THE NUTS AND BOLTS OF BLOOD PRESSURE MEASUREMENT

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INTRODUCTION: Why measure blood pressure

Blood pressure measurement is often not a routine part of small animal practice. This partially has to do with the equipment available to measure blood pressure as well as our patients (they tend not to hold still like we have to). This does not however change the fact that measuring blood pressure is

a. good medicine
b. a diagnostic test with considerable owner acceptance
c. a way to generate income with good medicine

Blood pressure can be determined through direct or indirect means. The direct method requires catheterization of a peripheral artery, generally a procedure reserved for monitoring of critical patients. Indirect means of blood pressure determination are more practical for day to day use. The indirect methods are non-invasive and cause little discomfort. The increasing availability of simple and relatively inexpensive means to indirectly measure blood pressure has lead to increased clinical application of this diagnostic tool.

DOPPLER

Doppler ultrasonic blood pressure machines have a transmitting and receiving transducer. The ultrasound waves generated by the transducer are used to detect motion of the arterial wall or the blood cells themselves. If an object is moving a frequency change occurs (Doppler effect) with the ultrasound waves, making the reflected sound beam go from ultrasonic range to audible range. This reflected signal is amplified by the Doppler machine. An inflatable cuff with an aneroid pressure gauge is usually also needed. The cuff applies pressure to a peripheral artery and the pressure values are displayed by the gauge. The cuff is inflated to levels greater than systolic pressure. This occludes the artery and wall motion stops so that a signal is not received. The cuff is slowly deflated to a level below systolic pressure, which then means that the pulses are heard again. This method can be used in practice. There are a variety of downsides to this method. The method is operator dependent and widely varying numbers can be obtained by different people. The noise of the unit can contribute to stress in the animal as does shaving to improve probe contact. The set up time is relatively long making this method poorly adaptable to routine blood pressure measurement. Generally two skilled people are needed, one to restrain the pet, the other to obtain the reading. One of the most significant downsides to this technology is the inability to routinely and accurately determine diastolic blood pressure.

OSCILLOMETRIC

Oscillometric blood pressure devices measure oscillations within a cuff bladder. The pulse wave traveling through an artery causes these oscillations. Several commercial devices are available. The machines automatically inflate the cuff and deflate it slowly. Pressures above systolic pressure are initially used to occlude the artery and stop wall motion. Once deflated to systolic pressure, oscillations begin. Though relatively reliable in dogs, to date this technique has been very difficult to use in cats. Since there is no hunt for an artery as with Doppler, in many cases getting a reading is more rapid with oscillometric. Each individual reading takes longer in that the devices automatically inflate and then deflate slowly. This is actually an advantage, because this means that blood pressure is sampled over a longer period of time. As a result, a more accurate reflection of blood

pressure can be determined.

HIGH DEFINITION OSCILLOMETRY (HDO)

HDO is also based on oscillometry, however that is similar to saying that a model T car is the same as a Lexus. HDO represents a generational leap in oscillometry. The processor is considerably more powerful allowing real time analysis of the oscillometric curve and exact control of the valves that determine inflation and deflation. This makes HDO accurate over a wider range of pressures (from 300 to 25 mmHg). It is also possible to visualize the oscillations as they are occurring using a computer. Seeing the curve allows the veterinarian to make important decisions as to whether the readings are accurate. With HDO it is possible to obtain blood pressure readings off the tail, even in awake ferrets. It is even possible to send the HDO unit home with the owner and most owners can obtain readings that are free from in hospital stress. This unit allows blood pressure measurement to truly become a routine and relatively easy diagnostic test in small animal patients.

TECHNIQUE

It is important that the measurements be taken in a manner that minimizes apprehension or movement in a conscious patient.

- Blood pressure measurements should be taken in a quiet room
- Visitors or employees should not walk in and out of the room while a patient is measured
- The animal should have a few minutes to get used to the environment and the overall situation
- The animal should be handled in a calm and patient manner
- The pet's owner should be present provided he or she is able to calm the animal
- In each clinic, one or more individuals should be responsible for appointed to obtain blood pressure measurements to ensure consistent technique
- Measurements should be taken in a relaxed position
- The appropriate equipment should be used and limitations (Doppler, conventional oscillometry, Plethysmography) should be well known to allow a correct interpretation of the results
- When using HDO technology, measurement is easiest on the base of the tail, but can also be obtained on the limbs

It is vital to take readings in the same manner each time, this way readings are more comparable. This means that a protocol should be established and followed in all patients, when this protocol is deviated from it should be noted in the record. Deviations could be which limb was used, which cuff or machine was used, etc. The readings should be taken by someone that is calm and there should be adequate time allowed to carry the procedure out. Measurements should be taken in a quiet area with minimal distractions. Often if the owner is present, the animal will be more relaxed. Letting the patient acclimate to the room is also a good idea. With Doppler it usually is ideal to shave the area where the transducer is to be placed and then use coupling gel to improve signal transmittance. It is recommended that at least 5 blood pressure measurements be obtained over 5 minutes or more to determine average values.

SOURCES OF ERROR

Many factors can adversely affect blood pressure measurement. The autonomic nervous system can alter blood pressure, especially in response to stress. This is termed white coat hypertension and occurs commonly in humans as well. Movement in limbs will cause false values. Cuff width will influence results if it deviates too much from the ideal of 40% of limb circumference. A cuff that

is too wide will result in lower readings and a cuff that is not wide enough will result in higher readings. Pronounced arrhythmias and slow heart rates can potentially also cause erroneous results. When using Doppler it is vital to have discipline when obtaining values. The tendency is to get 5 or 6 readings as fast as possible. This generally does not reflect true blood pressure. With Doppler you have to look at your watch and get measurements over 5 minutes. The later readings will generally be closer to true blood pressure since the animal will have had time to accommodate to the procedure.

CLINICAL IMPLICATIONS

Hypertension is classified as essential (primary, idiopathic, no underlying cause found) or secondary (disease condition found that is commonly associated with hypertension). Diseases known to cause secondary hypertension include Cushing's disease, hyperthyroidism, diabetes mellitus and renal disease (both chronic renal failure and glomerulopathies). In renal disease hypertension leads to further functional damage to the kidney.

How does hypertension develop?
In most instances hypertension develops because of increased vascular constriction, in some diseases such as hyperthyroidism increased cardiac output may also be a contributing factor. One of the main regulating systems responsible for hypertension via vasoconstriction is the RAAS - Renin-Angiotensin-Aldosterone-System. It is also activated in heart and renal insufficiency. Increased adrenergic tone or responsiveness to catecholamines may play a role in some diseases as well. In rare instances blood viscosity can increase leading to hypertension. This can be the case with gammopathies (ehrlichiosis, multiple myeloma) or polycythemia.

Depending on the underlying disease further mechanisms contribute to hypertension.

Target organ damage and therapy

1) The Heart as a Target Organ
High blood pressure means elevated preload but more importantly elevated afterload for the heart. Consequently the heart has to react to pressure load and compensate for the additional work. The increased wall tension is sensed by mechanoreceptors which then initiate the processes by which a variety of signals such as release of growth factors, intermediate peptides (e.g. endothelin and angiotensin II) and alpha adrenergic stimulation leads to changes in the myocardium. Both myocardial hypertrophy and myocardial hyperplasia occurs. The result of both is more or less marked wall thickening (concentric left ventricular hypertrophy) and increase in heart muscle mass.

2) The kidney
In an animal with impaired kidney function, hypertension provokes a more rapid progression of the kidney disease, as it damages the nephrons and can contribute to proteinuria. This is especially true in patients with renal disease as they have lost autoregulation, in other words the ability of the kidney to control renal blood flow and GFR. This sets up a vicious cycle where kidney disease increases blood pressure which then increases loss of renal function. Renal failure undoubtedly is the leading cause of hypertension in small animal practice.
With loss of autoregulation there is also a concomitant inability to maintain renal perfusion when hypotension occurs. This is especially important in patients with renal disease that are anesthetized. Hypertension (even with normal renal function) generally leads to a decreased ability to compensate for hypotension, renal failure can occur.

3) The eyes
The eyes are commonly affected by hypertension and as a result retinal examination of all

animals with suspected hypertension is recommended. Given that hypertension is most common in older patients including a retinal exam as part of the general physical exam in older cats should be considered. Blood supply to the retina is via the choroid and the retinal arteries. Retinal arteries have autoregulatory capability, as blood pressure increases they vasoconstrict. This is not true of the choroidal vessels. With prolonged hypertension this can lead to areas of ischemia with eventual rupture and hemorrhage (hypertensive retinopathy). With hypertensive choroidpathy, severe bullous retinal detachments are more common. A hypertensive optic neuropathy can also be encountered.

4) The brain

Although hypertension can cause damage to the brain it is important to remember that brain disease can lead to systemic hypertension as well via the Cushing reflex. If intracranial pressure increases there is a concomitant increased in systemic blood pressure to help maintain blood flow to the brain. The brain is another organ that possesses the ability to autoregulate blood pressure and blood flow to the brain. With hypertension, cerebral vessels are constricted to prevent the hypertension from being passed down to smaller arteries which would be more susceptible to injury and therefore potentially begin to hemorrhage. Persistent hypertension leads to chronic changes to blood vessels with hypertrophy. This can lead to areas of ischemia or hemorrhage. Hemorrhage into the brain is irritating resulting in inflammation (meningitis, myelitis, encephalitis). In the brain, hypertension can also result in edema which can further exacerbate dysfunction.

Suggested reading: B Egner, A Carr, S Brown (eds). Essential Facts of Blood Pressure in Dogs and Cats. A Reference Guide. 2nd English Edition, BE VetVerlag, 2007.