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Hypertension in Cats and Dogs

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PREVALENCE AND IMPORTANCE OF SYSTEMIC HYPERTENSION

"Systemic hypertension" (HT) refers to the persistent elevation of systemic blood pressure. Chronic elevation of systemic blood pressure results in damage to multiple end-organ systems; some of this damage may be clinically obvious but some may be insidious. Blood pressure is discussed in terms of systolic and diastolic values. In people, combined HT (systolic and diastolic values elevated), isolated systolic and isolated diastolic HT have differing morbidity and mortality rates. Little information about the prevalence and importance of isolated systolic or diastolic HT in dogs and cats is available[1-3], but it is clear that HT occurs in these species and is a cause of significant morbidity in some animals.

Systemic hypertension is typically classified as primary ("essential") HT or secondary HT. Some veterinary clinicians have attempted to distinguish essential HT from idiopathic HT (i.e., systemic HT in the absence of overt, clinically apparent causal disease). Use of the term "idiopathic" acknowledges that there may be a causal disease (e.g., renal disease) that is responsible for the HT but that the causal disease is in a pre-clinical phase[4,5]. In cases where the underlying disease is rare (e.g., pheochromocytoma), discovery of the cause of the HT is dependent on the thoroughness of the diagnostic testing.

Sporadic cases of apparent essential HT in dogs have been published[6-9] but the majority of hypertensive dogs and cats have developed HT as a complication of another systemic disease. The prevalence of HT varies with the population studied.

CATS

The prevalence of HT in the general feline population is unknown but HT is common in some subpopulations. Chronic renal failure is the disease most commonly associated with HT in cats; HT has been documented in 20–65% of cats with this condition[4,10,11]. Up to 86% of hyperthyroid cats had blood pressures above the normal range of values in one early clinical study[11], but more recent anecdotal evidence suggest that the prevalence rate of HT in hyperthyroid cats today is much lower (~7–10%[12]), perhaps due to increased screening and earlier detection of hyperthyroidism (i.e., before hypertensive complications develop). Detection of the true prevalence of HT in thyrotoxic cats is also complicated by the presence of concurrent renal insufficiency in many of these cats. Advanced age alone does not appear to be a significant risk factor for feline HT[11,13] but the risk of chronic renal disease or hyperthyroidism is higher in older cats. Breed and sex do not appear to be significant risk factors for HT in cats.

DOGS

The prevalence of HT in the general canine population appears to be low[14,15], but as is the situation in cats, prevalence of HT is much higher in certain populations. Numerous studies support chronic renal disease (especially glomerular disease), hyperadrenocorticism (HAC) and diabetes mellitus (DM) as the most common diseases associated with HT in dogs. Most studies report the prevalence of HT as 60–90% in dogs with chronic renal failure[1,6,16,17]. Similar prevalence values are reported for dogs with HAC (70–80%)[1,18]. Systemic HT is documented less frequently in dogs with DM (reported prevalence of HT: 25–45%)[1,2]. Less common conditions associated with HT in dogs include pheochromocytoma, acromegaly, primary hyperaldosteronism and use of hypertensive medications such as phenylpropanolamine. Although small increases in blood pressure have been documented with increasing age in dogs in one study[15], other studies found age and blood pressure were not significantly correlated[3,19]. Healthy sight hounds (e.g., greyhounds, deerhounds) have a higher normal range of blood pressures; normal resting blood pressure values may be up to 15 mmHg higher than other breeds of similar

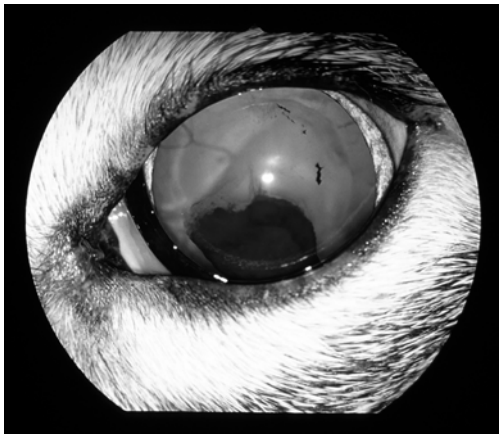
size[15,20]. Male dogs tend to have slightly higher blood pressure readings than females but the difference is unlikely to be clinically significant[15].

Development of HT in cats and dogs is almost always associated with the concurrent presence of one or more identifiable underlying diseases. The search for an underlying condition responsible for the development of HT is an essential component of the diagnosis of HT in cats and dogs.

SYSTEMIC EFFECTS OF SYSTEMIC HYPERTENSION

Clinical signs of HT are frequently not apparent until catastrophic damage has occurred (Figure 1).

Figure 1.
External ophthalmic examination of a cat with severe hyphema and retinal detachment secondary to systemic hypertension.



Earlier in the course of HT, subtle clinical signs of elevated blood pressure may be masked by the clinical signs of the underlying condition or the pet's owner reports no clinical signs. In many cases, the possibility of HT is investigated based on the suspicions of the clinician when suggestive clinical findings are present or a disease associated with HT is suspected or diagnosed. Several organ systems are recognized as "target organ systems" typically sustaining damage in the presence of chronic HT (Table 1, Figure 2).

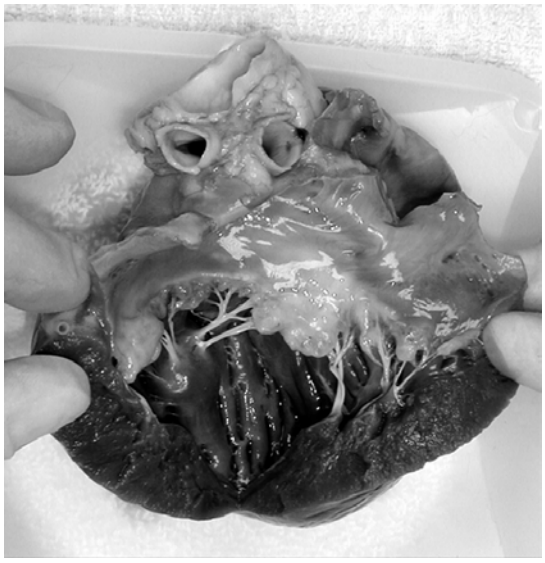
Table 1. End-Organ Effects of Hypertension[41-44]

Organ or System	Effect of HT	Effects More Likely	Comments
Kidneys	▪ Enhanced rate of decline of renal function ▪ Promotion of glomerulosclerosis ▪ Nephron loss ▪ Enhancement of proteinuria	If SBP > 160 mmHg	▪ Often difficult to determine whether renal disease is a cause or effect of HT in clinical patients
Eyes	▪ Exudative retinal detachment ▪ Retinal or vitreal hemorrhage, hyphema ▪ Retinal edema or papilledema ▪ Retinal vessel tortuosity	If SBP > 180 mmHg	▪ Referred to as "hypertensive retinopathy/choroidopathy"
Brain	▪ Disruption of blood flow autoregulation	If SBP > 180 mmHg acutely	▪ Clinical signs result from ischemic stroke and/or

	▪ Fibrinoid arteriolar necrosis ▪ Thrombosis with subsequent hypoxic damage ▪ Cerebral swelling/edema		hemorrhagic damage
Heart	▪ Concentric LV hypertrophy leads to increased wall stress and promotes ischemia ▪ Secondary murmurs/gallop rhythms	Unknown	▪ Pulse pressure or systolic pressure most reliable indicator of CV risk (human) ▪ In cats, cardiac changes may resolve with successful antihypertensive therapy

HT: hypertension, SBP: systolic blood pressure, LV: left ventricular, CV: cardiovascular

Figure 2.
Post-mortem cardiac specimen from a dog with left ventricular hypertrophy secondary to chronic systemic hypertension due to protein-losing glomerulopathy. Chronic valvular changes due to endocardiosis are also present.



DIAGNOSIS OF SYSTEMIC HYPERTENSION

Patient Selection

Multiple clinical studies of different methods of measuring blood pressure in conscious animals indicate that the most commonly-used non-invasive techniques yield results that are precise (i.e., repeatable) but of variable accuracy[15,19,21-23]. Blood pressure values exceeding normal ranges for the species may be viewed differently in the two populations of patients most likely to have blood pressure measured: patients screened as part of a yearly "wellness" exam, and patients presented with clinical signs suggestive of or systemic diseases known to be associated with HT.

"Screening" Examinations on Healthy Patients

Routine blood pressure measurement in asymptomatic patients that do not have a disease associated with HT is controversial. Some authors have suggested that individual dogs have "characteristic" blood pressures[22]; routine evaluation on every patient would establish a "normal" blood pressure for that animal. Theoretically, a significant increase in blood pressure from one measurement period to the next would trigger a more detailed

diagnostic work-up to search for a cause. Tests that are highly sensitive (i.e., high probability that an affected patient will have an abnormal test result) are usually recommended for screening a population of low prevalence (in this case, a healthy clinical population). Tests of high sensitivity carry a higher risk of false positive findings, so most clinicians recommend that healthy patients with apparently elevated blood pressure have this finding confirmed on multiple test occasions before proceeding with a diagnostic work-up or therapy.

Diagnostic Blood Pressure Measurements in Patients at Risk for Hypertension

Patients with clinical signs of HT or a disease that increases the risk of HT should have their blood pressure measured at the time of initial diagnosis. Risk factors for canine and feline hypertension differ from risk factors for human hypertension. Ocular hemorrhage, retinal hemorrhage or detachment, neurologic signs such as depression, obtundation or seizures, the presence of renal disease or findings of unexplained left ventricular hypertrophy should result in blood pressure evaluation in both species. In cats, a diagnosis of hyperthyroidism should include blood pressure evaluation. Screening blood pressure measurements in any cat with left ventricular hypertrophy is required before a diagnosis of idiopathic hypertrophic cardiomyopathy can be made with confidence. In dogs, in addition to the findings listed above for both species, a diagnosis of HAC, DM, acromegaly, pheochromocytoma or primary hyperaldosteronism should result in blood pressure evaluation. In all cases, evidence of ocular damage typical of HT or neurologic manifestations of HT is considered an emergency and treated as such with a goal of rapid reduction of blood pressure *prior* to pursuit of further diagnostics. Measurement of elevated blood pressure on one occasion is diagnostic for HT when clinical signs are present[24].

METHODS OF MEASURING BLOOD PRESSURE

Invasive Blood Pressure Measurement

Invasive blood pressure measurement involves arterial puncture (for acute measurement) or arterial cannulation with use of a blood pressure monitor providing pressure tracings[19]. Invasive blood pressure measurement provides a direct reflection of true intra-arterial pressure, but can be cumbersome for clinical use. With rare exception, direct blood pressure monitoring is used for anesthetic or acute critical care monitoring or in research situations.

Oscillometric Blood Pressure Measurement

Oscillometric blood pressure measurement is a common and useful technique that relies on detection of arterial pulsation through the use of an automatically inflating and deflating cuff that is wrapped around a distal limb or tail[19,25,26]. Oscillometric techniques have been shown to accurately track trends in blood pressure over time in conscious dogs[22], but individual measurements obtained oscillometrically may underestimate direct systolic blood pressure measurements by up to 5–20 mmHg[19,23,27]. Oscillometric diastolic pressure results in conscious dogs are poorly correlated to invasively measured diastolic pressure[19,23].

Doppler methods of Blood Pressure Measurement

Doppler blood pressure measurement using piezoelectric crystal detection of arterial pulsation with a hand-inflated cuff is a commonly-used and useful method of blood pressure measurement[19], and is the preferred method in cats[13]. Accuracy is dependent on user experience and meticulous attention to technique, and diastolic pressures can be difficult to discern in some animals.

Photoplethysmographic Blood Pressure Measurement

The photoplethysmographic method of blood pressure measurement estimates blood pressure based on attenuation of infrared radiation as a method of estimating arterial volume[28]. Although this method is commonly used for people, studies of its accuracy in conscious dogs and cats are not available.

General Measurement Recommendations

Noninvasive blood pressure measurement is preferred in most clinical situations. For acute blood pressure measurement in conscious animals, the current recommendations of the American College of Veterinary Medicine Hypertension Consensus Panel[12] include the following:

- Standardize the procedure in the clinic—blood pressure should be measured the same way in every patient
  - Doppler is currently the recommended method for cats, oscillometric or Doppler methods can be used for dogs
  - Cuff size: ~ 40% of circumference of limb or tail
  - Position cuff level with right atrium for readings
  - Discard first reading, then use mean of 3–5 measurements with 30 seconds to one minute between readings
- Patient considerations
  - Blood pressure measurements should be obtained prior to any other patient manipulation[29]
  - Client presence to calm the animal can be helpful to calm the patient
  - The patient should be conscious, calm and in sternal or lateral recumbency
  - A few minutes of acclimation to the position is recommended

INTERPRETATION OF RESULTS

Comparable normal values generated using direct and indirect methods in cats[11,13,29-33] and dogs[17,19,25,34,35] are available. Some authors have suggested that blood pressures greater than two standard deviations from the mean normal values should be considered diagnostic for hypertension[3,13], but relatively small increases in renal blood pressure may have detrimental effects on end organ function (e.g., progressive glomerular disease) and many clinicians find these guidelines too conservative. Current recommendations for both species suggest that systolic blood pressure >160 mmHg or diastolic blood pressure >95 mmHg measured by any method are reasonable values at which concern is warranted[12,24]. General guidelines for interpretation of systolic blood pressure (SBP, mmHg) are expressed in terms of risk of end-organ damage and are associated with recommendations for further action[12]:

- **SBP < 150/95:** minimal risk—no further diagnostics indicated
- **SBP 150/95 → 160/100:** low risk
  - Confirm by repeated measurement if no clinical signs or compatible disease
  - Search for underlying disease
  - Monitor over time if no disease found
- **SBP 160/100 → 180/120:** moderate risk
  - Careful search for underlying disease
  - Therapy warranted if clinical signs are present
  - Consider therapy if no clinical signs but rapid resolution of underlying disease is not anticipated
  - Monitor over time if no disease found
- **SBP > 180/120:** high risk
  - If ocular or neurologic signs are present → treat first, then proceed with diagnostic work-up for underlying disease
  - If high risk associated disease is present → therapy is indicated
  - If no clinical signs and no associated disease → recheck frequently: if consistently abnormal, consider therapeutic trial of antihypertensive medication

TREATMENT OF SYSTEMIC HYPERTENSION

Despite the large number of drugs available to treat hypertension in people, therapy of systemic hypertension in dogs[36] and cats[37-39] is still under-researched in the clinical population. Recommendations are frequently based on anecdotal information and theoretical concerns, especially in dogs. As controlled clinical trials accumulate, better information regarding rational choices of antihypertensive medications will guide clinical decision-making.

Emergency Therapy of Hypertension

Emergency therapy of HT in dogs in cats is primarily guided by the level of concern generated by clinical signs in the patient. Rapid oral (e.g., hydralazine) or intravenous therapy with vasodilating agents is warranted (Table 2). Nitroprusside or acepromazine can be used intravenously for rapid reduction of blood pressure; the short half-life of nitroprusside makes it easy to titrate to effect (i.e., hypotension can be quickly rectified by decreasing the infusion rate). Acepromazine is available in most clinics and can be used in an emergency situation, but the longer lasting effects of the drug make it harder to titrate to effect. Higher doses of acepromazine may result in over-sedation, hypotension and compromise of renal function, especially in geriatric patients.

Table 2. Medications used to treat systemic hypertension in cats and dogs*

Medication	Dose	Comment
Acepromazine	D/C: 0.03–0.1 mg/kg IV	▪ Start with low dose and use to effect. ▪ Use with extreme caution in geriatric patients and Boxers. ▪ Monitor heart rate and blood pressure closely
Atenolol	D: 0.25–1 mg/kg PO q12hr C: 3 mg/kg PO q12hr (or 6.25–12.5 mg/cat PO q12hr)	▪ Most useful in conjunction with another antihypertensive agent ▪ May be particularly useful in cases of hyperthyroidism or pheochromocytoma ▪ Monitor for bradycardia at higher doses
Propranolol	D: 0.2–1 mg/kg PO q8hr C: 0.4–1.2 mg/kg PO q8hr	▪ Titrate dose to effect, especially in combination with other antihypertensive medications ▪ May be particularly useful in cases of hyperthyroidism or pheochromocytoma ▪ Monitor for bradycardia at higher doses
Nitroprusside	D/C: 1–5 µg/kg/min IV as constant rate infusion	▪ Use only if constant arterial pressure monitoring available ▪ Titrate to effect ▪ Monitor closely for hypotension ▪ Protect medication from light
Hydralazine	D: 0.5 mg/kg PO (initial dose), 0.5–2.0 mg/kg PO q12hr C: 2.5 mg/cat PO q12–24hr	▪ Titrate to effect ▪ Monitor for hypotension
Amlodipine	D: 0.5–1 mg/kg PO q24hr C: 0.625–1.25 mg/cat q24hr	▪ Risk of adverse effects increases with doses higher than recommended range
Enalapril	D: 0.5 mg/kg PO q12–24hr C: 0.25–0.5 mg/kg PO q12–24hr	▪ Monitor renal function

Medication	Dose	Comment
Benazepril	D/C: 0.25–0.5 mg/kg PO q24hr	▪ Monitor renal function

*underlying diseases should be treated simultaneously in most cases

Chronic Therapy of Hypertension

A diet moderately restricted in sodium content is a reasonable recommendation for patients with HT and may assist in the control of blood pressure. Diuretics are not currently recommended as monotherapy for therapy of HT. Some patients may respond to discontinuation of other medications that tend to raise blood pressure (e.g., phenylpropanolamine). In patients receiving fluid therapy, reductions in the amount of fluid administered may allow for easier management of HT with vasodilating medications, but renal function should be monitored closely.

Chronic Therapy of Hypertension in Cats

Amlodipine besylate (a long-acting dihydropyridine calcium antagonist) is the current antihypertensive medication of choice for cats[12,38-40]. Beta-blocking agents such as atenolol or propranolol may be useful adjunctive therapy, especially in hyperthyroid cats, but beta-blocking agents are less successful when administered alone for management of HT. Angiotensin-converting enzyme inhibitors (e.g., enalapril or benazepril) have proven to be variable in their efficacy in controlling hypertension in cats but may have other beneficial effects (e.g., aldosterone antagonism) in these patients[37]. Other oral agents such as hydralazine may be useful in some situations but have not undergone wide clinical study.

Chronic Therapy of Hypertension in Dogs

Angiotensin-converting inhibitors are useful for therapy of HT related to protein-losing renal diseases in dogs, decreasing both blood pressure and renal protein loss[36]. The antihypertensive effect of these medications in dogs with HT secondary to other diseases appears to be variable, but ACEIs are usually well tolerated and can be initiated as a therapeutic trial in non-emergency HT patients. If response to ACEI alone is inadequate, other drugs may be added or substituted. Amlodipine besylate is commonly used for control of HT in dogs but higher doses may be needed to obtain clinical effects as compared to cats. Adverse effects may be seen at higher doses and caution is advised when increasing amlodipine doses for blood pressure control in dogs. When standard doses of amlodipine are not controlling blood pressure sufficiently, addition of an ACEI or beta-blocking agent may be helpful.

Diagnosis and therapy of HT in dogs and cats can be challenging. Careful assessment of all body systems is merited whenever HT is diagnosed. Conversely, the possibility of HT should be investigated whenever suspicious clinical signs or diseases known to be associated with HT are diagnosed in a clinical patient.

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