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Development of anesthetic protocols to facilitate cardiovascular studies in domestic swine

Caulkett N1, Brookfield C1, Boysen S1, Risling T1, Warren A1, Wourms V2

1University of Calgary, Calgary, Alberta, Canada, 2University of Manitoba, Winnipeg, Manitoba, Canada

**Introduction:** The goals of this study were to develop an anesthetic protocol that would enable spontaneous ventilation, provide an adequate plane of anesthesia, and have minimal effects on blood pressure.

**Methods:** Four treatments were developed using combinations of the following drugs administered IV: Midazolam 0.2 mg kg-1 hr-1 (M), lidocaine 0.03 mg kg-1 min-1 (L), ketamine 0.02-0.03 mg kg-1 min-1 (K), propofol 0.15-0.2 mg kg-1 min-1 (P), hydromorphone 0.025-0.05 mg kg-1 hr-1 (H) and alfaxalone 0.05-0.1 mg kg-1 min-1 (A). Groups were designated PMLH, PMKH, AMKH (n=8 pigs/group), and AMLH (n=7 pigs). Castrated male pigs (average weight of 31.3 kg) were premedicated with an estimated dose of 0.2 mg kg-1 of midazolam and 0.1 mg kg-1 of hydromorphone, induced to anesthesia with 4-6 mg kg-1 of propofol and maintained on isoflurane. They were instrumented with a pulmonary arterial catheter, bispectral index electrodes, ECG and a carotid arterial catheter. Following instrumentation, animals were maintained on 2% ET isoflurane and baseline measurements were performed for 30 minutes, after which, swine were transitioned onto the treatment protocols for 1 hour. Treatments were compared to each other and to isoflurane baseline using area under the curve and ANOVA (*P*<0.05).

**Results:** All groups demonstrated a significant increase in systolic, diastolic and mean arterial pressure compared to isoflurane. PaCO2 and cardiac output increased significantly in AMKH compared to isoflurane. Mean, systolic and diastolic blood pressure was significantly greater in alphaxalone vs propofol-based treatments. Comparison of AMKH vs. AMLH demonstrated a significantly lower PaCO2 in the AMLH treatment.

**Conclusion:** AMLH induced the least degree of respiratory depression while maintaining the highest direct blood pressure.

Comparison of the effects of xylazine bolus versus medetomidine constant rate infusion on the stress response, urine production, and recovery characteristics in horses anesthetized with isoflurane

Creighton C1, Lemke K2, Lamont L1, Horney B1, Doyle A2

1The University of Adelaide, Roseworthy, South Australia, Australia, 2University of Prince Edward Island, Charlottetown, PE, Canada

**Introduction:** The effects of xylazine bolus versus medetomidine constant rate infusion (MCRI) on cortisol and glucose concentrations, urine production, and recovery characteristics in dorsally recumbent spontaneously breathing isoflurane - anesthetized horses were studied.

**Methods:** Ten horses were used in a randomized crossover design. Horses were premedicated with xylazine or medetomidine. Anesthesia was induced with diazepam and ketamine and maintained with isoflurane for 150 minutes. In the xylazine treatment, end-tidal isoflurane (ETISO) was maintained at 1.7% and xylazine (0.2 mg kg-1) was administered at the end of anesthesia. In the MCRI treatment, ETISO was maintained at 1.4% and medetomidine (0.005 mg kg-1 hr-1) was infused throughout anesthesia. Serum cortisol and glucose were measured before, during, and after anesthesia. Urine specific gravity and volume were measured during anesthesia. Unassisted recoveries were recorded for evaluation by blinded observers. Baseline cortisol and glucose values, recovery times, mean attempt interval (MAI), and visual analog score (VAS) were analyzed using paired t-tests. Serum cortisol and glucose, and urine volume and specific gravity were analyzed using ANOVA for repeated measures and multiple comparison tests (p<0.05).

**Results:** Cortisol was lower and glucose was higher with MCRI compared to xylazine treatment. Time to sternal recumbency was longer with MCRI treatment. No difference was seen for times to extubation, first movement, or standing. Objective (MAI) and subjective (VAS) recovery scores were better with MCRI compared to xylazine treatment.

**Conclusion:** In isoflurane-anesthetized horses, premedication and administration of medetomidine CRI resulted in decreased cortisol levels, increased glucose levels, and superior recovery characteristics compared to conventional xylazine therapy.

Cardiorespiratory effects of butorphanol in sevoflurane-anesthetized guinea fowl (Numida meleagris)

Escobar A1, Valadão C2, Brosnan R3, Flores F2, Lopes M2

1Universidade Estadual do Centro-Oeste, Guarapuava, Paraná, 2Universidade Estadual Paulista, Jaboticabal, Sao Paulo, Brazil, 3University of California, Davis, California, USA

**Introduction:** Butorphanol (4 mg kg-1 IV) decreases sevoflurane MAC (MACSEV) by 20% in guinea fowl (*Numidameleagris*). The aim of this study was to evaluate the cardiorespiratory effects of butorphanol in sevoflurane anesthetized guinea fowls at MAC.

**Methods:** Eight adult guinea fowls were anesthetized with sevoflurane and allowed to ventilate spontaneously. After endotracheal intubation, end-tidal sevoflurane was adjusted to 1.0 individual MACSEV, which was previously determined in triplicate using a standard bracketing technique. The brachial artery was catheterized for direct pressure measurement and blood sampling. Heart rate and rhythm were monitored by electrocardiography and respiratory rate was recorded. Baseline data were initially evaluated 30 minutes after induction (T-30). End-tidal sevoflurane was adjusted to 0.8 individual MAC and after 15 minutes physiologic responses were measured (T0). Subsequently, 4.0 mg kg-1 of butorphanol was intravenously administered during 10 seconds and physiologic responses were evaluated after 1, 5, 10, 15, 20, 30 and 45 minutes of administration. Repeated measures ANOVA or Friedman test were applied as appropriate.

**Results:** Butorphanol administration was associated with arrhythmias, including atrioventricular block, sinus arrest, atrial and ventricular premature contractions and tachycardia. Heart rate and arterial blood pressures significantly decreased 1 minute after butorphanol administration compared to T0. Two animals had severe hypotension, apnea and ventricular fibrillation 5 minutes after administration, and one of them died.

**Conclusion:** The butorphanol dose that produces clinically relevant MACSEV reduction in guinea fowl caused severe cardiorespiratory side effects in some animals and was not considered safe under the conditions used in this study.

Assessment of unassisted recovery from repetitive general inhalant anesthesia in horses following post-anesthetic administration of xylazine, or acepromazine, or a combination of xylazine and ketamine

Valverde A, Black B, Cribb N

Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada

**Introduction:** Sedatives including acepromazine (A), xylazine (X) and xylazine/ketamine (XK) have been used but not compared in the post-anesthetic period to improve the quality of recovery in horses.

**Methods:** Fifteen horses (2-13 y.o.; 12-females, 2-geldings, 1-colt; 12-Standardbreds, 3-Thoroughbreds) undergoing three anesthetic episodes for magnetic resonance within 1-week (days 1,4,6) with xylazine/guaifenesin/ketamine induction and isoflurane maintenance (1.5% end-tidal) under IPPV were administered IV A-0.02 mgkg-1, or X-0.3 mgkg-1, or XK- 0.15/0.3 mgkg-1 in random order immediately after each anesthetic event during recovery. Quality of recovery was compared using a numerical and descriptive score and analyzed with a general mixed linear model (P<0.05).

**Results:** Horses administered X had better recovery scores (12.2/1.7- numerical/descriptive) than XK (15/2.2), due to better scores during the phases of move to sternal, strength and less number of attempts to standing. Horses administered A (12.8/1.8) had similar recovery scores to X and XK horses. Time to sternal recumbency (X-31, A-26, XK-25 min) and to extubation (X-39, A-32, XK-33 min) were statistically longer for X. Time to standing was similar (X-43, A-40, XK-38 min). Horses had better recoveries during the third anesthetic (1st-15.7/2.1; 2nd-13.3/2.1; 3rd-11.7/1.7) regardless of the sedative, due to better scores during the phases of strength and number of attempts to standing.

**Conclusion:** All recoveries were of good quality. Xylazine resulted in more controlled recoveries related to longer times to sternal recumbency and better. This study also indicates that regardless of the sedative, horses improve the quality of recovery during consecutive anesthetics, associated with longer time to sternal and to standing.

Pilot study for evaluating quality of anesthesia and recovery in horses anesthetized with total intravenous anesthesia using a drug combination of medetomidine, lidocaine, butorphanol and propofol (MLBP-TIVA)

Tamura J, Saito M, Yarita Y, Isizuka T, Itami T, Miyoshi K, Yamashita K

Rakuno Gakuen University, Ebetsu, Hokkaido, Japan

**Introduction:** Propofol is useful for total intravenous anesthesia (TIVA) but provides poor analgesic property and unpredictable quality of induction in horses. These disadvantages might be improved by multimodal analgesia. The purpose of this study was to evaluate the quality of anesthesia and recovery in horses anesthetized with TIVA using medetomidine, lidocaine, butorphanol and propofol (MLBP-TIVA).

**Methods:** Twenty-one healthy adult horses were anesthetized with MLBP-TIVA for castration (n=11) or surgical relocation of right carotid artery to subcutaneous position (CA-loop: n=10). Anesthesia was induced with lidocaine (1mg kg-1:IV) and propofol (3mg kg-1:IV) following premedications with medetomidine (0.005mg kg-1:IV) and butorphanol (0.02mg kg-1:IV), and then maintained by propofol infusion combined with constant rate infusions of medetomidine (0.0035mg kg-1 h-1), lidocaine (3mg kg-1 h-1) and butorphanol (0.024mg kg-1 h-1). Horses breathed room air during anesthesia for castration. During anesthesia for CA-loop horses breathed 100% oxygen and were administered lactated Ringer’s solution (10ml kg-1 hr-1:IV). Quality of anesthetic induction, maintenance and recovery were categorized by subjective scoring systems [Umar MA, *et al.* 2006. *J Am Vet Med Assoc.* 228:1221-1227.].

**Results:** MLBP-TIVA provided satisfactory surgical anesthesia. Induction was judged as fair to good, although a transient paddling after recumbency was observed in 13/21 horses. Mean ± SD propofol infusion rate were 0.11 ± 0.03 mg kg-1 min-1 for castration and 0.11 ± 0.02 mg kg-1 min-1 for CA-loop. Quality of maintenance and recovery were considered good to excellent and satisfactory to excellent, respectively. Times to standing after the cessation of anesthesia were 34 ± 7 min for castration and 52 ± 12 min for CA-loop.

**Conclusion:** MLBP-TIVA provides clinically acceptable anesthesia and recovery, although transient paddling following induction can occur.

Effects of hypercapnic hyperpnea on recovery from isoflurane or sevoflurane anesthesia in horses.

Brosnan R, Steffey E, Escobar A

University of California, Davis, Davis, CA, USA

**Introduction:** We tested the hypothesis that hypercapneic hyperpnea produced using endotracheal insufflation with 5-10% CO2 in oxygen could be used to shorten anesthetic recovery time in horses, and that recovery from sevoflurane would be faster than from isoflurane.

**Methods:** Eight healthy adult horses were studied using a randomized crossover design. After 2 hours’ administration of constant 1.2 times MAC isoflurane or sevoflurane, horses were disconnected from the anesthetic circuit and administered 0, 5, or 10% CO2 in balance O2 via endotracheal tube insufflation at 15 L/min. End-tidal gas samples were collected to measure anesthetic washout kinetics, and arterial and venous blood samples were collected to measure respiratory gas partial pressures. Horses recovered in padded stalls without assistance, and each recovery was videotaped and evaluated, using a VAS and objective measures, by reviewers who were blinded to the anesthetic agent and insufflation treatment used.

**Results:** Compared to isoflurane, sevoflurane caused greater hypoventilation and was associated with longer recovery times. CO2 insufflation significantly decreased anesthetic recovery time compared to insufflation with O2 alone without significantly increasing CO2 tensions in blood. Pharmacokinetic parameters during recovery from isoflurane with CO2 insufflation were statistically indistinguishable from sevoflurane recovery without CO2. Neither anesthetic agent nor insufflation treatment affected recovery quality from anesthesia.

**Conclusion:** Hypercapnic hyperpnea decreases recovery time from anesthesia in horses without influencing anesthetic recovery quality. Although the lower blood gas solubility of sevoflurane should favor a shorter recovery time compared to isoflurane, this advantage is negated by the greater respiratory depression from sevoflurane in horses.

Analgesic effects of sublingual buprenorphine in colts undergoing castration.

Messenger K1, Davis J1, Posner L1, Chinnadurai S1, Kruger K1, Thelan M2, Fogle C1

1North Carolina State University College of Veterinary Medicine, Raleigh, NC, USA,  2SAS Institute, Cary, NC, USA

**Introduction:** The objective of this study was to compare the analgesic efficacy of sublingual administration of buprenorphine with placebo in colts undergoing routine castration.

**Methods:** In a blinded, randomized clinical trial using 14 client-owned colts, horses received either treatment with buprenorphine (0.006 mgkg-1) sublingual or placebo (saline) immediately prior to anesthesia and surgery. All horses received flunixin (1.1 mgkg-1) IV prior to surgery. Horses were anesthetized and surgery performed in an identical and routine manner. After surgery, horses were monitored for pain by 2 blinded observers using a dynamic interactive visual analog scale (DIVAS) and behavior scoring system. Time points assessed were -1 (baseline score, prior to surgery), 0, 1, 2, 3, 4, 6, 8, 10, and 16 hours post-operatively. Rescue analgesia (butorphanol 0.1 mgkg-1) was administered if DIVAS >50 and/or behavior score >18. A Wilcoxon rank-sum test was used to compare DIVAS and behavior scores on pooled observer scores.

**Results:** In the treatment group, behavior scores were significantly lower at 2, 6, and 10 hours post-operatively, and DIVAS score was lower at 2 hours. DIVAS and behavior scores were both significantly higher in the treatment group immediately after surgery (time 0); and DIVAS scores were also higher at 16 hours. Two of seven horses in the placebo group required rescue analgesia, while no horses in the treatment group required rescue analgesia.

**Conclusion:** In this study, flunixin alone did not provide sufficient analgesia in 2 horses, whereas the combination of flunixin plus sublingual buprenorphine was sufficient in all horses.

Determination of alfaxalone concentrations required to sedate and anesthetize Goldfish, Carassius auratus

Bauquier S1, Greenwood J2, Whittem T3

1University of Melbourne, Melbourne, Victoria, Australia, 2Bittern, Victoria, Australia, 3University of Melbourne, Werribee, Victoria, Australia

**Introduction:** Anecdotal publications describe induction of anesthesia in fish with alfaxalone. This study‘s objective was to determine the water concentrations of alfaxalone required to sedate and anesthetize Goldfish.

**Methods:** The study was conducted as an unmasked, parallel design, dose-escalation trial with five groups of six healthy Goldfish, *Carassiusauratus.* Fish with a mean length (±SD) of 8.5 (±2.5) cm, were immersed in individual water tanks with controlled temperature (23-25oC), pH (6.8-7.2) and osmolality (38-45 mOsm/L), at concentrations of 0.15, 0.5, 2.0, 5.0 and 7.5 mg alphaxalone complexed with hydroxypropyl-beta cyclodextrin (Alfaxan, Jurox, Rutherford, Australia) per liter. Monitoring of fish included recording activity, maintenance of equilibrium, response to noxious stimuli and respiratory effort. Determination of depth of anesthesia was based on a published scale. Fish were recovered in alfaxalone free water after surgical anesthesia was achieved or after four hours.

**Results:** An alfaxalone concentration of 0.15 mgL-1 was insufficient to induce sedation or anesthesia. Mean sedation induction time ±SD (range) after immersion at concentration of 0.5 and 2.0 mgL-1 were 37±7 min (34-50) and 7±1 min (5-8) respectively. Anesthesia was not achieved at those concentrations. After immersion in alfaxalone at 5.0 and 7.5 mgL-1 mean sedation induction times were 4±2 min (2-6) and 2±1 min (1-2) respectively, mean anesthesia induction times were 28±8 min (16-35) and 14±2 min (12-18) respectively and mean full recovery times were 32±18 min (20-67) and 36±13 min (23-53) respectively. No adverse events were seen.

**Conclusion:** Accordingly, minimum alfaxalone concentrations of 0.5 mgL-1 and 5 mgL-1 induced sedation and anesthesia respectively.

The effects of a reduced fractional inspired oxygen concentration on ventilation and A-a gradient in Isoflurane anesthetized horses

Crumley M, McMurphy R, Hodgson D, Kreider S

Kansas State University, Manhattan, KS, USA

**Introduction:** Hypoventilation (PaCO2> 45 mmHg) and large P(A-a)O2 gradients due to V/Q mismatch and shunt, are common during isoflurane anesthesia in horses. A fraction of inspired oxygen< 50% has been shown to improve ventilation and decrease intra-operative atelectasis in humans and some animals. The study compared the effects of two different fractions of inspired oxygen, 50% versus >95%, on ventilation, respiratory pattern, and P(A-a)O2 gradient in isoflurane anesthetized horses.

**Methods:** Eight mature horses were sedated with IV xylazine (1.0 mgkg-1) and anesthetized with diazepam (0.05 mgkg-1) and ketamine (2.2 mgkg-1) twice. Anesthesia was maintained with isoflurane (ET 1.5 vol%) in either 50 or >95% oxygen for 90 minutes. Both treatments were randomly assigned to each horse with a one week interval in between treatments. Horses were positioned in dorsal recumbency, connected to a preloaded circle breathing system and allowed to spontaneously ventilate. Measurements included inspiratory and expiratory peak flow and time, tidal volume, respiratory frequency, ETCO2, CO2, O2, PaO2, PaCO2, pH, SaO2, heart rate, and arterial blood pressure. Calculated values included PAO2, P(A-a)O2, and physiologic dead space. Statistical analysis was performed using repeated measures crossover design ANOVA.

**Results:** FiO2 of 50% resulted in a lower PaO2, SaO2, PAO2, and P(A-a)O2. No significant change in PaCO2, ventilatory pattern, or any remaining measured variables was observed (p<0.05).

**Conclusion:** A FiO2 of 50% when compare to >95% did not improve ventilation, oxygenation, or alter the respiratory pattern in isoflurane anesthetized horses. The decreased P(A-a)O2 may be indicative of a decrease in absorption atelectasis.

Evaluation of serial venous and arterial lactate values in healthy sheep undergoing ovariectomy during general anesthesia

Mathews L, Barletta M, Graham L, Quandt J

University of Minnesota, Saint Paul, Minnesota, USA

**Introduction:** Blood lactate measurement has been used to assess tissue perfusion, oxygenation, and prognosis of veterinary patients. It was hypothesized that venous lactate would be higher than arterial lactate.

**Methods:** Twelve healthy ewes (4-7 yrs; 62-77 kg) had venous jugular samples drawn preoperatively (PreOv) for measurement of lactate, packed cell volume and total protein. Ewes were administered a standard anesthesia protocol. Forty minutes into the procedure, jugular venous (IntraOv) and peripheral arterial (IntraOa) blood samples were obtained. Venous and arterial samples were collected again in recovery (PostOv and PostOa). Levels were compared among PreOv, IntraOv and IntraOa, PostOv and PostOa with paired t-test and repeated measure analyses of variance (ANOVA) with PreOv as a covariate (p-value ≤ 0.05).

**Results:** Mean lactate levels PreOv were 5.87 mmol L-1 +/- 2.33, IntraOv 2.59 mmol L-1 +/- 1.21, IntraOa 1.89 mmol L-1 +/- 1.00, PostOv 3.03 mmol L-1 +/- 1.29, and PostOa 2.59 mmol L-1 +/- 1.31. Mean non-fasting lactate was 4.49 mmol L-1 +/- 1.14. IntraO lactate levels decreased from baseline. There were significant differences between arterial to venous levels IntraO and PostO (IntraO p=0.0003, PostO p=0.0002). PostO lactate levels increased, though not statistically significant (PostOa p=0.08, PostOv p=0.27). Non-fasting and PreOv fasted lactate levels were found not significantly different (p=0.08).

**Conclusion:** Healthy anesthetized sheep had lower lactate values compared to sheep in the PreO, PostO and non-fasting periods. IntraOv samples resulted in higher overall mean values compared to arterial. Therefore, anesthetic status and sample source should be considered when interpreting lactate values in healthy sheep.

Pharmacodynamics of alfaxalone after single-dose intramuscular administration in Red Eared Sliders (Trachemys scripta elegans): a comparison of two different doses at two different ambient temperatures

Shepard M, Braun C, Divers S, Hofmeister E

University of Georgia College of Veterinary Medicine, Athens, Georgia, USA

**Introduction:** Published anesthetic effects of alfaxalone in chelonians are currently limited to anecdotal and case reports. This blinded crossover experimental study compares the pharmacodynamics of two different intramuscular alphaxalone doses administered to red eared sliders in two different ambient temperatures.

**Methods:** Following 2-week acclimation at 72-77 degrees F, nine adult female sliders were randomly assigned to two groups: IM10 (10 mg kg-1) and IM20 (20 mg kg-1). Each turtle received each dose, with a minimum 7-day washout period. A blinded observer evaluated heart rate, palpebral and corneal reflex, muscle relaxation and ease of handling (described via 3-point scale), and pain sensitivity (toe-pinch stimulus) pre-injection and 5, 12, 20, 30, 45, 60 and 120 minutes post-injection. Turtles then acclimated to 65-68 degrees F for 60 days, and the experiment repeated. Repeated-measures ANOVA followed by a Tukey's post hoc test was used to compare AUC for each parameter among treatment groups.

**Results:** IM20 turtles were more relaxed than IM10 turtles in the warm condition. Cold-temperature turtles had lower heart rates regardless of dose, more relaxation with the IM20 dose, and were more likely to lose palpebral reflex with the IM20 dose. Cold IM20 turtles had easier handling than IM20 turtles in the warm condition. Cold IM20 turtles were less pain-responsive than cold IM10 turtles.

**Conclusion:** The behavioral responses we observed in this study suggest that IM alfaxalone is a viable injectable agent for turtles undergoing minimally-invasive procedures (i.e. IV catheterization, minor laceration repair).

Determination of cardiac output by ultrasound velocity dilution in normovolemia and hypovolemia in juvenile horses

Queiroz P1, Bornkamp J2, Bandt C3, Nickell J3, Vigani A2, Romain P1, Ricco C4, Shih A2

1Department of Small Animal Clinical Sciences, School of Veterinary Medicine, Louisiana State University, Baton Rouge, LA, USA, 2Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL, USA, 3Department of Small Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, Fl, USA, 4Department of Small Animal Clinical Science, College Veterinary Medicine. Virginia Maryland Regional College of Veterinary Medicine Virginia Tech, Blacksburg, VA, USA

**Introduction:** Lithium dilution (LiDCO) is a validated method for cardiac output (CO). Potential drawbacks with LiDCO include blood loss and accumulation of the indicator. Saline ultrasound velocity dilution (UD) is a minimally invasive CO method that does not involve blood loss and uses a physiologic signal (saline). Our hypothesis was that UD would have good agreement compared to LiDCO.

**Methods:** Eleven anesthetized and ventilated juvenile horses (1-4 mo, 70-130 kg) were anesthetized and instrumented to measure blood pressure, arterial blood gases and CO by LiDCO and UD (duplicate measurements). To measure CO using UD, an arterio-venous extracorporeal loop was attached between metatarsal arterial and central venous catheter, a ultrasound flow sensor was placed close to venous catheter and the arterial catheter respectively. UD is calculated from a decrease in the ultrasound velocity curve caused by a saline bolus administration (0.5 mL kg-1). LidCO lithium dose was 0.003 mmol kg-1. Animals were studied at normovolemia (Base), after blood withdrawal to mean arterial pressure (MAP) of 40mmHg (Hemo) and after retransfusion (Resu). Agreement was determined using Bland & Altman analysis and concordance correlation coefficients.

**Results:** Lithium determinations of CO averaged between 2.0 ± 1.2 and 7.5 ± 2.7 L minute-1. Concordance correlation was 0.89 (P < 0.0001). The bias was -0.2 ± 1.2 (limits of agreement LOA: -2.4 to 2.0) and relative bias was -10 ± 18 % (LOA: -45 to 25%). There was no significant effect of state of CO on bias or relative bias.

**Conclusion:** When compared to lithium dilution, the UD technique is a viable method in juvenile horses.

A novel way to detect cardiac output and cardiac shunting using saline velocity dilution

Shih A1, Maisenbacher III H2, Vigani A1, Estrada A2, Pogue B2, Berry C2, Thuramalla N3, Schrank H1, Bandt C2

1Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL, USA, 2Department of Small Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL, USA, 3Transonic Systems Inc. Ithaca, NY, USA

**Introduction:** Saline ultrasound velocity dilution (UD) is a minimally invasive method used to determine CO. This technique may also be useful in detecting right to left (R-L) intra-cardiac shunting. Our hypothesis was that UD is a good method to determine CO and shunting in a porcine atrial septal defect (ASD) model.

**Methods:** Nine piglets (1 mo of age 9.0-11.5 kg body weight) were anesthetized with xylazine, ketamine and isoflurane. Animals were instrumented to measure direct blood pressure, CO by UD, pulmonary artery flow (Qp) and aortic blood flow (Qs). Qp and Qs were measured by surgically implanted ultrasound flow probes. Shunt fraction was calculated as Qp/Qs. ASD was created using a fluoroscopy guided septostomy balloon catheter. ASD defect size was 16 mm in all animals and patency of ASD shunt was confirmed by angiogram. Animals were studied at baseline (base) and after ASD with partial pulmonary artery (PA) occlusion (ASD R-L). Data were analyzed using repeated measure ANOVA on ranks and CO agreement to Qp and Qs by Bland Altman plot analysis.

**Results:** UD produced good agreement to Qp with a bias of 0.14 ± 0.5 L min-1 limits of agreement (LOA) -0.8 and 1.4. The relative bias was 11.8 ± 0.3% LOA-0.4 to 0.8 with no difference when base was compared to ASD-RL stage. UD success rate in detecting R-L shunt was 83% when Qp/Qs <0.80 and 100% when Qp/Qs <0.5.

**Conclusion:** UD is a useful method to measure CO and identifying R-L shunt in small animals. Further clinical studies are needed to confirm this finding.

Effect of positioning during anesthesia on cardiovascular function in mechanically ventilated horses anesthetized with total intravenous anesthesia using a drug combination of medetomidine, lidocaine, butorphanol and propofol (MLBP-TIVA)

Itami T, Ishizuka T, Sudo K, Tamura J, Miyoshi K, Yamashita K

Rakuno Gakuen University, Ebetsu, Hokkaido, Japan

**Introduction:** Total intravenous anesthesia using medetomidine, lidocaine, butorphanol and propofol (MLBP-TIVA) provides clinically acceptable anesthesia/recovery in horses. The purpose of this study was to determine effects of positioning on cardiovascular function in mechanically ventilated horses during MLBP-TIVA.

**Methods:** Five healthy adult horses were anesthetized with MLBP-TIVA for 2 hours on 2 occasions at 4 week intervals in lateral (LR) or dorsal (DR) recumbency. Anesthesia was induced with lidocaine (1 mg kg-1:IV) and propofol (3 mg kg-1:IV) following premedication with medetomidine (0.005 mg kg-1:IV) and butorphanol (0.02 mg kg-1:IV), and then maintained by constant rate infusions of medetomidine (0.0035 mg kg-1 h-1), lidocaine (3 mg kg-1 h-1), butorphanol (0.024 mg kg-1 h-1) and propofol (0.1 mg kg-1 min-1). All horses were mechanically ventilated to maintain arterial CO2 between 40-50 mmHg. Cardiopulmonary parameters were measured every 20 min. Data were compared between groups using repeated-measures ANOVA. The level of significance was set at P<0.05.

**Results:** It took 55 ± 17 min (mean ± SD) in LR group and 62 ± 31 min in DR group for instrumentation. Mean pulmonary arterial pressure and mean atrial blood pressure were significantly decreased in DR compared to LR group (18-20 mmHg vs 27-31 mmHg, P=0.001 and 8-9 mmHg vs 15-17 mmHg, P=0.003, respectively). There were no significant differences in heart rate, mean arterial blood pressure and cardiac output measured by thermodilution technique between DR and LR groups (33-35 beats min-1vs 29-31 beats min-1, P=0.146, 115-123 mmHg vs 98-123 mmHg, P=0.590 and 17-21 L min-1vs 17-20 L min-1, P=0.862, respectively). Arterial O2 pressure was significantly lower in DR than in LR group (171-301 mmHg vs 385-416 mmHg, P=0.043).

**Conclusion:** Cardiovascular function using MLBP-TIVA was clinically acceptable in horses regardless of body position (DR and LR). DR was associated with significant reductions in preload and arterial O2 pressure compared to LR.

Evaluation of cardiopulmonary effects of total intravenous anesthesia using a drug combination of medetomidine, lidocaine, butorphanol and propofol (MLBP-TIVA) with or without controlled ventilation in horses

Ishizuka T, Nagaro T, Tamura J, Itami T, Miyosi K, Yamashita K

Rakuno Gakuen University, Ebetsu, Hokkaido, Japan

**Introduction:** Total intravenous anesthesia using medetomidine, lidocaine, butorphanol and propofol (MLBP-TIVA) provides clinically acceptable anesthesia/recovery in horses. The purpose of this study was to evaluate cardiopulmonary effects of MLBP-TIVA with or without controlled ventilation in horses.

**Methods:** Five healthy adult horses were anesthetized with MLBP-TIVA for 2 hours on 2 occasions at 4 week intervals using controlled mechanical ventilation (CMV) and during spontaneous breathing (SB). Anesthesia was induced with lidocaine (1 mg kg-1:IV) and propofol (3 mg kg-1:IV) following premedication with medetomidine (0.005 mg kg-1:IV) and butorphanol (0.02 mg kg-1:IV), and then maintained by propofol infusion combined with constant rate infusions of medetomidine (0.0035 mg kg-1 h-1), lidocaine (3 mg kg-1 h-1) and butorphanol (0.024 mg kg-1 h-1). All horses breathed 100% oxygen and received IV infusion of lactated Ringer’s solution (10 ml kg-1 hr-1) during anesthesia. CMV horses were mechanically ventilated to maintain arterial CO2 pressure (PaCO2) between 40-50 mmHg. Cardiopulmonary parameters were measured every 20 min. Data were compared between groups using repeated-measures ANOVA. The level of significance was set at P<0.05.

**Results:** Cardiovascular parameters were maintained within acceptable ranges in SB (heart rate: 37-39 beats min-1, mean arterial blood pressure: 109-115 mmHg, mean pulmonary arterial pressure: 28-29 mmHg, mean right atrial pressure: 19-21 mmHg, cardiac output measured by the thermodilution technique: 27-30 L min-1). However, severe hypercapnia with insufficient oxygenation was observed PaCO2 (83-103 mmHg), arterial O2 pressure (PaO2) (155-171 mmHg). In CMV horses, significant decreases in heart rate (29-31 beats min-1, P=0.020), cardiac output (17-21 L min-1, P=0.005) and PaCO2 (42-50 mmHg, P=0.001) and a significant increase in PaO2 (395-419 mmHg, P=0.005) were observed compared to SB horses.

**Conclusion:** Cardiovascular functions were maintained within acceptable range during MLBP-TIVA in horses. Controlled ventilation is useful for improving hypercapnia and oxygenation during MLBP-TIVA.

Anesthetic induction with guaifenesin and propofol in adult horses

Brosnan R1, Steffey E1, Escobar A2, Palazoglu M2, Fiehn O2

1Surgical and Radiological Sciences, School of Veterinary Medicine, University of California, Davis, CA, USA,2Metabolomics Core Facility, Genome Center and Bioinformatics Program, University of California, Davis, CA, USA

**Introduction:** We tested the hypotheses that guaifenesin can prevent adverse anesthetic induction events (excitement, myotonus, and paddling) caused by propofol, and that a guaifenesin-propofol induction combination exhibits brief cardiovascular effects commensurate with rapid plasma drug washout.

**Methods:** To induce anesthesia in 8 healthy adult horses, guaifenesin was administered intravenously for 3 minutes followed by a 2 mg kg-1 propofol bolus. Additional propofol was administered if purposeful movement was present. Anesthesia was maintained for 2 hours using either isoflurane or sevoflurane at 1.2 times minimum alveolar concentration with controlled normocapnic ventilation. Normotension was maintained using a dobutamine infusion. Plasma drug concentrations were measured every 30 minutes. Data were analyzed using ANOVAs.

**Results:** Mean (±SD) guaifenesin and propofol doses producing anesthesia in 50% of horses were 73 ± 18 and 2.2 ± 0.3 mg kg-1, respectively. No adverse anesthetic induction events were observed. By 70 min, there was no significant temporal change in the dobutamine infusion rate required to maintain normotension for horses anesthetized with either isoflurane or sevoflurane. Plasma guaifenesin concentrations were 122 ± 30, 101 ± 33, 93 ± 28, and 80 ± 24 μM at 30, 60, 90, and 120 min post-induction, respectively. All plasma propofol concentrations were below the limit of quantitation.

**Conclusion:** Guaifenesin can prevent adverse anesthetic induction events caused by propofol. Data suggest that 90 mg kg-1guaifenesin followed by 3 mg kg-1propofol can effectively immobilize >99% of calm, healthy, adult horses. Induction drug washout was rapid, and there was no change in inotrope requirements after 70 min of anesthesia.

Pharmacokinetics and cardiovascular pharmacodynamics of a single intravenous administration of bupivacaine in chickens (Gallus domesticus) anesthetized with isoflurane

da Cunha A1, Messenger K2, Stout R3, Tully T3, Barker S1, Nevarez J1, Pariaut R1, Queiroz-Williams P1, Papich M2

1Louisiana State University, Baton Rouge, Louisiana, USA, 2North Carolina State University, Raleigh, North Carolina, USA, 3Louisiana State University, School of Veterinary Medicine, Baton Rouge, Louisiana, USA

**Introduction:** Pharmacokinetics and cardiovascular effects of bupivacaine were determined in six healthy layer chickens weighing 1340 ± 193.4 grams, anesthetized with isoflurane.

**Methods:** After oro-tracheal intubation, venous and arterial catheterization was performed and ETiso was maintained at 1.5% throughout the procedure. Invasive blood pressure, HR and rhythm were monitored continuously. One milliliter of blood was collected before and at 1, 2, 5, 10, 15, 30, 60, 90, 120, 180 and 240 minutes after 2 mg kg-1 IV bupivacaine was injected. Plasma was separated and immediately frozen at -80oC until assayed for presence of bupivacaine by HPLC.

**Results:** The data best fit a two-compartment model and pharmacokinetics parameters were calculated as: clearance: 0.06 ± 0.01 mL kg-1 min-1; elimination half-life: 17.9 ± 6.9 minutes; volume of distribution at steady state: 1.44 ± 0.43 L kg-1; area under the curve 35.4 ± 7.2 min µg-1 mL-1 and mean residence time 26.7 ± 13.4 min. Additionally, within 50 seconds after the IV bupivacaine injection, an ECG conduction disturbance was observed. This was characterized by a widening of the QRS complexes due to a slow intraventricular conduction of the electrical impulses resulting in a rate dependent widening of the QRS complexes with an atrio-ventricular conduction delay causing occasional type-I second degree AV block. Transient major hypotension (MAP = 78 ± 40 mmHg) was observed. Two minutes after injection, the blood pressure normalized and sinus rhythm returned.

**Conclusion:** In conclusion, our methods were able to determine bupivacaine’s pharmacokinetics in chickens, which is significantly different when compared with other species. Intravenous bupivacaine resulted in significant hemodynamic compromise for 2 minutes after injection.

Effects of ketamine and lidocaine constant rate infusion on the sevoflurane minimum alveolar concentration in alpacas

Queiroz-Williams P1, Doherty T2, da Cunha A1, Leonardi C3

1School of Veterinary Medicine - Louisiana State University, Baton Rouge, LA, USA, 2College of Veterinary Medicine - University of Tennessee, Knoxville, TN, USA,3Biostatistics-Health Sciences Center, School of Public Health – Louisiana State University, New Orleans, LA, USA

**Introduction:** The objectives were to investigate the effects of ketamine and lidocaine (K+L) infusion on the minimum alveolar concentration of sevoflurane (MACsevo) in alpacas. It was hypothesized that K+L would significantly reduce MACsevo.

**Methods:** Eight healthy, male-adult alpacas were used in a non-blinded, crossover design. Anesthesia was induced with sevoflurane by face-mask and alpacas were intubated and maintained with sevo in oxygen. Baseline MAC (MACB) determination began 45 minutes after induction. MAC estimation was performed using a standard bracketing technique and clamping of the claw as the supramaximal stimulus. Treatments (bolus and infusion) were randomly administered: saline (10 mL, infusion at same volume of K+L); K (0.5 mg kg-1, infusion 25 μg kg-1 min-1) + L (2 mg kg-1, infusion 50 μg kg-1 min-1). Washout period was 8 days. Post-treatment MAC (MACT) was determined in duplicate starting 30 minutes after infusion. Blood was collected and analysed for K, L and metabolites GX and MEGX. Data are reported as LSM ± SEM. Observation of the stem leaf diagram and the W statistic of Shapiro-Wilk were used. Homogeneous variance was verified by plotting residuals vs. treatment means. P-value of <0.05 are considered statistically significant.

**Results:** The mean MACB was 1.88 and 1.89 for saline and K+L groups, respectively. K+L decreased (p<0.05) MACsevo by 56.9%. Saline did not significantly change MACT. Time to determine MAC or order of treatment did not significantly affect MACB or MACT. Recovery time was not different between treatments and on average lasted 23 minutes.

**Conclusion:** K+L infusion significantly reduced MACsevo by 57% and did not affect recovery time.

Effect of needle size and length on epidural injection pressure

Son W1, Kim J1, Yoon J1, Lee L2, Lee I1

1Seoul National University, Seoul, Republic of Korea,2Western University of Health Sciences, Pomona, CA, USA

**Introduction:** Injection pressure of varying spinal needles was examined *in vitro* in order to better understand in selecting a needle of appropriate size and length for different clinical presentations

**Methods:** The commonly available spinal needles of two sizes (22 and 25 gauge) for 5 cm group and 8 sizes (18, 19, 20, 21, 22, 24, 25 and 26 gauge) for 9 cm groups were used to measure change in pressure during injection of solution. The spinal needle was connected to a pressure measurement tube and pressure transducer, and following zeroing the line to atmosphere, one ml of distilled water in a 5 mL syringe was injected into each spinal needle by a syringe pump at a rate of 1 mL min-1. The peak pressure during injection from each size and length was compared using one and two-way ANOVA, respectively.

**Results:** The mean (± SD) pressure of each 5 cm spinal needle of 22 and 25 gauge was 6.67 ± 0.04 and 22.37 ± 0.11 mmHg, respectively, and that of each 9 cm spinal needle ranging from 18 to 26 gauge increased as the needle diameter decreases (0.48 ± 0.02, 1.34 ± 0.05, 2.05 ± 0.05, 2.61 ± 0.05, 9.60 ± 0.03, 41.71 ± 0.20, 72.43 ± 0.26, and 116.10 ± 1.50 mmHg, respectively). Significant differences were observed for injection pressure in relevance to needle size and length (*P*< 0.01).

**Conclusion:** Injection pressure of solution was greatly influenced by diameter and length of a spinal needle. Therefore, it is recommended to use relatively a larger and shorter needle to reduce effect on epidural injection pressure.

Cardiovascular effect of active compression decompression device (ACD) during cardiopulmonary resuscitation– a proof of concept for veterinary patients

Shih A1, Udassi S2, Bandt C1, Garcia Pereira F3, Schrank H1, Udassi J2

1Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida Gainesville, FL, USA, 2Division of pediatric critical care medicine, Department of Pediatrics, College of Medicine, University of Florida, Gainesville, FL, USA, 3Michigan State University Veterinary Medical Center, East Lansing, East Lansing, MI, USA

**Introduction:** During cardiopulmonary resuscitation (S-CPR) chest wall should be allowed to fully recoil to maximize venous return. Active compression-decompression (ACD-CPR) causes active lifting of the chest wall creating more negative intra-thoracic pressure (IttP), and better CPR efficacy. Current ACD-CPR devices are too large and cumbersome for cats and dogs; a new ACD design consisted of a modified glove with velcro patch sewn into it and the counter patch adhered to the animal’s chest wall was developed (Adhesive glove device-AGD). We hypothesized that ACD-CPR with AGD would improve CPR hemodynamics

**Methods:** Twenty-four (2 months old~12 kg) piglets were anesthetized and instrumented to measure direct blood pressure, right atrial pressure (RA), intrathoracic pressure (IttP) and carotid blood flow (CBF). A non-coated guide wire was advanced into the right ventricle and electrical current was delivered to induce ventricular fibrillation (VF). Electrical VF was maintained for 4 minutes and animals were randomized to either S-CPR or ACD-CPR for 2 minutes. Data (mean ± SD) were analyzed using one-way ANOVA.

**Results:** RA pressure (mmHg) during decompression (diastolic) phase of CPR was 8.3 ± 3.43 in S-CPR group, compared to ACD-CPR -0.8 ± 8.05 (p=0.006). IttP during decompression was -0.3 ± 4.2 in S-CPR, compared to ACD-CPR -13.4 ± 6.7 (p=0.01). Carotid blood flow (% of baseline ml/min) was 29.1 ± 12.5% in S-CPR group vs. 67.5 ± 33.1% in ACD-CPR group, p=0.04.

**Conclusion:** Active compression-decompression resulted in improved CPR hemodynamic. The clinical use in veterinary medicine might be dictated by our ability to refine this device to different body weight, chest conformation and does not require pre-clipping of hair to work.

Accuracy and precision of a neurostimulating catheter in the epidural space of dogs

Garcia-Pereira F1, Shih A2, Saunders R1, Hauptman J1

1Michigan State University, East Lansing, MI, USA, 2University of Florida, Gainesville, FL, USA

**Introduction:** The use of neurostimulating catheters allow accurate placement of drugs without imaging. Their use to facilitate epidural anesthesia in anesthetized dogs has not been previously studied.

**Methods:** Eight dogs (1 ± 0.17 yrs and 12.9 ± 1.14 kg) were anesthetized with propofol and maintained with isoflurane. Using the lumbosacral approach, an insulated epidural catheter was inserted and connected to a neurostimulator (1 mA, 0.1 ms, 1 Hz). To assess accuracy of catheter placement in specific spinal cord segments, catheter was placed in three different levels of the spinal cord (C4-C6), (T5-T10) and (L2-L5). A needle was previously placed on the subcutaneous tissue on the three different levels, then catheter was inserted to match needle location only by muscle contraction. The position of the catheter in relationship to the needle was verified by fluoroscopy. Zero was assigned when catheter and needle were in the same vertebral body, pluses or minuses were given to the number of vertebrae apart between catheter and needle. The mean and SD of the catheter was calculated for accuracy and precision assessment.

**Results:** The catheter mean was 0.3 ± 2.03. Therefore, 67% of the catheter placements were no more than 2 vertebral bodies from the needle position.

**Conclusion:** Although accuracy was good, precision was marginal. Experience and time to place catheter might have influenced precision. Clinically, 2 vertebral bodies difference from target site maybe acceptable. The catheter can be placed without radiographic assistance and could be beneficial for segmental spinal anesthesia in dogs.

Comparison of ultrasound and electrostimulator-guided techniques for sciatic and femoral nerve blockade in dogs

Ricco C, Henao-Guerrero N, Rossmeisl J, Tyson R, Inzana K

Dept Small Animal Clinical Sciences, Virginia-Maryland Regional College of Veterinary Medicine, Virginia Tech, Blacksburg, Virginia, USA

**Introduction:** Objective was to compare ultrasound (US) and electrostimulator-guided (ES) techniques for sciatic (SN) and femoral (FN) nerve blockade.

**Methods:** Ten adult beagles (10.6 ± 1.4 kg) were anesthetized twice with a week interval for a prospective, randomized, placebo-controlled, blinded, crossover study. Sciatic and femoral nerve blocks were performed on both pelvic limbs with saline or lidocaine using one of the techniques. The following week, the opposite technique was used. Volumes were 0.1 mL kg-1 (FN) and 0.05 mL kg-1 (SN). Sensory nerve conduction studies and hemodynamic data were collected at baseline, 10, 20, and 30 minutes after injection. Heart rate, cardiac index, invasive blood pressure (SAP, MAP, DAP), stroke volume index, and systemic vascular resistance were recorded with a calibrated LidCOplus monitor before and after each electrical stimulation. Neurological examination was done before and 24-48 hours after each treatment. Data were analyzed using mixed-model ANOVA, ANCOVA and Tukey’s procedure for multiple comparisons (p≤0.05).

**Results:** No significant differences in nerve conduction velocity were detected between time points or between groups. Nerve conduction was absent in only 1/10 dogs in both groups at both nerves. One dog had very mild neurological deficit at 24 hours that resolved at 48 hours post procedure. ES-lidocaine had less hemodynamic response to stimulation than ES-saline, but not US-lidocaine or US-saline. US-lidocaine had similar hemodynamic response than any saline-treated group.

**Conclusion:** The evaluation methods used were unable to detect a difference between techniques. Electrostimulator-guided technique resulted in less hemodynamic response than US-guided technique. Reasons for potential block failure must be considered.