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Advanced Pulse Oximeter Shiz

Pulse oximetry is an established standard of anesthetic monitoring providing an insight to the assessment of circulation and oxygenation. The ACVAA recommends its monitoring in all phases of sedation and anesthesia. Invented in the 1940s, routine use in human medicine began in the 1980s with veterinary medicine embracing its use by the 1990s. Pulse oximeters provide patient pulse rates and a non-invasive measurement of hemoglobin saturation (SpO_2) which is dependent on perfusion to the tissue where the probe is placed and oxygenation of the blood. They are can be used as independent, portable units or as part of a multi-parameter monitor. They are reusable, inexpensive and do not require advanced training or skill to implement; making them a useful assessment tool for all veterinary hospitals.

Pulse oximetry functions on the premise that the various forms of hemoglobin in our blood absorb different amounts of light. The probes, either transmittance or reflectance, emit light from one side, through perfused tissue and measures the difference in light that passes through or absorbed. Oxygenated hemoglobin absorbs a greater amount of light in the near infrared spectrum while deoxygenated hemoglobin absorbs more light in the visible red spectrum. This measurable difference is calculated with an empirical algorithm to generate a percentage of oxyhemoglobin compared to total hemoglobin (SpO_2). It is important to recognize that the algorithm most commercialized pulse oximeters utilize were established for humans and results are similar enough for dog, cat, horse, cow and pig; other species, specifically avian and reptiles, can underestimate actual saturation[1].

Pulse oximetry is not without its limitations. Accuracy depends on many factors such as ability of light to travel through tissue (i.e. pigmentation and hair cause issue) and the presence of perfusion to the tissue where the probe is placed. Pulse oximetry is a non-invasive approach to *approximate* oxygen bound to hemoglobin in the blood (SaO_2) and ultimately, providing insight to the status of patient oxygenation. Understanding the relationship between SpO_2 or SaO_2 and partial pressure of arterial oxygen dissolved in the blood (PaO_2) with the oxyhemoglobin dissociation curve is vital for successful outcomes when anesthetizing cardiopulmonary compromised patients. Normal SpO_2 regardless of the fraction of inspired oxygen (FiO_2) is above ~95% as this correlates with approximately 80 mmHg PaO_2. Hypoxemia is defined as a PaO_2 of <60 mmHg, which correlates to a SpO_2 ~90%. Patients may not appear cyanotic until they are below 90% SpO_2!

In addition to monitoring SpO_2 and providing a heart rate, advancements in plethymography are assisting in the stabilization and treatment of hypotensive critical patients! *Perfusion index* (PI) and *plethysmograph variability index* (PVI) are rapidly emerging terms we should strive to understand as we watch this space in its applications to veterinary species. In humans, variations in the plethysmography waveform amplitudes correlate to variation in blood volume status. This measurable difference helps predict fluid responsiveness in critical patients[2]. PI is a measured variable, reflecting the change in amplitude of the pulse oximeter waveform between inspiration and expiration. It can be helpful in

determining the degree of perfusion at the area of probe placement and guide the user to modify probe placement. It has also been used to assess successful placement of loco-regional blocks[3]. Local anesthetics cause vasodilation. Where vasodilation occurs, perfusion should increase causing an increase in PI. Gatson B et al observed an increase in PI 10-15 minutes following successful sciatic nerve blocks in dogs. Dogs with a lack of increase in PI were associated with partial or complete failure of the block[3].

PVI is being considered for use in humans as a non-invasive tool to assess patients as fluid or non-fluid responders. Excessive fluid administration is associated with increased morbidity and mortality in critical human patients [4]. PVI is a calculated value which measures the dynamic change in PI over a minimum of two respiratory cycles during mechanical ventilation. A quick review-there is no denying intermittent positive pressure ventilation (IPPV) is useful and/or necessary in patients under anesthesia. It is important that when implemented the anesthetist understand the impact IPPV has on intrapleural pressure. During inspiration of IPPV, there is an increase in intrapleural pressure, causing compression of the great vessels, reducing venous return and cardiac output. This dynamic is exacerbated in patients with hypovolemia and hypotension. While invasive techniques can more accurately monitor these fluctuations, e.g. pulse pressure variability (PPV) and systolic pressure variability (SPV), they require placement of an arterial catheter and monitor capable of invasive blood pressure. Drozdzynska MJ et al established a PPV of ≥ 13% in dogs reliably predicted cardiovascular response to fluid loading in 82.8% of dogs undergoing abdominal surgery. Also, in 82.7% of the fluid responders, hypovolemia was detected with PPV before hypotension (MAP <60 mmHg) was detected[5]. The next logical question is: Can PVI provide a non-invasive alternative, with reliable agreement to PPV? Klein et al found that in anesthetized, mechanically ventilated dogs where hypotension was induced via controlled hemorrhage, both PVI and PPV increased and returned to pre-hemorrhage levels after volume replacement[6]. In another study of controlled hemorrhage, sevoflurane anesthetized, mechanically ventilated dogs, Endo et al established that PPV has relevant correlation with a PVI and that a PVI ≥ 12% identified fluid responsiveness[7]. Therefore, PVI shows promise as a non-invasive option to monitor volemic status, effectively treat hypotension and avoid excessive volume loading.

It is important to keep in mind these technologies are rapidly emerging and while showing promise require further validation in our veterinary species in various clinical situations. During anesthesia, we strive to maintain normal hemodynamic parameters with balanced technique, fluid therapy and pharmaceutical support. We know maintaining blood pressure (BP), a measurable value, is vital to maintaining adequate tissue perfusion while acceptable BP does not ensure adequate perfusion. Tissue perfusion is not as easily measured and changes in BP are not always linear with perfusion. Fluid therapy is a readily available treatment in any veterinary hospital however as mentioned above, excessive fluid administration is associated with increased morbidity and mortality in critical human patients [4]. PVI monitoring shows promise in reducing lactate levels and total volumes of fluid administration to surgical patients [8]. Currently the only unit commercially available that employs this technology is the Masimo Radical-7 pulse oximeter (Masimo Corp., CA, USA) in a standalone unit or incorporated into units with the technology as part of a multiparameter unit. These new technologies have the potential to provide further insight to advanced monitoring of the critical patients by adapting

their interpretations to help direct our intra-operative management. This makes it vital as we progress in our attempts to improve monitoring that we consider implementing PVI into our standard of care, especially for the hemodynamic monitoring of the critical patient.

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