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Peripheral perfusion index does not accurately reflect hypoperfusion in healthy dogs undergoing elective ovariohysterectomy

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ABSTRACT

This study evaluated the variability of the peripheral perfusion index (PI) in 22 anaesthetised female dogs undergoing elective ovariohysterectomy and examined the relationship between peripheral PI and heart rate, blood pressure, blood pH, end tidal CO_2 ($EtCO_2$), O_2 saturation (SpO_2), core-peripheral temperature gradient (ΔTc-p), partial pressure of CO_2 (PCO_2), and concentrations of glucose, cortisol, lactate and bicarbonate (HCO_3^-). Blood pH, lactate and glucose concentrations were determined 15, 30, 45 min into the ovariohysterectomy procedure and after extubation. Cortisol concentrations were assessed before anaesthesia and after extubation. Other variables were recorded at every 5 min throughout the ovariohysterectomy procedure. Hyperglycaemia was observed in 59% of bitches during surgery, but serum cortisol concentrations remained unchanged. Most measures of perfusion (ΔTc-p, pH, PCO_2, $EtCO_2$, SpO_2) and heart rate remained unchanged throughout anaesthesia and did not correlate with peripheral PI. Mean arterial pressure increased during the ovariohysterectomy procedure, while peripheral PI decreased, resulting in negative correlations between these variables at 30 and 45 min. Lactate concentrations decreased from baseline to the time of measurement post-extubation. Peripheral PI gradually decreased during the ovariohysterectomy procedure, probably reflecting vasoconstriction induced by nociceptive stimuli. Using lactate concentrations as the reference standard for peripheral perfusion, low peripheral PI in healthy bitches undergoing ovariohysterectomy might not represent peripheral hypoperfusion.

Introduction

Peripheral vasoconstriction redirects blood flow away from peripheral organs, such as the skin and skeletal muscle, towards central organs, such as the kidneys, heart and brain, potentially causing peripheral tissue hypoxia. Peripheral vasoconstriction occurs mainly in critically ill patients, but can also occur under general anaesthesia due to hypotension, hypovolaemia and nociceptive stimuli (Quinn et al., 2013; Toyama et al., 2013).

The most common modes of assessing peripheral perfusion are capillary refill time (CRT), core-peripheral temperature gradient (ΔTc-p), pulse plethysmography, lactate concentrations and peripheral perfusion index (PI), determined using optical monitoring devices (van Genderen et al., 2012). The peripheral PI is derived from the photoplethysmography waveform produced by a pulse oximeter and is the ratio between pulsatile and non-pulsatile tissue blood flow. The peripheral PI is a reliable tool for detecting hypoperfusion, predicting mortality and as a measure of resuscitation in human patients (Lima et al., 2002; He et al., 2015).

Healthy human beings have a mean peripheral PI of 1.4% (range 0.3–6.3%); however, values <1.4% can indicate peripheral hypoperfusion (Lima et al., 2002). In dogs, the relationship between peripheral PI and both variables associated with peripheral perfusion are largely unknown. Few studies have been published regarding the impact of anaesthesia on peripheral PI. Nociceptive stimuli have an effect on peripheral PI through stimulation of the sympathetic nervous system (Takeyama et al., 2011; Høiseth et al., 2015). However, the relationships between nociceptive stimuli and catecholamines or other stress markers, such as serum cortisol or glucose concentrations, have not been established.

In this study, examined peripheral PI variability was examined in anaesthetised healthy dogs undergoing elective ovariohysterectomy

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and sought to determine the effects of heart rate and blood pressure on peripheral PI. Additionally, relationships between peripheral PI and other markers of hypoperfusion, such as lactate, CRT, ΔTc-p, arterial blood gases or stress, including glucose and cortisol concentrations, were examined.

Materials and methods

Animals, anaesthesia and surgery

This study was approved by the Ethical Committee on Animal Use (CEUA) of Universidade Federal de Santa Maria (protocol number CEUA 6908041016; date of approval 7th June 2017). Twenty-two female dogs were included in the study, with the written informed consent of the owners for the use of data obtained during the procedure. Animals weighing 5–20 kg and 1–5 years of age were selected according to their pre-operative health status, determined by clinical, haematological and serum biochemistry evaluation. Only dogs classified as having American Society of Anesthesiologists (ASA) physical status class I (McMillan and Brearley, 2013) were enrolled.

Food and water were withdrawn for 12 and 2 h, respectively, prior to surgery. Pre-anaesthetic medication consisted of 0.5 mg/kg methadone (Metadon, Cristália), administered intramuscularly. After 10 min, fur was clipped from both ears, thoracic limbs, the interdigital space of the right thoracic limb and the abdomen, followed by catheterisation of both cephalic veins with a 22 G catheter for administration of fluids and medication.

General anaesthesia was induced by intravenous injection of 4 mg/kg propofol (Propovan, Cristália) and maintained by inhalation with isoflurane (Isoflurano, Cristália) in 100% oxygen with orotracheal intubation. Intraoperative analgesia was provided by an intravenous constant rate infusion of 10 μg/kg/h fentanyl (Fentanest, Cristália). Lactated Ringer's solution (5 mL/kg/h; Solução de Ringer com Lactato, Isofarma Industrial Farmacêutica) was administered intravenously throughout the procedure. Orotracheal intubation was followed by the catheterisation of the intermediate auricular artery for invasive arterial pressure measurement; electrocardiograph (ECG) electrodes, oesophageal and interdigital thermometers, and side stream capnography sensors, were then placed. After stabilisation of the anaesthetic plane, ovariohysterectomy was performed by a veterinary surgeon according to MacPhail (2013).

Collection of samples and measurements

The peripheral PI and oxygen saturation by pulse oximetry (SpO_2) were measured using the same probe, attached to centre of the tongue. Mean arterial blood pressure (MAP), heart rate (HR) and respiratory rate were determined. Core and peripheral temperature were determined using oesophageal and interdigital thermometers, respectively, and the core-peripheral temperature gradient (ΔTc-p) was calculated. The end tidal CO_2 partial pressure ($EtCO_2$) was measured. Values were calculated using a multiparameter monitor (Digicare LifeWindow LW9xVet) coupled to a Masimo Rainbow Set CO-oximetry monitor, which enables measurement of peripheral PI. CRT was measured by pressing a finger on the gum above the canine tooth for 5 s and then registering the time for blood flow to return.

Measurements were taken continuously and recorded at 5 min intervals, beginning 5 min after induction of anaesthesia until the end of the procedure. The pulse oximeter probe was repositioned on the tongue every 10 min to avoid compression of the capillary bed site.

Blood was collected from the jugular vein for determination of glucose and lactate concentrations before pre-anaesthetic medication administration, then every 15 min until a final sample was obtained immediately post-extubation. Arterial blood was collected from the auricular artery at 15 min intervals for blood gas analysis (pH, $PaCO_2$, PaO_2, HCO_3^-). Glucose and lactate concentrations were assessed using a blood glucometer (Accu-Check Active, Roche) and lactimeter (Accutrend Plus, Roche), respectively, and compared to the reference interval of 70–110 mg/dL for glucose concentration (Nelson et al., 2004) and 0.7–2.8 mmol/L for lactate concentration (Allen and Holm, 2008).

Blood for evaluation of serum cortisol concentrations was collected before pre-medication and post-extubation. Samples were centrifuged at 3000 *g* for 10 min after clot formation. The serum was separated and stored frozen at −80 °C in polypropylene (Eppendorf) tubes until analysis was performed. The cortisol concentration was measured using a chemiluminescence technique and compared to the reference interval of 1.0–6.0 μg/dL (Nelson et al., 2004).

Statistical analysis

Data were evaluated for all parameters at 15, 30 and 45 min, and immediately post-extubation. Differences among HR, respiratory rate, MAP, CRT, ΔTc-p, $EtCO_2$, SpO_2, pH, $PaCO_2$, PaO_2, along with HCO_3^-, glucose, lactate and serum cortisol concentrations, at each of the four time-points, were analysed by analysis of variance (ANOVA) for repeated measures and the Tukey-Kramer post-hoc test. Peripheral PI was analysed using Friedman's test and Dunn's multiple comparisons test. Non-parametric data are presented as the median (range). Differences were considered statistically significant at $P < 0.05$. Statistical tests were performed using SAS/STAT. Correlations between variables and PI were assessed by repeated measures correlation using R (R Foundation for Statistical Computing).

Results

A total of 22 female dogs with a median (range) age of 2 (1–6) years and weight of 9.3 (6.2–13.8) kg were enrolled in the study. Total time of anaesthesia was 54.8 ± 8.5 min, while surgery lasted 26.6 ± 4.9 min. A total of 88 measurements were obtained from the 22 dogs. No dog received any vasoactive drugs during the study. Values of all variables measured before and during anaesthesia are listed in Table 1.

Mean arterial pressure increased from 15 min (65.1 ± 13.4 mmHg) to 45 min (91.5 ± 25.5 mmHg) during the ovariohysterectomy procedure ($P = 0.0121$) and immediately post-extubation (117.1 ± 32.0 mmHg; $P < 0.001$). The mean (range) peripheral PI was 1.8 (0.45–5.4) % at 15 min, but decreased from this time point to the end of the procedure, presenting a median (range) value of 0.37% (0.14–2.10%) ($P < 0.001$). Peripheral PI did not change from 30 to

Table 1
Descriptive analysis and statistical difference among different time points of assessment.

	Pre-operative	15 min	30 min	45 min	Post-extubation	*P* value
Heart rate	120 ± 18	98.3 ± 25.1	89.7 ± 22.2	91 ± 27	93 ± 23	0.67
Respiratory rate	49 ± 31	13.7 ± 15.0[c]	8 ± 6[c]	14 ± 13	27 ± 15	<0.001
Tc (°C)	38.7 ± 0.5	37.1 ± 0.5	36.6 ± 0.4	36.1 ± 0.6	36.1 ± 0.6	ND
ΔTc-p (°C)	–	1.97 ± 1.57	1.55 ± 1.53	1.38 ± 1.77	1.86 ± 1.60	0.61
pH	–	7.21 ± 0.06	7.19 ± 0.054	7.21 ± 0.06	7.24 ± 0.052	0.079
MAP (mmHg)	–	65 ± 13	92 ± 25[a,d]	91 ± 25[a,d]	117 ± 32[a,b]	<0.001
PCO_2 (mmHg)	–	51 ± 10	51 ± 10	49 ± 9	46.4 ± 7.9	0.27
SpO_2 (%)	–	97.3 ± 2.5	98 ± 1 <	96.7 ± 2.8	96.5 ± 2.3	0.080
Bicarbonate (HCO_3^-) (mM)	–	20.2 ± 2.8	19.1 ± 2.7	19.3 ± 1.7	19.37 ± 2.02	0.54
Perfusion index (%)	–	1.8 (0.5–5.4)	1.0 (0.4–4.4)	0.71 (0.21–5.50)[a]	0.37 (0.14–2.10)[a,b]	<0.001
Capillary refill time (s)	1.4 ± 0.5	1 ± 0	1 ± 0	1.14 ± 0.35	1.13 ± 0.35	0.086
Lactate (mmol/L)	4.05 ± 1.13	2.51 ± 0.97	2.13 ± 0.98[a]	2.66 ± 1.68[a]	2.60 ± 1.06[a]	<0.001
Glucose (mg/dL)	89 ± 12	104 ± 25	117 ± 27[a]	120 ± 28[a]	123 ± 40[a]	<0.001
Cortisol (μg/dL)	6.81 ± 3.36	–	–	–	7.92 ± 3.11	0.21

Data are expressed as mean ± standard deviation (SD) or median (range) for non-parametric data.
Tc (°C), core temperature; ΔTc-p (°C), core to peripheral temperature difference; MAP, mean arterial pressure; PCO_2, partial pressure of carbon dioxide; SpO_2, oxygen saturation by pulse oximetry; ND, *P* value not determined (value used to calculate ΔTc-p).
[a] $P < 0.05$ vs. 15 min.
[b] $P < 0.05$ vs. 30 min.
[c] $P < 0.05$ vs. 45 min.
[d] $P < 0.05$ vs. post-extubation.