DOPP IT LIKE IT'S HOT: BLOOD PRESSURE REVIEW

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The importance of Doppler blood pressure monitoring in the clinical setting cannot be overestimated. Accurate and reproduceable measurements in awake and anesthetized patients are used to drive decisions about fluid therapy, shock intervention, and treatment for systemic hypertension. Veterinary technicians are frequently responsible for assessing Doppler blood pressure in small animal patients and clinicians must have confidence in their ability. Comprehensive understanding of Doppler physics, technique, interpretation, and troubleshooting are essential skills for veterinary technicians in the emergency, critical care, and general practice settings.

The Doppler effect is named after eponymous Austrian physicist Christian Doppler, who first described it in 1842, and refers to the change in sound wavelength caused by motion in the source of the sound. The best example of Doppler effect, and one most often cited, is that of a police car or ambulance. If an observer is sitting in their vehicle and an ambulance approaches from the rear, the sound of the siren has a higher pitch as the ambulance approaches than after it has passed by the stationary observer (it sounds louder and higher in pitch when it is behind the observer than once it has passed by), when the pitch becomes lower. This has to do with compression of the sound wavelength as the source of the sound (the siren) moves. The Doppler effect is used in multiple applications in both human and veterinary medicine, including Doppler ultrasonography (primarily to determine velocity and direction of blood flow in the heart and great vessels, but also in neonatology and obstetrics) and Doppler blood pressure assessment. In the case of Doppler blood pressure assessment, it is arterial blood flow, arterial wall movement, and red blood cell movement within the artery that create the motion needed to assess a wavelength shift.

Systemic arterial pressure is assessed via invasive and non-invasive methods; these are also known as direct or indirect. Direct/invasive arterial pressure is assessed via arterial catheter and blood pressure transducer. This method provides a waveform tracing, continuous minute-to-minute assessments, and is the gold standard for blood pressure monitoring in veterinary patients. There are four non-invasive methods available in veterinary medicine: oscillometry, high definition oscillometry, optical plethysmography, and Doppler ultrasonography. The auscultatory method is also non-invasive but used primarily in human medicine; it is inapplicable to veterinary patients due to their variability of limb size, vessel size, and pulse pressure. Oscillometric methods (most commonly part of multi-parameter monitors such as the Cardell or Surgivet that have automated cuff inflation) rely on estimates of systolic/diastolic/mean pressure generated via algorithm. High definition oscillometry is also available. Optical plethysmography utilizes the light-emitting probe of a pulse oximeter, inflatable cuff, and sphygmomanometer to detect pulsatile changes in blood volume and to generate a waveform. Doppler blood pressure assessment relies on an ultrasound transmitter, amplifier, coupling gel, and sphygmomanometer to obtain measurement of systolic blood pressure but cannot reliably determine diastolic pressure. The Doppler probe itself contains two piezoelectric ultrasound crystals—one transmits ultrasound through the overlying tissues and through the arterial wall, and the second acts as a receiver of the "echo" reflected back from the circulating cells and arterial wall. Several models are available, including the Parks Medical and Vet-Dop.

When arterial blood pressure is assessed, there are three components: systolic, diastolic, and mean. Systolic pressure is the peak arterial wall pressure of each heartbeat; diastolic pressure is the trough arterial wall pressure before the next heartbeat, and mean arterial pressure is the average arterial pressure for that cardiac cycle. Mean arterial blood pressure is the product of cardiac output and systemic vascular resistance (MABP = CO x SVR) and can be calculated from the systolic and diastolic blood pressures using the following equation: MAP = [(DAP x2) + SAP] ÷ 3 where DAP = diastolic arterial pressure and SAP = systolic arterial pressure. Not all methods of blood pressure assessment provide all components. Each method has advantages and disadvantages. Non-invasive methods are generally simple to use (some are automated) and Doppler is inexpensive. Invasive methods require specialized equipment and technical skill in the placement of a peripheral arterial catheter; in addition, they pose risks to the patient (primarily in the form of hemorrhage should the arterial catheter become damaged or dislodged, adverse reaction to drugs accidentally administered via an arterial catheter, or thrombus formation that threatens arterial blood flow to tissues distal to the clot). Normal systolic blood pressure in dogs is 90-140 mm Hg and in cats is 80-140 mm Hg. Normal diastolic blood pressure in dogs is 50-80 mm Hg and in cats is 55-75 mm Hg. Normal mean arterial pressure for the dog is 60-100 mm Hg and the cat is 60-100 mm Hg.

To assess Doppler blood pressure, gather the necessary equipment: Doppler speaker with attached crystal, assorted inflatable cuffs, sphygmomanometer, alcohol, and ultrasound gel. Cuffs should be checked for leaks by inflating them with the sphygmomanometer and ensuring it maintains pressure. The Doppler crystal is checked on the operator's wrist pulse to ensure that it, and the amplifier, are in good working order; the speaker volume should

be turned down after checking the crystal and before using on the patient. Once it is ascertained that the equipment works, a peripheral artery site should be selected. The most common sites are the digital arteries of the front and hind feed, but other sites such as the dorsal pedal artery of the metatarsus or the coccygeal artery of the tail should not be overlooked. In order to complete a measurement successfully, the artery must be distal enough that a cuff can be placed circumferentially around the limb or tail above the artery. The tail is an excellent site in patients that have limb trauma, but it cannot be used in patients with bob tails or coccygeal trauma. It is helpful to palpate the peripheral arterial pulse prior to making an attempted measurement.

For best accuracy, the site should be contiguous with the level of the patient's heart; this may require placing the patient in lateral recumbency. Values assessed while the patient is standing may be elevated. It is optimal for the patient to be calm; if necessary, move the patient to a quiet room and allow him/her to acclimate to the space before positioning for an assessment and wait again before taking the blood pressure. "White coat hypertension" is a documented phenomenon in veterinary patients who have elevated blood pressure due to their anxiety at being in the clinic environment and handled by strangers. A soft bed, gentle handling, dim lighting, and the owner present may be necessary for patients who are anxious.

Once a site has been chosen, a cuff is selected. Appropriate cuff size is essential to accurate blood pressure measurement; a cuff that is too large/loose will produce a measurement that is skewed low and a cuff that is too small/tight will produce a measurement that is skewed high. Cuffs come in whole sizes 1-10 and beyond, depending on manufacturer. Unfortunately, half sizes are not available, so measurements taken on small, pediatric, or neonatal patients should be interpreted with caution. To size a cuff, take the short axis and wrap it around the limb or tail where it will be placed for a measurement; for canine patients, it should be 40% (slightly less than half) the circumference of the limb/tail and for cats, 30-40%. The tubing of the cuff should be positioned parallel to the artery. Once the cuff is in place, the artery site should be well dampened with alcohol. Clipping of the hair is not necessary and may distress the patient to the point that blood pressure is elevated; many veterinary patients resent handling of their feet, particularly with vibrating clippers and cold gels/liquids. In these patients, the dorsal pedal artery or coccygeal artery sites may be preferable since they minimize touching of the feet. The tail artery can be quite useful in feline patients, even fractious cats.

Once the arterial pulse is identified/palpated and the site dampened with alcohol, coupling gel is applied to the concave side of the Doppler probe and the probe is applied to the arterial pulse site, parallel to blood flow in the artery. Once the probe is in place, the volume can be increased on the speaker until the heartbeat is audible. Earbuds or headphones can be very helpful in a busy treatment area, or the technician's stethoscope can be placed on the speaker (taking care to protect the operator's hearing by keeping volume low). If the heartbeat is not heard, small millimeter by millimeter adjustments are made until the sound is heard, taking care not to press so hard on the probe that the arterial pulse is occluded. If desired, the patient's heartbeat can be counted; if the patient has a cardiac arrhythmia, it may be noted at this time as an irregular heartbeat. The sphygmomanometer is used to inflate the cuff until the heartbeat is no longer audible—many patients react to the pressurized feeling of cuff inflation, so it is best done slowly. Once the sound is no longer audible, the cuff is slowly deflated; arterial blood flow returns and with it the audible heartbeat sound. Make a note of the number where the needle stops on the sphygmomanometer when the sound returns—this is the systolic or peak arterial pressure. Although specific recommendations vary (between 3, 5, and 7 measurements), a best practice is to take several measurements and calculate an average; some also recommend discarding the lowest and highest values prior to calculating an average. Consistency is key for accuracy, so if possible, the same cuff/sphygmomanometer/site/operator should be used for sequential measurements.

Troubleshooting Doppler blood pressure depends on the issue. If probe malfunction is suspected, the first step is to test the probe on the operator—if no sound is heard (even the static created due to gel application), the speaker is charged, power on, and the volume is turned up, the probe may have failed. Excessive static or loud, fluctuating tones may be due to a short in the probe wires. It is best to start with the volume turned down when applying the probe to the patient since many patients are frightened by the static produced before the signal is located. If the patient is peripherally vasoconstricted due to disease, drug therapy, hypothermia, or anesthetic depth it may be difficult to locate the signal, but if the equipment is functional and a pulse is palpable, it should be possible to take a measurement. Additional gel or alcohol may be needed in these patients. Use of ear buds, headphones, or a stethoscope may also be necessary in patients that have probable hypotension. If one site is not producing results, another can be tried.

Doppler blood pressure monitoring is popular because it is inexpensive, not invasive, relatively easy to perform, and provides reasonable accuracy in certain patient populations (stable, euvolemic animals of species where the method has been validated). However, Doppler BP has limitations and may not be the best choice for patients that are significantly hypotensive or hypertensive; in addition, if the cuff cannot be sized accurately (as in

pediatric patients or exotic species), the pressure values must be interpreted with caution. Evidence for and against Doppler blood pressure changes frequently and veterinary professionals must stay current; when evaluating research, principles to keep in mind include the species studied, site assessed, whether the patient was awake or anesthetized, concurrent drug therapy, and statistical methods of analysis in a given study. While each study in the literature has a different design, statistical analysis, and enrollment population, consensus across the literature indicates that Doppler blood pressure is less accurate in patients with hypotension, hypertension, and in cats. The American College of Veterinary Internal Medicine issued comprehensive guidelines for the screening, diagnosis, and management of systemic hypertension in dogs and cats in 2007 that are an excellent resource.

A prospective cross-sectional study conducted on 146 dogs undergoing general anesthesia at Tufts University and the University of Georgia veterinary teaching hospitals in 2018 compared Doppler blood pressure readings with direct arterial blood pressure readings recorded simultaneously every 5 minutes during the anesthetic event. In this study, hypotension was defined as MAP <60 or Doppler pressure <90 mm Hg. While no statistically significant differences in specificity or sensitivity were noted based on limb shape, IV catheter size used for direct BP assessment, or side of the paired measurements (same side of body v. opposite), the study found that Doppler blood pressure was not reliable for screening dogs for hypotension but that in dogs with documented hypotension, Doppler values could be trusted to confirm hypotension. The University of Pennsylvania conducted a prospective observational study in 2018 of 93 dogs presented to the emergency service to assess the relationship between peripheral arterial pulse palpation and Doppler blood pressure. This study was designed to test the concept of "the poor man's Doppler," which states that if a patient's pedal or digital pulses are palpable, the systolic BP is ≥90 mm Hg and if the femoral pulses are palpable, the systolic BP is ≥60 mm Hg. In the study, pulse quality was assessed at both sites and scored as strong, weak, or absent and a Doppler BP was assessed on the forelimb or hind limb of each patient. This study found that absent pedal pulses are highly specific for hypotension but that dogs with palpable dorsal pedal pulses are not always normotensive. Correlations with specific blood pressure measurements were not conclusive. Pulse palpation should therefore not replace evaluation of all perfusion and cardiovascular parameters and does not take the place of blood pressure measurement. In their two-part review published in 2020, Skelding and Valverde make the following recommendations regarding Doppler BP in dogs: it can provide an estimate of systolic BP but may under-diagnose hypotension in anesthetized dogs and cannot take the place of direct arterial BP in very sick patients. However, in dogs smaller than 5 kilograms, Doppler may provide an estimate of systolic BP that more closely matches direct arterial BP. Their conclusions regarding oscillometric BP stress that the accuracy of this method depends on the monitor/machine that is used, with the Cardell providing reliable estimates of mean arterial BP in normotensive dogs and cats based on literature review; in their assessment the Surgivet is also good at estimating mean arterial BP and diagnosing hypotension in dogs.

The role and value of Doppler blood pressure assessment in cats has been more contentious; systolic measurements obtained on cats may be closer to mean arterial pressure in that species, and Doppler may be preferable to oscillometric methods. A 2017 prospective randomized trial conducted at the University of Tennessee assessed age, body condition score, and muscle condition scores in conjunction with systolic BP collected from the radial (forelimb) and coccygeal sites on 66 cats. This study recommended use of the coccygeal site in elderly cats or those with significant muscle wasting (sarcopenia). A 2020 study by Cerna et al published in the Journal of Feline Medicine and Surgery compared oscillometric and Doppler blood pressure measurements in 23 conscious cats and found that oscillometric and Doppler methods could not be used interchangeably in awake cats. Multiple studies have established concerns that oscillometric methods are not as accurate as other methods in this species, although it is important to remember that invasive methods are considered most accurate of all. Multiple studies have established the coccygeal arterial site as one that is well tolerated and yields reliable results in this species; however, a 2021 study by De Rosa, Drobatz, and Reineke comparing radial to coccygeal indirect blood pressure in 85 cats presented to a university emergency room found that median coccygeal pressure was greater than radial artery pressure in sick cats. The cats had evidence of both normal and hypoperfusion. The researchers concluded that coccygeal and radial indirect blood pressure measurements could not be used interchangeably and recommended that both sites be assessed initially before the site/value is selected that most closely correlates to the patient's clinical perfusion parameters. It is also important to note that Skelding and Valverde, upon review of the available literature, recommend Doppler as a reasonable estimation of direct arterial *mean* BP in cat. In cats, consistency of site, cuff, and operator may be more significant than in dogs due to variance between coccygeal and radial sites.

No blood pressure method is without pros, cons, and limitations. It is important to understand the advantages conferred by direct arterial blood pressure assessment but also to be aware that this method may not be necessary or appropriate for all patients. While Doppler blood pressure also has limitations, it is one of the most reliable non-invasive methods available at this time to provide systolic trends that can drive therapeutic decision making. Oscillometry is convenient and very easy to perform but is also not without limitations. In order to

mitigate the limitations of non-invasive blood pressure monitoring, veterinary technicians can standardize their technique and educate themselves about the advantages and disadvantages of each method.

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