastolic (DAP) carotid arterial pressures, mean pulmonary arterial pressure (PAP), central venous pressure (CVP), pulmonary arterial temperature (TEMP), and cardiac output. Horses were warmed up for 3 minutes at 4 m $second^{-1}$, then exercised to the point of fatigue at 115% VO_2max and immediately anesthetized using detomidine (0.04 mg kg^{-1} IV) followed by tiletamine-zolazepam (1.25 mg kg^{-1} IV). Anesthesia was maintained using 1.3 MAC isoflurane (ISO) vaporized in either 100% O_2 (O), 60% N_2 : 40% O_2 (N), or 60% He : 40% O_2 (H). End-tidal ISO concentration was measured using a RASCAL II anesthetic gas analyzer. Minute ventilation (MV) was measured during ISO anesthesia using a heated, calibrated pneumotachometer and differential pressure transducer. Ventilation during ISO anesthesia was controlled to maintain constant, similar minute ventilation between the O, N and H treatment groups. Cardiovascular data and samples for arterial and mixed venous blood gas analysis were recorded while the horse stood quietly prior to exercise, 30 seconds after the point of fatigue, immediately prior to isoflurane anesthesia and 15, 30, 45 and 60 minutes after initiating isoflurane anesthesia. Data were analyzed using repeated measures ANOVA with posthoc differences between means identified using Bonferroni's method ($p < 0.05$).

Exercise was associated with significant increases in HR, SAP, MAP, DAP, PAP, CVP, TEMP and significant decreases

in pH, HCO_3^- and BE. Anesthesia was associated with a return of HR, SAP, MAP, DAP, PAP and CVP to pre-exercise values. MV measured during ISO was not different between groups. Horses in the O group had significantly higher values for PaO_2 (156.7 mm Hg, 20.9 kPa) compared to the N group (93.6 mm Hg, 12.5 kPa) or the H group (90.4 mm Hg, 12.1 kPa). No other differences between treatments were identified. We conclude that use of H as a carrier gas does not improve gas exchange in horses anesthetized immediately following exercise.

Effect of an inhaled β-2 adrenergic receptor agonist on arterial partial pressure of oxygen in hypoxemic anesthetized horses

J Bailey,* S Robertson,* L Pablo,* S Cantwell, W Davis
University of Florida, Gainesville, Florida, USA

All too commonly, and despite high inspired oxygen concentration, anesthetized horses develop low arterial oxygen tension, potentially compromising oxygen delivery. Traditional methods of addressing hypoxemia have proven inadequate. This clinical evaluation was designed to test the hypothesis that a specific β-2 adrenergic receptor agonist, albuterol sulfate, when delivered by metered-dose inhaler (MDI) would affect arterial partial pressure of oxygen in hypoxemic anesthetized horses, and demonstrate a safe, effective alternative medical approach to treatment.

Client owned animals ($n = 22$; 16 males, six female) which approached ($PaO_2 < 90$ mm Hg, < 12 kPa and declining) or became hypoxemic ($PaO_2 < 60$ mm Hg, < 8 kPa) under anesthesia were administered albuterol sulfate at 2 μg kg^{-1} (rounded to the nearest 45 kg) through a MDI connected to a linear aerosolization chamber, after all other treatment modalities were attempted. Blood gases were drawn following MDI therapy (mean 24.6 ± 2.2 minutes). The mean and standard error of the mean (mean ±SEM) were calculated for all data and a *t*-test for paired samples was calculated to evaluate significance of differences. A *p*-value less than 0.05 was adopted as significant.

The collective increase in PaO_2 was 54.9 ± 11.4 mm Hg (7.3 ± 1.5 kPa). This difference was statistically and clinically significant. Evaluation of only those horses with unequivocal hypoxemia ($PaO_2 < 60$ mm Hg) demonstrated a larger mean increase in PaO_2 (61.7 ± 14.9 mm Hg, 8.2 ± 2 kPa) than those horses with merely low PaO_2 (< 90 mm Hg, < 12 kPa and declining) (50.2 ± 16.7 mm Hg, 6.7 ± 2.2 kPa). A second evaluation of client owned animals ($n = 42$; 17 males, eight geldings, 17 females; 8.7 ± 0.9 year; 495.1 ± 16.8 kg; dorsal recumbency, $n = 36$; right lateral recumbency, $n = 3$; left lateral recumbency, $n = 3$) determined to be hypoxemic ($PaO_2 = 63.9 \pm 2.8$ mm Hg, 8.5 ± 0.4 kPa) under anesthesia were administered 900 μg of albuterol sulfate by MDI. Arterial pH, $PaCO_2$, HCO_3^-, and BE did not change significantly with treatment. A statistically significant increase (48.2 ± 7.7 mm Hg, 6.4 ± 1 kPa) in PaO_2 from 63.9 ± 2.8 mm Hg (8.5 ± 0.4 kPa) to 112.2 ± 9.1 mm Hg (15 ± 1.2 kPa) was detected. Careful monitoring of heart rate, ECG, blood pressure and electrolytes revealed no deleterious side-effects of the therapy, with the exception of sweating. Albuterol sulfate delivered by MDI inhalation therapy was an effective means of increasing arterial oxygen concentration. A controlled study including measurement of cardiac output will be necessary to define the mechanism and support these clinical findings.

Case-control analysis for determining possible causes of airway complications during anesthetic recovery in horses

JW Ludders,* HN Erb, RD Gleed,* PF Moon*
Cornell University, Ithaca, New York, USA

Anesthetic complications have multiple causes making it difficult to distinguish between inciting causes and coincidental events. Case-control analysis is used to analyze clinical cases retrospectively and identify causes of complications. This approach was used to identify causes of airway complications that occurred during recovery in 30 horses at Cornell University between 1990 and 1997. In the 30 index cases, airway complications included airway obstruction ($n = 6$), bronchial asthma (1), dyspnea (8), pulmonary edema (14), and respiratory arrest (1).

Based on breed, age, gender and surgical procedure, each index horse was matched to six control horses, three that were operated on prior to surgery on the index case, and three that were operated on after surgery on the index case. Data were analyzed using chi-square analysis; significance was set at $p \leq 0.05$.

Factors not significantly associated with the index horses included: breed, gender, day of the week, physical status, surgical body region, surgeon, type of complication that may have occurred intraoperatively, fluid volume, drugs given intraoperatively, and use of nasotracheal or nasopharyngeal tubes during recovery. Factors that were associated with the index cases included: a nonsignificant tendency to be older than controls; significantly longer anesthetic episodes; fewer than expected received antibiotics, anti-inflammatory drugs, and tetanus toxoid compared with controls; and more received colloid and hypertonic saline than controls.

This study did not identify a specific cause of the airway complications, but it allowed us to rule out a number of possible causes while identifying some factors that warrant further investigation such as plasma oncotic pressure effects on airway-associated complications.

Analgesic, hemodynamic and respiratory effects of caudal epidural meperidine HCl solution in mares

RT Skarda,* WW Muir*
The Ohio State University, Columbus, Ohio, USA

Among clinically used opioids, meperidine exerts the strongest local anesthetic effect. It has been used successfully for

local and regional anesthesia in human beings but not horses. Our aim was to determine the analgesic, hemodynamic and respiratory effects, sedation and ataxia in mares after epidural administration of meperidine.

Avoidance response, sedation, ataxia, and cardiovascular and respiratory parameters were determined in seven healthy mares weighing from 510 to 610 kg before and at 15 minute intervals for 5 hours after caudal (S5-Co1) epidural administration of 5% meperidine HCl solution (8 mL; 0.8 mg kg^{-1}) (EM, test) or 0.9% NaCl (8 mL; ES, control) in a randomized, blinded, cross-over study design with 2 weeks between experiments. Sensory blockade, sedation and ataxia were scored by evaluating avoidance to deep needle prick, head drop and position of pelvic limbs, respectively. Arterial blood samples were collected before and at 30 minute intervals for 5 hours after EM or ES. Two-way ANOVA and Dunnett's *t*-test were used for statistical analysis ($p < 0.05$).

EM induced profound analgesia ranging from coccygeal to the first sacral vertebra in 27 ± 10 minutes (mean ± SD), and lasting 300 ± 51 minutes with minimal sedation, ataxia and cardiopulmonary effects in conscious mares. Analgesia to electrical stimulation (> 40 milliamps) at the perineal area was achieved in 12 ± 4 minutes and lasted over 5 hours. EM and ES did not significantly change HR, RR, carotid ABP, arterial PO_2, PCO_2, SaO_2, pH, standard HCO_3^- and BE, PCV, and TS concentrations of mares ($p > 0.05$).

EM (5%, 8 mL 500 kg^{-1}) produced > 5 hours bilateral perineal analgesia with minimal side-effects in standing mares.

Evaluation of anesthesia maintained with halothane and epidural xylazine for hind limb surgery in horses

FJ Teixeira Neto, W McDonell,* S Pearce, C Kerr,* M Hurtig, S Durongphongtorn
University of Guelph, Canada

This study compared the quality of anesthesia and hemodynamic parameters with previously determined equipotent anesthetic concentrations of halothane (HAL) and HAL/epidural xylazine (XYL) during hind limb surgery in horses.

Ten adult horses, weighing 495 ± 80 kg were randomly assigned to two groups. After epidural injection of 0.15 mL kg^{-1} of saline (control group, $n = 5$) or 0.15 mg kg^{-1} of XYL diluted in 0.15 mL kg^{-1} of saline (experimental group, $n = 5$), anesthesia was induced with a XYL/guaifenesin/ketamine combination and maintained with HAL in oxygen. $PaCO_2$ was maintained at 48 ± 3 mm Hg (6.4 ± 0.4 kPa) by using IPPV. Anesthetic concentrations equivalent to 1.5 MAC were maintained throughout in both groups (1.4% ET-control or 0.9% ET-experimental, based on a previously published study). Surgical depth was evaluated clinically and the dose of supplemental ketamine (KET, 0.2 mg kg^{-1} boluses) necessary to maintain surgical anesthetic depth was noted. Dobutamine (DOB) infusions (0.5–4 μg kg^{-1} $minute^{-1}$) were given as needed to maintain mean arterial pressure (MAP) above 60 mm Hg in both groups. DOB was stopped at least 10 minutes before hemodynamic measurements, which were performed before surgery (T1), after skin incision (T2), before skin closure (T3), and during the casting procedure (T4). Butorphanol (0.02 mg kg^{-1} IV) was given 5 minutes before surgery in both groups. Data were analyzed by ANOVA for repeated measures, followed by a Dunnett's (comparison within groups) or a Tukey's (comparison between groups) test. Recovery scores were compared by a Wilcoxon Mann–Whitney test ($p \leq 0.05$).

There were no significant differences between groups in heart rate, MAP and central venous pressure. Cardiac index (CI) was higher in the HAL/epidural XYL group: 34.3 ± 8.2 mL kg^{-1} $minute^{-1}$ for HAL *versus* 39.2 ± 6.7 mL kg^{-1} $minute^{-1}$ for HAL/epidural XYL (pooled data). Surgical stimulation increased MAP (T1 = 63 ± 5 to T3 = 78 ± 8 mm Hg) and systemic vascular resistance index (T1 = 78.3 ± 8.1 to T3 = 136.4 ± 35.6 dynes seconds cm^{-5} kg^{-1}) in both groups, and decreased both CI (T1 = 45.9 ± 5.9 to T2 = 30.6 ± 6.2 mL $kg^{-1}$$minute^{-1}$) and stroke volume index (T1 = 1.3 ± 0.2 to T2 = 0.9 ± 0.1 mL beat kg^{-1}). Three horses from the HAL/epidural XYL group needed supplemental KET (1.04 ± 0.37 mg kg^{-1}). DOB was used in all animals from the control group (39 ± 22 μg kg^{-1} total dose), whereas only one animal from the HAL/epidural XYL group received inotropic support (8 μg kg^{-1} total dose). Two horses became severely ataxic during epidural injection of XYL prior to induction. The recovery score (HAL = 2 ± 0.8 *versus* HAL/epidural XYL = 2.2 ± 0.8) did not differ between groups.

We concluded that the use of MAC-based equipotent concentrations of HAL and HAL/epidural XYL did not produce clinically similar surgical anesthetic depths, although the quality of anesthesia in the horses receiving epidural XYL was good. The decreased necessity for inotropic support and improved CI in the epidural group may be attributed to the reduced halothane requirement, and possibly increased sympathetic response to surgical stimulation. Our data provide additional evidence that increased arterial pressure in response to surgical stimulation does not necessarily improve tissue perfusion.

LABORATORY ANIMALS AND EXOTIC SPECIES

Evaluation of anesthetic and cardiorespiratory effects of tiletamine-zolazepam-ketamine-xylazine-butorphanol and medetomidine-butorphanol-ketamine in guinea pigs

WC Kuo,[1] JCH Ko,*[2] BR Collins,[3] RD Keegan*[1]
[1]*Washington State University, Pullman, Washington, USA;* [2]*Oklahoma State University, Stillwater, Oklahoma, USA;* [3]*University of Florida, Gainesville, Florida, USA*

Five female and four male guinea pigs, 2.0 ± 0.5 months of age and weighing 702 ± 72 g, were used in a crossover design to compare sedative and anesthetic effects of IM injection (INJ) of tiletamine-zolazepam (10 mg kg^{-1}) – ketamine (4 mg kg^{-1}) – xylazine (5 mg kg^{-1}) – butorphanol (0.1 mg kg^{-1}) (TKXB-H), tiletamine-zolazepam (5 mg kg^{-1}) – ketamine (2 mg kg^{-1}) – xylazine (2.5 mg kg^{-1}) – butorphanol (0.05 mg kg^{-1}) (TKXB-L), and medetomidine (0.5 mg kg^{-1}) – ketamine (20 mg kg^{-1}) – butorphanol (0.2 mg kg^{-1}) (MBK) combinations. Yohimbine (YOH), 2 mg kg^{-1} IM, YOH, 1 mg kg^{-1} IM, and atipamezole (ATI), 2.5 mg kg^{-1} IM, were used to reverse (REV) xylazine and medetomidine in three groups, respectively, at 100 minutes after INJ. Heart rate (HR), Doppler systolic blood pressures (BP) (neonatal size cuff), respiratory rate (RR), and SpO_2 were measured at baseline and every 10 minutes after INJ and at 5 and 10 minutes following REV. Jaw tone, palpebral reflex, corneal reflex, toe pinch, skin pinch, ECG and body temperature were monitored every 10 minutes after INJ for 100 minutes. In addition, four female and three male guinea pigs from the original group were anesthetized with TKXB-H for castration and ovariohysterectomy. Cardiorespiratory functions were monitored during the surgery. Following surgery, YOH (2 mg kg^{-1} IM) was used to shorten recovery. ANOVA for repeated measures and Tukey's honestly significant test were used for analysis ($p < 0.05$).

The results of this study showed:

1. All three combinations effectively induced lateral recumbency in the guinea pigs within 2 minutes.
2. All three combinations depressed cardiorespiratory function of the guinea pigs. BP decreased significantly after INJ in both TKXB groups (TKXB-H: 74 ± 13–54 ± 10 mm Hg; TKXB-L: 64 ± 10.to 43 ± 9 mm Hg). BP did not change significantly in the anesthetized guinea pigs with or without surgery. RR decreased significantly in all groups following INJ.
3. The TKXB-H group had significantly longer analgesic duration (skin pinch analgesia 30.0 ± 18.0 minutes; toe pinch analgesia 27.2 ± 15.6 minutes) and was suitable for castration and ovariohysterectomy (average surgery time was 29.5 ± 7.4 and 41.2 ± 9.7 minutes, respectively).
4. Yohimbine did not shorten recovery time in the treated animals following surgery.

Evaluation of oscillometric blood pressure monitoring during immobilization of free-ranging Baird's tapirs (Tapirus bairdii) in Costa Rica

JE Bailey,*[1] SH Foerster,[2] CR Foerster.[3]
[1]*University of Florida, Gainesville, Florida, USA;* [2]*Cornell University, Ithaca, New York, USA;* [3]*Proyecto Danta/Baird's Tapir Project, Parque Nacional Corcovado, Costa Rica*

The study of free-ranging, endangered species almost always requires immobilization for collection of biological samples and radiotransmitter placement. Although monitoring assists in assuring safe immobilization, scant information is available regarding physiological monitoring of tapirs. This study was designed to test the effectiveness of noninvasive, oscillometric arterial blood pressure monitoring (NIBP) in wild captured tapirs.

Six adult Baird's tapirs (*Tapirus bairdii*) estimated to weigh 235 ± 23.6 kg (mean ±SEM) were attracted to a capture area using ripe bananas as bait. Animals were darted with a mixture of 50 mg butorphanol (0.23 ± 0.03 mg kg^{-1}) and 100 mg xylazine (0.46 ± 0.07 mg kg^{-1}) using a CO_2 pistol. Propofol (100 μg kg^{-1} $minute^{-1}$ IV, $n = 2$; 200 μg kg^{-1} $minute^{-1}$ IV, $n = 2$) or ketamine (0.35 ± 0.05 mg kg^{-1} IV, $n = 1$) were delivered to maintain immobilization in all but one case. A commercial blood pressure cuff (cuff bladder width to limb circumference ratio 0.399 ± 0.01) was applied to the thoracic limb, and a 20-ga, 3.8 cm catheter was placed in the facial artery on the nondependent side of the laterally recumbent tapir. A laser line-level and careful positioning were used to assure the cuff center and pressure transducer were at the same level, and were at the approximated level of the right atrium. Systolic (SAP), diastolic (DAP) and mean arterial pressure (MAP) were recorded simultaneously (at end cuff decompression). The lower limits of the range of invasive arterial blood pressure (IBP) were 94 ± 18 mm Hg, 58 ± 18 mm Hg and 74 ± 17 mm Hg for SAP, DAP and MAP, respectively. The upper limits of the range of IBP were 114 ± 13 mm Hg, 74 ± 11 mm Hg and 87 ± 13 mm Hg for SAP, DAP, and MAP, respectively. Mean heart rate was 52 ± 9 beats $minute^{-1}$. To assess agreement and correlation between IBP and NIBP methods of measurement, both correlation analysis and Bland-Altman analysis of agreement (bias and limits of agreement) were performed.

Pearson's correlation coefficients were 0.858, 0.801 and 0.912 for SAP, DAP and MAP, respectively. Bias (mean differences) were −9 mm Hg, −12 mm Hg and −7 mm Hg for SAP, DAP and MAP, respectively. The lower limits of agreement were −21 mm Hg, −29 mm Hg and −24 mm Hg for SAP, DAP and MAP, respectively. The upper limits of agreement were 3 mm Hg, 4 mm Hg and 9 mm Hg for SAP, DAP and MAP, respectively.

Both correlation and agreement analysis indicated noninvasive oscillometric blood pressure measurement is satisfactory for field blood pressure monitoring, but tend to read falsely low using the described technique.

Cardiopulmonary and anesthetic effects of sevoflurane in the Greater Bush Baby

G Langan, R Harvey,* D O'Rourke, MB Fontenot, J Schumacher
University of Tennessee, Knoxville, Tennessee, USA

This study was conducted to assess the cardiopulmonary and anesthetic effects of sevoflurane anesthesia on Garnett's Greater Bush Baby (*Otolemur garnettii*).

Anesthesia was induced via face mask in 10 animals, six male and four female, ranging in age from 2 to 8 years (mean weight 1.02 kg), with 8% sevoflurane in oxygen at

2 L minute^{-1}. Animals were then intubated and maintained on a nonrebreathing system at 2.5% end tidal sevoflurane at 2 L minute^{-1} oxygen for 30 minutes. Induction (time to recumbency and lack of voluntary movement) and recovery time (time from discontinuation of sevoflurane to extubation) were recorded. Heart rate, respiratory rate (RR), end-tidal CO_2 concentration ($ETCO_2$), temperature (T) and oxygen retardation by pulse oximetry (SpO_2) were monitored every minute for 5 minutes and then every 5 minutes thereafter. Indirect arterial blood pressures were monitored at 4 and 5 minutes and then every 5 minutes until the end of the study. PaO_2 and $PaCO_2$ values were recorded at 10 and 30 minutes. Pre (1 week prior) and post study CBC and serum biochemistry results were also compared. Statistical analysis was determined by ANOVA. Results were considered significant at $p \leq 0.05$.

Induction was rapid (76 ± 9 seconds) (mean ±SEM) and smooth. Heart rate showed a significant increase during the first three minutes, and then significantly decreased over the remaining 30 minutes. There were no significant changes to RR, SpO_2, $ETCO_2$, SAP, MAP and DAP during the 30 minutes of anesthesia. PaO_2 significantly increased from the 10 minute (326 ± 51 mm Hg, 43.4 ± 6.8 kPa) to the 30 minute (431 ±48 mm Hg, 57.5 ± 6.4 kPa) sample and $PaCO_2$ values remained similar between the 10 minute (36 ± 2 mm Hg, 4.8 ± 0.3 kPa) and 30 minute (33 ± 2 mm Hg, 4.4 ± 0.3 kPa) samples. CBC and serum biochemistry results were within normal limits for both samplings, however, a significant decrease was noted in the WBC count, Ca, and TP compared to prestudy results. Recovery was smooth and rapid with extubation occurring at 24 ± 6 seconds after discontinuation of sevoflurane.

At the concentration used in this study sevoflurane appears to be a safe and effective agent for induction and maintenance of anesthesia in *O. garnettii*.

Midazolam/butorphanol/ketamine and the clinically effective dose of isoflurane anesthesia of ostriches (*Struthio camelus*)

JE Bailey,*[1] D Heard,[1] J Schumacher,[2] A Bennett,[1] LS Pablo*[1]

[1]*University of Florida, Gainesville, Florida, USA;* [2]*University of Tennessee, Knoxville, Tennessee, USA*

Ostrich production facilities expanded exponentially in the United States, leading to crowded conditions and new disease states that required close examination and, occasionally, surgical intervention. Manual restraint was usually inadequate and often dangerous to both the ostrich and the handler, and necessitated chemical immobilization. Few repeatable anesthetic techniques have been established for ostriches. This report describes a predictable general anesthetic technique for ostriches.

Seven adult, domesticated ostriches (three male; four female), estimated to weigh 99.2 ± 6.2 kg (mean ±SEM) were hand injected with 0.2 mg kg^{-1} midazolam and 0.4 mg kg^{-1} butorphanol IM in the mid-dorsum. Sedative effects were evident and anesthesia was induced 34.13 ± 1.88 minutes after sedation with ketamine (8.69 ± 0.51 mg kg^{-1} IV in the right jugular vein), followed by intubation and isoflurane anesthesia under controlled ventilation ($PaCO_2$ 35–45 mm Hg, 4.7–6 kPa) for surgery (proventriculotomy, $n = 6$; neck laceration, $n = 1$). The laceration subject required a second anesthesia one month later. Temperature, ECG, pulse oximetry, blood gases, exhaled gases and arterial blood pressures were monitored and supported. To assess inhalant anesthetic requirement a simple step-down, step-up method (10–20% change) was applied, maintaining a given end-tidal isoflurane (ET_{ISO}) concentration for a minimum of 15 minutes during surgical stimulation and observing gross purposeful head movement. Movement was noted at ET_{ISO} 1.69 ± 0.11% at the first step-down approach ($n = 8$), 1.66 ± 0.09% ($n = 5$) at the second and 1.78 ± 0.06 ($n = 4$) at the third. Body temperature at instrumentation was 37.2 ± 0.3 °C and dropped to 35.8 ± 0.5 °C by the end of the procedure. Time from induction to start of the step-down analysis was 80.9 ± 20.0 minutes with a total anesthesia time of 268.3 ± 37.4 minutes. In recovery ET_{ISO} for head movement was 0.48 ± 0.06%. This movement was followed immediately by 5 mg butorphanol IV, and provided 14.4 ± 2.3 minutes before the next head movement. The second movement was followed immediately by naloxone (0.01 mg kg^{-1} IV) and minimal delirium in recovery.

A relatively controlled, repeatable method for anesthesia of domesticated ostriches was established.

ANESTHESIA EDUCATION

Use of the human patient simulator to teach veterinary medicine students

JH Modell, SL Cantwell, JF Hardcastel, SA Robertson,* L Pablo*

University of Florida, Gainesville, Florida, USA

Simulators developed at Stanford University and at the University of Florida permit students and physicians to administer anesthesia in real time. The patient has breath sounds, a heartbeat, pulses, neuromuscular transmission and produces urine. The patient can be monitored with an electrocardiogram; arterial, venous and pulmonary pressures; pulse oximetry; temperature; respiratory gases and cardiac output. The instructor can instantly program the patient, anesthesia machine and monitors to react to complications such as, but not limited to, equipment failure, laryngospasm, endobronchial intubation, pulmonary edema, atelectasis, tension pneumothorax, bronchospasm, hemorrhage, shock, heart failure, malignant hyperthermia, excessive anesthetic depth, anaphylaxis, ventricular tachycardia and cardiac arrest. The student analyzes data displayed on real time monitors and examines the patient, after which he/she initiates therapy and the patient responds.

Students of veterinary medicine at our institution receive a very limited time learning anesthesia (a lecture series, a two-week core clinical rotation and, for approximately one-half of the students, another two-week elective). Yet, when these students graduate, a substantial number of them will anesthetize their own patients in the clinic. It is doubtful in a two to four week rotation, that they will encounter critical events that lead to significant complications or even mortality. Therefore, we have tailored an experience with the simulator for our veterinary medicine students. Our students work in small groups of 4–6 students at a time taking care of 'Joe the Chimp', but for the appearance of the mannequin, could be 'Fido the Dog'. The experience is challenging and virtually 'real life' so that the students talk about 'their patient' without sacrificing live animals. They display concern, sweat when things go wrong, jump in to help each other, and breathe a sigh of relief when their treatment is appropriate. Between 1 November 1999 and 15 June 2000, 48 students have taken the course. Each student evaluates the course in a narrative written response. They are enthusiastic, report this is an excellent way to apply book knowledge to 'real life' without sacrificing animals and want more such classes. We conclude that this is a valuable teaching tool and has considerable promise for the future.