Hypertension in Dogs and Cats

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ABSTRACT:
The veterinary community has been slow to embrace the practice of routine screening for hypertension despite the realization that persistent elevations in blood pressure can have serious and even life-threatening consequences. This reluctance has been attributable to the absence of a standard definition of hypertension as well as confusion about which indirect blood pressure measurement techniques are accurate. There has also been little consensus on how to determine which patients are at risk of developing hypertension and how to develop an effective treatment protocol. This article presents a rational approach to identifying patients at risk, methods of accurately measuring blood pressure in the clinical setting, and recommendations for treatment.

B ecause of its silent nature, hypertension is possibly one of the most underdiagnosed systemic illnesses that affect companion animals. Often, patients with hypertension are not presented for evaluation until they suffer retinal detachments and acute blindness. Nevertheless, many veterinarians have been reluctant to introduce testing, diagnosis, and treatment of hypertension into clinical practice because of uncertainty involving the definition of hypertension, an inability to determine the population at risk, and questions involving the validity of indirect blood pressure measurement. In addition, protocols for treating hypertension in cats and dogs have historically not been well defined.

PATHOPHYSIOLOGY
Blood pressure is ultimately a function of cardiac output and systemic peripheral resistance (Figure 1), both of which are directly and indirectly affected by the complex interaction among the autonomic nervous system, the renin-angiotensin system, and endothelial signaling mechanisms. For example, activation of the renin-angiotensin system of the kidneys has a direct effect on the vasculature, causing increased systemic peripheral resistance and indirectly increasing cardiac output by affecting stroke volume. Therefore, regulation of blood pressure and development of hypertension are complicated multifactorial processes that involve the heart, autonomic nervous system, endothelial signaling intercellular mechanisms, vasculature, and kidneys.

ETIOLOGY
Patients with elevated blood pressure are clinically classified as having primary (essential) or secondary hypertension:

- Primary hypertension is the result of an imbalance in the relationship between cardiac output and systemic vascular resistance, although the exact cause is not known.
- Secondary hypertension is elevated blood pressure that occurs because of systemic disease or medication.

Although primary hypertension accounts for more than 90% of all cases of hypertension in
humans, secondary hypertension accounts for almost all identified cases of elevated blood pressure in veterinary patients. This distinction is important because it allows definition of patients at risk of developing elevated blood pressure on the basis of the diagnosis of a predisposing illness.

Patients with the following conditions or treatments have a significant risk of developing hypertension and warrant blood pressure evaluation (Table 1):

- Hyperadrenocorticism\textsuperscript{3,4}
- Renal disease\textsuperscript{4–7}
- Thyroid disease\textsuperscript{4,5,8}
- Diabetes mellitus\textsuperscript{4,9,10}
- Hepatic disease\textsuperscript{4}
- Use of drugs: erythropoietin,\textsuperscript{11} steroids\textsuperscript{3}
- Uncommon causes: polycythemia, pheochromocytoma,\textsuperscript{12} hyperaldosteronism,\textsuperscript{12} chronic anemia

The exact definition of normal blood pressure in cats and dogs has been the subject of significant research, debate, and confusion because previous studies used systolic blood pressures ranging from 141 to 185 mm Hg to define hypertension.\textsuperscript{6,13–15} There has been even less consensus about normal values for diastolic blood pressure. Nevertheless, it is now believed that blood pressure values higher than 150/95 mm Hg on three separate
visits in a patient that demonstrates no clinical signs directly attributable to the pressure elevation is compatible with hypertension, as is a single reading higher than 150/95 mm Hg in a symptomatic patient. 

In cases of mild to moderate elevations in systolic blood pressure, physical examination findings and laboratory data are often consistent with the underlying disease. For example, hyperadrenocorticism in dogs often leads to polyuria and polydipsia, alopecia, muscle wasting, pendulous abdomen, and hepatomegaly. Elevations in liver enzyme values (i.e., alkaline phosphatase, alanine aminotransferase), hypercholesterolemia, stress leukogram, and isosthenuria are common laboratory findings. However, often no clinical signs are directly attributable to the elevated blood pressure.

**CONSEQUENCES**

As elevations in blood pressure become more pronounced, clinical signs directly attributable to hypertension may become apparent. The first signs of hypertension often manifest in the eyes, heart, brain, and kidneys. Hypertensive retinopathy and choroidopathy are common sequelae to unregulated hypertension. Hypertensive retinopathy is characterized by retinal edema, tortuous vessels, and hemorrhage. Choroidal arteriolar constriction in response to systemic hypertension results in ischemic necrosis of the choroidal capillaries and the associated retinal pigmented epithelium. Choroidopathy manifests clinically as retinal detachment (Figure 2). As previously mentioned, a loss of vision, rather than signs related to an underlying disease, often prompts the office visit.

A cardiac murmur, arrhythmia, and gallop rhythm can develop as afterload (pressure against which the heart must pump) increases with blood pressure. Cardiac changes detectable by echocardiography in cats include thickening of the interventricular septum and left ventricular free wall, reduced diastolic ventricular internal diameter, and dilation of the proximal aorta; dogs are more likely to demonstrate left ventricular hypertrophy and secondary mitral valve insufficiency. Hypertensive encephalopathy, as evidenced by head tilt, ataxia, depression, disorientation, and seizures, is caused by a systolic blood pressure that is higher than can be accommodated by the cerebral vasculature autoregulatory mechanisms. This condition is associated with a poor prognosis.

The initial response of the kidneys to elevated systemic blood pressure is increased renal excretion of sodium and water. This condition, referred to as pressure natriuresis, initially acts to reduce blood volume and thereby helps control systemic hypertension. Eventually, elevations in renal arterial blood pressure lead to renal tubular degeneration and interstitial fibrosis, whereas glomerular hypertension results in glomerulosclerosis, glomerular atrophy, and proliferative glomerulitis. Together, these changes are associated with glomerular hyperfiltration and progression of glomerular and tubular damage. The end result is worsening of the hypertension and eventual renal failure.

**MEASURING BLOOD PRESSURE**

The most accurate way to measure blood pressure is by catheterizing a suitable artery (e.g., femoral) and using a
When possible, the owner should be present because this is likely to have a calming effect. Several sequential blood pressure measurements should be taken. The first attempt can be used to allow the animal to become accustomed to the procedure, and the following pressure measurements should be compared with each other to verify accuracy. If there are great variances in the individual readings, the series should be repeated. Although it may be ideal to measure the blood pressure of all patients, this is not practical in most clinical settings. Therefore, it is recommended that efforts focus on patients with known predisposing clinical conditions or patients receiving drugs known to increase blood pressure.

**Doppler Flow Detector**

Doppler flow detection is a common method of measuring blood pressure in the clinical setting. Doppler ultrasound machines (Figure 3) work by emitting ultrasound waves and then “listening” for the waves to be reflected back. If there is movement, such as blood cells through an artery, the frequency of the reflected ultrasound wave is shifted (the Doppler effect), and this change in frequency is amplified and made audible. The change in frequency is heard as the characteristic “swoosh” sound when the transducer is placed over an artery. The only materials needed other than the Doppler flow detector is a sphygmomanometer, selection of cuffs of different sizes, and ultrasound gel. Although measuring systolic blood pressure is easy, measuring diastolic (and therefore mean arterial) pressure is technically more challenging.

Any leg or distal artery can be used, but it is best to always measure blood pressure on the same leg to develop a consistent technique. A single elevated blood pressure value in an otherwise asymptomatic animal must be interpreted with caution, especially if that patient does not have an underlying disease compatible with hypertension.

Blood pressure should always be evaluated in a quiet area away from other animals and distractions, after the patient has been allowed to acclimate. When possible, the owner should be present because this is likely to have a calming effect. Several sequential blood pressure measurements should be taken. The first attempt can be used to allow the animal to become accustomed to the procedure, and the following pressure measurements should be compared with each other to verify accuracy. If there are great variances in the individual readings, the series should be repeated. Although it may be ideal to measure the blood pressure of all patients, this is not practical in most clinical settings. Therefore, it is recommended that efforts focus on patients with known predisposing clinical conditions or patients receiving drugs known to increase blood pressure.
Once the clear and consistent sound of pulsating blood can be heard via the Doppler detector, the pressure can be measured. The cuff should be inflated using the sphygmomanometer until blood flow can no longer be heard.\textsuperscript{26} It is best to inflate the cuff 20 to 30 mm Hg past the point at which blood flow was last detected.\textsuperscript{25,26} The point at which flow sounds return while the pressure in the cuff is slowly released is the systolic blood pressure.\textsuperscript{26} A second sound can often be heard as the cuff pressure continues to be slowly released; this sound represents the diastolic blood pressure.\textsuperscript{26} This process should be repeated three to five times to ensure an accurate reading.

### Oscillometry

An oscillometric blood pressure device (Figure 4) works by inflating a cuff around an extremity until arterial blood flow stops; then, while slowly reducing the inflation, the unit monitors pulse waves generated by arterial pulsations.\textsuperscript{21,24} These devices are conveniently automated, measure systolic and diastolic pressure as well as mean arterial pressure (MAP), and are reasonably accurate for medium-sized and large dogs.\textsuperscript{3,21} However, these devices should not be used in small dogs or cats because they consistently underestimate blood pressure in these animals.\textsuperscript{3,21}

### Photoplethysmography

Photoplethysmography is a technique used in human medicine that relies on infrared light transmission to measure arterial volume on a digit. Although its use is limited to cats and small dogs that weigh approximately 22 lb (10 kg) or less, this technique can provide continuous blood pressure measurements.\textsuperscript{21} These devices are not widely available for veterinary use except in some teaching hospitals and research settings.\textsuperscript{3,21}

### TREATMENT

An important factor in treating hypertension is the ability to distinguish between hypertensive urgency and hypertensive emergency. An urgency exists when an animal presents with elevated blood pressure but does not demonstrate clinical signs directly attributed to the elevation. In these animals, it is imperative that blood pressure be lowered, but it should be done in a gradual and controlled fashion. Cerebral blood flow remains constant for a wide range of MAPs because of autoregulatory mechanisms.\textsuperscript{27,28} Above a certain MAP, cerebral blood flow and pressure increase.\textsuperscript{27,28} However, in patients that experience a long-term, gradual elevation in blood pressure, changes in the walls of the cerebral vasculature allow them to withstand abnormally high MAPs with no deleterious effects.\textsuperscript{27,28} Because of

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**Figure 4.** Oscillometric blood pressure devices are suitable only for medium-sized and large dogs.

**Figure 5.** Because of autoregulatory mechanisms, cerebral blood flow remains constant for a wide range of MAPs. The solid line represents a normotensive animal; the dotted line represents a chronically hypertensive animal.

Although hypertension is often clinically silent, signs directly attributable to it include hypertensive retinopathy, certain cardiac changes, renal failure, and hypertensive encephalopathy.
changes in their vasculature, these patients can have decreased cerebral perfusion and necrosis at blood pressures that would be optimal for normotensive patients.\(^\text{27,28}\) Therefore, blood pressure should be changed slowly and gradually.\(^\text{27–29}\)

A hypertensive emergency (malignant hypertension) occurs when an animal presents with an elevated blood pressure and demonstrates clinical signs directly attributable to hypertension.\(^\text{30}\) These patients must be treated quickly and require monitoring in a critical care facility.\(^\text{3}\)

**Recommendations for Hypertensive Emergencies**

Hypertensive emergencies should be treated only at 24-hour hospitals with experience in critical care and continuous blood pressure monitoring equipment. Potentially dangerous medications such as nitroprusside and hydralazine may be used.\(^\text{30}\) Nitroprusside is a potent arterial and venous vasodilator that may begin to act in seconds and has a half-life of 2 to 3 minutes, so it must be given by constant-rate infusion.\(^\text{31}\) Nitroprusside contains 44% cyanide by weight, and toxicity secondary to using nitroprusside in humans has caused cardiac arrest, coma, convulsions, and irreversible neurologic abnormalities despite sophisticated monitoring.\(^\text{28}\) Hydralazine is a rapid arteriolar dilator with an unpredictable nature and has been associated with potentially lethal side effects.\(^\text{28,31}\) Its use in human medicine is now discouraged because safer alternatives are available.\(^\text{28}\) Such medications are best used in experienced hands, with patients receiving 24-hour care.

**Recommendations for Hypertensive Urgency**

Because most identified cases of hypertension in veterinary medicine are secondary to other disease processes, the first course of action should be to determine whether a predisposing condition exists and to institute appropriate therapy. Although treating the underlying disease may resolve associated hypertension in some patients, other patients require management of the primary disease process plus antihypertensives\(^\text{3,8,10}\) (Table 2). An important principle in treating hyperten-

### Table 2. Commonly Used Oral Antihypertensives and Their Dosages

<table>
<thead>
<tr>
<th>Drug</th>
<th>Class</th>
<th>Canine Dosage</th>
<th>Feline Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enalapril</td>
<td>ACE inhibitor</td>
<td>0.5–1 mg/kg q12–24h</td>
<td>0.25–0.5 mg/kg q12–24h</td>
</tr>
<tr>
<td>Benazepril</td>
<td>ACE inhibitor</td>
<td>0.25–0.5 mg/kg q12–24h</td>
<td>0.25–0.5 mg/kg q12–24h</td>
</tr>
<tr>
<td>Amlodipine</td>
<td>Calcium-channel blocker</td>
<td>0.05–0.2 mg/kg q24h</td>
<td>0.625–1.25 mg q24h</td>
</tr>
<tr>
<td>Atenolol</td>
<td>β-Adrenergic blocker</td>
<td>0.25–1 mg/kg q12–24h</td>
<td>6.25–12.5 mg q12–24h</td>
</tr>
<tr>
<td>Propranolol</td>
<td>β-Adrenergic blocker</td>
<td>2.5–10 mg q8–12h</td>
<td>2.5–5 mg q8–12h</td>
</tr>
<tr>
<td>Prazosin</td>
<td>α-Adrenergic blocker</td>
<td>0.5–2 mg q12h</td>
<td>—</td>
</tr>
<tr>
<td>Spironolactone</td>
<td>Aldosterone inhibitor</td>
<td>1–2 mg/kg q12h</td>
<td>1 mg/kg q12h</td>
</tr>
</tbody>
</table>

Hypertension in companion animals is often associated with underlying disease processes. Thus treating the underlying disease may resolve associated high blood pressure.
Drug Therapy

Angiotensin-converting enzyme (ACE) inhibitors are often used as the initial treatment of choice to control canine hypertension.\textsuperscript{3,10} ACE inhibitors exert their effect by competitively inhibiting conversion of angiotensin I to angiotensin II.\textsuperscript{32} Because angiotensin II is a potent vasoconstrictor, systemic vasodilation occurs when its synthesis is inhibited.\textsuperscript{32,33} In addition, angiotensin II stimulates aldosterone release, leading to sodium and water retention and increased blood volume.\textsuperscript{32,33} Also, angiotensin II directly stimulates the kidneys to retain sodium, resulting in increased blood volume.\textsuperscript{32,33} Renal function values (i.e., blood urea nitrogen and creatinine levels) should be evaluated before and periodically after starting treatment because the condition of patients with renal insufficiency may worsen.\textsuperscript{32}

The effect of ACE inhibitors in cats is less predictable. As many as 50\% of hypertensive cats do not respond to enalapril, the most commonly used ACE inhibitor.\textsuperscript{13,34} Although benazepril has a statistically significant antihypertensive effect in cats with renal failure, actual blood pressure reductions achieved with this drug are small.\textsuperscript{35} Therefore, using ACE inhibitors as primary antihypertensives in cats is not recommended.

Calcium-channel blockers are usually considered the drug of choice for feline hypertension.\textsuperscript{36–38} Patients should be started at the low end of the dose range, with the dose increased as needed based on follow-up blood pressure measurements.\textsuperscript{30} Calcium-channel blockers act by blocking the influx of calcium needed to cause smooth muscle contraction, thereby decreasing systemic vascular resistance.\textsuperscript{30,32} Amlodipine besylate may be the most widely used drug to control hypertension in cats. It is long acting, which allows once-daily dosing, and has a gradual effect, which prevents rapid reductions in blood pressure.\textsuperscript{30}

There is concern about using calcium-channel blockers as primary antihypertensives in dogs.\textsuperscript{30,37} Studies in humans and diabetic dogs showed that when drugs in this class are used alone, they can accelerate renal damage despite lowering systemic blood pressure.\textsuperscript{30} One possible explanation for this paradoxical effect is that calcium-channel blockers may preferentially dilate the afferent arteriole of the glomerulus and thus cause glomerular hypertension.\textsuperscript{30,37} Nevertheless, these drugs appear safe and effective when used as primary antihypertensives in cats or as adjunctive therapy in dogs.\textsuperscript{7,30,37,38}

β-Adrenergic blockers are useful in dogs and cats when the primary antihypertensive fails to produce the desired decrease in blood pressure.\textsuperscript{3} β-Adrenergic antagonists act by reducing cardiac output.\textsuperscript{39} β-Adrenergic receptors are found in both the heart (β\textsubscript{1}) and lungs (β\textsubscript{2}).\textsuperscript{38} Although block-
The blockade of \(\beta_1\)-adrenergic receptors slows the heart, blockade of \(\beta_2\)-adrenergic receptors leads to bronchial constriction. When prescribing a \(\beta\)-adrenergic blocker for a patient with asthma, it is best to choose a \(\beta_1\)-selective antagonist (e.g., atenolol) to avoid bronchial constriction.

Stimulating postsynaptic \(\alpha\)-adrenergic receptors on blood vessels leads to vasoconstriction and increased systemic vascular resistance. \(\alpha\)-Adrenergic blockers exert their antihypertensive effects by selectively antagonizing \(\alpha\)-adrenergic receptors on systemic vessels, which causes vasodilation and decreased systemic vascular resistance. Prazosin, a potent \(\alpha\)-adrenergic receptor antagonist, may be used as primary or adjunctive therapy for hypertension in dogs. Prazosin, when started before \(\beta\)-adrenergic blockers, has also been effective in medically managing hypertension caused by pheochromocytomas.

Certain studies involving companion animals suggested that aldosterone inhibitors (e.g., spironolactone) may protect against deleterious effects of increased blood pressure on the brain, heart, and kidneys. This class of drugs works not only by lowering blood pressure but also by reducing fibrosis that results from hypertension. Although this information is preliminary and more studies are needed to fully evaluate the benefit of these drugs, hypertensive patients may benefit from this adjunctive treatment.

**Supportive Care**

Canine and feline blood pressure may respond differently to a patient’s body condition. Although there is no apparent correlation between obesity and hypertension in cats, studies in dogs demonstrated small but predictable elevations in blood pressure as weight increased. There is also no definitive evidence that sodium-restricted diets benefit hypertensive dogs and cats as they may benefit humans. Thus there is no conclusive evidence that companion animals should be fed very low-sodium or highly calorie-restricted diets. However, high-sodium diets and clinical obesity are unlikely to help any medical condition. Therefore, good body condition and a moderately sodium-restricted diet are reasonable goals for all patients. Exercise should be encouraged: Dogs that exercise regularly have lower blood pressures than more sedentary animals.

**CONCLUSION**

Confusion about the definition of hypertension, the reliability of indirect methods of blood pressure measurement, the definition of at-risk populations, and treatment protocols has delayed acceptance of routine screening for and treatment of hypertension by the veterinary community. It is now believed that normal systolic blood pressure in both cats and dogs is less than 150 mm Hg and that higher pressures are associated with damage to the eyes, heart, brain, and kidneys. Three different noninvasive methods of determining blood pressure have been shown to measure systolic pressure accurately. Patients with certain underlying diseases are at increased risk of developing hypertension, so diagnostic efforts should focus on a specific population of patients. Also, treatment protocols have been developed and documented to help control hypertension. The study of hypertension in companion animals is still in its infancy, and although much of the information now available will likely be modified as experience grows, this should not be an excuse for ignoring a treatable disease.
REFERENCES


ARTICLE #1 CE TEST

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1. Which method of measuring blood pressure is least appropriate for use in cats and small dogs?
   a. oscillometry
   b. Doppler flow detection
   c. photoplethysmography
   d. catheterizing an appropriate arteriole and using a pressure sensor
   e. any method

2. When measuring blood pressure with a Doppler flow detector, cuff width should be
   a. 30% to 40% of the limb's circumference.
   b. 30% to 40% of the limb's width.
   c. 20% to 30% of the limb's circumference.
   d. 20% to 30% of the limb's width.
   e. none of the above

3. Which disease is not commonly associated with hypertension?
   a. diabetes
   b. hyperadrenocorticism
   c. lymphoma
   d. renal disease
   e. hepatic disease

4. Hypertensive retinopathy can be characterized by
   a. tortuous vessels.
   b. retinal hemorrhage.
   c. retinal detachment.
   d. blindness.
   e. all of the above

5. Which statement regarding drug therapy for hypertension is most accurate?
   a. Aldosterone inhibition decreases hypertension and may prevent fibrosis of the heart, kidneys, and brain.
   b. Administering ACE inhibitors prevents the conversion of angiotensinogen to angiotensin I.
   c. Administering ACE inhibitors is considered the first-line therapy for feline hypertension.
   d. Administering hydralazine is indicated for routine control of blood pressure in dogs.
   e. all of the above

6. Which factor can influence the accuracy of measuring blood pressure?
   a. operator technique
   b. environmental factors such as noise
   c. proper cuff size
   d. patient stress
   e. all of the above

7. Which disorder is not recognized as a sequela of hypertension?
   a. left ventricular hypertrophy
   b. hypertensive retinopathy
   c. renal failure
   d. hepatic failure
   e. neurologic disease

8. Blood pressure is a function of
   a. cardiac output and systemic vascular resistance.
   b. serum calcium levels.
   c. endothelial intercellular message systems.
   d. all of the above
   e. a and c

9. In asymptomatic patients, blood pressure should be
   a. lowered as quickly as possibly to below 180 mm Hg.
   b. lowered slowly and gradually.
   c. reduced as quickly as possible to below 200 mm Hg and then slowly lowered to less than 180 mm Hg.
   d. aggressively lowered to around 150 mm Hg.
   e. none of the above

10. Mildly elevated blood pressure usually manifests as
    a. left ventricular hypertrophy.
    b. hypertensive retinopathy.
    c. renal failure.
    d. neurologic disease.
    e. clinical signs associated with an underlying disease.