

Compendium

Treatment of Systemic Hypertension Associated With Kidney Disease

Simona Buoncompagni, DVM, MS, DACVIM

Mary H. Bowles, DVM, DACVIM

Oklahoma State University

Abstract: Systemic hypertension is an increasingly diagnosed disorder in dogs and cats and frequently occurs secondary to chronic kidney disease. Prevention of damage to organs such as the kidneys, brain, heart, and eyes is one of the primary concerns in the management of veterinary patients with hypertension. This article reviews the guidelines for antihypertensive therapy in patients with, or at risk for, kidney disease, including the initiation of treatment and currently recommended medications.

Hypertension can be classified as primary (essential) or secondary. Essential hypertension refers to hypertension for which the cause remains unknown after extensive diagnostic testing, whereas secondary hypertension is associated with underlying disease or administration of hypertensive agents. In contrast to humans, essential or idiopathic hypertension is rare in veterinary patients.^{1,2} In cats and dogs, systemic hypertension is most often associated with another disease or condition (**BOX 1**).²⁻⁷

Renal disease, especially chronic kidney disease (CKD), is the most common cause of hypertension in dogs and cats. Of animals with renal disease, approximately 20% to 60% of cats^{8,9} and 31% to 93% of dogs¹⁰ may be hypertensive.

Healthy kidneys are able to maintain adequate renal blood flow and glomerular filtration rate despite transitory systemic hypertension. Preexisting CKD and persistent systemic hypertension can affect this autoregulatory mechanism, leading to glomerular hypertension and the development of glomerulosclerosis.¹⁰ Pathologic elevation of systemic blood pressure is a recognized cause of organ damage in dogs and cats. The predominant sites of injury are the eyes, central nervous system, heart, and kidneys. The term *target organ damage* (TOD) is often used to describe this type of injury and is a cause of morbidity in dogs and cats.¹¹

Therapy for systemic hypertension associated with canine and feline renal disease is the focus of this article. Further information

Box 2. Recommended Method for Blood Pressure Measurement^{11,a,b}

1. Acclimate patient in a quiet environment to avoid the “white coat effect.”
2. Place the patient in a preferred position:
 - Dogs—left lateral recumbency
 - Cats—natural, nonstressful position (commonly sternal recumbency)
3. Use a cuff size (width) that is approximately 40% of the circumference of the cuff site (forelimb, hindlimb, or tail).
4. If possible, obtain five separate measurements with <20% variability.
5. Use the same cuff size and site for recheck measurements.

^aDoppler ultrasonography is more accurate for cats and small dogs (<20 kg).

^bIncreases in heart rate increase blood pressure, but not proportionately.

about the pathogenesis and diagnosis of hypertension and descriptions of TOD have been published elsewhere.^{11,12}

Antihypertensive Therapy

Treatment of systemic hypertension is recommended to prevent or slow the progression of TOD. The initiation of antihypertensive treatment should be considered in any dog or cat with a systolic blood pressure ≥ 150 mm Hg and/or a diastolic pressure ≥ 95 mm Hg, especially if TOD is present. Treatment is always indicated when the systolic blood pressure is ≥ 180 mm Hg and/or the diastolic blood pressure is ≥ 120 mm Hg.¹¹ A recommended method for measuring blood pressure is presented in **BOX 2**.

Considerations Before Initiating Therapy

Many factors need to be considered before implementing a treatment protocol for hypertension (**BOX 3**). Before initiating treatment, it is important to review all medications administered to the

Box 1. Canine and Feline Diseases Commonly Associated With Hypertension

- | | |
|-------------------------------------|---|
| • Hyperadrenocorticism ² | • Primary hyperaldosteronism ^{3,5} |
| • Hyperthyroidism ³ | • Diabetes mellitus ^{2,3,6} |
| • Pheochromocytoma ⁴ | • Renal disease ^{3,7} |

Box 3. Factors to Consider Before Initiating Therapy for Hypertension

- Patient medications contributing to hypertension
- Presence of concurrent hypertensive diseases
- IRIS stage system classification and subclassification of the patient
- Presence or absence of target organ damage

patient that could cause an elevation in blood pressure, such as corticosteroids, phenylpropanolamine, NSAIDs,¹¹ and erythropoietin.¹³ Medications that may be contributing to hypertension should be discontinued or at least reduced to the lowest efficacious dose.

In human medicine, initial therapy for hypertension often includes restriction of salt intake. Although avoiding high salt intake would be a reasonable measure in the therapy of canine and feline hypertension, specific efforts to restrict salt intake have not shown the same benefit in managing hypertensive dogs and cats as in humans.^{11,14} In addition, reduction of salt intake can have deleterious effects, including activation of the renin-angiotensin-aldosterone system (RAAS) and kaliuresis. Consequently, diet selection for hypertensive canine and feline patients should be based more on the underlying disease and patient age than on salt content.

Because hypertension in dogs and cats is most often a secondary disease, identification and treatment of the primary disease are essential to resolve systemic hypertension. Most renal diseases associated with hypertension are irreversible, and management of hypertension is necessary to reduce the progression of the kidney disease as well as prevent damage to other target organs. Some patients with renal disease may have concurrent disease(s) contributing to hypertension (**BOX 1**). Effective management of such diseases is important to the overall success of controlling the patient's hypertension and related clinical complications.

Patients with clinical conditions requiring volume resuscitation should have their fluid needs addressed before treatment with an antihypertensive agent is initiated.

The American and European Societies of Veterinary Nephrology and Urology have accepted the International Renal Interest Society (IRIS) staging system for CKD. The primary IRIS staging system is based on the patient's plasma or serum creatinine values (**TABLE 1**). Subclassifications of the IRIS staging system have also been developed based on blood pressure values with potential for TOD (**TABLE 2**) and proteinuria, as assessed by the urine protein:creatinine ratio (UPC; **TABLE 3**). These IRIS subclassifications can be particularly helpful in determining indications for initiation of antihypertensive therapy in CKD patients.

One way to approach antihypertensive treatment is to categorize high blood pressure on the basis of risk for developing subsequent TOD.¹¹ Antihypertensive therapy is suggested for most patients at blood pressure stage 2 of the IRIS system, particularly those with TOD, and for all patients at stage 3 of the IRIS system (**TABLE 2**).

Table 1. IRIS Chronic Kidney Disease Staging System Based on Patient Fasting Plasma or Serum Creatinine Concentration^{a,b}

Stage	Fasting Creatinine Values (mg/dL)		Description
	Dog	Cat	
1	<1.4	<1.6	Nonazotemic
2	1.4–2.0	1.6–2.8	Mild azotemia
3	2.1–5.0	2.9–5.0	Moderate azotemia
4	>5.0	>5.0	Severe azotemia

^aAdapted from IRIS Web site (www.iris-kidney.com).

^bThe creatinine values listed in this table should be interpreted in conjunction with evaluation of the patient's urine specific gravity.

Table 2. IRIS Subclassification of Chronic Kidney Disease Staging System Based on Blood Pressure and Target Organ Damage^a

Substage	Blood Pressure (Systolic/Diastolic)	Risk of Target Organ Damage
0	<150/95 mm Hg	Minimal
1	150–159/95–99 mm Hg	Mild
2	160–179/100–119 mm Hg	Moderate
3	≥180/120 mm Hg	Severe

^aAdapted from IRIS Web site (www.iris-kidney.com).

Table 3. IRIS Subclassification of Chronic Kidney Disease Staging System Based on Proteinuric Status^{16,a}

Patient Proteinuric Status	Urine Protein:Creatinine Ratio ^b	
	Dog	Cat
Proteinuric (P)	>0.5	>0.4
Borderline proteinuric (BP)	0.2–0.5	0.2–0.4
Nonproteinuric (NP)	<0.2	<0.2

^aAdapted from IRIS Web site (www.iris-kidney.com).

^bUrine protein:creatinine ratio should be calculated from urine with inactive sediment.

Elevated blood pressure has been associated with an increased magnitude of proteinuria in dogs, cats, and humans with CKD. Proteinuria appears to promote the progression of renal injury. Consequently, successfully treating hypertension can secondarily decrease urinary protein loss and slow the progression of renal disease and the development of glomerular fibrosis (glomerulosclerosis).^{10,15}

The IRIS subclassification pertaining to proteinuria can help determine whether antihypertensive therapy is indicated based on the degree of proteinuria detected through use of the UPC. One study also indicated that microalbuminuria testing is useful in identifying early proteinuria in hypertensive dogs with CKD.¹⁶ If

Box 4. Indications for Antihypertensive Therapy in Patients With Chronic Kidney Disease

- IRIS blood pressure stage 2 or 3 ± proteinuria
- IRIS blood pressure stage 1 + proteinuria

a CKD patient is identified as proteinuric, antihypertensive therapy may be considered even at IRIS blood pressure stage 1 (TABLE 2 and TABLE 3).

BOX 4 summarizes the guidelines for initiation of antihypertensive therapy in CKD patients based on IRIS subclassifications for blood pressure and proteinuria.

Antihypertensive Therapy in Dogs

Because activation of the RAAS is one of the main causes of hypertension in dogs with CKD,¹⁷ an angiotensin-converting enzyme inhibitor (ACEI) is usually recommended as the initial antihypertensive agent of choice in dogs.¹¹ In addition, ACEIs can serve an important function in reducing proteinuria and, consequently, improving clinical outcome.^{17,18} Activation of the RAAS results in vasoconstriction of the postglomerular arterioles, which increases glomerular filtration pressure, intraglomerular hypertension, and secondary proteinuria. ACEIs preferentially dilate the efferent (postglomerular) arterioles, and the subsequent decreases in intraglomerular pressure and proteinuria, if present, help protect the kidneys. However, the reduced glomerular filtration pressure and decreased protein loss also lead to decreased elimination of blood urea nitrogen (BUN) and creatinine.

Consequently, monitoring these biochemistry values before and after initiating ACEI therapy is indicated to help prevent the development of acute renal failure.¹¹ Other potential adverse reactions to ACEIs include hypotension, hyperkalemia, lethargy, and anorexia.

Benazepril and enalapril are the ACEIs most commonly recommended for use in dogs (TABLE 4). Benazepril has been associated with reductions in (1) glomerular capillary hypertension, (2) release of extracellular matrix and collagen from mesangial and tubular cells, and (3) degree of glomerular and interstitial fibrosis.¹⁷ However, in one study involving dogs with induced chronic renal insufficiency,¹⁸ enalapril treatment achieved results similar to those obtained with benazepril treatment in the above-mentioned study.¹⁷

Combination therapy with different classes of antihypertensive agents is often necessary to satisfactorily decrease systemic blood pressure in dogs.¹⁹ ACEIs are frequently

used in combination with calcium-channel blockers (CCBs). In addition to having an enhanced antihypertensive effect, the combination of these two classes may reduce the adverse effects of each medication. The vasodilation of the afferent arterioles induced by CCBs is compensated for by the vasodilation of the efferent arterioles induced by ACEIs, thereby stabilizing the glomerular filtration pressure.¹⁹ Gingival hyperplasia is a potential adverse effect of long-term use of the CCB amlodipine in dogs.²⁰

Antihypertensive Therapy in Cats

Multiple studies in hypertensive cats have demonstrated that oral amlodipine, a second-generation dihydropyridine CCB, is a highly effective antihypertensive agent with a low incidence of adverse effects when administered once daily.²¹ Although infrequent, adverse effects of amlodipine in cats and dogs include lethargy, azotemia, weight loss, and hypokalemia. Amlodipine is currently considered the drug of choice for treatment of hypertension in cats with CKD.^{22,23}

The main mechanism of action of amlodipine is vasodilation of the afferent renal arteriole secondary to decreased calcium influx.²⁴ This dilation can cause increased intraglomerular pressure and secondary proteinuria. However, a small study conducted in cats did not show a significant difference in UPCs between a group treated with amlodipine alone and a group treated with amlodipine and an ACEI.²⁵ Other studies have evaluated amlodipine in feline research subjects and clinical feline patients and found that the drug can decrease systolic blood pressure by an average of 30 to 60 mm Hg and lead to a reduction in proteinuria.^{23,26}

Although oral administration of amlodipine has been the traditional recommendation, a prospective study²⁷ evaluated transdermal

Table 4. Oral Dosages of Antihypertensive Agents in Dogs and Cats^{11,a-c}

Drug Name (Classification)	Oral Dosage	
	Dog	Cat
Enalapril (ACEI)	0.25–1 mg/kg q12–24h	0.25–0.5 mg/kg q12–24h
Benazepril (ACEI)	0.25–1 mg/kg q12–24h	0.25–1 mg/kg q12–24h
Amlodipine (CCB)	0.1–0.2 mg/kg q24h up to 0.5 mg/kg q24h	• Cat ≤6 kg: 0.625 mg/cat q24h • Cat >6 kg: 1.25 mg/cat q24h
Prazosin (α-blocker)	0.5–2 mg/dog q8–12h	0.25–0.5 mg/cat q8–24h
Phenoxybenzamine (α-blocker)	0.25–1 mg/kg q8–12h	0.25–0.5 mg/kg q12h
Atenolol (β-blocker)	0.25–1 mg/kg q12–24h	6.25–12.5 mg/cat q12–24h
Hydralazine (direct arterial dilator)	0.5–2 mg/kg q12h	2.5–5 mg/cat q12–24h

ACEI = angiotensin-converting enzyme inhibitor, CCB = calcium channel blocker.

^aCarr AP. Treatment of hypertension. In: Ettinger SJ, Feldman EC. *Textbook of Veterinary Internal Medicine*. 7th ed. St. Louis, MO: Saunders; 2010:583–585.

^bPlumb DC, ed. *Plumb's Veterinary Drug Handbook*. 7th ed. Ames, IA: Wiley Blackwell Publishing; 2011.

^cRamsey I, ed. *BSAVA Small Animal Formulary*. 6th ed. Quedgeley, UK: BSAVA; 2008.

administration of amlodipine for the control of hypertension in six cats. The results of this study showed that transdermal amlodipine could maintain a reduction in blood pressure in hypertensive cats; however, the degree of reduction was less than that obtained with oral amlodipine.

ACEIs can also be beneficial in the treatment of feline hypertension through reduction of blood pressure and proteinuria potentially caused or exacerbated by the patient's hypertensive state. However, in clinical situations, the use of an ACEI alone in cats rarely achieves adequate reduction in systemic blood pressure.^{1,28} This insufficient response may be due to the role of the RAAS in the pathogenesis of hypertension in cats. Studies have suggested that feline hypertensive CKD may not involve stimulation of the RAAS,²⁸ limiting the antihypertensive effect of ACEIs in cats. In addition, the proven efficacy of amlodipine as an antihypertensive agent in cats may be an indication that increased vascular tone, not RAAS stimulation, is the main mechanism for the pathogenesis of feline hypertension.²⁹ Consequently, ACEIs such as enalapril and benazepril (**TABLE 4**) have been used primarily to reduce proteinuria in cats,^{30,31} although an additive antihypertensive effect has been reported in cats when benazepril was added to amlodipine therapy.²⁵

Other Therapeutic Options

α -Blockers

α_1 -Adrenergic receptors are located inside vessel walls and cause vasoconstriction. The primary effect of blocking α_1 -adrenergic receptors is peripheral vasodilation without changing heart contractility, as may occur with β -adrenergic receptor blockade. α -Blockers are normally used when acceptable blood pressure control is not achieved with ACEIs and CCBs. The α -blockers prazosin and phenoxybenzamine can be considered as alternative or additive antihypertensive medications (**TABLE 4**). Potential adverse effects from these medications include hypotension, tachycardia, vomiting, anorexia, and urinary incontinence.¹¹

β -Blockers

β -Blockers can decrease blood pressure not only by decreasing heart rate and stroke volume but also by inhibiting the release of renin. However, β -blockers are frequently ineffective in the treatment of hypertension in cats, whereas in dogs, the effect depends on the underlying disease causing hypertension.^{28,32} If a β -blocker is being considered for use as an alternative antihypertensive agent, the patient's heart rate should be evaluated before initiation of therapy due to the negative chronotropic effect of β -blockers. In addition, patients with decompensated heart disease or impaired atrioventricular conduction are not good candidates for β -blocker antihypertensive therapy.

Hydralazine

Hydralazine, a direct arterial dilator, is often considered an emergency drug due to the rapid reduction of blood pressure after parenteral administration. This drug has been used after renal transplantation surgery in cats to control hypertension.³³ Hydralazine

can be used orally in dogs and cats as an alternative antihypertensive drug when amlodipine and ACEIs do not satisfactorily control patient hypertension. The possible adverse effects of hydralazine include symptomatic hypotension and tachycardia; therefore, it is particularly important to initiate hydralazine therapy at the low end of the dosage range and gradually titrate upward to effect.

Therapeutic Goal

The therapeutic goal in hypertensive cats and dogs is not necessarily to restore the blood pressure to normal values but to lower the blood pressure. A logical approach is to start with the lowest recommended dose of one or more antihypertensive agents and recheck the blood pressure every week, with the aim of reducing systolic blood pressure to around 140 to 150 mm Hg. If the blood pressure does not decrease satisfactorily after 1 week of treatment, we suggest increasing the dose of the medications by about 25% of the initial dose. Increasing the frequency of ACEI administration from every 24 hours to every 12 hours can also be considered.

If the patient's blood pressure does not decrease after appropriate combination therapy with ACEIs and CCBs, a different class of antihypertensive agent, such as an α -blocker, can be added to the initial regimen or tried as a sole therapeutic agent. The blood pressure measurement should always be performed using the same method (**BOX 2**).

Monitoring protocols for hypertensive CKD patients should include periodic urinalysis, evaluation of blood creatinine level, and examination for evidence of TOD. In addition, occasional evaluation of the UPC along with blood pressure measurement can help determine the efficacy of the antihypertensive therapy and aid in monitoring patients for development or exacerbation of proteinuria.¹¹ Checkup intervals may vary from a few days to 3 to 4 months, depending on the stability of the patient and the degree of hypertension. Ideally, a recheck appointment that includes determination of blood pressure and creatinine values should be scheduled within 1 to 2 weeks of any dosage adjustments in antihypertensive medication.

Potential Future Therapeutic Options

Carvedilol

A nonselective α - and β -blocker, carvedilol, has been studied for the treatment of hypertension in humans.³⁴ This agent can decrease systemic blood pressure through its α -blocker effect, which reduces vascular resistance, but maintains cardiac output and heart rate as a result of its β -blocker cardioprotective effect.³⁴ Further studies are necessary to establish the utility of carvedilol as an antihypertensive agent in dogs and cats.

Aldosterone Inhibitors

Aldosterone is a mineralocorticoid hormone that regulates sodium and potassium exchange (reabsorption of sodium and secretion of potassium) in classic target tissues such as the kidneys, colon, and salivary glands. Recently, mineralocorticoid receptors have been discovered in fibroblasts in heart, endothelial, vascular smooth muscle, and brain cells.

Aldosterone is considered to be proinflammatory and profibrotic and to cause endothelial dysfunction secondary to vascular remodeling and vasoconstriction. There is evidence that aldosterone may play a role in mediating hypertension and kidney injury in humans.³⁵

Aldosterone concentration seems to be elevated in hypertensive cats with CKD compared with healthy cats.²⁸ Although the aldosterone inhibitor spironolactone has been reported to be ineffective in reducing hypertension related to aldosterone-secreting tumors of cats,⁵ such inhibitors may be a future option for the therapy of hypertension in CKD patients. Further studies are necessary to identify the role of aldosterone and its inhibition in CKD-related hypertension in dogs and cats.^{28,36}

Conclusion

Antihypertensive therapy in dogs and cats can help prevent damage to the kidneys and other target organs. The decision to initiate antihypertensive therapy depends on a number of factors, including IRIS classification and subclassification of CKD. Current recommendations for antihypertensive therapy in cats and dogs with kidney disease include the use of CCBs and ACEIs as well as the alternative options of α -blockers, β -blockers, and hydralazine.

References

- Littman MP. Spontaneous systemic hypertension in 24 cats. *J Vet Intern Med* 1994; 8(2):79-86.
- Bodey AR, Michell A. Epidemiological study of blood pressure in domestic dogs. *J Small Anim Pract* 1996;37(3):116-125.
- Maggio F, DeFrancesco TC, Atkins CE, et al. Ocular lesions associated with systemic hypertension in cats: 69 cases (1985-1998). *J Am Vet Med Assoc* 2000;217(5):695-702.
- Maier ER, McNiel EA. Pheochromocytoma in dogs and cats. *Vet Clin North Am Small Anim Pract* 1997;27(2):359-380.
- Ash RA, Harvey AM, Tasker S. Primary hyperaldosteronism in the cat: a series of 13 cases. *J Feline Med Surg* 2005;7(3):173-182.
- Struble AL, Feldman EC, Nelson RW, et al. Systemic hypertension and proteinuria in dogs with diabetes mellitus. *J Am Vet Med Assoc* 1998;213(6):822-825.
- Acierno MJ, Labato MA. Hypertension in renal disease: diagnosis and treatment. *Clin Tech Small Anim Pract* 2005;20(1):23-30.
- Syme HM, Barber PJ, Markwell PJ, et al. Prevalence of systolic hypertension in cats with chronic renal failure at initial evaluation. *J Am Vet Med Assoc* 2002;220(12):1799-1804.
- Kobayashi DL, Peterson ME, Graves TK, et al. Hypertension in cats with chronic renal failure or hyperthyroidism. *J Vet Intern Med* 1990;4(2):58-62.
- Jacob F, Polzin DJ, Osborne CA, et al. Association between initial systolic blood pressure and risk of developing a uremic crisis or of dying in dogs with chronic renal failure. *J Am Vet Med Assoc* 2003;222(3):322-329.
- Brown S, Atkins C, Bagley R, et al. Guidelines for the identification, evaluation, and management of systemic hypertension in dogs and cats. *J Vet Intern Med* 2007;21(3):542-558.
- Jepson RE. Feline systemic hypertension: classification and pathogenesis. *J Feline Med Surg* 2011;13(1):25-34.
- Krapf R, Hultner HN. Arterial hypertension induced by erythropoietin and erythropoiesis-stimulating agents (ESA). *Clin J Am Soc Nephrol* 2009;4(2):470-480.
- Buranakarl C, Mathur S, Brown SA. Effects of dietary sodium chloride intake on renal function and blood pressure in cats with normal and reduced renal function. *Am J Vet Res* 2004;65(5):620-627.
- Finco DR. Association of systemic hypertension with renal injury in dogs with induced renal failure. *J Vet Intern Med* 2004;18(3):289-294.
- Bacic A, Kogika MM, Barbaro KC, et al. Evaluation of albuminuria and its relationship with blood pressure in dogs with chronic kidney disease. *Vet Clin Pathol* 2010;39(2):203-209.
- Tenhülfeld J, Wefstaedt P, Nolte IJ. A randomized controlled clinical trial of the use of benazepril and heparin for the treatment of chronic kidney disease in dogs. *J Am Vet Med Assoc* 2009;234(8):1031-1037.
- Brown SA, Finco DR, Brown CA, et al. Evaluation of the effects of inhibition of angiotensin converting enzyme with enalapril in dogs with induced chronic renal insufficiency. *Am J Vet Res* 2003;64(3):321-327.
- Atkins CE, Rausch WP, Gardner SY, et al. The effect of amlodipine and the combination of amlodipine and enalapril on the renin-angiotensin-aldosterone system in the dog. *J Vet Pharmacol Ther* 2007;30(5):394-400.
- Thomason JD, Fallaw TL, Carmichael KP, et al. Gingival hyperplasia associated with the administration of amlodipine to dogs with degenerative valvular disease (2004-2008). *J Vet Intern Med* 2009;23(1):39-42.
- Snyder PS. Amlodipine: a randomized, blinded clinical trial in 9 cats with systemic hypertension. *J Vet Intern Med* 1998;12(3):157-162.
- Mathur S, Syme H, Brown CA, et al. Effects of the calcium channel antagonist amlodipine in cats with surgically induced hypertensive renal insufficiency. *Am J Vet Res* 2002; 63(6):833-839.
- Elliott J, Barber PJ, Syme HM, et al. Feline hypertension: clinical findings and response to antihypertensive treatment in 30 cases. *J Small Anim Pract* 2001;42(3):122-129.
- Cooke KL, Snyder PS. Calcium channel blockers in veterinary medicine. *J Vet Intern Med* 1998;12(3):123-131.
- Elliott J, Fletcher M, Souttar K, et al. Effect of concomitant amlodipine and benazepril therapy in the management of feline hypertension [abstract]. *J Vet Intern Med* 2004; 18(5):788.
- Snyder PS, Sadek D, Jones GL. Effect of amlodipine on echocardiographic variables in cats with systemic hypertension. *J Vet Intern Med* 2001;15(1):52-56.
- Helms SR. Treatment of feline hypertension with transdermal amlodipine: a pilot study. *J Am Anim Hosp Assoc* 2007;43(3):149-156.
- Jensen J, Henik RA, Brownfield M, et al. Plasma renin activity and angiotensin I and aldosterone concentrations in cats with hypertension associated with chronic renal disease. *Am J Vet Res* 1997;58(5):535-540.
- Syme H. Hypertension in small animal kidney disease. *Vet Clin North Am Small Anim Pract* 2011;41(1):63-89.
- King JN, Gunn-Moore DA, Tasker S, et al. Benazepril in renal insufficiency in cats study group. Tolerability and efficacy of benazepril in cats with chronic kidney disease. *J Vet Intern Med* 2006;20(5):1054-1064.
- Mizutani H, Koyama H, Watanabe T, et al. Evaluation of the clinical efficacy of benazepril in the treatment of chronic renal insufficiency in cats. *J Vet Intern Med* 2006;20(5): 1074-1079.
- Keele SJ, Smith KC, Elliott J, et al. Adrenocortical morphology in cats with chronic kidney disease (CKD) and systemic hypertension. *J Vet Intern Med* 2009;23(6):1319-1350.
- Kyles AE, Gregory CR, Wooldridge JD, et al. Management of hypertension controls postoperative neurologic disorders after renal transplantation in cats. *Vet Surg* 1999; 28(6):436-441.
- Stafylas PC, Sarafidis PA. Carvedilol in hypertension treatment. *Vasc Health Risk Manag* 2008;4(1):23-30.
- Tomaschitz A, Pilz S, Ritz E, et al. Aldosterone and arterial hypertension. *Nature Rev Endocrinol* 2009;6(2):83-93.
- Syme H, Markwell P. Aldosterone and plasma renin activity in cats with hypertension and/or chronic renal failure [abstract]. *J Vet Intern Med* 2002;16(3):354.



3 CE Credits

This article qualifies for 3 contact hours of continuing education credit from the Auburn University College of Veterinary Medicine. CE tests must be taken online at Vetlearn.com; test results and CE certificates are available immediately. Those who wish to apply this credit to fulfill state relicensure requirements should consult their respective state authorities regarding the applicability of this program.

1. Which organs are most likely to sustain target organ damage (TOD) caused by systemic hypertension?

- a. eyes, kidneys, liver, central nervous system
- b. eyes, kidneys, central nervous system, heart
- c. heart, kidneys, pancreas, lungs
- d. kidney, central nervous system, liver, intestine

2. The term *essential hypertension* refers to

- a. persistent systemic hypertension.
- b. systemic hypertension that does not respond to treatment.
- c. systemic hypertension that does not have a known cause.
- d. systemic hypertension secondary to an underlying disease.

3. When is treatment of systemic hypertension always indicated in dogs and cats?

- a. systolic blood pressure ≥ 160 mm Hg
- b. diastolic blood pressure ≥ 90 mm Hg
- c. systolic blood pressure ≥ 180 mm Hg
- d. diastolic blood pressure ≥ 100 mm Hg

4. Which of the following drugs is the drug of choice for treatment of hypertension in cats with chronic kidney disease (CKD)?

- a. amlodipine
- b. benazepril
- c. phenoxybenzamine
- d. carvedilol

5. Which of the following findings should prompt initiation of antihypertensive therapy in a CKD patient?

- a. IRIS blood pressure stage 0
- b. IRIS blood pressure stage 1
- c. IRIS blood pressure stage 1 plus crystalluria
- d. IRIS blood pressure stage 1 plus proteinuria

6. In addition to blood pressure measurement, typical monitoring protocols for hypertensive CKD patients should include periodic

- a. examination of the patient for evidence of TOD as well as evaluation of urinalysis results and blood protein and

creatinine levels.

- b. examination of the patient for evidence of TOD as well as evaluation of urinalysis results, the urine protein:creatinine ratio (UPC), and the blood creatinine level.
- c. evaluation of UPC and blood urea nitrogen (BUN) and blood protein levels.
- d. evaluation of urinalysis results and BUN and blood protein levels.

7. Angiotensin-converting enzyme inhibitors exert a renoprotective effect by

- a. dilating the afferent renal (preglomerular) arterioles.
- b. dilating the efferent renal (postglomerular) arterioles.
- c. constricting the afferent renal (preglomerular) arterioles.
- d. constricting the efferent renal (postglomerular) arterioles.

8. Which species frequently require(s) therapy with a combination of drugs for adequate control of hypertension?

- a. dogs
- b. cats
- c. dogs and cats
- d. none of the above

9. What is the therapeutic goal when treating canine and feline hypertension?

- a. restore blood pressure to normal values in 24 hours
- b. reduce the systolic blood pressure to <120 mm Hg
- c. reduce the systolic blood pressure to approximately 100 mm Hg
- d. reduce the systolic blood pressure to approximately 150 mm Hg

10. Antihypertensive medications should be started at the

- a. lowest recommended dose for cats and dogs.
- b. highest recommended dose for cats and dogs.
- c. lowest recommended dose for cats and the highest recommended dose for dogs.
- d. highest recommended dose for cats and the lowest recommended dose for dogs.