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A Comparison of Oxygen Saturation in White-tailed Deer Estimated by Pulse Oximetry and from Arterial Blood Gases

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ABSTRACT: Physiologic monitoring is important when chemically immobilizing wildlife. Blood oxygenation is usually monitored by pulse oximetry in the field; however, there is some question whether this technique accurately reflects oxygen saturation in wild white-tailed deer (*Odocoileus virginianus*). We evaluated different doses of medetomidine (125, 150, 175, or 200 μg/kg) mixed with ketamine (1.5 mg/kg), and tiletamine-zolazepam (1.0 mg/kg) in 22 female white-tailed deer at the University of Georgia Whitehall Deer Research Facility in Athens, Georgia on 14–15 and 21 May 2009. Deer were hand-injected intramuscularly while physically restrained in a squeeze chute, and then they were released into a pen for monitoring. Hemoglobin saturation estimated using pulse oximetry (SpO_2) was compared with hemoglobin saturation value from arterial blood gases (SaO_2) at 0, 10, and 20 min postimmobilization with deer in a sternal position. We made 56 simultaneous comparisons of oxygen saturation using SpO_2 (range, 54–95%) and SaO_2 (range, 60–95%). We used a Bland-Altman analysis for determining agreement between the two methods. Hemoglobin saturation estimated using SpO_2 was generally greater than SaO_2 when the mean of the two measurements was >80%. At mean values <80% oxygen saturation, there is not sufficient agreement between the techniques. Multiple readings over time may help recognition of outliers.

Key words: Arterial blood gases, *Odocoileus virginianus*, pulse oximetry, white-tailed deer.

Capture of free-ranging white-tailed deer (*Odocoileus virginianus*) by darting requires safe and effective anesthetic drugs. Physiologic monitoring should occur during the immobilization process to detect changes in the animal's cardiorespiratory status, effectiveness of supportive care, and depth of anesthesia, to promote animal well-being (Heard, 2007). Pulse oximeters are commonly used in the field to estimate arterial hemoglobin oxygen saturation. They are readily available, easy to use, and require minimal operator training. Alternatively, oxygenation may be measured by arterial blood gas analysis, but this requires obtaining samples from an artery and evaluation with specialized equipment in a short time or storage on ice before analysis (Heard, 2007). Because many field researchers do not have the ability to measure arterial blood gases, we compared estimated hemoglobin saturation from portable pulse oximetry and from arterial blood gases in anesthetized captive deer.

All animal procedures were approved by the University of Tennessee and University of Georgia Institutional Animal Care and Use Committees (UT-IACUC 1788 and UGA-IACUC A2007-10093-m1). Female deer (ages 2–15 yr) housed at the University of Georgia Warnell School of Forestry and Natural Resources Whitehall Deer Research Facility (33°53′N, 83°21′W) were physically restrained in a squeeze chute and hand-injected with 1.5 mg/kg ketamine (100 mg/ml Ketaset®; Fort Dodge Animal Health, Fort Dodge, Iowa, USA), 1.0 mg/kg tiletamine-zolazepam (50 mg/ml tiletamine and 50 mg/ml zolazepam, 100 mg/ml total of Telazol®, Fort Dodge Animal Health), and either 125 (MKT-125), 150 (MKT-150), 175 (MKT-175) or 200 (MKT-200) μg/kg medetomidine (20 mg/ml; ZooPharm, Fort Collins, Colorado,

USA) in their left hindquarter (Muller et al., 2012). For each deer, hemoglobin saturation was measured using a Rad-5 SET handheld pulse oximeter (SpO_2; Masimo, Irvine, California, USA; placing the probe on the tongue) and a VetStat arterial blood gas analyzer (IDEXX, Westbrook, Maine, USA; cassettes were warmed to 37.0±0.1 C), including the partial pressure of oxygen (P_aO_2) and arterial oxygen saturation (S_aO_2) at time of immobilization (time 0), and 10 and 20 min (time 10 and 20) after immobilization. We collected <1 ml of blood from the auricular artery into heparinized syringes. We immediately mixed the blood by gentle rolling the syringes, and we loaded them into the single-use respiratory/blood gas cassette (VetStat, IDEXX) to measure arterial blood gases.

We conducted a Bland-Altman analysis using SAS 9.2 (SAS Institute, Cary, North Carolina, USA) to compare the two methods of measuring hemoglobin saturation (with the pulse oximeter and from arterial blood gases; Bland and Altman, 1986). We also performed regression analysis (SAS Institute) to compare the two methods.

Regression of SpO_2 and SaO_2 had an r^2 value of 0.56. There was one outlier, in the upper range, that occurred with one animal because of a low SpO_2 reading at time 0; however, the values by the two methods were similar at 10 and 20 min. Removal of this 0 time point increased the r^2 value to 0.64. Mean difference of the two methods (SpO_2–SaO_2) was 0.38 (+2 SD, −12.02 to 12.78). However, hemoglobin saturation estimated using SpO_2 was generally greater than SaO_2 when the mean of the two measurements was >80%, but within 2 SD when removing the outlier (Figs. 1, 2). Visually (Fig. 2), there seemed to be closer agreement between techniques >80%. The difference between the two techniques when the mean was >80% only ranged from −4 to +7, which may be more acceptable when determining oxygen status. Below 80% oxygen saturation, there does not seem to be sufficient agreement between values to use both methods interchangeably.

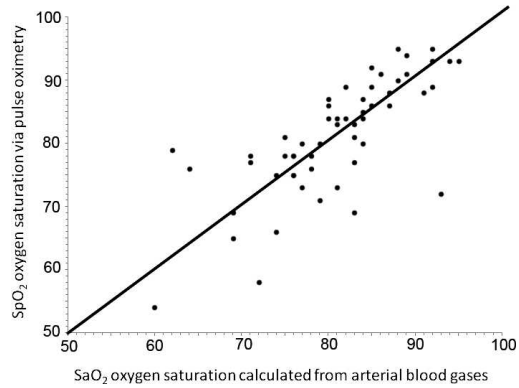

FIGURE 1. Bland-Altman analysis plot of identity to compare hemoglobin oxygen saturation measured by two methods on captive white-tailed deer (*Odocoileus virginianus*) injected with ketamine (1.5 mg/kg), tiletamine-zolazepam (1.0 mg/kg), and selected doses of medetomidine (125, 150, 175, or 200 μg/kg) at the University of Georgia Whitehall Deer Research Facility in Athens, Georgia, USA, on 14–15 and 21 May 2009. SpO_2 was measured using a pulse oximeter. SaO_2 was measured from arterial blood gases. The line of identity is where y=x and is indicated by a solid black line.

Hypoxemia is a common problem in anesthetized deer (Caulkett and Haigh, 2007) and is particularly associated with the use of α_2-adrenoreceptor agonists (Read, 2003). When using these drugs, physiologic monitoring is critical; Heard (2007) felt that further research was needed to evaluate pulse oximetry in wild animals to facilitate this monitoring. The SaO_2 is measured by the blood gas analyzer using three optical measurements taken directly on the blood, and it is validated for humans. The SpO_2 values were usually greater than SaO_2 (Figs. 1, 2) when >80% hemoglobin oxygen saturation. Storms et al. (2005, 2006) also found SpO_2 generally overestimated SaO_2 when evaluating deer treated with carfentanil-xylazine and carfentanil-xylazine-ketamine. However, this overestimation depended on the drug treatment (Storms et al., 2006). These deer were considered hypoxemic because the hemoglobin oxygen saturation (SpO_2 <90%) but had PaO_2

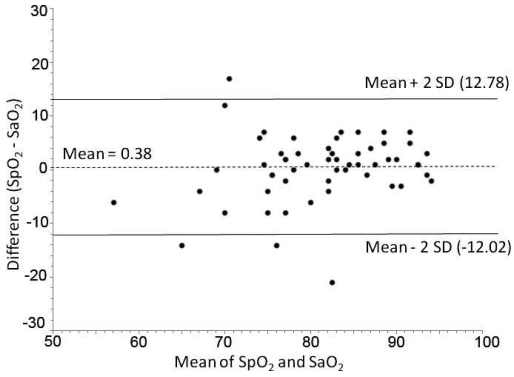

FIGURE 2. Bland-Altman analysis to compare hemoglobin oxygen saturation measured by two methods on captive white-tailed deer (*Odocoileus virginianus*) injected with ketamine (1.5 mg/kg), tiletamine-zolazepam (1.0 mg/kg), and selective doses of medetomidine (125, 150, 175, or 200 μg/kg) at the University of Georgia Whitehall Deer Research Facility in Athens, Georgia, USA, on 14–15 and 21 May 2009. SpO_2 was measured using a pulse oximeter. SaO_2 was measured from arterial blood gases. The solid black lines represent the upper and lower 95% confidence limits. Above 80% hemoglobin oxygen saturation, there was general consistency between values of SpO_2 and SaO_2. There was one outlier in this range that occurred because of a low SpO_2 reading at time 0; however, the values by the two methods became similar at 10 and 20 min. Below 80%, there is not sufficient agreement between values to use both methods interchangeably.

values indicating high oxygenation (PaO_2 >60 mmHg). The pulse oximeter used by Storms et al. (2006) calculated SaO_2 based on a human oxygen–hemoglobin dissociation curve. The PaO_2 (where hemoglobin is 50% saturated P_{50}) has been shown to be shifted to the right with a lower affinity of hemoglobin for oxygen in Sika deer (*Cervus nippon nippon*; P_{50}=28 mmHg; Ochiai and Enoki, 1975) compared with humans (P_{50}=27; Ochiai and Enoki, 1975) or horses (*Equus caballus*; P_{50}=27; Doherty and Valverde, 2006). Perhaps deer hemoglobin in general has a lower affinity for oxygen than other species and therefore would have higher values of SaO_2 if based on deer-derived data. Alternatively, the measurements for SpO_2 must be taken through tissue whereas the SaO_2 is measured directly from the arterial blood.

Mich et al. (2008) found inconsistencies between changes in SpO_2 and PaO_2 when low oxygenation occurred, but SpO_2 underestimated oxygenation when supplemental oxygen was used. The measurement of hemoglobin oxygen saturation by pulse oximetry may not be accurate when <80%. A difference of approximately 12% in oxygen saturation by the two methods we used may be clinically important. Below 80% oxygen saturation, caution must be used when relying on SpO_2 alone, because there is poor agreement between the two methods.

The type of pulse oximeter, species, and placement of probe can affect accuracy and failure to produce a reading (Matthews et al., 2003). Storms et al. (2006) found variations in SpO_2 depending on location of probe. We placed the probe on the tongue throughout our study and did not have problems with failures.

Therefore, pulse oximetry was a useful tool over most of the range of oxygen saturation in our study, but caution should be taken when using pulse oximetry as the only monitoring device when dealing with extremes of high or low oxygen saturation. We also suggest evaluating capillary refill time, respiration rate, and heart rate as supplemental information to accurately assess the physiologic state of immobilized animals. Multiple readings over time may facilitate accurate evaluation of oxygen saturation.

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