

# Acute Kidney Injury

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# Disclosures

- None, just working for The Man

# Case

- A 67 y.o. female was admitted to the hospital for a 3 days hx of nausea, anorexia and diarrhea. She had been in good health except for s/s of GERD dating back a decade. Her previous PCP recommended omeprazole OTC 20mg tablets daily which she had been taking for over 10 years. 10 days ago she c/o of the “flu” and was rx’d amoxicillin 500mg T.I.D. which she had taken the entire 10 day course.
- PMH, PSH, Allergies and SH are negative, full lab profile 3 years ago all normal
- Her current meds include: multivitamin and omeprazole
- ROS is significant for decreased oral intake, nausea and watery diarrhea for the past 3 days, general malaise and fatigue. She denies any rash, perioral ulcerations, hematuria, pyuria, f or c, otherwise ROS neg.

# Case

- PE: A thin ill appearing 67 y.o. female

VS 88/60, 116, 22, 94% sat. on RA

HEENT: pale sclera, mild bi-temporal wasting, dry mucous membranes

NECK, Lungs, Heart: +tachycardia

Abd.: increased BS, mild diffuse non focal tenderness, no rebound, mass, HSM

Skin/Ext: poor turgor no rashes, of joint effusions

Neuro: neg.

# Lab/Imaging

- Na 129, K 2.9, Cl 100, CO2 17, BUN 30, Creatinine 3.3, Ca 7.5, PO4 3.8, Alb 3.9, LFTs N,
- WBC 9.6, H/H 11.0/34.5, PLT 289K, Indices N, 72 PNM, 1 band, 25 Lymph, 1 Bas, 1 Eos
- ESR 29, C3/C3 N, ANA neg
- UA: 1.030, +blood, prot., ketones, 2-5 WBC/hpf 2-5 RBC/hpf, no Eos.
- Abdominal CT w/o: diffuse scatter colonic gas, no mass, obstruction

# Definition of Acute Renal Failure/Acute Kidney Injury

- An abrupt increase in the BUN and Creatinine with corresponding problems in handling of fluids, potassium, phosphorus, and acid-base balance. This is usually a greater than 25- 50% decline in the GFR.
- Decreased urine output may or may not be an early manifestation of AKI

# Problems with the Definition

- Serum Creatinine may NOT reflect the degree of renal dysfunction or improvement
- Urine output or lack of may also not reflect the degree of dysfunction
- A better definition may be Acute Kidney Injury (AKI)

# RIFLE VS AKIN

## RIFLE

	Cr/ GFR Criteria	Urine Output (UO) Criteria
<b>Risk</b>	Increased Cr x1.5 or GFR decreases >25%	UO <0.5 ml/kg/hr x 6 hr
<b>Injury</b>	Increased Cr x 2 or GFR decreases >50%	UO <0.5 ml/kg/hr x 12 hr
<b>Failure</b>	Increased Cr x 3 or GFR decreases >75% or Cr $\geq$ 4 mg/dl (with acute rise of $\geq$ 0.5 mg/dl)	UO <0.3 ml/kg/hr x 24 hr or anuria x 12 hr
<b>Loss</b>	Persistent ARF = complete loss of renal function for > 4 weeks	
<b>ESRD</b>	End Stage Renal Disease	

## AKIN

	Cr Criteria	Urine Output (UO) Criteria
<b>Stage 1</b>	Increased Cr x1.5 or $\geq$ 0.3 mg/dl	UO <0.5 ml/kg/hr x 6 hr
<b>Stage 2</b>	Increased Cr x 2	UO <0.5 ml/kg/hr x 12 hr
<b>Stage 3</b>	Increased Cr x 3 or Cr $\geq$ 4 mg/dl (with acute rise of $\geq$ 0.5 mg/dl)	UO <0.3 ml/kg/hr x 24 hr or anuria x 12 hr

Patients who receive renal replacement therapy (RRT) are considered to have met the criteria for stage 3 irrespective of the stage that they are in at the time of commencement of RRT.



# Epidemiology

- 1 % at time of admission, 2-5% during the time of admission
- 67% of all critical care admissions
- 23.7% incidence of resulting in either CKD or worsening of CKD
- In hospital mortality of AKI 40-50%
- ICU mortality >50% even with dialysis
- Patients die with AKI rather than from AKI

*Anesthesia*. 2009; 110(3):505-15.

*Adv. Chronic Kidney Dis*. 2008; 15(3): 297-307.

*Clin J Am Soc. Nephrol*. 2016; 11(2): 2123-2131.

# Phases of Acute Kidney Injury

- Initiation Phase-drop in BP, nephrotoxins, early sepsis—rise in BUN/Cr, decreasing urine output
- Oliguric Phase-usually less than 400 ml/da, may require dialysis
- Recovery/Diuretic Phase-increasing urine output, decreasing BUN/Cr, Potassium, Phosphorus, and Magnesium

# Differentiation of AKI

Acute Tubular Necrosis 45%

Pre-Renal 21%

Acute on Chronic R.F. 13%

Obstruction 10%

Glomerulonephritis/vasculitis 4%

Acute Interstitial Nephritis 4%

Athroemboli 1%

Based on 748 cases from 13 tertiary care centers

*Kidney Int* 1996; 50(3):811

# Diagnosis of AKI

- Increase of BUN/creatinine or increase from baseline (0.3 mg)
- Decreased urine output
- Renal ultrasound (poor man's biopsy)-can differentiate acute from chronic, obstruction, masses, symmetry, abdominal fluid
- Bladder scan
- Angiography: polyarteritis nodosa, vasculitis
- Intraabdominal pressure: Hepatorenal syndrome, abdominal compartment syndrome

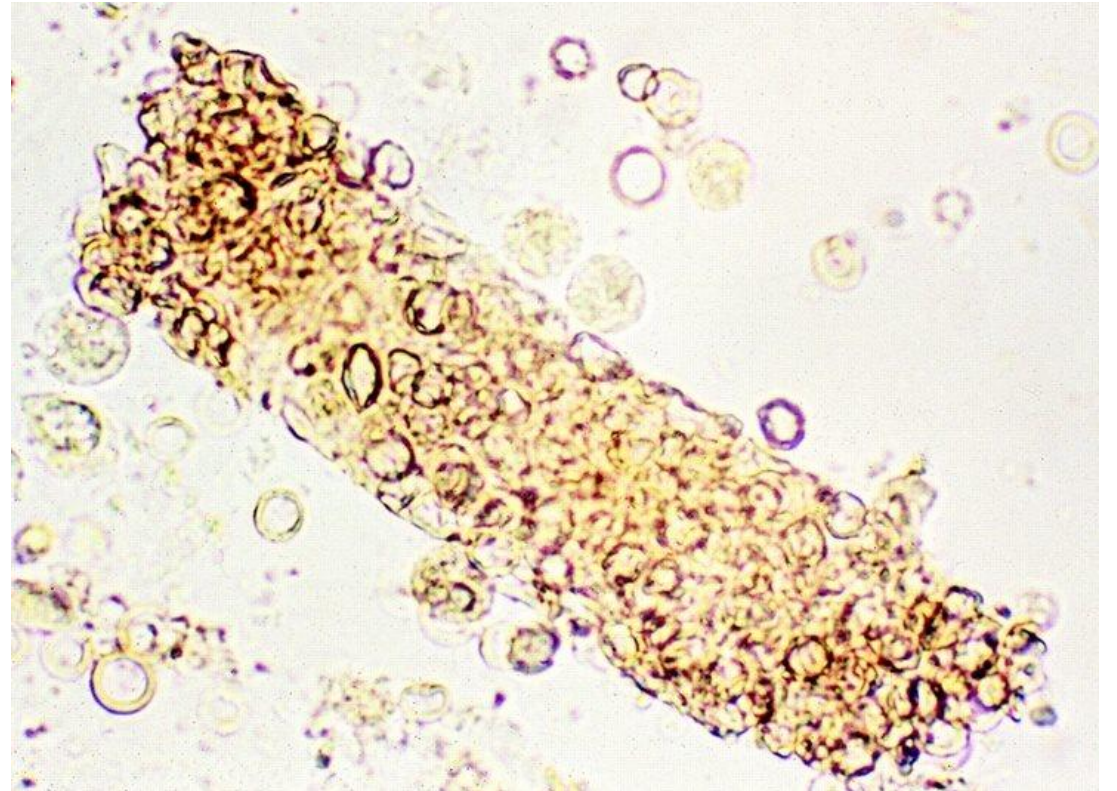
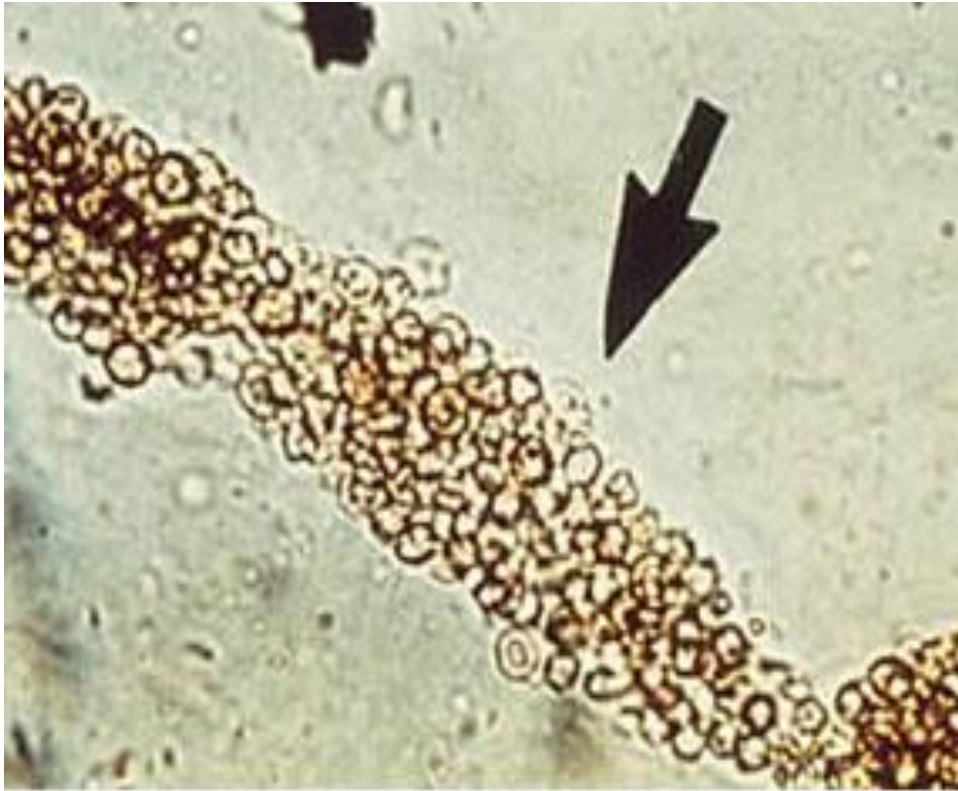
# Laboratory Tests

- Multi-chem profile
- Urinalysis w/ micro, eosinophils, urine electrolytes, osmolarity, creatinine, protein/creatinine ration
- Specific test are dependent on the clinical presentation and suspicions

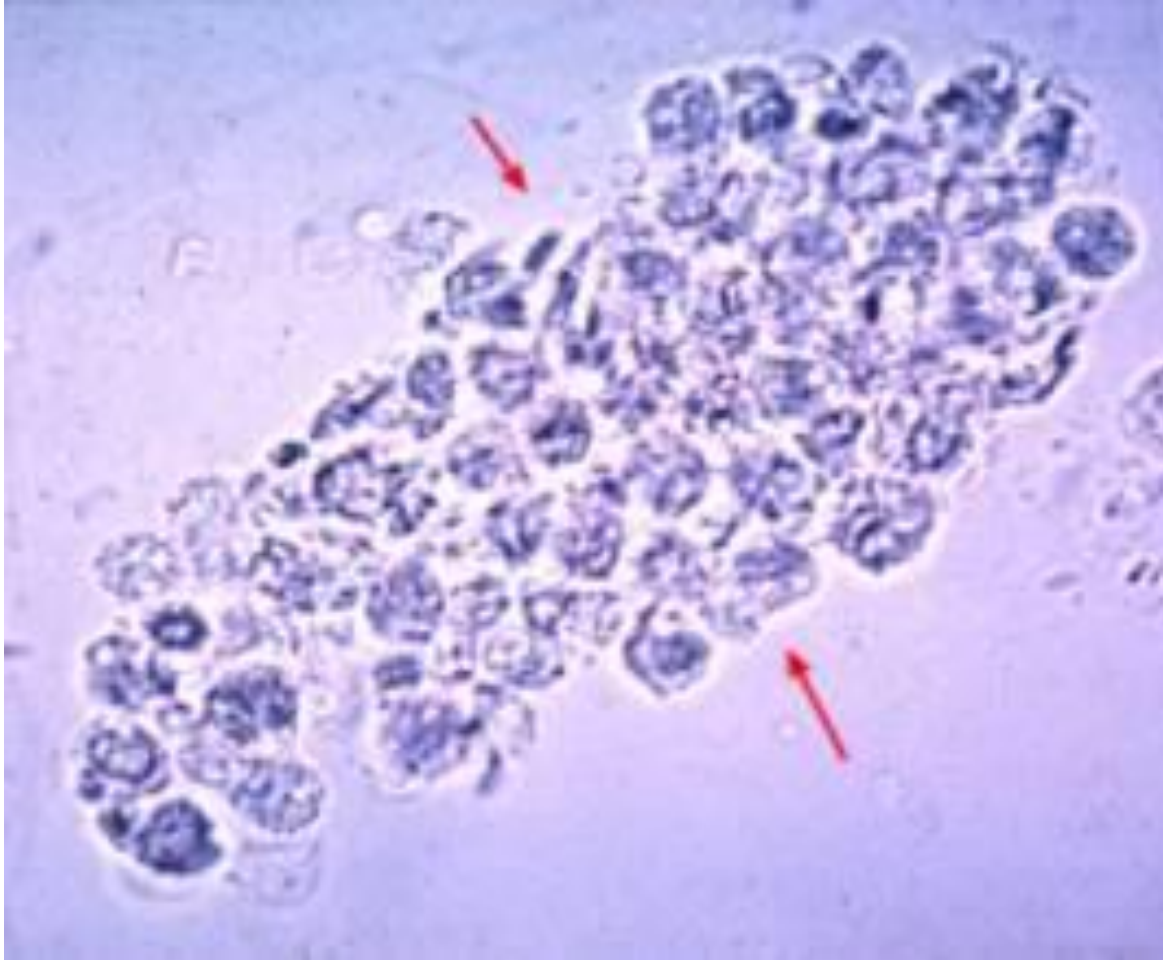
# Supporting Laboratory Tests for ATN

- ANCA (P, C, MPO, PR3), anti-GBM, ANA (anti-DS DNA specific for end organ damage, anti-Histone for drug induced SLE)
- C3, C4, CH50, ESR, CRP, uric acid\*
- Hepatitis B, C, HIV, RPR, cryoglobulins, SPEP, UPEP
- CBC, peripheral smear, reticulocyte count
- Haptoglobin, LDH, CPK
- Cultures, blood, urine etc.
- Renal biopsy

# RBC Casts



# WBC Casts





# Renal Biopsy

## Indications

- Unexplained AKI
- Hematuria, proteinuria
- Establish a diagnosis
- Guide therapy and prognosis

## Contraindications

- Small contracted, echodense kidneys
- Solitary kidney (maybe)
- Active infection
- Uncontrolled hypertension
- Coagulopathy or anticoagulants
- Uncooperative patient

# AKI vs CKD

## Acute Kidney Injury

- Well defined precipitating event: sepsis, hypovolemia, drugs, obstruction, etc.
- Normal sized non- echodense kidneys on US
- Normal PTH, H/H, phosphorus, calcium
- RBC or WBC and/or Granular casts on UA

## Chronic Kidney Disease

- Chronic underlying conditions: DM, HTN, SLE, NSAID use, etc. or has not seen a physician in decades
- Small echodense kidneys on US
- Normocytic normochromic anemia
- Elevated PTH, phosphorus, low calcium

# Types of AKI

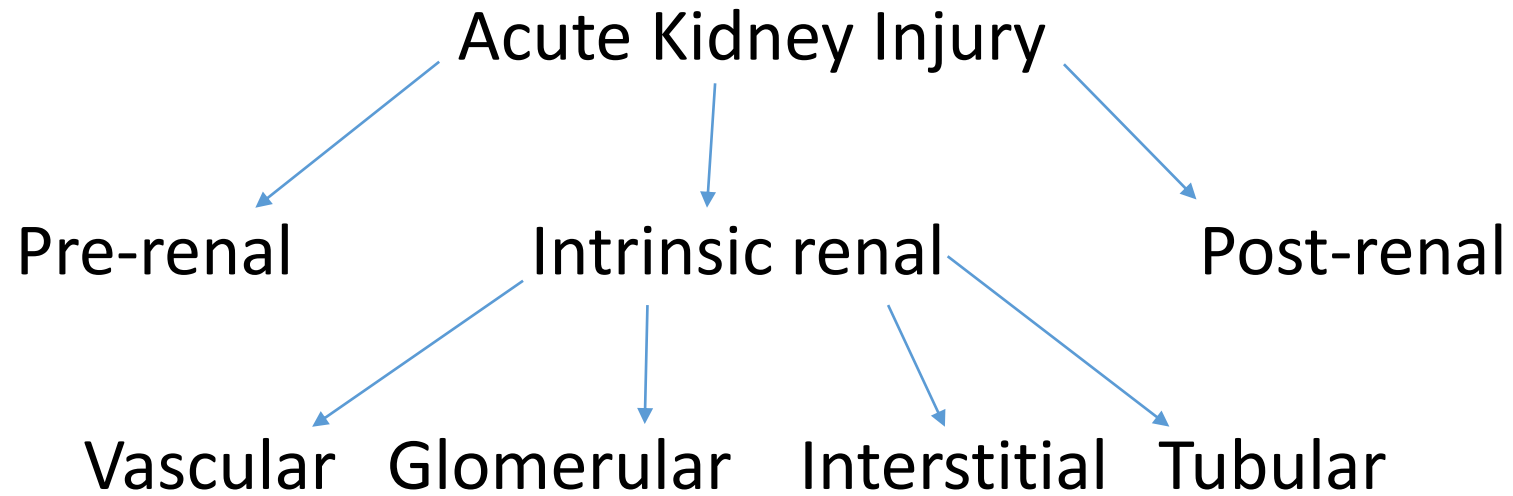
## Oliguric vs Non-oliguric

- > or < 400 ml/da urine output
- 400 ml/da minimal u/o/da to clear the daily osmotic load
- 50-60% Non-oliguric
- Non-oliguric has a better prognosis
- Anuria < 100 ml/da

## Anatomic injury

- Pre-renal: decreased in actual or effective circulating blood volume (CHF)
- Intrinsic: Direct injury to the vascular, glomerular, interstitial or tubular components
- Post-renal: Obstruction to the flow of urine

# AKI



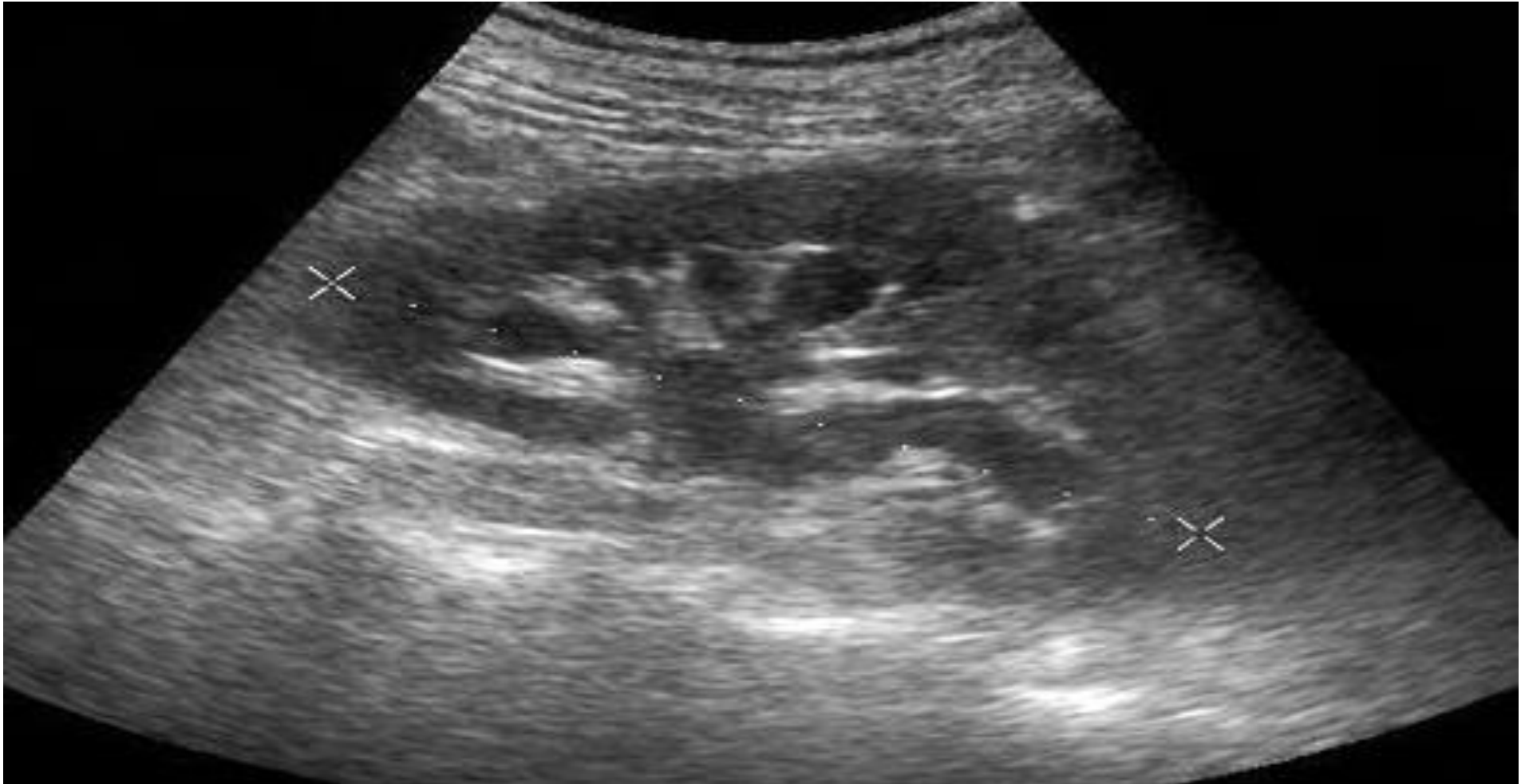
# Post renal/Obstructive

- May be acute, chronic or acute on chronic
- Functional renal recover depends on duration of the obstruction
- Post obstructive diuresis may lead to AKI unless fluid and electrolyte deficits are appropriately replaced
- In a patient with tense ascites, check the intraabdominal pressure if >13 mm Hg, get an US and paracentesis. Very high risk if >25 mmHg
- The nephrologists role is to contact the urologists or interventional radiologists to relieve the obstruction or the nurse to place a Foley catheter

# Post-renal/Obstructive AKI

- Renal stones: Ca oxalate MCC, uric acid, struvite (infection-esp. *proteus*)
- Strictures, retroperitoneal hematoma, fibrosis or tumor
- Obstructing casts e.g. myeloma, rhabdomyolysis, ATN
- BPH, cancer, neurogenic bladder
- Intrarenal or extra-renal tumors
- Renal vein thrombosis
- Intra-abdominal pressure  $>\sim 13$  mmHg (tense ascites)

# Post-renal/Obstructive



# Pre-renal AKI

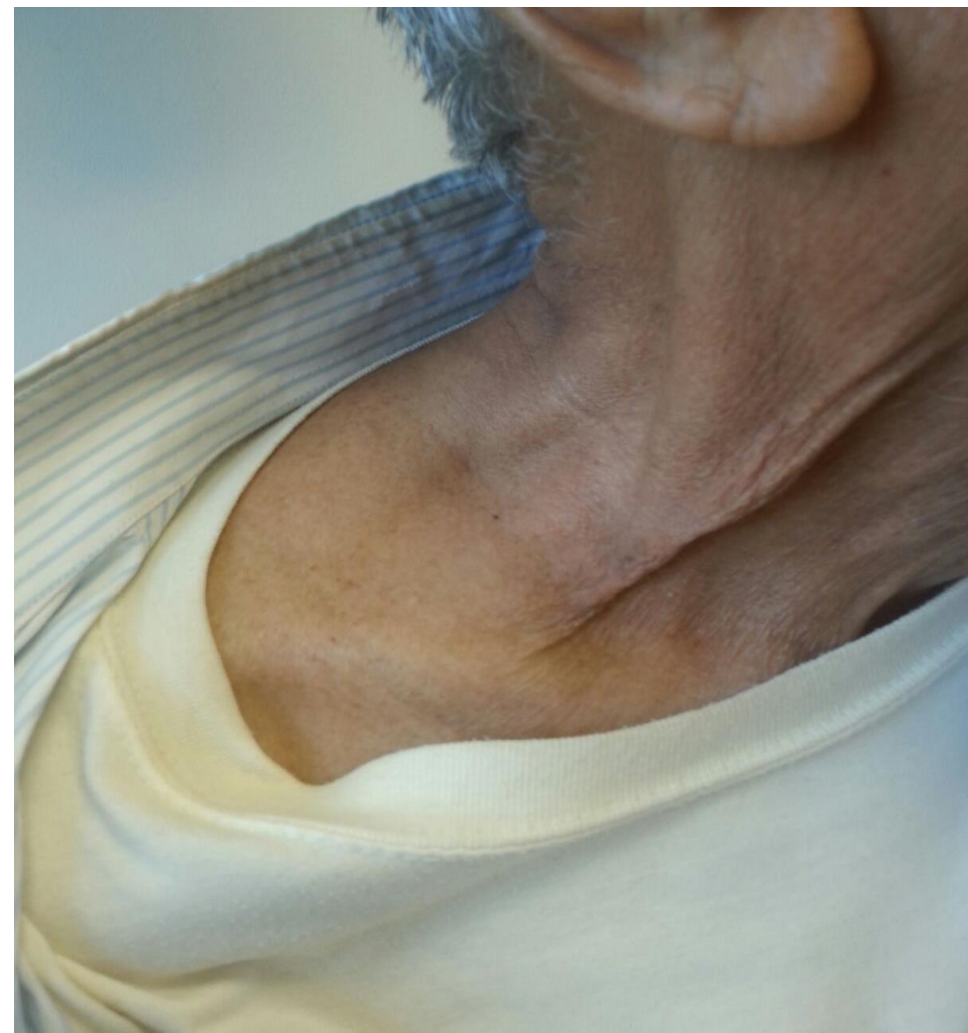
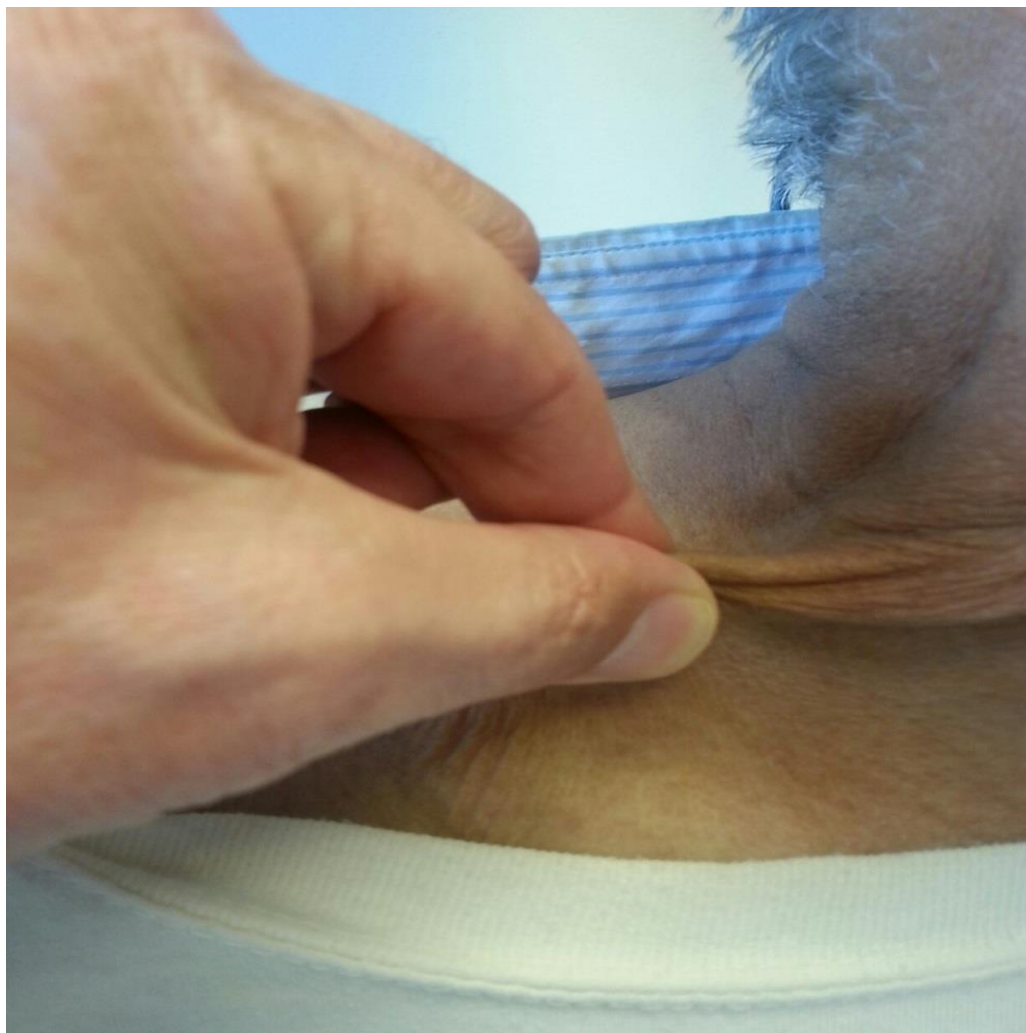
- A decrease in total circulating volume or effective circulating blood volume (ECBV) e.g. CHF, sepsis.
- This leads to activation of Sympathetic Nervous System (SNS), Renin Angiotensin Aldosterone System (RAAS) and Antidiuretic Hormone (ADH) in an attempt to restore the real or perceived volume loss. This leads to enhances sodium and water reabsorption by the tubules.
- Urine Na will be  $<10$  and Urine Osmolarity will be  $>500$



# Pre-renal AKI

- Review I's and O's
- Blood pressure: even a transient drop in BP e.g. SBP 90-100 mmHg may be enough to cause AKI, especially in the face of other factors e.g. nephrotoxins, sepsis CHF
- A thorough evaluation of the patient's volume status is essential:  
Skin turgor, axillary moisture, mucous membranes, orthostatics, CVP

# Poor Man's Swan-Ganz Catheter



# Causes of Pre-renal AKI

- Dehydration, hemorrhage, steroids, protein loading
- GI losses: vomiting, diarrhea, NG, fistulas, GI bleed
- Sepsis
- Excessive sweating, prolonged hyperventilation
- CHF, Cirrhosis, nephrotic syndrome/ cardiorenal, hepatorenal syndromes-decreased ECBV
- “3<sup>rd</sup> space losses”
- Diuretic phase of AKI, over-diuresis
- Rapid correction of HTN

# Fractional Excretion of Sodium ( $FE_{Na}$ )

- May be helpful in differentiating Pre-renal from Intrinsic AKI
- Normal value 1%
- Not accurate in CKD, A on CKI, or after patient has received diuretics
- $FE_{Na} = (S_{Creatinine} \times U_{Na} / S_{Na} \times U_{Creatinine}) \times 100$

# Urinary Indices in AKI

	<u>Pre-renal</u>	<u>Acute Tubular Necrosis</u>
<u>BUN/Cr</u>	>15-20:1	<10-15:1
<u>Spec grav</u>	>1.020	<1.010
<u>U osm</u>	>500	~300
<u>U Na</u>	<10	>30-40
<u>FENa</u>	<1%	>2-3%
<u>Sediment</u>	Nothing or a few hyaline casts	Dirty brown/granular casts

# Intrinsic Renal AKI

- Vascular
- Glomerular
- Interstitial
- Tubular
- Usually intrinsic AKI will involve multiple segment of the nephron  
e.g. RPGN with ATN

# Pulmonary Renal Syndromes

- Patients will frequently present with pulmonary hemorrhage, hematuria and AKI (Crescentic RPGN)
- SLE
- Goodpasture's syndrome
- IgA Berger's, HSP
- ANCA mediated, systemic vasculitis
- Post streptococcal GN
- Immune complex GN

# Vascular Intrinsic AKI

- Renal artery obstruction: Vasculitis, polyarteritis nodosa, embolism, thrombosis, dissection
- Renal vein thrombosis: may be asymptomatic
- Malignant hypertension, scleroderma renal crisis
- Severe and sustained hypotension (sepsis, dehydration)
- Post heart surgery (increased cross clamp, pump time)
- Athroembolic disease/cholesterol emboli
- Microangiopathy: DIC, Hemolytic uremic syndrome/TTP, preeclampsia
- Transplant rejection



# Glomerular Intrinsic AKI

- Rapidly progressive glomerulonephritis (RPGN): ANCA mediated: Granulomatosis with polyangiitis(Wegner's), Eosinophilic granulomatosis w/ polyangiitis (Chrug-Strauss), microscopic polyangiitis, anti-GBM disease (Goodpasture's syndrome), SLE, post-infectious GN,
- Immune complex mediated: SLE, cryoglobulinemia (Hepatitis C), membranoproliferative GN
- IgA mediated: Berger's disease, Henoch-Schoenlein Purpura

# Interstitial Intrinsic AKI

- Acute Interstitial Nephritis
- Medications: Sulfas (TMP/STX), penicillin/methicillin, NSAIDs, PPIs, cephalosporins, allopurinol, indivar, rifampin, mesalimine, any medication should be suspected
- Infectious: pyelonephritis, viral, fungal/protozoan
- Systemic illness: lymphoma, leukemia, sarcoid, Sjorgren syndrome, Reiter's syndrome

# Tubular Intrinsic AKI

- Can be ischemic or cytotoxic
- Acute Tubular Necrosis: ischemic  
Cytotoxic:
- Drugs: aminoglycosides, lithium, acyclovir, amphotericin B, pentamidine, cisplatin, foscarnet, vancomycin, radiocontrast media, effects of drugs ALWAYS magnified in the face of volume depletion and hypotension
- Crystals: tumor lysis syndrome, hyperuricemia, hypercalcemia, ethylene glycol, acyclovir, megadose Vit. C, indinavir, sulfas, methotrexate
- Tubular obstruction: Rhabdomyolysis, intravascular hemolysis

# PPI's linked to Numerous Adverse Effects

- Since 2007 FDA has issues warnings to people taking PPI's for increased risk:
- Fractures
- Decreased effectiveness of clopidogrel w/ omeprazole
- *C. difficile* diarrhea
- Pneumonia (community and hospital acquired)
- Cutaneous Lupus reactions
- Renal effects

FDA.gov:

8/9/2007,12/10/2007,5/28/2010,6/26/2010,4/5/2011,3/2/2011,3/11/2011,3/23/2011,4/5/2011,  
2/8/2012,6/24/2016,8/30/2016, 11/1/2016, 2/23/2017

# Renal Side Effects Linked to PPI's

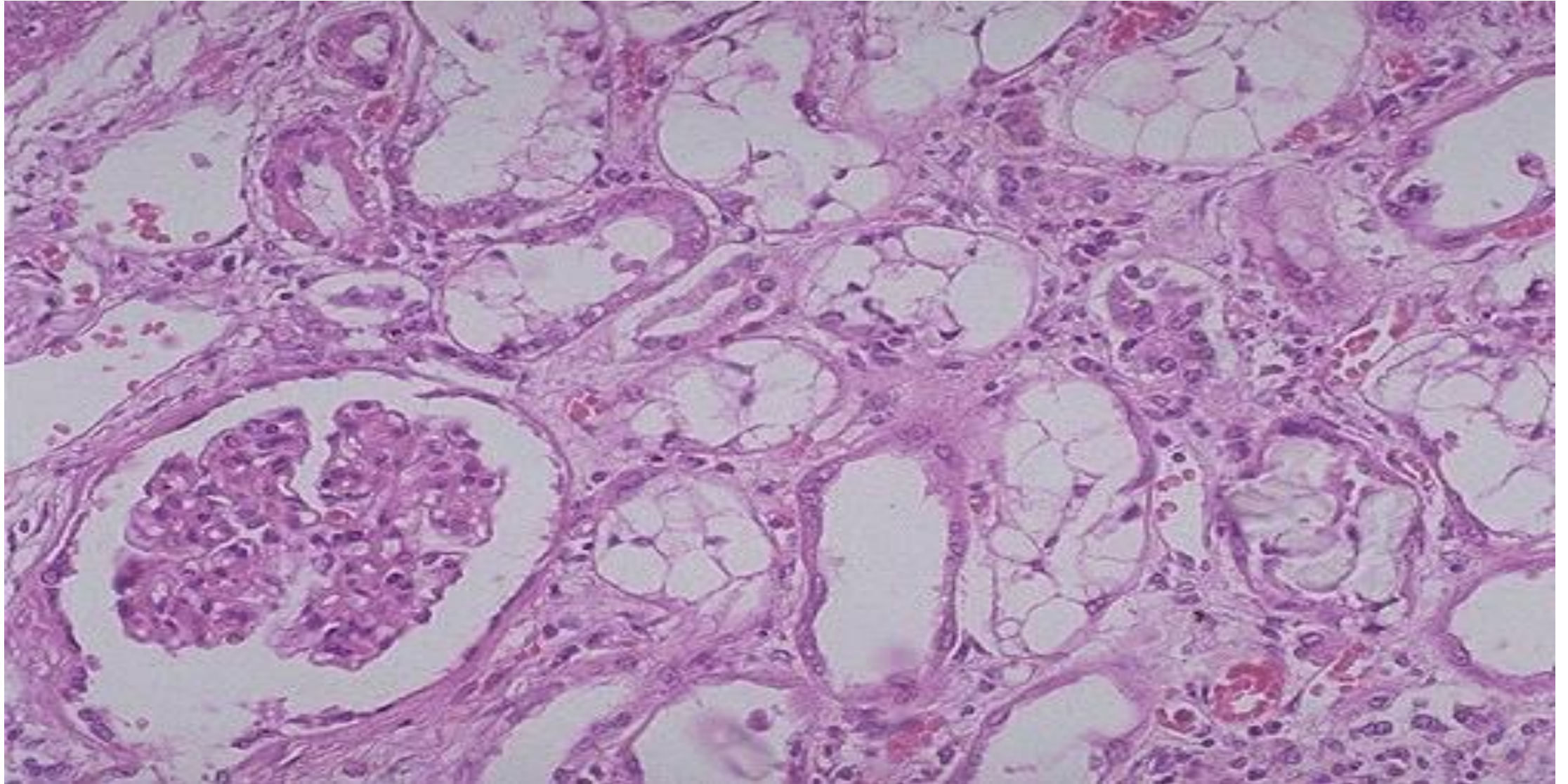
- Acute interstitial nephritis
- Acute kidney injury from pneumonia or *C. diff.* diarrhea
- Chronic interstitial nephritis
- Hyponatremia
- Hypomagnesemia
- Hypokalemia
- ESRD

*J Gastroenterol Hepatol* 2017;32:1295-1302. *J Nephrol.* 2016;29:611-616

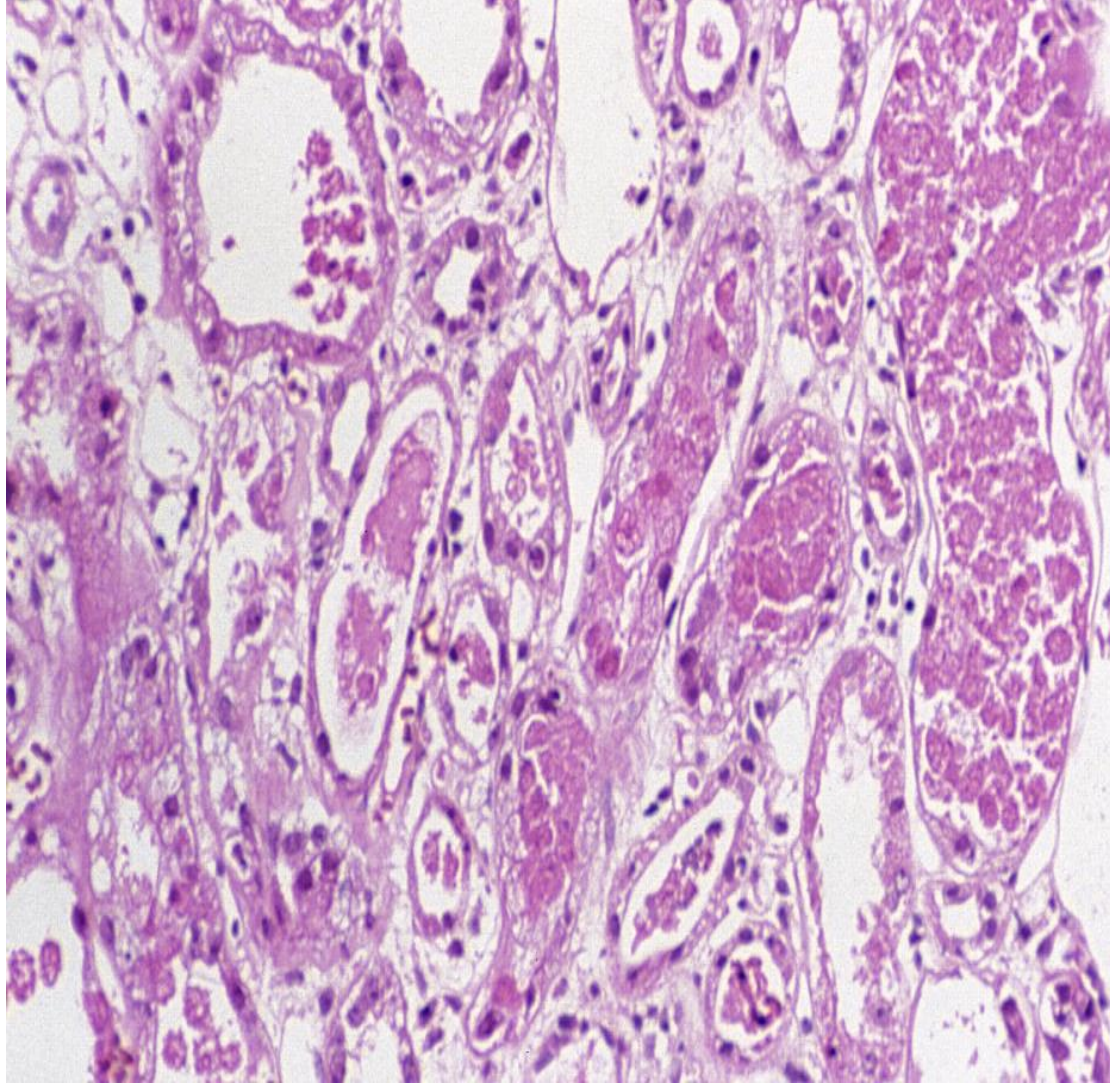
# Acute Tubular Necrosis

- Thrombosis of the vasa recta/tubular microvasculature leading to ischemia of the tubular cells, which causes cellular edema, rupture and intra-tubular obstruction
- May be from a variety of causes such as sepsis, immune mediated, drugs
- The final common pathway of all untreated pre-renal or post-renal causes

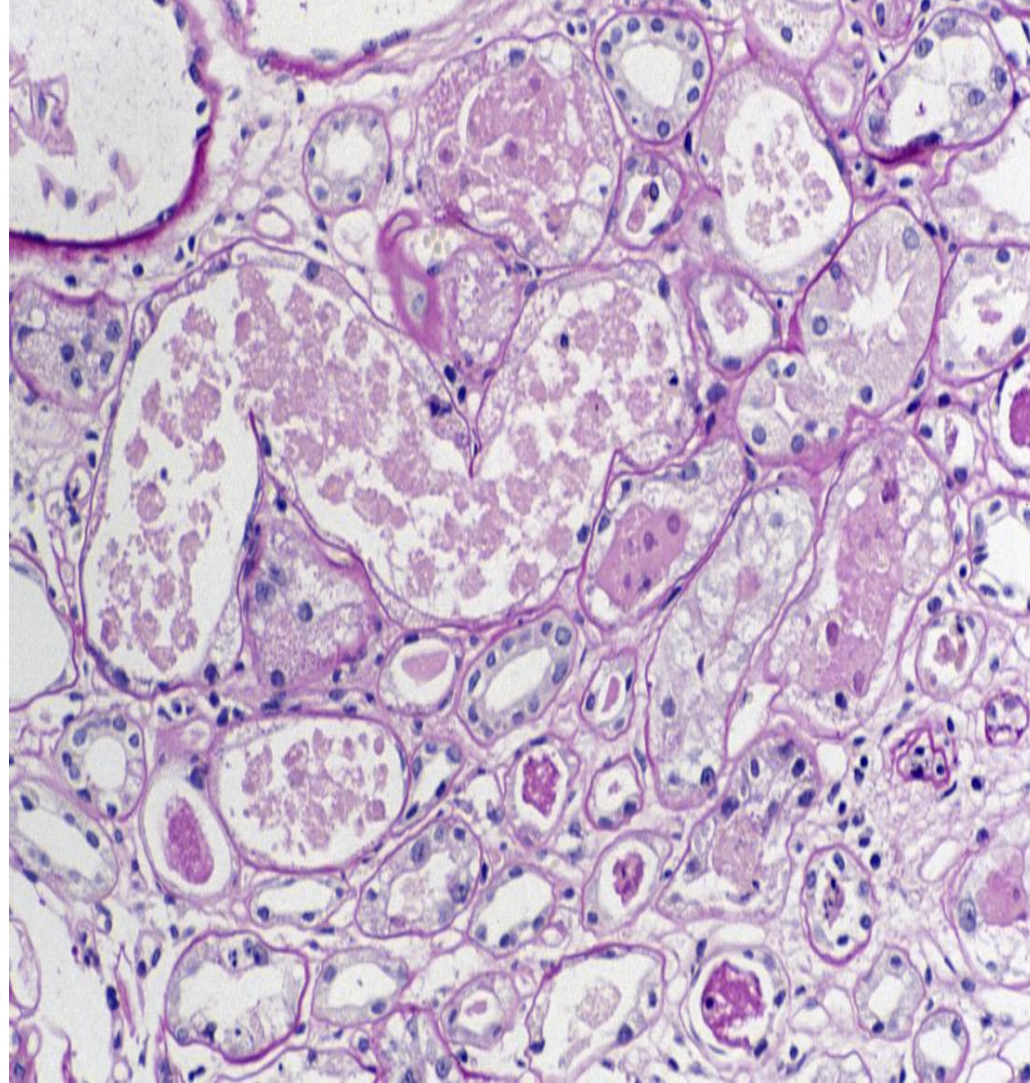
# ATN



# ATN



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# Management of Acute Kidney Injury

- In absence of hemodynamic shock, isotonic crystalloid is preferred over albumin or starches for volume expansion (More below)
- No difference in saline vs Ringer's for fluid, but Ringers has K and Ca which a pt. in AKI does not need
- Closely follow hemodynamic and oxygenation parameters in at risk patients
- Keep blood glucose in the 110-149 mg/dl range
- Do not use diuretics to prevent AKI
- Use loop diuretics in AKI ONLY to treat volume overload

# General Principles of Management of AKI

- High dose loop diuretics: sorry, 20 mg of furosemide in a patient with a creatinine of 3.8 mg/dl probably will not work (Think industrial strength doses 60-240 mg)
- Bolus vs infusion of loop diuretics: no difference (DOSE Trial, *NEJM* 2011; 364:797-805)
- Correct anemia, hypoalbuminemia (if <2.2 gm/dl)
- Correct acidosis
- Nutrition-early and use gut if possible
- Avoid or d/c nephrotoxins if possible
- ?Allopurinol

# Management

- “Renal dose dopamine” does not work
- Repeated doses of loop diuretics in the face of ongoing anuria has no effect
- Fenoldopam, atrial natriuretic peptide, statins, recombinant insulin growth factor, N-acetyl cysteine or eye of newt does not work
- Dialysis with biocompatible membranes does decrease mortality
- Place Foley catheter-may cure AKI but can help monitor fluid balance

KDIGO Clinical Guidelines for Acute Kidney Injury. *Kidney Inter., Suppl*, 2012; 2: 1-138.

# Fluid Management

## FACTT Trial 2011 Follow-up

- Multicenter trial, 306 AKI patient
- Liberal vs conservative fluid management +furosemide in AKI
- Liberal fluid group ( 10.2 L fluid accumulation over 6 days) had a higher mortality vs the conservative group (3.2 L over 6 days)
- Higher furosemide use (562 mg vs 159 mg) had a lower mortality rate, but little effect on fluid balance

*Clin J AM Soc Nephrol.* 2011; 6(5): 966-973.

# Contrast Induced Nephropathy Prophylaxis

- Hold metformin 48 hrs. before\*
- IV hydration with NS or 3 amps of Na bicarbonate in D5W or sterile water 1 ml/kg/ hr. 6-12 hrs. before and after procedure
- Higher the creatinine, longer the IVF
- N-acetyl cysteine has mixed reviews and cannot substitute hydration, use if IVF cannot be used
- Non ionic contrast, minimize the volume of contrast and increase time between studies

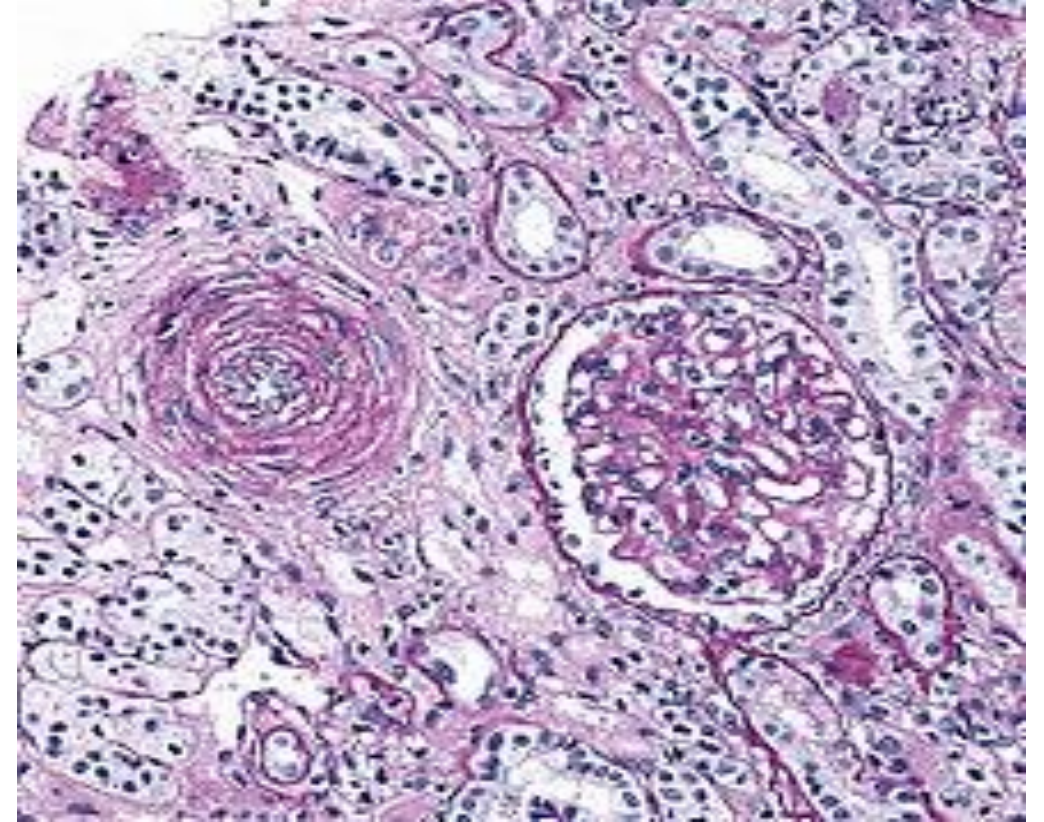
\*Most important

Gupta, RK, Semin Intervent Radiol 2010;27:348–59.

Nallamotheu BK, Am J Med 2004;20:193–200.

# Malignant HTN/Scleroderma Renal Crisis

- Hyperdynamic murmur, S4,S3
- CHF
- Headache
- Hematuria
- AKI
- “Onion skinning” of vessels
- ACE-I or ARB for Scleroderma crisis



# Polyarteritis nodosa

- Painful skin rash, livedo
- M>F, 4-5<sup>th</sup> decade, Hep. B/C
- Hematuria, proteinuria, AKI
- HTN, polyneuropathy
- Abdominal pain, myalgia, arthralgias
- Classic angio: “cherries on a tree”
- Steroids, cyclophosphamide



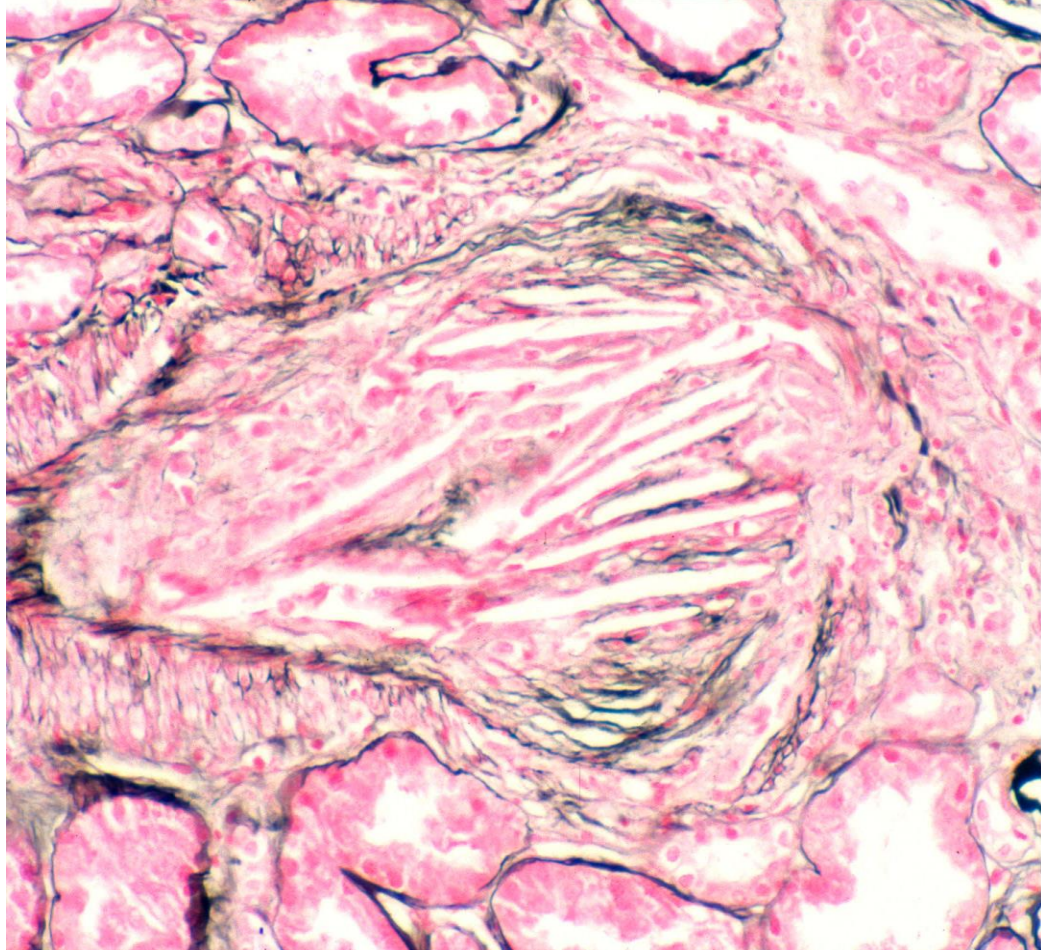
# Cholesterol/Athroemboli Syndrome

- Post Cath, CABG, CV surg.
- Spontaneously in severe PVD or warfarin tx
- Blue toes, rash(ant. tibia), livedo
- “Stair stepping” of renal fx
- AKI, eosinophil in blood, urine
- WBC casts, elevated ESR, low complements
- Cholesterol clefts in sm. vessels on bx, w/local rxn

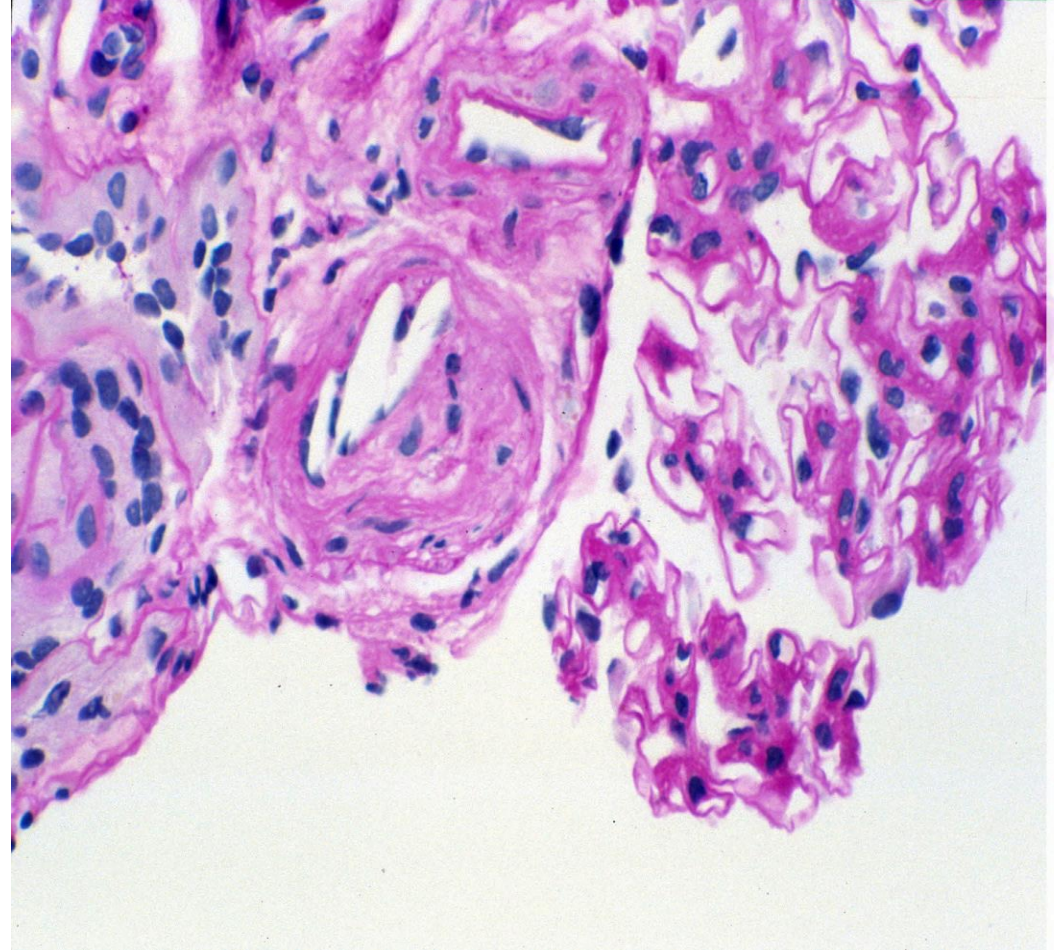




# Cholesterol Emboli



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# Hemolytic Uremic Syndrome/TTP

- AKI+microangiopathic hemolytic anemia, thrombocytopenia
- E. Coli 0157:H7 and 0104:H4-Shiga-like toxin, verocytotoxin
- Pregnancy, cancer, transplant associated
- Mitomycin, cyclosporine, OC
- Bloody diarrhea (+ prog. sign)
- Purpuric rash, abdom. pain, HTN
- Hematuria, RBCs w/casts, AKI
- Anemia, thrombocytopenia
- Elevated LDH, low retic. count and haptoglobin
- Pulmonary, CNS involvement (poor prog.)
- Schistocytes, helmet cells

# HUS vs TTP

- TTP: Toxins disable ADAMTS-13, leading to thrombosis from activated vWF, AKI less common, usually low ADAMTS-13
- HUS: Dysregulation of the alternate pathway of complement, AKI much more common, N ADAMTS-13

E. Coli 0157:H7 and 0104:H4-Shiga-like toxin

**New!**

**99¢**

**Grilled e.Colita**

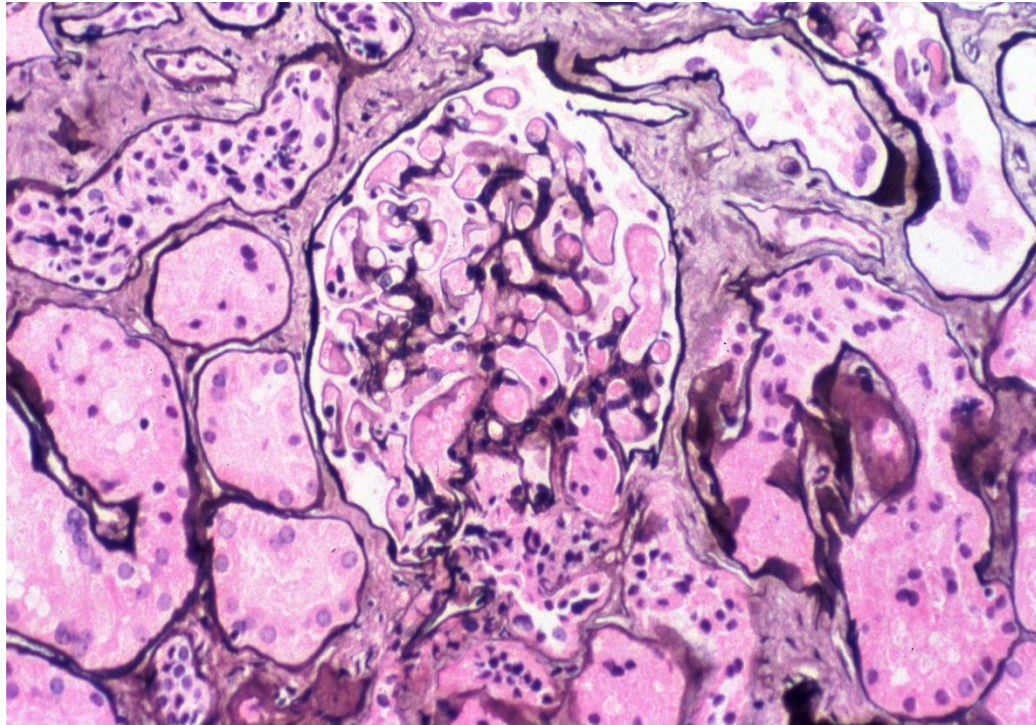
Try this delicious combo of  
Free Range Rodent,  
Tainted Tomato,  
Savory Salmonella Sauce  
...and Lettuce

**BIG BOWL  
VALUE  
MENU**



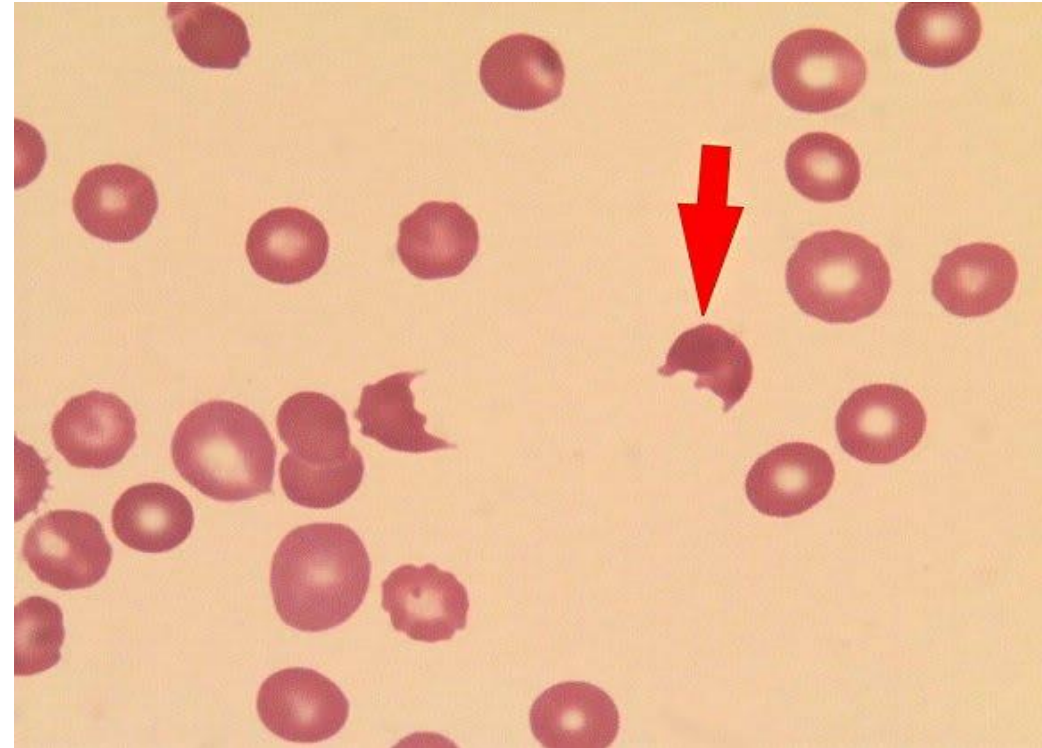
# HUS/TTP

**ATN, fibrinoid necrosis**



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**Schistocytes, helmet cells**



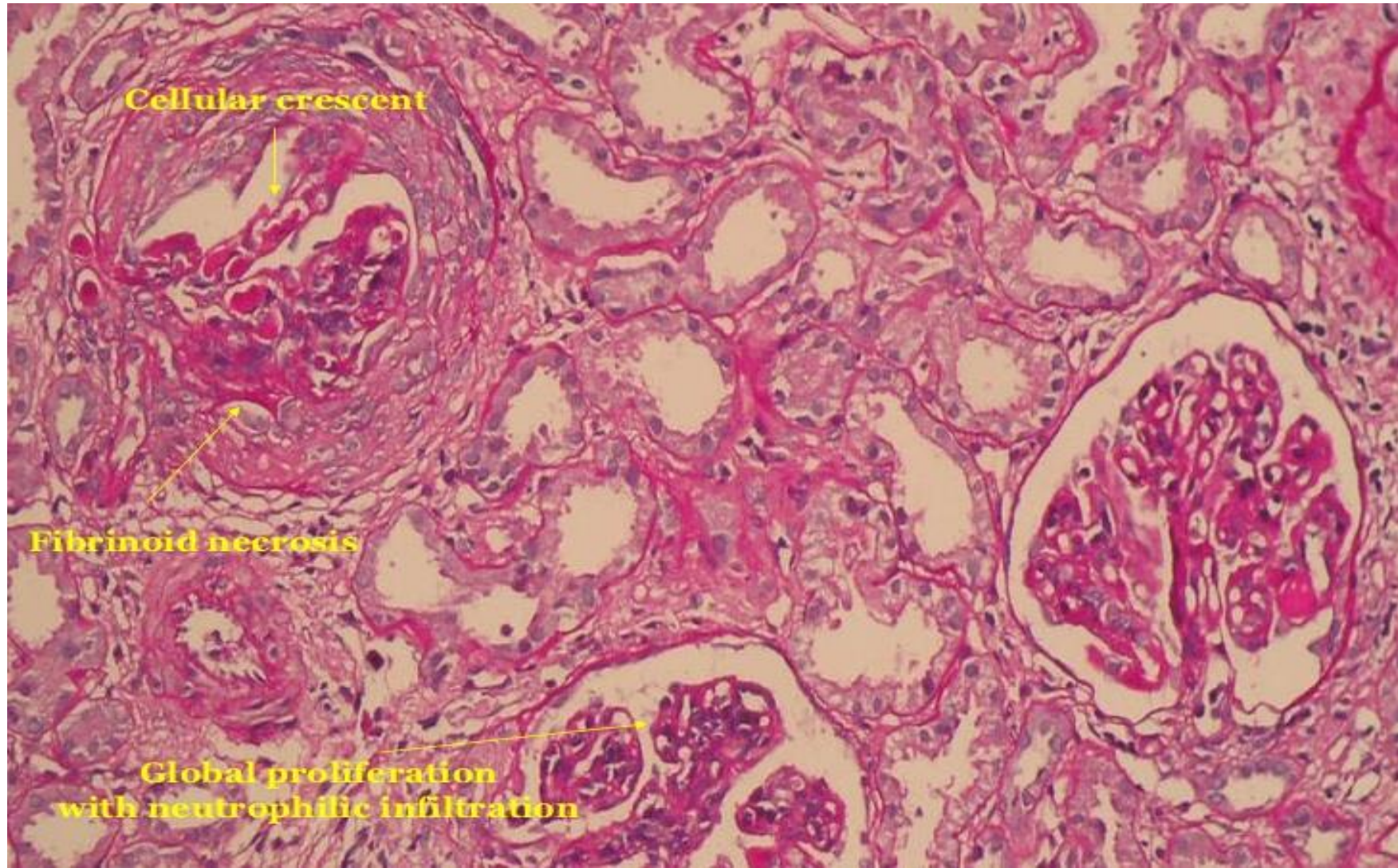
# Treatment HUS

- Steroids
- Plasma exchange
- Eculizumab, Rituximab (esp. for CNS involvement)
- Dialysis

# Rapidly Progressive Glomerulonephritis (RPGN)

- Crescentic GN
- Pulmonary renal syndromes
- Preceding URI, rash, hematuria, AKI, abdominal pain, arthralgias
- ANCA (C,P,MPO PR3), SLE
- Granulomatosis w/ polyangiitis(Wegner's), Eosinophilic granulomatosis w/ polyangiitis (Churg- Strauss), Microscopic polyangiitis,
- Anti-GBM, IgA/HSP(rare)
- Hematuria, hemoptysis, anemia, elevated ESR, low complements(maybe)
- RBCs, WBC, casts, granular casts
- Associated w/asthma, IBD, primary sclerosing cholangitis, RA
- ANCA –IF on bx(pauci-immune)

# Crescentic GN





# Henoch-Schoenlein Purpura (HSP)

- Children, adults 6<sup>th</sup> decade
- IgA mediated multisystem dz.
- Palpable purpura, arthralgia, fever
- Abdominal pain, intussusception (more common in kids)
- Hemoptysis, hematuria, AKI
- AKI more common in adults
- Poorer prognosis w/ AKI
- RBCs+casts, proteinuria
- Renal bx: ATN, crescents, +IgA on IF

# HSP

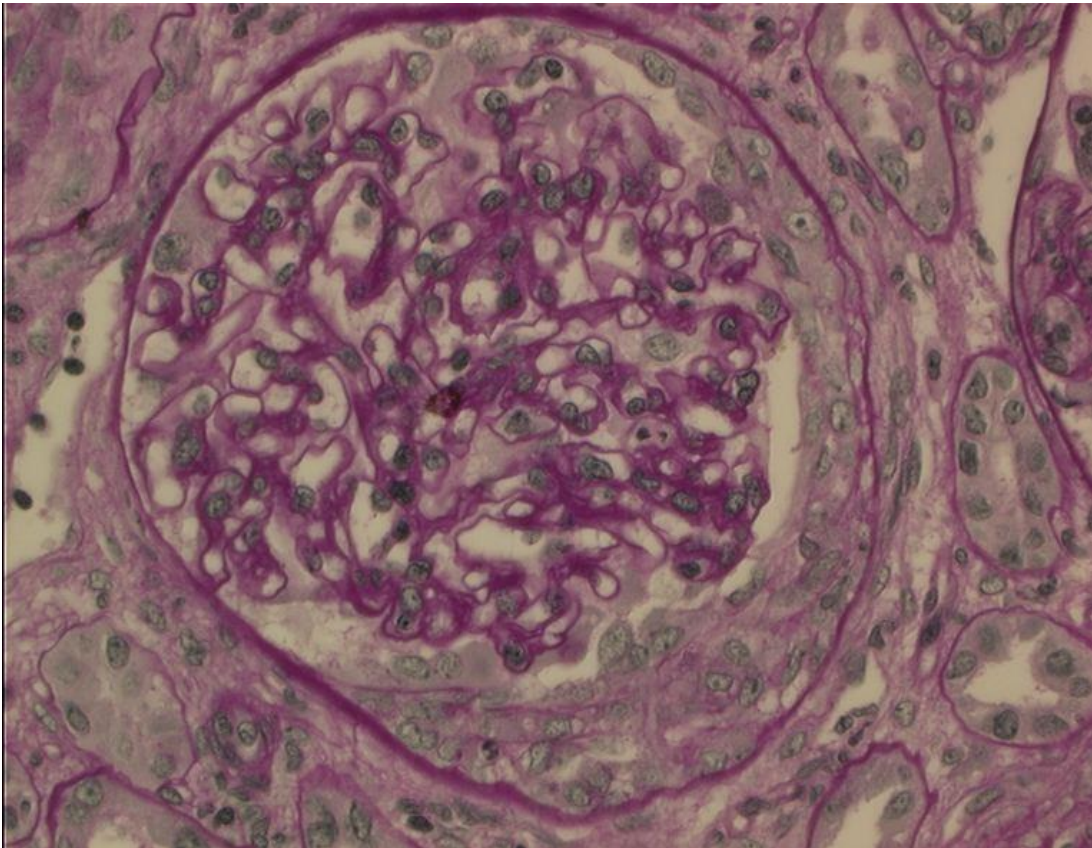


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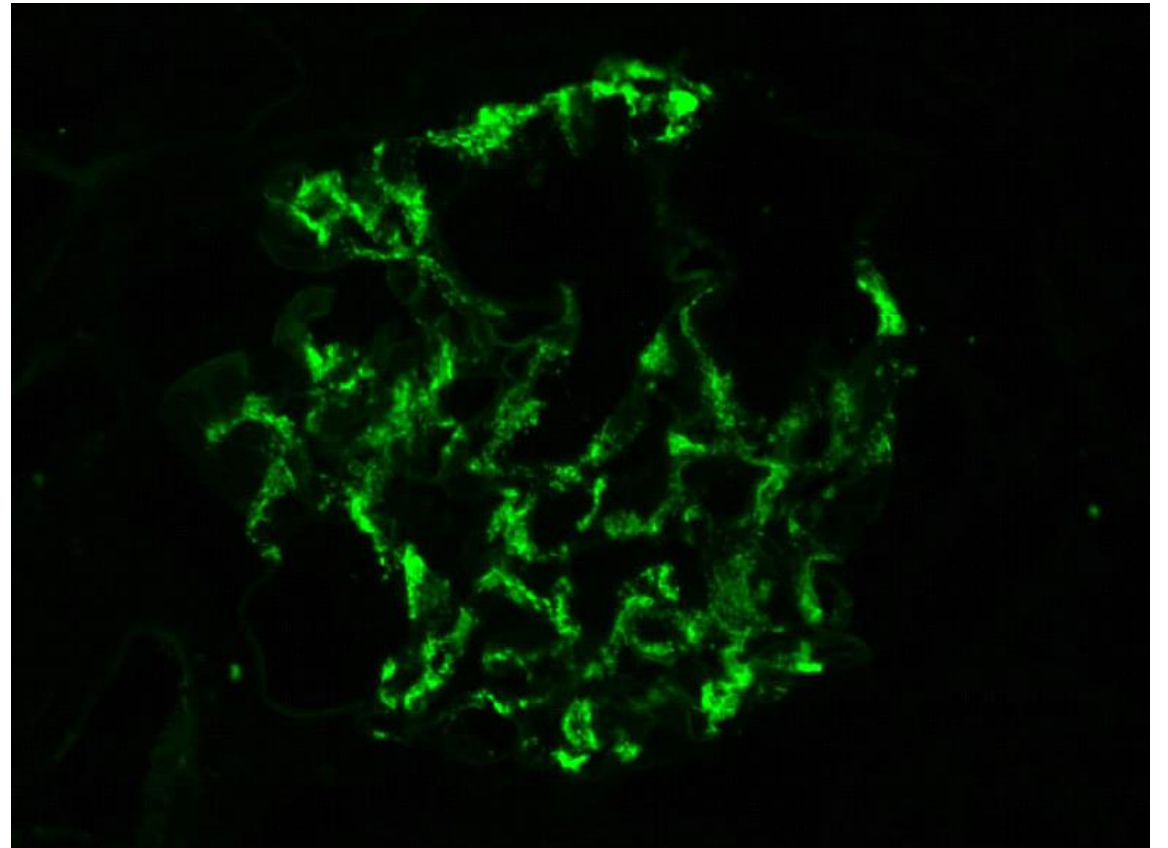


# Renal Bx HSP

**Crescents**



**+IgA IF**



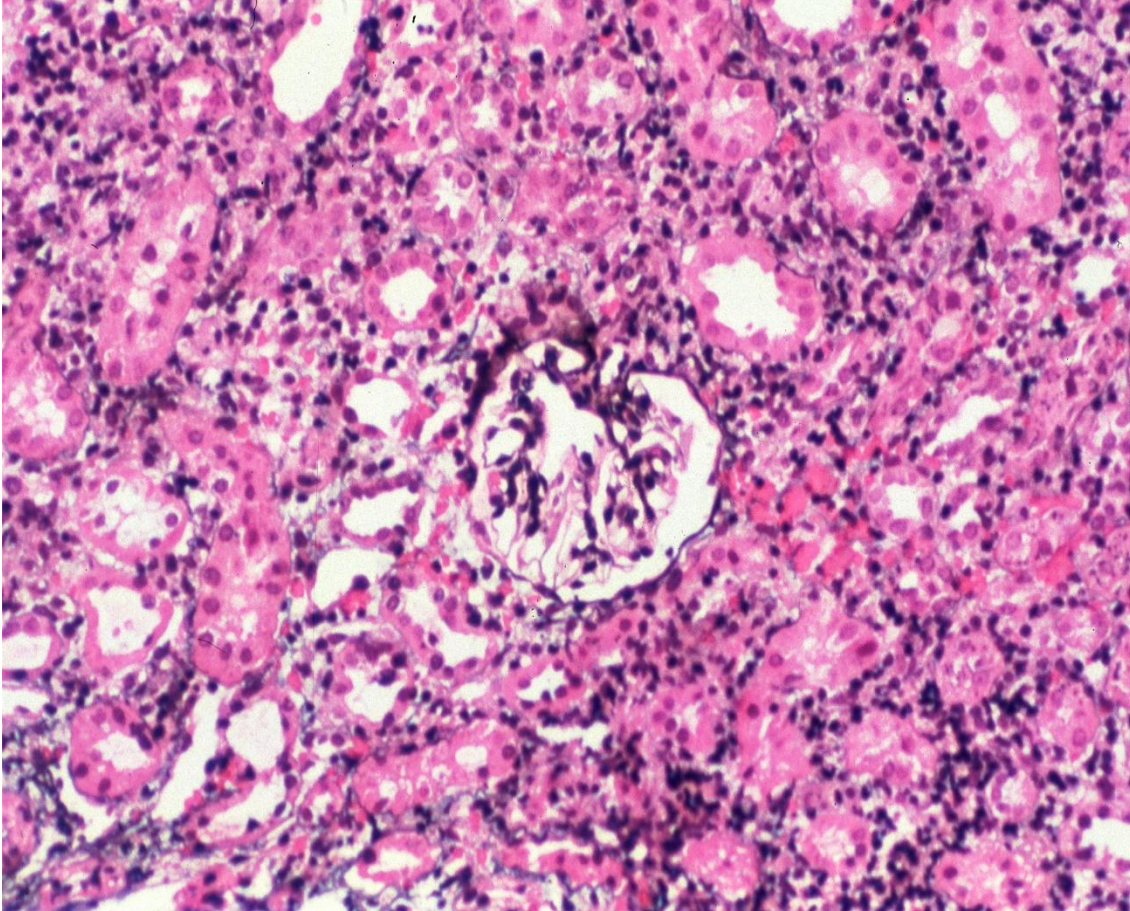
# Anti-GBM Goodpasture's Syndrome

- IgG Ab to the alpha-3 chain of Type IV collagen (only found in glomerular and alveolar BM)
- May present as acute GN and pulmonary hemorrhage or GN alone
- Renal and lung manifestations usually occur in sequence and not together
- 30-40% w/ hemoptysis
- High risk in smoker or recent URI/pneumonia
- AKI, hematuria, RBC casts, dysmorphic RBCs, HTN, edema
- +anti-GBM, ANCA may be +
- Linear deposits of IgG and crescents
- M>F teens-20's lung and renal
- F>M in 40-50's Renal more common

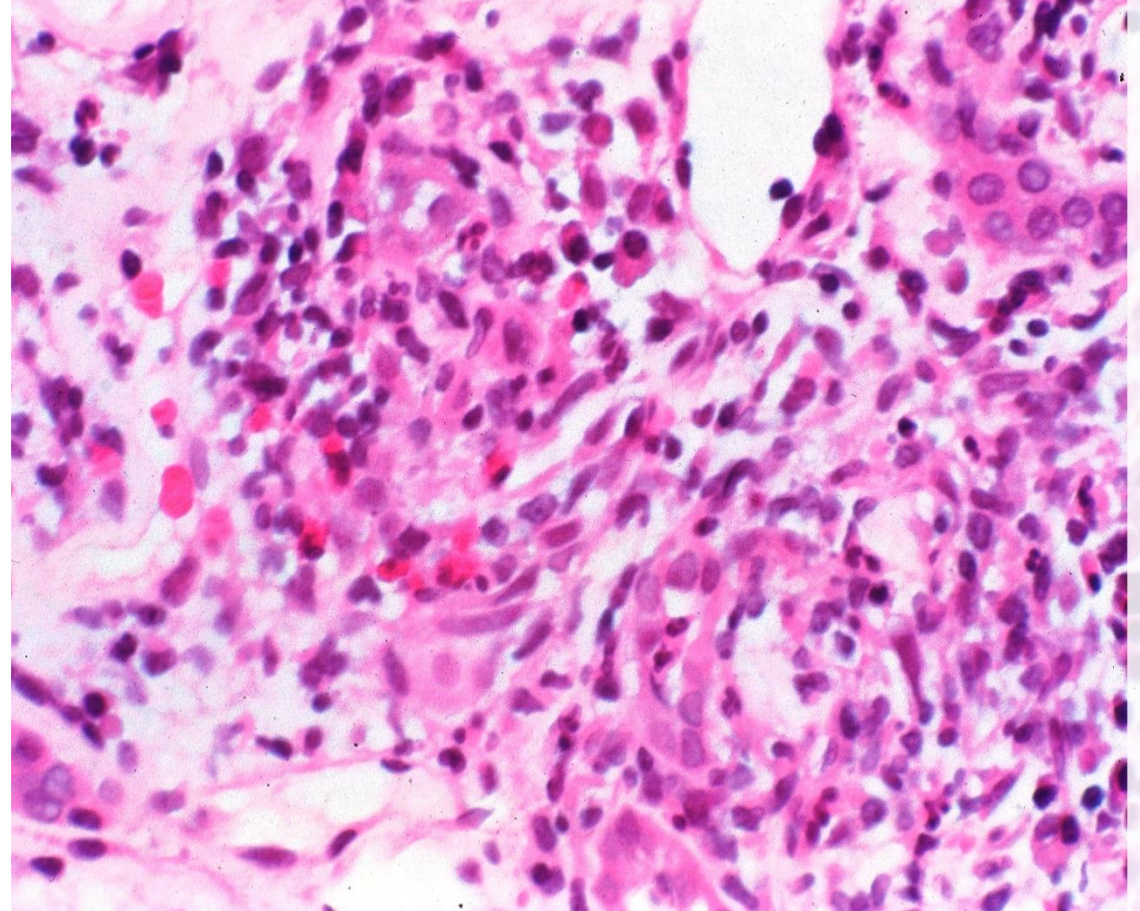
# Acute Interstitial Nephritis (AIN)

- Classically associated w/ drugs
- Need to be on a drug for 7-10 days before AIN develops
- Any drugs can induce AIN but esp. w/ sulfas, penicillins, PPIs, cephalosporins, NSAIDs, COX-2, rifampin, allopurinol
- Infection-CMV, leptospirosis, legionella, strep, pyelonephritis
- Autoimmune-Sarcoid, Sjorgren
- Malignancy-Leukemia, lymphoma
- Fever, rash, malaise, arthralgias, AKI
- Eosinophilia, Eosinophiluria (only 30% of cases!! (Hansel's stain)
- WBCs and casts in urine
- Elevated ESR, low complements
- Supporting studies may be neg.
- Mild proteinuria(<1 gm)
- Bx-infiltration of eos. and WBCs around tubules

# Renal Bx in AIN



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# Treatment of AIN

- STOP THE DRUG!
- Usually reverses on its own
- In severe cases steroids may be of benefit, but no large trials have been done

# Rhabdomyolysis

- Well recognized in trauma but frequently seen in a non trauma setting
- Diffuse muscle breakdown leading to AKI from tubular obstruction from myoglobin casts and hypovolemia
- Impaired level of consciousness (LOC) frequent factor
- CVA, drug OD, ETOH, head trauma, prolonged seizure, excess activity in an unconditioned person e.g trying to run a marathon w/o training
- Statins!!!!
- Low phosphorus, magnesium, refeeding, McArdle's, Gas gangrene, necrotizing fasciitis



# Rhabdomyolysis

- \*Key: large blood on urine dip but few RBCs, CPK>5000-250K
- Creatinine rises>>BUN
- Elevated-lactate, K, Phos., LDH
- Low Ca
- Compartment syndrome may be seen
- Early and aggressive IVF
- D5W w/ bicarb+20 gm mannitol once hydrated to alkalinize the urine, but no proof that this is any more effect than other IVF, but cautiously recommended
- Dialysis may be needed but prognosis good

# Indications for Acute Dialysis

- Acute uremia-encephalopathy, pericarditis, bleeding
- Refractory CHF
- Refractory electrolyte imbalances-usually K
- Refractory acid-base disorders
- Toxin removal

# Toxins Removed by Dialysis

- ASA
- Lithium
- Barbiturates, INH, Depakote, carbamazepine
- Theophylline & Digoxin (to some degree)
- ETOH, methanol, ethylene glycol, isopropyl alcohol
- Note: tricyclics are NOT removed, if you see this on a question