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RESEARCH PAPER

Evaluation of indirect blood pressure monitoring in awake and anesthetized red-tailed hawks (*Buteo jamaicensis*): effects of cuff size, cuff placement, and monitoring equipment

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Abstract

Objective To compare Doppler and oscillometric methods of indirect arterial blood pressure (IBP) with direct arterial measurements in anesthetized and awake red-tailed hawks.

Study design Prospective, randomized, blinded study.

Animals Six, sex unknown, adult red-tailed hawks.

Methods Birds were anesthetized and IBP measurements were obtained by oscillometry (IBP-O) and Doppler (IBP-D) on the pectoral and pelvic limbs using three cuffs of different width based on limb circumference: cuff 1 (20–30% of circumference), cuff 2 (30–40%), and cuff 3 (40–50%). Direct arterial pressure measurements were obtained from the contralateral superficial ulnar artery. Indirect blood pressure measurements were compared to direct systolic arterial pressure (SAP) and mean arterial pressure (MAP) during normotension and induced states of hypotension and hypertension. Measurements were also obtained in awake, restrained birds. Three-way ANOVA, linear regression and Bland–Altman analyses were used to evaluate the IBP-D data. Results are reported as mean bias (95% confidence intervals).

Results The IBP-O monitor reported errors during 54% of the measurements. Indirect blood pressure Doppler measurements were most accurate with cuff 3 and were comparable to MAP with a bias of 2 (−9, 13 mmHg). However, this cuff consistently underestimated SAP with a bias of 33 (19, 48 mmHg). Variability in the readings within and among birds was high. There was no significant difference between sites of cuff placement. Awake birds had SAP, MAP and diastolic arterial pressure that were 56, 43, and 38 mmHg higher than anesthetized birds.

Conclusions and clinical relevance Indirect blood pressure (oscillometric) measurements were unreliable in red-tailed hawks. Indirect blood pressure (Doppler) measurements were closer to MAP measurements than SAP measurements. There was slightly better agreement with the use of cuff 3 on

either the pectoral or pelvic limbs. Awake, restrained birds have significantly higher arterial pressures than those under sevoflurane anesthesia.

Keywords avian, bird, Doppler, indirect blood pressure, norepinephrine, oscillometric, red-tailed hawk, sphygmomanometer.

Introduction

The ability to accurately monitor arterial blood pressure is an important part of the assessment of tissue perfusion during anesthesia. Direct arterial blood pressure (DBP) monitoring is the most accurate method of assessing blood pressure. However, arterial catheter placement in avian species can be difficult because of their small size and tendency for intense arteriospasm secondary to increased arterial wall elasticity (Smith et al. 2000).

Methods used to measure indirect blood pressure (IBP) include Doppler, photoplethysmographic or photoacoustic probes with a sphygmomanometer or oscillometric monitors (IBP-O). Currently, a Doppler ultrasonic probe to detect the arterial flow, a pressure cuff to occlude arterial blood flow and a sphygmomanometer to measure pressures (IBP-D) is the most commonly used technique for monitoring IBP in birds (Lichtenberger 2005a). There is a need to validate common methods of determining IBP in birds as the structure and pressure dynamics of avian blood vessels differ from those of mammals. Avian arteries have a higher resilience (Speckmann & Ringer 1966) and much thicker walls (Bussow 1973), which may affect how quickly vessels respond to changes in cardiac output and subsequently affect peripheral blood pressures. Research using duck and turkey arteries has demonstrated anatomical differences, compared with mammals, within the arterial wall that allow for increased extension of more elastic lamellae (Smith et al. 2000). This may be an adaptation to the significant changes in cardiac output that may be required for high energy activities, such as flight. The importance of these physiologic differences between birds and mammals as it relates to peripheral blood pressure determination is unclear.

To the authors' knowledge, there are only two reports comparing DBP measurements to IBP measurements in any avian species. Little agreement was found between DBP and IBP-D measurements obtained from anesthetized Hispaniolan Amazon parrots (*Amazona ventralis*), via the pectoral limb or the pelvic limb using a 30–40% cuff width (Acierno et al. 2008). One IBP-O device was also evaluated and found to be unreliable in this species. Additionally, a comparison of DBP and IBP-D measurements in Pekin ducks (*Anas domesticus*) has been reported in conference proceedings (Lichtenberger et al. 2004) but complete results have yet to be published.

Several factors can affect the accuracy of IBP measurement in any species. These include the type of blood pressure monitor, cuff size in relation to the limb being measured, site of cuff placement, blood pressure (Hall et al. 2001a) and the use of pharmacologic agents that may affect peripheral vascular resistance. Appropriate cuff size is critical to accurate IBP measurement in any species. The currently accepted range for cuff width:limb circumference is 40–60% for small animals (Hall et al. 2001a). To our knowledge, the optimal cuff width:limb circumference ratio has not been previously established in any avian species. The effect of cuff site appears to vary in different species. In rabbits, pectoral limb IBP-O measurements correlated more closely with systolic arterial pressure (SAP) whereas the pelvic limb more closely correlated with mean arterial pressure (MAP) at the abdominal aorta (Ypsilantis et al. 2005). No difference in IBP-O was reported between pectoral and pelvic limb cuff placement in the dog (McMurphy et al. 2006) or one study in cats (Branson et al. 1997). However, a separate study evaluating three different IBP monitors (IBP-D, IBP-O, and photoplethysmographic) in cats reported a significant difference between cuff placement on either the tail or the pelvic limb for all monitors (Binns et al. 1995). Birds have a propatagium, a web of skin, muscles and tendons that connects the scapulohumeral joint to the radiocarpal joint of the pectoral limb, which makes the pectoral limb less cylindrical than the pelvic limb. This could potentially interfere with appropriate occlusion of the superficial ulnar artery by the pressure cuff. It is currently unknown whether pectoral or pelvic limb cuff placement affects the accuracy of IBP monitoring in avian species.

Differences in the arterial blood pressure of awake and anesthetized birds have yet to be thoroughly evaluated. Birds must be restrained to evaluate IBP, which may be expected to increase arterial blood pressure. Direct arterial blood pressure measurement is impractical in most awake animals and most DBP values established to date in any avian species have been determined under anesthesia