Evaluation of Pulse Oximetry in Anesthetized Dogs
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Continuous determination of arterial oxygenation is quite important in the management of anesthetized animals. Analysis of arterial blood gases is reliable, but is invasive and only provides intermittent information. Recently, pulse oximetry has been introduced into medical diagnosis. Pulse oximetry functions only by positioning pulsating arterial vascular bed between the two-wavelength light source and the detector by means of non-invasive procedure [4], and has been reported as a highly useful method for continuous evaluation of arterial oxygenation [3]. This study was conducted to evaluate the accuracy of pulse oximetry for the broad range of arterial saturations and to determine a reliable probe site in anesthetized dogs.

Six adult mongrel dogs weighing 6.5 to 15 kg (4 females and 2 males) were induced to anesthesia with thiopental sodium (25 mg/kg, iv) and orotracheally intubated. Anesthesia was maintained with halothane in an oxygen/nitrogen mixture. The end-tidal halothane concentration was measured with a multigas analyzer (Datex, AGM-103) and maintained at a level of 1.5 minimal alveolar concentration (1.3%). A cephalic venous catheter was placed for intravenous infusion of lactated Ringer’s solution, and a femoral arterial catheter was inserted both to measure blood pressure and to obtain blood specimens for analysis. After paralysis with vecuronium bromide (0.1 mg/kg, iv), the lungs were mechanically ventilated (Kimura, KV-1+1) to maintain PaCO2 at the level of approximately 35 to 40 mmHg. Rectal temperatures were maintained at 37.6 to 39.0°C by means of plastic sheets to cover the dog and heating blankets. A multi-site probe (Datex, 874634) connected to a pulse oximeter (Datex, CMO-104) was alternatively placed on either of the ear, the interdigit, the tongue, or the tail, and the pulse wave pattern and oxygen saturation by the pulse oximeter (SpO2) were continuously recorded. Hair of the skin for the probe to be placed was all clipped prior to the experiment.

When the ear and the interdigit were used as probe sites, the stable recordings of the pulse wave pattern could not be obtained and malfunction warnings were displayed. Clear and stable pulse wave pattern was recorded with the probe placed at the tongue, and the more stable and larger pulse wave pattern was obtained with the probe placed at the tail except one a dog with dark pigmented skin at the tail.

Based upon the results in these preliminary works, the accuracy of pulse oximetry was evaluated using the tongue (6 dogs) and the tail (5 dogs) as the probe sites. During the experiment, the inspired fraction of oxygen (FIO2) which was measured with a multigas analyzer was varied from 1.0 to 0.05 using mixture of oxygen and nitrogen, and maintained constant at each level until pulse oximeter readings were stable. Then arterial blood specimens were withdrawn into heparinized syringes and analyzed for % oxyhemoglobin (arterial oxygen saturation: SaO2), % methemoglobin and % carboxyhemoglobin with a CO-Oximeter (Instrumentation Laboratory Inc., IL282) which was calibrated for canine blood. All data at each site were pooled for statistical analysis, and linear regression analysis was used to compare the SaO2 with the simultaneous SpO2.

Eighty-three and 75 pairs of SaO2 and SpO2 measurements were carried out with the probe at the tongue and the tail, respectively. At each site, the stable pulse wave pattern was recorded continuously at the same position without any evident complications through the experimental period at least for 2 hr.

When the probe was placed at the tongue, analysis of linear regression demonstrated an excellent correlation between SpO2 and SaO2 for the broad range of arterial saturations and yielded the equation y = 34.8 + 0.63x with a standard error of the y estimate and a correlation coefficient of 2.7 and 0.98, respectively (Fig. 1). At this site, the pulse oximeter underestimated SaO2 at the range

![Fig. 1. Simultaneous measurements (n=83) of pulse oximeter SpO2-ordinate] versus CO-Oximeter SaO2 (abscissa) at the tongue. Regression analysis yields the line y = 0.63x + 34.8, r = 0.98.
of \( \text{SaO}_2 > 95\% \), and overestimated at the range of \( \text{SaO}_2 < 95\% \). The bias between \( \text{SpO}_2 \) and \( \text{SaO}_2 \) increased with the decrease of \( \text{SaO}_2 \).

When the probe was placed at the tail, analysis of linear regression also demonstrated an excellent correlation between \( \text{SpO}_2 \) and \( \text{SaO}_2 \) and yielded the equation \( y = 21.9 + 0.75x \) with a standard error of the \( y \) estimate and a correlation coefficient of 3.2 and 0.98, respectively (Fig. 2). At this site, the pulse oximeter underestimated \( \text{SaO}_2 \) at the range of \( \text{SaO}_2 > 85\% \), and overestimated at the range of \( \text{SaO}_2 < 85\% \). \( \text{SpO}_2 \) values at the tail more closely reflected \( \text{SaO}_2 \) values than those at the tongue. In the clinically relevant saturation range (\( \text{SaO}_2 > 70\% \)), the mean differences between \( \text{SpO}_2 \) and \( \text{SaO}_2 \) at the tongue and the tail were +2.6\% and +0.1\%, respectively.

In this study, analysis of linear regression demonstrated excellent correlations between \( \text{SpO}_2 \) and \( \text{SaO}_2 \) when the probe was placed at the tongue and tail. It has been reported that the absorption spectra of canine hemoglobin over the range of 600–1,050 nm was virtually identical to those of human hemoglobin [1]. The pulse oximeter used in the present study measures absorption at two wavelengths within this spectra (660 and 910 nm). This may cause an excellent correlations between \( \text{SpO}_2 \) and \( \text{SaO}_2 \) in dogs.

The accuracy of oxygen saturation measured with pulse oximeter is also affected by the algorithm programmed into each device [2]. The anatomical structure of the tail in the dog is more similar to that of human finger which is commonly used in clinical applications than the tongue, and this might cause the more close reflection between \( \text{SpO}_2 \) and \( \text{SaO}_2 \) with the probe placed at the tail.

In conclusion, The pulse oximetry provides the continuous, real-time and relatively accurate informations on arterial oxygenation non-invasively and appears to be useful in clinical management of anesthetized dogs. Although hair clipping is needed to detect a pulse and the measurement is not available in the animal with dark pigmented skin, the tail may be the most suitable site for the probe application in the dog.

REFERENCES