MAP Out Your Plan:
Safe Anesthesia for the Kidneys

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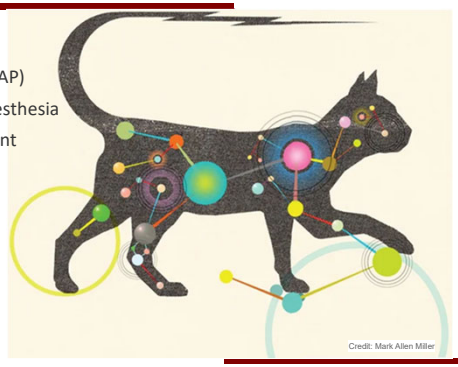
Discussion points

- Kidney's role
- Mean arterial pressure (MAP)
- Renal perfusion during anesthesia
- Renal disease and treatment
- Case examples
- Questions



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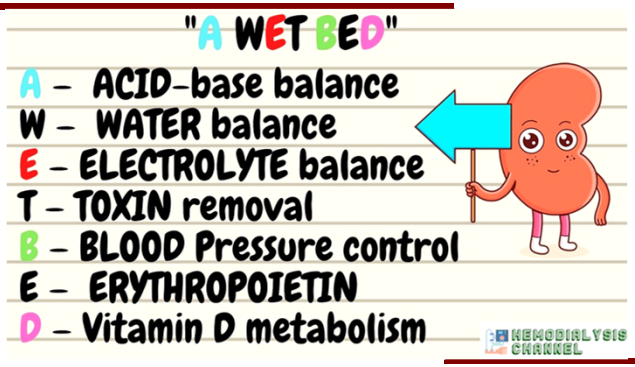
THE KIDNEY - Overview



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THE KIDNEY - Biomarkers

1. **IDEXX SDMA (Symmetric DiMethylArginine)**
   a. *"... indirect measurement of glomerular filtration rate (GFR), closely reflecting changes in kidney function."* (www.vetconnectplus.com)
   b. *"...usually the most sensitive indicator of loss of kidney function, identifying as little as 25% function loss."* (www.vetconnectplus.com)
2. **Creatinine**
   a. Byproduct of muscle
   b. Biomarker of kidney function
   c. Typically increased with 75% kidney function loss
   d. Consider values >1.4 mg/dL in dogs and >1.6 mg/dL in cats as *abnormal* (www.iris-kidney.com)
3. **BUN (blood urea nitrogen)**
   a. Byproduct of protein metabolism
   b. Biomarker of kidney (and liver) function

IDEXX SDMA	* 13	0 - 14 µg/dL
Creatinine	1.1	0.9 - 2.3 mg/dL
BUN	21	16 - 37 mg/dL

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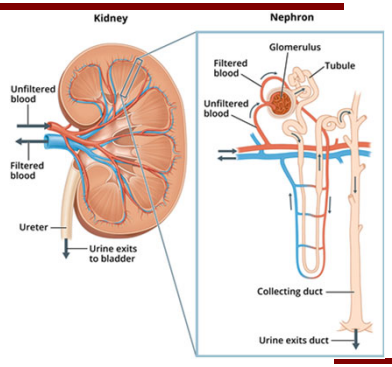
THE KIDNEY



National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health.

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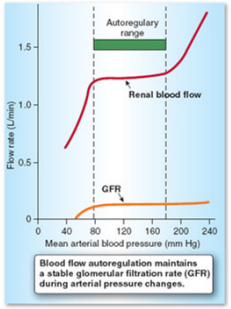
THE KIDNEY - RBF/GFR

1. **Renal blood flow (RBF)**
   a. ~20% of cardiac output (CO)
2. **Glomerular filtration rate**
   a. Filters ~10% of RBF
   b. ~99% of filtered fluid returns to circulation
3. ***Renal medullary**
   a. ~2% of RBF
   b. Urine output (UO) = 1-2 mL/kg/hr in healthy animals

RBF/GFR are autoregulated when:

Mean arterial pressure (MAP) = 60-80 mmHg> MAP <150-180 mmHg



https://aneskey.com/the-renal-system/

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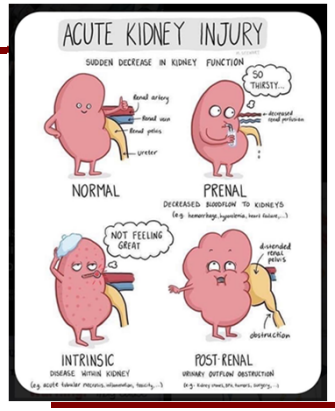
THE KIDNEY - RBF/GFR

1. **Decreased RBF - hypoperfusion**
   a. **Pre-renal**
      i. Hypovolemia
      ii. Hypotension
      iii. Heart failure
   b. **Intrinsic**
      i. Renal disease
   c. **Post-renal**
      i. Outflow obstruction



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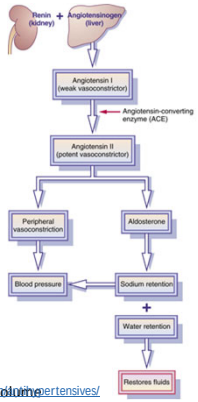
THE KIDNEY - RAAS

Renin-angiotensin-aldosterone system (RAAS)

1. **Renin**
   a. Hormone secreted by kidneys to regulate blood pressure
      i. Drop in MAP, Na+, blood volume → increased renin release
2. **Angiotensinogen**
   a. Inactive protein present in circulatory system
   b. Binds with renin → angiotensin I is released
3. **Angiotensin converting enzyme (ACE)**
   a. Present in kidneys vascular endothelium
   b. ACE + angiotensin I → angiotensin II (vasoconstriction)
   c. ACE + bradykinin (vasodilator) → breakdown of bradykinin
4. **Aldosterone**
   a. Hormone (steroid) produced by adrenal gland
   b. Increased release with presence of angiotensin II and hyperkalemia
   c. Causes retention of Na+ and release of K+ → increased intravascular volume



https://www.medscape.com/viewarticle/...hypertensives/

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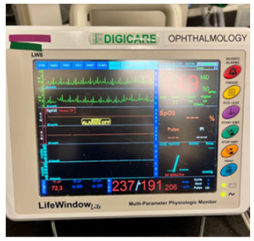
THE KIDNEY - Pain/Stress

Pain/stress/anxiety induces a physiologic stress response

a. GOAL of stress response: to maintain homeostasis
b. catecholamines
   i. released from adrenal gland
   ii. increase oxygen demand
c. RAAS
d. cortisol



Tachycardia
(decreased preload → decreased CO)

Hypertension
(vasoconstriction → renal arterial and glomerular vessel damage)

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MEAN ARTERIAL PRESSURE

MAP: *Mean arterial pressure*

CO: *Cardiac output*

SVR: *Vascular tone*

HR: *Beats per minute*

Stroke volume: *Ejected blood volume*

Preload: *End diastolic volume (blood volume returned to heart during diastole - "stretch")*

Afterload: *Arterial pressure (ventricular muscle pressure required during systole - "squeeze")*

Contractility: *Strength of cardiomyocytes to contract during systole*

MAP = CO x systemic vascular resistance (SVR)

Heart rate (HR) x Stroke volume (SV)

Preload **Afterload**

Contractility

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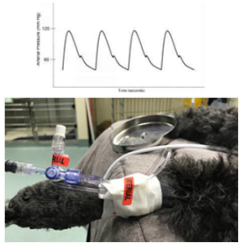
MEAN ARTERIAL PRESSURE

Doppler

Oscillometric



Invasive

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RENAL PERFUSION DURING ANESTHESIA

Isoflurane and Sevoflurane: *Inhalant anesthetic ag*

1. **Dose-dependent cardiovascular depression =**
2. **Vasodilation** → hypotension; **Decreased CO** →

MAP = CO x systemic vascular resistance (SVR)

Heart rate (HR) x Stroke volume (SV)

Preload **Afterload**

Contractility

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RENAL PERFUSION DURING ANESTHESIA

Opioids: *Pure mu agonist agents used for analgesia and sedation, MAC-sparing*

1. **Minimal impact on CO = minimal impact on RBF**

MAP = CO x systemic vascular resistance (SVR)

Heart rate (HR) x Stroke volume (SV)

Preload | **Afterload**

Contractility

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RENAL PERFUSION DURING ANESTHESIA

Induction agents: *Rapid onset to facilitate endotracheal intubation and initiation of GA*

1. **Dose-dependent cardiovascular depression***
2. **Vasodilation** → hypotension; **Decreased CO** → bradycardia, decreased cardiac contractility
3. ***Minimal effects on RBF with moderate to low doses**
4. **Etomidate: No significant effect on RBF**

MAP = CO x systemic vascular resistance (SVR)

Heart rate (HR) x Stroke volume (SV)

Preload | **Afterload**

Contractility

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RENAL PERFUSION DURING ANESTHESIA

Benzodiazepines: *Produce muscle relaxation, co-induction agents to reduce induction agent requirements*

1. **No change in cardiovascular function: <0.25 mg/kg (midazolam) or <0.5 mg/kg (diazepam)**

MAP = CO x systemic vascular resistance (SVR)

Heart rate (HR) x Stroke volume (SV)

Preload | **Afterload**

Contractility

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RENAL PERFUSION DURING ANESTHESIA

Phenothiazines: *Sedative, reduce patient stress*

1. **Dose-dependant vasodilation*** → hypotension
2. *Maintains normal RBF and GFR in healthy dogs/cats during GA: 0.005-0.02 mg/kg IV/IM in euvolemic patients with compensated renal disease

MAP = CO x systemic vascular resistance (SVR)

Heart rate (HR) x Stroke volume (SV)

Preload | **Afterload**

Contractility

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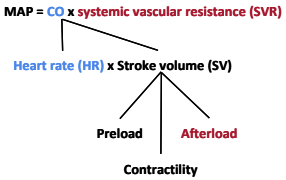
RENAL PERFUSION DURING ANESTHESIA

Alpha-2 agonists: *Sedative, reduced patient stress, some analgesic properties*

1. **Vasoconstriction** → hypertension; **Decreased CO*** → bradycardia
2. *Decreased CO causes redistribution of blood flow → decreased renal perfusion
3. **Avoid in patients with decompensated renal disease**



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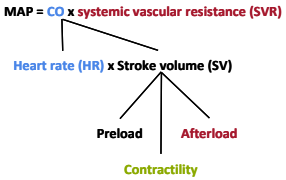
RENAL PERFUSION DURING ANESTHESIA

Dissociatives: *Injectable anesthetic, some analgesic properties (NMDA)*

1. **Vasoconstriction** → hypertension; **Increased CO** → increased HR; **Myocardial depressant** → decreased contractility
2. **Increases RBF**
3. Partially dependent on renal excretion, use with caution with underlying renal dz



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RENAL PERFUSION DURING ANESTHESIA

Drug (moderate to low doses)	RBF	GFR
Inhalants	Slight decrease	Decrease
Opioids	No change	No change
Propofol/alfaxalone	No change	No change
Etomidate	No change	No change
Benzodiazepines	No change	No change
Phenothiazines	No change	No change
Alpha-2 agonists	Decrease	Decrease
Dissociatives	Increase	No change

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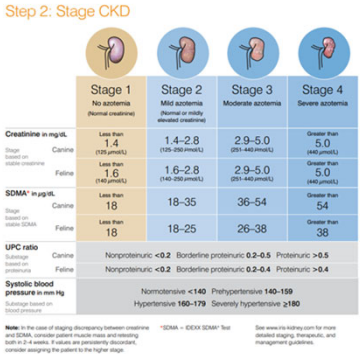
RENAL DISEASE



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RENAL DISEASE - Therapeutic drugs

1. **ACE-inhibitors:** *Decrease angiotensin II and breakdown of bradykinin*
   a. Decrease angiotensin II production → less vasoconstriction
   b. Increase bradykinin concentrations → more vasodilation
   c. Drugs: enalapril, benazepril, imidapril, ramipril
2. **Angiotensin II blockers (antagonist):** *Decrease production of angiotensin II*
   a. Decrease angiotensin II → less vasoconstriction
   b. Decreases cardiac afterload → decreased cardiac workload
   c. Drugs: telmisartin
3. **Aldosterone blockers (antagonist):** *Decrease production of mineralocorticoid aldosterone*
   a. Less retained Na+ → less intravascular volume
   b. Decreases cardiac preload → decreased cardiac workload
   c. Increases urine output
   d. Drugs: spironolactone

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FLUID THERAPIES

1. **Fluid therapy**
   a. **Crystalloids** are balanced isotonic fluids for maintaining hydration
      i. Fluid rate tailored to individual patient needs = **a+b+c+d+e**
         1. Sources of water loss
            a. **Insensible (respiratory, skin, saliva)**
               i. 1 mL/kg/hr
            b. **Urine output**
               i. 1-2 mL/kg/hr (normal)
               ii. 6-8 mL/kg/hr (polyuric)
            c. **Blood loss**
               i. Replace 3x amount (%) of blood loss
                  1. Dog total blood volume = 90 mL/kg
                  2. Cat total blood volume = 60 mL/kg
                  3. Administration rate should match rate of blood loss
            d. **Pre-existing dehydration**
               i. dehydration (%) x body weight = liters of fluid to administer over 12-24 hours
            e. **Other (vomiting, diarrhea) - contributes to dehydration**
   b. **Synthetic colloids**
      i. Used for increasing intravascular volume and in presence of hypoproteinemia
      ii. Excreted by kidneys
      iii. Not recommended for us in patients with underlying CKD as delay in clearance can lead to circulatory overload

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PERIANESTHETIC COMPLICATIONS - Hypertension

1. **MAP >120 mmHg; SAP >160 mmHg**
2. **Preoperative**
   a. Anxiety - pretreat with trazodone (dog) or gabapentin (cat)
   b. Pain
   c. Compensatory
      i. Vasoconstriction secondary to hypovolemia
   d. Underlying disease (Cushing's, hyperthyroidism, renal, pheochromocytoma)
      i. Consider maintaining intraoperative MAP 80-100 mmHg
3. **Intraoperative hypertension**
   a. Light anesthetic plane/response to noxious stimuli
   b. Drug induced (ketamine, anticholinergics, alpha adrenergic agonists, etc.)
4. **Postoperative**
   a. Anxiety
   b. Pain

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PERIANESTHETIC COMPLICATIONS - Hypotension

1. **MAP <60 mmHg; SAP <90 mmHg**
2. **Deep anesthetic depth**
   a. Decrease inhalant % → less myocardial depression/vasodilation → increased BP
3. **Bradycardia**
   a. Administer anticholinergic → increase HR → increase CO → increased BP
4. **Hypovolemia**
   a. Typically seen with tachycardia and/or increase pulse variability index (PVI) on SPO2 waveform
   b. Administer fluid bolus → should see decrease in HR/increase in BP
5. **Decreased myocardial contractility**
   a. Administer positive inotrope → increase cardiac contractility → increased BP
6. **Vasodilation**
   a. Administer CRI (i.e. fentanyl) → MAC-sparing → decrease inhalant → increased BP
   b. Administer alpha adrenergic agonist (higher dose dopamine, norepinephrine)→ offset inhalant-induced vasodilation → increased BP

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PERIANESTHETIC COMPLICATIONS - Cardiac disease

1. **Dogs**
   a. **Dilated cardiomyopathy (DCM)**
      i. Poor cardiac contractility
      ii. Increased risk for congestive heart failure (CHF)
      iii. Beta-1 adrenergic agonist (dobutamine CRI) → positive inotrope → increased cardiac contractility
      iv. Judicious fluids - consider 0.45% NaCl (less water retention to reduce risk of CHF)
      v. Avoid tachycardia and hypertension
   b. **Degenerative valve disease - mitral/tricuspid regurgitation**
      i. Normal LA/Ao <1.5
         1. Compensated
            a. Reduced fluid rate to prevent increased preload
            b. Dopamine CRI
            c. Avoid tachycardia and hypertension
      ii. LA/Ao >1.5
         1. Decompensated
            a. Increased risk for CHF
            b. Judicious fluids
            c. Dopamine vs dobutamine
            d. Avoid tachycardia and hypertension

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PERIANESTHETIC COMPLICATIONS - Cardiac disease

1. **Cats**
   a. **Hypertrophic cardiomyopathy (HCM)**
      i. Decreased CO due to decreased ventricle size
      ii. Judicious fluids
      iii. Avoid tachycardia and hypertension
      iv. Opioid CRI (MAC-sparing)

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The Case of the happy-go-lucky puppy

- Trazodone at home prior to admit
- IM premedication to facilitate IVC placement
- Analgesia plan
- IVF therapy
- Pediatrics rely on HR to maintain CO
- Testicular nerve block

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The Case of the dog with a big heart

- Trazodone at home prior to admit
- IM premedication to facilitate IVC placement
- Analgesia plan
- IVF therapy
- Positive inotropes
- CRIs for MAC-sparing
- Avoid tachycardia/hypertension
- Locoregional anesthesia

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The Case of the vocalizing cat

- Consider IM premedication to facilitate IVC placement
- Analgesia plan
- IVF therapy
- ECG to monitor for arrhythmias
- Coccygeal nerve block
- Avoid ketamine and dexmedetomidine

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The Case of the missing sock

- Vomiting → dehydration
- Gastric distension → risk of regurgitation
- Avoid abdominal pressure pre-op
- Analgesia plan
- IVF therapy
- Pediatrics rely on HR to maintain CO
- Locoregional anesthesia

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The Case of the fearful dog

- Trazodone at home the morning of surgery
- IM premedication to facilitate IVC placement
- Analgesia plan
- IVF therapy
- Locoregional anesthesia

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The Case of the crunchy cat

- Gabapentin at home the morning of surgery, if anxious
- IM premedication to facilitate IVC placement
- Analgesia plan
- IVF therapy
- Low body condition - increased risk for hypothermia
- Consider underlying osteoarthritis
- Locoregional anesthesia

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References:

Grimm KA, Lamont LA, Tranquilli WJ: Essentials of Small Animal Anesthesia and Analgesia, ed 2, 2011, Wiley Blackwell

Duke-Novakovski T, de Vries M, Seymour C: BSAVA Manual of Canine and Feline Anaesthesia and Analgesia, ed 3, 2016, Wiley Blackwell

THANK YOU!!

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