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**Blood pressure: A critical factor**

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It has been stated that: ‘Systemic hypertension associated with kidney disease is a very real problem, and has been diagnosed in over 60% of cats with chronic renal disease. Hypertension can have multi-systemic effects if left untreated, including left ventricular hypertrophy and cardiac failure, retinal detachment and blindness, cerebrovascular hemorrhage, and progression of renal dysfunction.’ (Rosemary Henik, DVM, MS, DACVIM)

While this is true, let’s look at the applicability of measuring blood pressure, methods of assessment and the interpretation of results in clinical practice.

**Key points**

1. Systemic arterial pressure = pressure within the arteries and arterioles
2. Systolic pressure = pressure when the aortic valve is open and the heart is ejecting blood (120 mm Hg)
3. Diastolic pressure = pressure when the aortic valve is closed and the heart is resting (80 mm Hg)
4. Mean arterial pressure is closer to diastolic as the heart spends most of its time resting in diastole (90 mm Hg)
5. Excitation, stress and pain can transiently raise the values, but as there are mechanisms in place to limit the elevations, consistent systolic values exceeding 170 mm Hg (range 168-180) are accepted as reflecting hypertension.
6. To minimize the effects of ‘white coat syndrome’, allow the patient to acclimate to the environment for ten minutes before measuring blood pressure (BP). Measure BP before performing other evaluations (TPR, examination, etc). Take measurements over several minutes until a series of five values are obtained that vary by no more than 10 mm Hg.
7. A mean arterial pressure of >60 mmHg is necessary to maintain perfusion to the brain, heart and kidneys.
8. Doppler measurement of systolic pressure underestimates values obtained by direct invasive measurement of arterial pressure. This may be corrected by the equation: Doppler + 14 mm Hg = direct systolic pressure.

**Whose blood pressure should we measure?**

Non-invasive, indirect arterial measurements of blood pressure should be made in all anaesthetized, high-risk patients to detect and manage hypotension. This technique should be used widely as a screening method for the pre-clinical detection of hypertension in patients with renal disease, hyperthyroidism, ocular changes consistent with hypertension, a cardiac murmur, left ventricular hypertrophy, neurological dysfunction and all cats over eight years of age.

**How to measure**

In an anaesthetized patient, Doppler or oscillometric methods are reliable. In conscious cats, oscillometric measurements using devices reported in published papers do not correlate with radiotelemetrically obtained values; Doppler, PetMap or MEMO methodology should be used. Use of forelimb or hindlimb is equally valid. It is very important to use the appropriate cuff size: it must measure 40% of the circumference of the limb at the placement site. Shaving helps achieve good probe contact but is not essential; I do not recommend shaving a conscious patient as this raises their fear level. Wetting the fur in the metatarsal or metacarpal area with alcohol is adequate. It is important to avoid alcohol touching the probe; use gel generously. Record the limb and cuff size used, for future comparisons, in the medical record.

**Causes of artificially high values**

Fear, noise and the sensation of the cuff inflating and deflating can contribute. Gentle inflation and deflation of the cuff minimize the strangeness of the experience for the patient. Use a stereo headset to help reduce noise for the cat as well as facilitate the operator hearing the signal. Be quiet, take the readings on the client’s lap whenever possible. Using a cuff that is too small will also cause artificially high BP readings.

**Other methods of measurement**

- Oscillometric measurement using Critikon™, Dinamap,Datascope Passport is not reliable in conscious cats and small dogs (<25 lbs). These are appropriate for monitoring anaesthetized patients.
- MEMO Diagnostic unit is an excellent oscillometric unit that is accurate in cats.
- Central Venous Pressure (CVP) measurement: CVP while easy and cheap is an under-utilized technique. It is the most accurate, but is invasive and is not an outpatient procedure. Arterial BP reflects right atrial pressure associated with volume changes, and assesses adequacy of perfusion of vital tissues.

**Causes of hypertension**

Chronic renal insufficiency and hyperthyroidism are indisputably the most common disease conditions associated with hypertension in older cats. The reported
percentage of hypertensive patients with these two underlying causes varies quite widely (CRI 41-92%; hyperthyroidism 8 - 97%). Approximately 60% of cats with CRI and 40-60% of cats with hyperthyroidism are hypertensive. It is logical to recommend that blood pressure monitoring be part of the examination of any feline patient with renal disease, hyperthyroidism, ocular changes reflective of hypertension, a cardiac murmur or echocardiographic changes shown to be associated with increased afterload, epistaxis, or neurological dysfunction as well as all cats over 8 years of age. Less common causes of hypertension include excessive dietary sodium, pheochromocytoma and as an uncommon adverse effect in erythropoeitin therapy. Whether idiopathic or ‘essential’ hypertension occurs in cats is unknown. Unlike humans, diabetes mellitus does not appear to predispose cats to hypertension.

An increase in blood pressure has also been shown to occur in healthy cats associated with increasing age.

Pathogenesis of hypertension

When hypertension occurs in feline chronic renal disease (CRD), the speculated mechanism of action involves the renin-angiotensin-aldosterone (RAA) axis. One study showed a lack of difference in plasma renin activity and angiotensin levels between cats with CRD and normal cats but reported a significantly higher aldosterone level in hypertensive CRD cats. Another, which compared a small number of Persian cats with polycystic kidney disease (PKD) to normal cats, cites a higher aldosterone:renin ratio in half of the PKD cats, although the cats with PKD had only slightly higher BP levels than normal cats. A different paper studying PKD patients showed normotension in both PKD and normal cats. This implies, albeit in a very small number of patients, that PKD does not result in hypertension, a situation that is different from other forms of chronic renal disease.

In hyperthyroid cats, the mechanism of hypertension appears to be due to high cardiac output. In fact, unless hyperthyroidism is accompanied by chronic renal insufficiency, the degree of hypertension is mild. Therapy directed towards controlling hyperthyroidism is usually all that is required to control hypertension in these cats. If inadequate, then the hyperdynamic state should be addressed using a beta-blocker to dampen the tachycardia induced by thyroid hormones.

When renal insufficiency is associated with hypertension, reduction of arteriolar constriction may be achieved using the calcium channel blocker amlodipine. The most obvious clinical effects of hypertension are those affecting the ocular structures: retinal hemorrhage, hyphema and retinal detachment resulting in obvious changes in the appearance of the cat’s eye (persistent papillary dilation or hyphema) or an acute onset of blindness. Hypertension affects other tissues, which also have a rich arteriolar supply, cardiovascular and renal structures.

Persistent hypertension results in an increased afterload for the heart and concentric hypertrophy. If hypertrophy is more than mild, the trophic effect of hyperthyroidism should be suspected. The effects of systemic hypertension on cardiovascular parameters have been reported as mild left ventricular hypertrophy, subtle asymmetrical hypertrophy with thicker interventricular septum, and distal aortic root measurements that were greater in hypertensive cats compared to age-matched, older healthy cats.

The effects of hypertension on the feline kidneys appear to be somewhat different than those recognized in dogs and humans. The feline pre-glomerular vessels are more resistant to the detrimental effects of hypertension and are able to compensate better than in those other species. While albuminuria (but not increases in urine protein:creatinine ratios) correlates with hypertension in experimentally induced renal failure, this effect has not been documented in hypertensive cats to date.

Chronic renal insufficiency as a cause of hypertension is being studied intensively. Cats with CRI lose the normal auto regulatory capacity of the glomerular arterioles. This may cause systemic hypertension (50-60% of cats with CRI?) and also promote progression of renal insufficiency through glomerular injury. Treatment of hypertension should be considered in cats whose systolic BP is consistently >170 mm Hg. Amlodipine is the most efficacious agent (0.625 mg/cat PO q24h, titrate up as needed) as it has a direct effect on the calcium channels of the peripheral vasculature. Angiotensin-converting enzyme inhibitors (ACEI) will reduce vasconstriction of efferent arterioles, increasing overall renal flow, reduce glomerular hypertension (beneficial in the case of renal protein loss); but they can concurrently reduce driving force for GFR by which we may create, in essence, a pre-renal azotemia. If ACEI are used, monitor BUN and creatinine after 1 or 2 doses and respond accordingly. Beta-blockers reduce renin secretion, which will have the same net effect. Combination therapy using amloidipine along with an ACEI may be advantageous by reducing BP via the systemic vasodilation (preglomerular) while also dilating efferent arterioles (post-glomerular), thereby balancing the effects on GFR and on glomerular capillary pressure.

Benazepril (an ACEI) is currently undergoing a large, multi-institutional study to assess its effects on CRI in cats. Interim results for this study (presented WSAVA 2001, ACVIM 2002) show that using benazepril or placebo made no significant difference in survival time for CRI cats. For cats with urinary protein loss, benazepril treated cats had longer survival times and better appetite than...
placebo treated urinary protein losing cats. Benazepril was well tolerated by all cats. Subsequent studies have not shown compelling reasons to use this agent routinely in CRI.

When to treat
Normal values are ~120 mm Hg systolic, but due to fear-induced hypertension, reassess when the values are consistently above 170 mmHg.

How to treat
1) Identify and treat the underlying cause
2) Medical management? ONLY if you can and will monitor the BP. Classes of drugs used in the treatment of hypertension include diuretics, ACE inhibitors, beta-blockers, calcium channel blockers, and vasodilators. The drug chosen must depend on the underlying cause as well as the hydration status, renal and cardiac function and response to therapy. From reported studies it can be concluded that amlodipine is safe and effective when used long-term at a dose of 0.625 mg/cat/day (or 1.25 mg/cat/day to effect in cats weighing more than 5 kg) at the average dose of 0.18 +/- 0.03 mg/kg PO q24h. Other agents (propranolol, enalapril, captopril, furosemide) had a high incidence of side effects and were not reliably effective in reducing blood pressure.
3) Sodium restriction in diet?
4) Weight reduction if obese or overweight
5) MONITOR! after 5-7 days and adjust dose if necessary, check again in 2-3 weeks ...then every two to three months. Monitoring is essential, as over treatment, causing hypotension could cause acute renal failure or cardiac collapse and coma. Rechecks should include assessment of heart rate and function, hydration, body weight, general condition and quality of life, renal values, urinalysis, ophthalmic and neurologic status.

Causes of hypotension
Anaesthesia commonly causes hypotension. Mean arterial BP must be above 60 mm Hg (approx 80-90 systolic BP) to provide adequate perfusion to the brain, heart and kidneys. If this is not achieved, organ dysfunction will result. Monitoring the blood pressure of anaesthetized patients along with other parameters allows for appropriate and timely adjustment of anaesthetic depth, fluid support and the use of supportive drugs. One paper showed a dramatic decrease in cardiac parameters along with blood pressure when 2.0 minimum alveolar concentration (MAC) isofluorane was compared to 1.30 MAC in cats. Despite assisted ventilation, cardiac indices remained impaired. Other causes of hypotension include hypoperfusion due to pain, hypovolemia, cardiac arrhythmias, heart failure, blood loss, sepsis, DIC. Artificially low values can arise from using a cuff that is too large and is occluding the artery, taping the cuff too snugly.

Treatment of hypotension
Treat the underlying cause (provide analgesia, reduce the inhalant anaesthetic flow, use appropriate antibiotics, etc.) and support hypovolemia with oxygen, fluids, dopamine or dobutamine. Refractory hypotension, with or without cardiovascular collapse, development of respiratory disease, or disseminated intravascular coagulation (DIC) are all associated with a poor prognosis in patients with septic peritonitis, thus recognition, treatment and monitoring of hypotension is of critical importance in caring for these patients.

References
References available on request.