



**UNDER PRESSURE**

Blood Pressure Measurement  
& Treatment of Hypertension

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(Internal Medicine)



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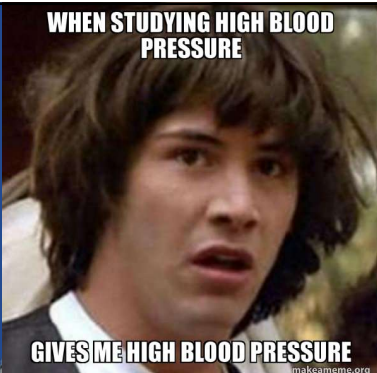
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**HYPERTENSION**

Persistent elevation  
in systemic  
arterial blood  
pressure



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**Physiologic Control of Blood Pressure**

BP = PVR x CO  
BP = PVR x HR x SV

Controlled by CNS and  
neurohormonal activity



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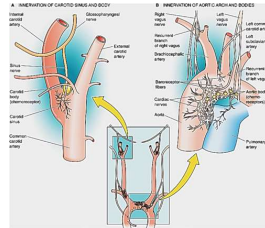
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## Physiologic Control of Blood Pressure

Baroreceptors (carotid sinus/aortic arch)

Vasomotor area in rostral ventrolateral medulla

Control of HR and SV via sympathetic and parasympathetic tone




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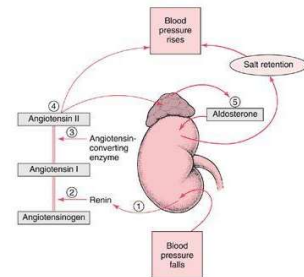
## Physiologic Control of Blood Pressure

Renin-Angiotensin-Aldosterone System (RAAS)

Sympathetic stimulation of beta-adrenergic receptors

Decreased arterial pressure  
Decreased renal intraluminal chloride

Juxtaglomerular apparatus in macula densa secretes renin




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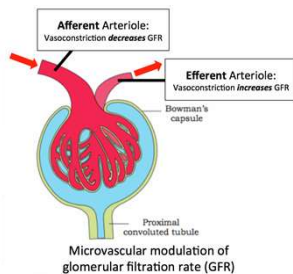
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## Physiologic Control of Blood Pressure



Autoregulation

Change in tone of afferent and efferent arterioles in nephrons

Effective at maintaining glomerular capillary hydrostatic pressure between 80mmHg-180mmHg

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## Measuring Blood Pressure

Intra-arterial  
(gold standard)



Doppler



Oscillometric




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## Measuring Blood Pressure

- Isolated, quiet environment with 5-10 minutes of acclimation.
- Comfortable position, ideally in ventral or lateral recumbency (ideally with site of measurement in same vertical plane as heart).
- The cuff width should be approximately 30%-40% of circumference of the cuff site.
- The cuff may be placed on a limb or the tail, taking into account animal conformation and tolerance, and user preference.
- The first measurement should be discarded. A total of 5-7 consecutive consistent values should be recorded. In some patients, measured BP trends downward as the process continues. In these animals, measurements should continue until the decrease plateaus and then 5-7 consecutive consistent values should be recorded.
- Average all remaining values to obtain the BP measurement.

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## Blood pressure evaluation form

Date: Date	Cat's name: Sex	Owner: Address	Direction: Owner
Position of the cat			
<input type="checkbox"/> Sitting	<input type="checkbox"/> Standing	<input type="checkbox"/> Dorsal	<input type="checkbox"/> Lateral
<input type="checkbox"/> Other (specify)			
Site of the cuff			
<input type="checkbox"/> Right brachial	<input type="checkbox"/> Right femoral	<input type="checkbox"/> Right tarsal	<input type="checkbox"/> Tail
<input type="checkbox"/> Left brachial	<input type="checkbox"/> Left femoral	<input type="checkbox"/> Left tarsal	
Equipment used:			
Location (room):		Site of cuff:	
Performed by:		Other present:	
Subjective assessment of stress:			
<input type="checkbox"/> None	<input type="checkbox"/> Slightly tense	<input type="checkbox"/> Nervous	<input type="checkbox"/> Very nervous
<input type="checkbox"/> Agitated			
Record of all SBPs measured (average)			
1.	2.	3.	4.
5.	6.	7.	8.
9.	10.		
Mean Systolic Blood Pressure (average):			
Mean of 5-7 consecutive readings (average):			

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## Measuring Blood Pressure

Factors that can affect blood pressure:

- Breed (sight hounds 10-20mmHg higher)
- Sex (questionable effect, but likely to be a very small contributor)
- Obesity (likely small contribution)
- Sarcopenia (may have more effect on radial versus coccygeal measurements in cats)




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## Parameters

Classification of blood pressure:

- <150: normotensive (minimal risk)
- 140-159mmHg (prehypertensive or low risk)
- 160-179mmHg: hypertensive (moderate risk)
- $\geq 180$ mmHg: severely hypertensive (high risk)




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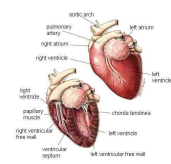
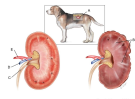
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## Consequences of Hypertension

**!!!!!!TARGET ORGAN DAMAGE!!!!!!**




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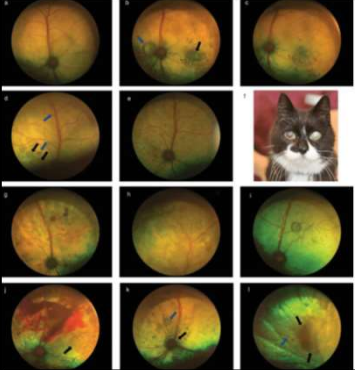
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### Target Organ Damage

- Acute blindness
- Exudative retinal detachment
- Retinal hemorrhage/edema
- Retinal vessel tortuosity
- Perivascular edema
- Papilledema
- Vitreous hemorrhage
- Hyphema
- Secondary glaucoma
- Retinal degeneration

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### Target Organ Damage

Centrally localizing neurologic signs



- Lethargy
- Seizures
- Altered mentation
- Altered behavior
- Disorientation
- Balance Disturbances



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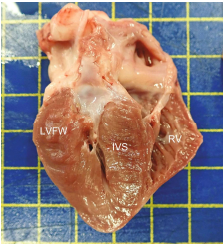

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### Left ventricular hypertrophy

- Gallop rhythm
- Arrhythmias
- Systolic heart murmur
- Cardiac failure
- Hemorrhage

### Target Organ Damage

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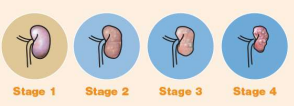
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**Serial increases in creatinine**




**Decrease in GFR**

**Proteinuria**

**Microalbuminuria**

**Target Organ Damage**




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**Underlying Causes of Hypertension**

**Situational hypertension**  
Check for target organ damage  
If there is no evidence of target organ damage, take repeated measurements over time

**Secondary hypertension**  
Caused by many underlying pathologies

**Idiopathic**  
"Essential" hypertension  
May represent up to 13-20% of cases in cats



**CURE FOR WHITE COAT HYPERTENSION**

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**Secondary Hypertension: Disease Processes**

	Stage 1 No azotemia Renal insufficiency	Stage 2 Mild azotemia Renal insufficiency	Stage 3 Moderate azotemia	Stage 4 Severe azotemia
<b>Creatinine in mg/dL</b>	Lowest: 1.4 Range: 1.4-2.8 Highest: 2.8	Lowest: 1.6 Range: 1.6-2.8 Highest: 2.8	Lowest: 2.9 Range: 2.9-5.0 Highest: 5.0	Lowest: 5.0 Range: 5.0-10.0 Highest: 10.0
<b>SDMA in mg/dL</b>	Lowest: 8 Range: 8-18 Highest: 18	Lowest: 10 Range: 10-25 Highest: 25	Lowest: 15 Range: 15-35 Highest: 35	Lowest: 20 Range: 20-50 Highest: 50
<b>UPC ratio</b>	Nonproteinuric: <0.2 Proteinuric: >0.2	Nonproteinuric: <0.2 Proteinuric: >0.2	Nonproteinuric: <0.2 Proteinuric: >0.2	Nonproteinuric: <0.2 Proteinuric: >0.2
<b>Systolic blood pressure in mmHg</b>	Nonproteinuric: <140 Proteinuric: 140-159	Nonproteinuric: <140 Proteinuric: 140-159	Nonproteinuric: <140 Proteinuric: 140-159	Nonproteinuric: <140 Proteinuric: 140-159

- Chronic kidney disease (BP is used to substage for IRIS)
- Acute kidney injury
- Hyperadrenocorticism
- Hyperthyroidism
- Diabetes mellitus
- Primary hyperaldosteronism
- Pheochromocytoma
- Hypothyroidism (uncommon)
- Immune-mediated disease? (e.g. IMHA)
- Cardiac disease/failure

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### Secondary Hypertension: Therapeutic Agents/Toxins

- Glucocorticoids
- Mineralocorticoids
- Erythropoiesis-stimulating agents (EPO, darbepoetin)
- Phenylpropanolamine (PPA, Proin)
- Phenylephrine hydrochloride
- Ephedrine
- Pseudoephedrine (high doses)
- Toceranib phosphate
- Chronic, high-dose NaCl
- Cocaine
- Methamphetamine/amphetamine
- 5-hydroxytryptophan
- Caffeine, ma huang, tacrolimus, licorice, bitter orange




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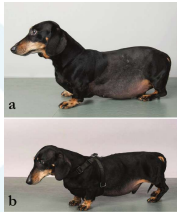
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### Which Patients Need Blood Pressure Measurements?



- Patients with evidence of target organ damage on physical examination or lab work
- Patients with disease processes that predispose them to hypertension
- Patients in which we are using or want to use therapeutics that may cause hypertension




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### When to Start Anti-Hypertensive Therapy

If TOD is present, one measurement may be enough

Prehypertension/hypertension with moderate risk of TOD:  
recheck 2 times over 4-8 weeks

Severe hypertension: recheck in 1-2 weeks

If BP is persistently elevated, consider antihypertensive therapy

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## Goals of Treatment

Address the underlying disease process (but don't wait to treat!)

Gradual decrease in blood pressure

Maximally decrease risk of TOD

Ideally <140mmHg, but at least <160mmHg

Weakness/lethargy, tachycardia, and/or syncope combined with a blood pressure <120mmHg may indicate hypotension

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## Strategies and Drugs to Reduce Blood Pressure

Dietary salt restriction

ACE inhibitors and angiotension receptor blockers (ARBs)

Calcium channel blockers

Diuretics

Emergency anti-hypertensives

Specific therapies for certain disease processes




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## Angiotension Converting Enzyme (ACE) Inhibitors and Angiotensin Receptor Blockers (ARBs)

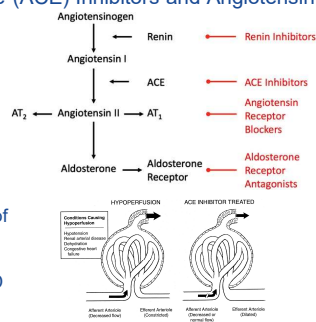
Enalapril, benazepril, Ramipril, telmisartan, losartan

Reduce BP by 10-20mmHg

Can result in decreased GFR

Should not be used during periods of volume depletion

May be beneficial for dogs with CKD long-term




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### Angiotension Converting Enzyme (ACE) Inhibitors and Angiotensin Receptor Blockers (ARBs)

First line therapy for dogs with moderate hypertension

Telmisartan may be an appropriate first line agent in cats, particularly if there is suspicion for significant RAAS activation

ACEi not generally recommended as first line agent for cats as they are largely ineffective alone

These medications are often also first line therapies for patients with proteinuria

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### Calcium Channel Blockers

Amlodipine

Typically reduces BP by 30-50mmHg

Can have a synergistic effect with ACEi/ARBs (may reduce risk of increased glomerular pressure from preferential afferent arteriole dilation)

First line therapy for hypertensive cats and severely hypertensive dogs

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### Diuretics

Not heavily utilized in dogs and cats, except for specific disease processes

### Beta Blockers

Has only mild effects on blood pressure

Helpful for rate control (e.g. hyperthyroidism)

### Emergency anti-hypertensives

Hydralazine, enalaprilate, esmolol, nitroprusside

Repeated amlodipine administration  
Fenoldopam, labetalol, phentolamine




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### Therapies for Specific Disease Processes

- Pheochromocytoma
  - Phenoxybenzamine (alpha-adrenergic blockade) +/- adrenalectomy
- Hyperaldosteronism
  - Spironolactone
  - Calcium channel blocker
  - Potassium supplementation
  - Adrenalectomy




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Angiotensin converting enzyme inhibitor	Benazepril	D: 0.5 mg/kg q12-24h C: 0.5 mg/kg q12h
	Enalapril	D: 0.5 mg/kg q12-24h C: 0.5 mg/kg q24h
Aldosterone receptor blocker	Telmisartan	C: 1 mg/kg q24h D: 1 mg/kg q24h
	Atenolol	D/C: 0.1-0.25 mg/kg q24h (up to 0.5 mg/kg in cats and dogs) C: 0.025-1.25 mg per cat q24h
Calcium channel blocker	Flunarizine	D: 0.5-2 mg/kg q8-12h C: 0.25-0.5 mg/cat q24h
α blocker	Phenoxybenzamine	D: 0.25 mg/kg q8-12h or 0.5 mg/kg q24h C: 2.5 mg per cat q8-12h or 0.5 mg/cat qd
Direct vasodilator	Acetaminophen	D/C: 0.5-2 mg/kg q12h (start at low end of range)
	Hydralazine	C: 2.5 mg/cat q12-24h D/C: 1-0.2-0 mg/kg q12h D: 0.2-1.0 mg/kg q8h (titrate to effect)
Aldosterone antagonist	Spironolactone	C: 2.5-5 mg/cat q8h
β blocker	Propranolol	D: 0.25-1.0 mg/kg q12h C: 6.25-12.5 mg/cat q12h
Thiazide diuretic	Hydrochlorothiazide	D/C: 2-4 mg/kg q12-24h
Loop diuretic	Furosemide	D/C: 1-4 mg/kg q8-24h

### Dosing Anti-Hypertensives

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### QUESTIONS?




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