PI Session: 2021.10.20_D and T_Radiology: Imaging of Genitourinary system_ Preparatory_Marcus John Julius, M.D.

<u>**Objectives**</u>: At the end of this session, students will be able to:

1. Analyze the role of sonography in the workup of acute kidney injury (AKI).
2. Compare and contrast the imaging modalities used in the assessment of renal colic and painless hematuria.
3. Utilize a variety of radiologic examinations to assist in the assessment of renovascular hypertension.
4. Describe the hallmark CT findings in renal and urinary bladder trauma.

<u>**PATHOLOGIC CONDITIONS**</u>

<u>**Acute kidney injury (AKI)**</u>: Sudden onset of renal failure within hours to days

-<u>Sonography</u>: Initial imaging modality of choice to assess AKI

-Differentiating pre-renal/renal (i.e. medical renal disease) from post-renal (i.e. obstructive) etiologies

-<u>Pre-renal</u>: hypoperfusion, renal artery thrombosis, renal vein thrombosis

-ATN (hypotensive ischemia)

-renal sonography may be normal

-Renal artery thrombosis

-absent arterial flow (on Doppler)

-peripheral hypoechoic wedge-shaped areas of infarction

-foci of atrophy (if chronic)

-Renal vein thrombosis

-renal enlargement; poor corticomedullary differentiation; edema (hypoechoic parenchyma); venous thrombus (on Doppler)

-<u>Renal</u> (medical renal disease):

-Specific sonographic findings depend on underlying etiology (but, at least initially, renal sonogram may be normal)

-ATN (from toxins)

-renal enlargement; increased cortical echogenicity; accentuated corticomedullary junction

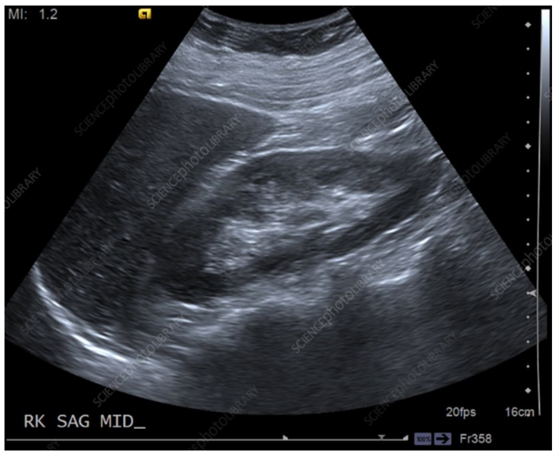
-Acute glomerulonephritis

-normal renal size (9cm<X< 12cm) initially

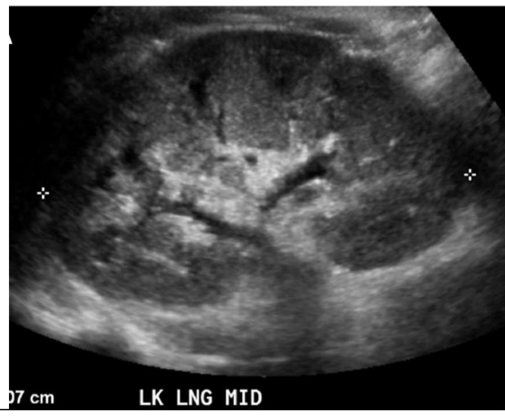
-renal enlargement develops; increased cortical echogenicity; medullary sparing

-Interstitial nephritidies

-renal enlargement; increased cortical echogenicity



Normal renal sonogram (for reference)



ATN: Increased renal size; slightly-increased cortical echogenicity
(cjasn.asnjournals.org)

<u>Note</u>: Sonography provides imaging guidance for potential renal biopsy (in patients with non-obstructive AKI)

<u>Note</u>: In <u>*chronic kidney disease (CKD)*</u>:

-small (atrophic), echogenic kidneys

-poor corticomedullary differentiation

CKD: small, echogenic right kidney
(Radiology key.com)

<u>Note</u>: Normal kidney: Cortex (medium echogenicity)

Medulla (relative hypoechogenicity)

` **Renal sinus (relative hyperechogenicity)**

-<u>Post-renal</u> (obstruction)

-hydronephrosis (with potential to visualize proximal hydroureter, depending on level of obstruction)

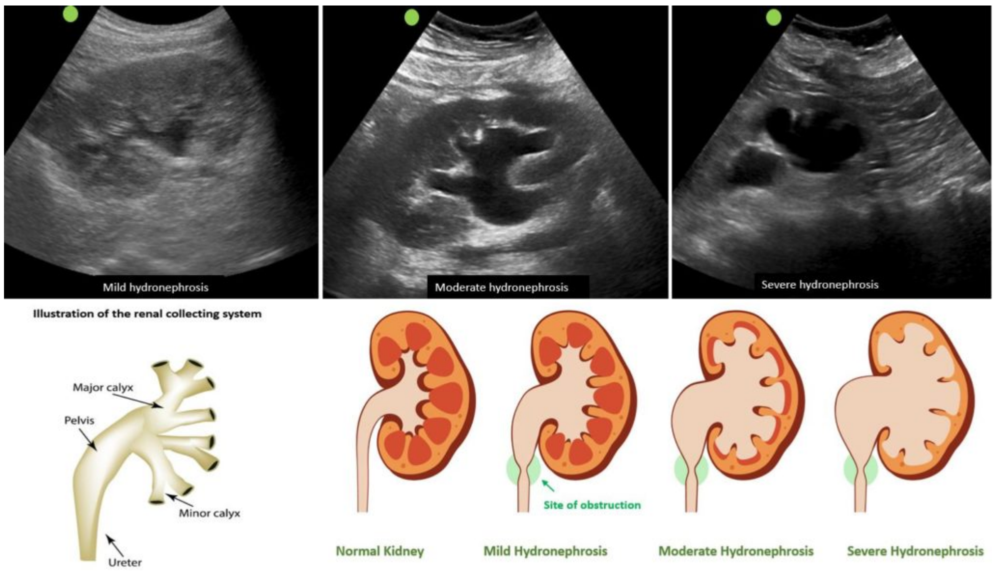
-bladder sonography may be of value if bladder outlet obstruction is suspected

-*unenhanced* CT or MRI (in light of renal failure) allow visualization of entire GU system (kidneys/ureters/bladder)

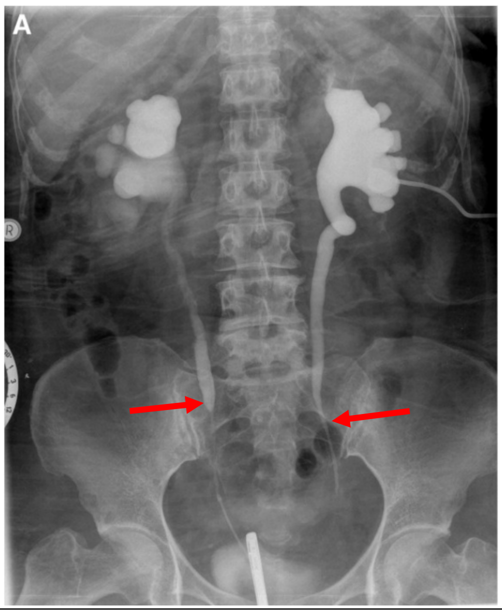
<u>Note</u>: Urologic consultation is of value in cases of obstructive uropathy

-<u>Cystoscopy/ureteroscopy</u>: surgical visualization of the bladder/ureters

-<u>Retrograde pyelogram</u>: imaging of the ureters/collecting systems after contrast injection at distal ureteral orifices



Grades of hydronephrosis
(Renalfellow.com)

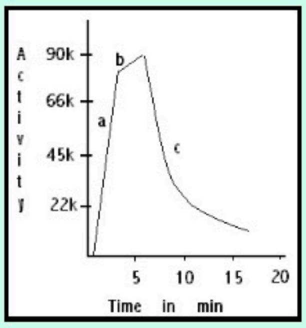


Bilateral obstructive uropathy, secondary to mid-to-distal ureteral strictures (red arrows) on retrograde pyelogram
(www.researchgate.net)

-<u>Nuclear medicine imaging</u>:

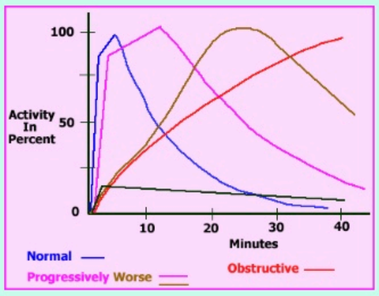
-allows for assessment of renal perfusion, renal function, and renal drainage

-calculation of differential renal function allows for comparison of individual kidneys



i. A - Vascular (flow phase) - Shows blood flow and initial uptake
ii. B - Cortical transit (tissue-function phase) - Peaks at 3-5 minutes
iii. C - Excretory (drainage phase) - T1/2 should be less than 10 minutes

Normal renogram curve (for reference)
(www.researchgate.net)



What does a time activity curve look like as the kidney continue to fail? Several key points have to noted.

1. As renal failure continues all three phases of the time-activity curve are extended.
2. Purple goes to brown goes to red in the different curves are example of the kidneys progressively getting worse.
3. Red also indicates total obstruction
4. Black line indicates total renal failure

Degrees of renal failure on NM renogram
(www.people.vcu.edu)

<u>Renal colic</u>: abdominal pain symptomatology ('waves' of pain from flank to groin, corresponding to ureteral peristalsis in the presence of obstruction

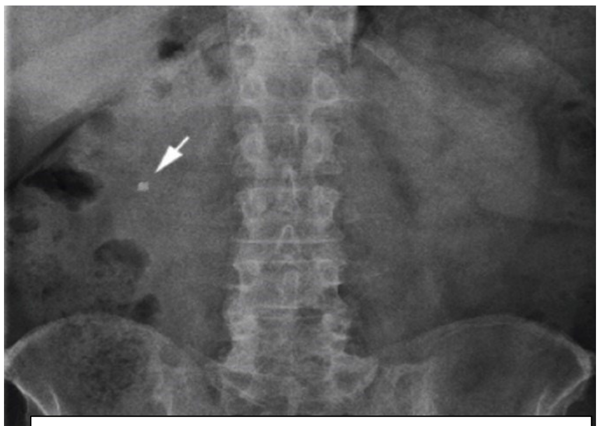
-commonly associated with ureteral calculi (may also be seen with obstruction by blood clots and renal papillae)

-three common sites of urinary tract obstruction

-UPJ (ureteropelvic junction)

-At crossing of ureter with iliac vessels

-UVJ (ureterovesicle junction)



Right mid pole renal calculus (white arrow)
(www.williampenn.com)

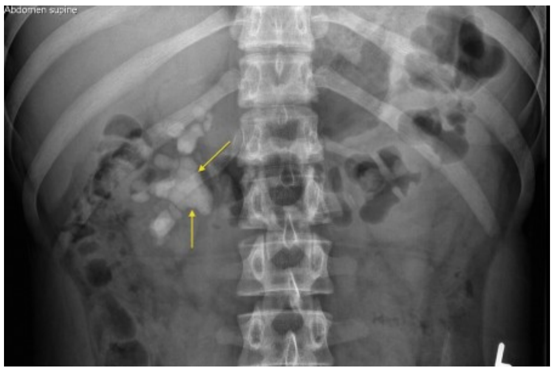
<u>Radiography</u>: KUB will demonstrate urinary tract calculi approximately 80-90% of the time

-calcium oxalate, calcium phosphate, magnesium ammonium phosphate (opaque on KUB)

-cystine (less opaque on KUB than calcium-containing calculi)

-uric acid (lucent on KUB)

-mucoprotein and calculi associated with protease inhibitor therapy (lucent on KUB)

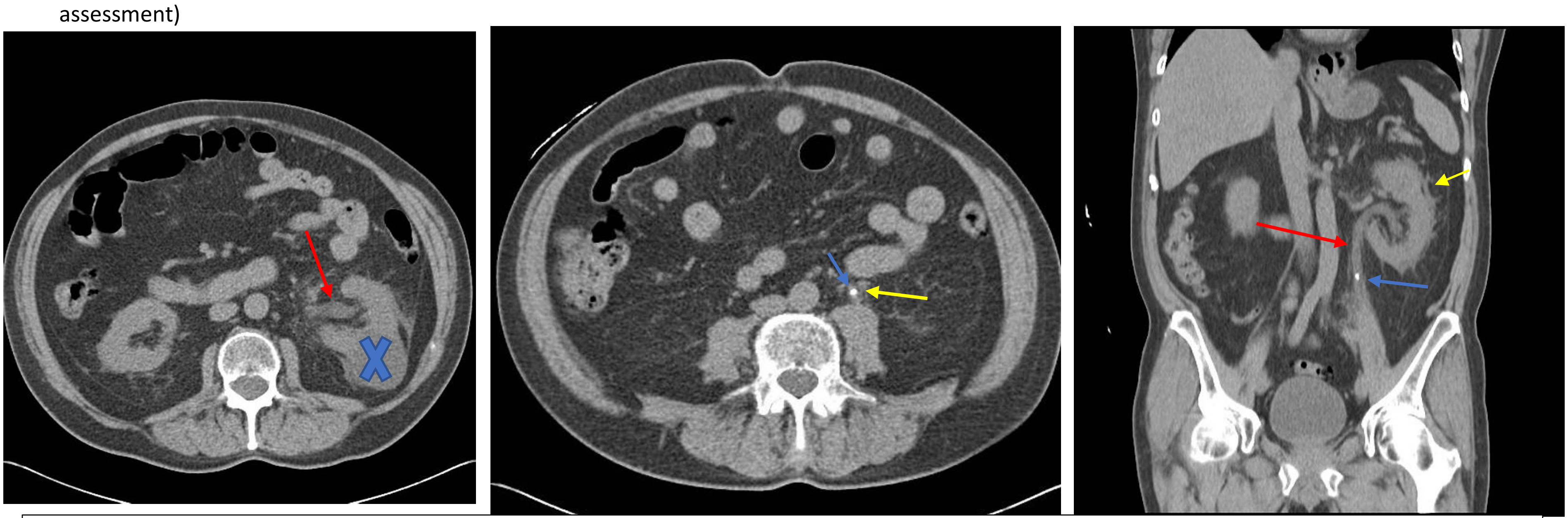


Right-sided staghorn calculus (yellow arrows)
(Diagnostic/interventional radiology for medical students)

Computerized axial tomography (CT): *Unenhanced* abdominal and pelvic CT (no IV nor PO contrast)

- -examination of choice to assess for suspected obstructive urinary tract calculi ('painful hematuria')
  - -has essentially replaced IVP examinations (in the majority of cases)
- -demonstrates 99% of urinary tract calculi themselves
  - -EXCEPT: mucoprotein and calculi associated with protease inhibitor
- -other CT signs of obstruction (present with *all* types of calculi, including mucoprotein/retroviral therapy)
  - -hydronephrosis/hydroureter
  - -perinephric/periureteral fat plane obscuration

Note: In pregnant patients, sonography would be preferred initial examination for renal colic (with unenhanced MRI available for further assessment)



Left ureteral calculus (blue arrows); Hydroureter and hydronephrosis (red arrows); Perinephric and periureteral standing (yellow arrows); X: renal cyst
(https://radiopaedia.org/cases/obstructing-renal-calculus)

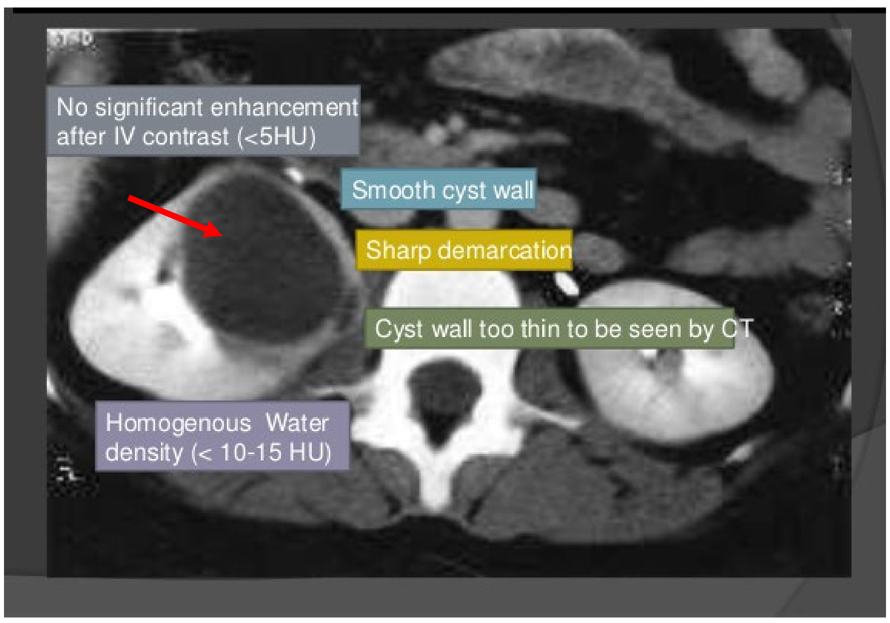
Hematuria: blood in the urine

- -macroscopic ('frank'):
  - -D/D: infection, urolithiasis, trauma, hydronephrosis, neoplasia
- -microscopic:
  - -D/D: renal parenchymal disease/medical renal disease

Radiography: Intravenous pyelogram (IVP), once the intial examination for painless hematuria, has been replaced by CT imaging

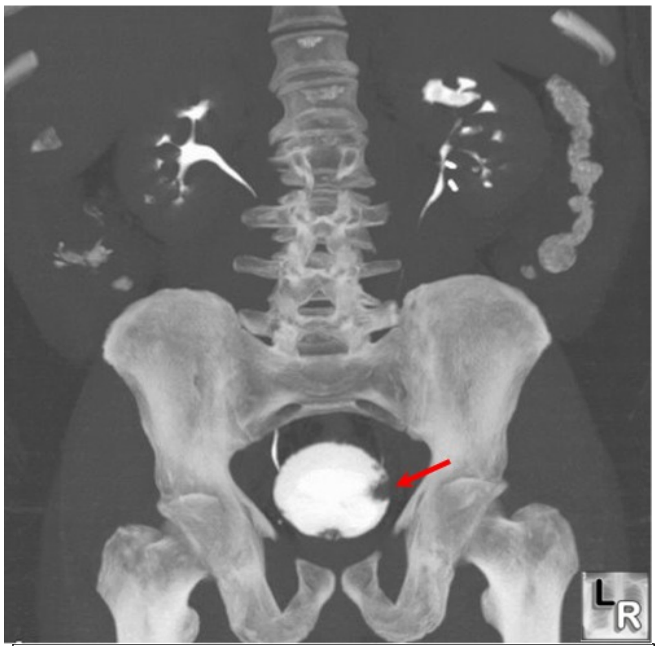
Computerized axial tomography (CT)

- -multiphasic CT imaging of the abdomen and pelvis allows for optimal assessment of the entire urinary tract (CT-urography)
  - -unenhanced phase: assessment of urinary tract calculi
  - -nephrogram phase: assessment and characterization of renal masses
    - -'corticomedullary': 30-70 seconds after IV contrast administration
    - -'homogeneous' (more optimal timing for renal mass assessment): 90-180 seconds after IV contrast administration
  - -excretory phase: assessment of renal calyces, renal pelvis, ureters, and urinary bladder (after 5-10 minute delay)

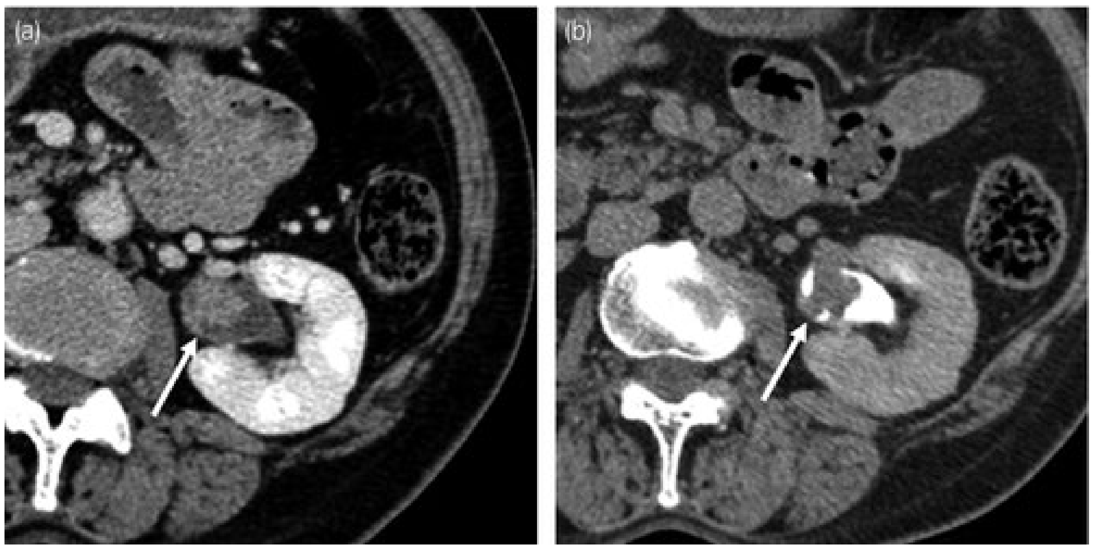


Right renal cyst (red arrow)
(M.Saifullah)

Heterogeneously enhancing left renal mass (red arrow)



Left-sided urinary bladder mass (red arrow)
(Learning radiology.com)



Left renal pelvic mass (TCC): White arrows (Nephrogram phase on left and excretory phase on right)
Wiley online library

Note: Renal mass enhancement by CT imaging:
- -less than 10 HU difference between unenhanced and enhanced phases is acceptable as '*no abnormal enhancement'.*
- -10 HU < X < 20 HU: '*indeterminate'* enhancement (requiring additional imaging and/or invasive assessment)
- ` -greater than 20 HU difference between unenhanced and enhanced phases: '*abnormal enhancement' (i.e. neoplasia).*

Note: MR-urography may be performed utilizing gadolinium contrast (in patients with iodine allergy, precluding CT-urography)
- -gadolinium contrast necessitates normal renal function (as does iodine contrast administration)

Note: Sonography allows for characterization of renal masses as 'cystic' or 'solid'.
- -sonography also provides imaging guidance for renal biopsy

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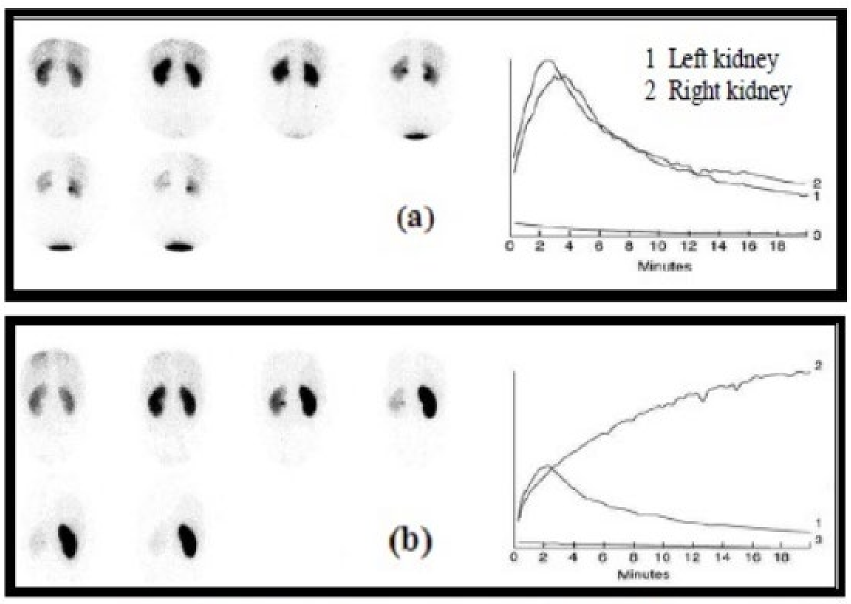
Renovascular hypertension (RVH): systemic hypertension, secondary to renal artery disease (and activation of renin-angiotensin-aldosterone system). Causative in 2.5% of hypertensive patients

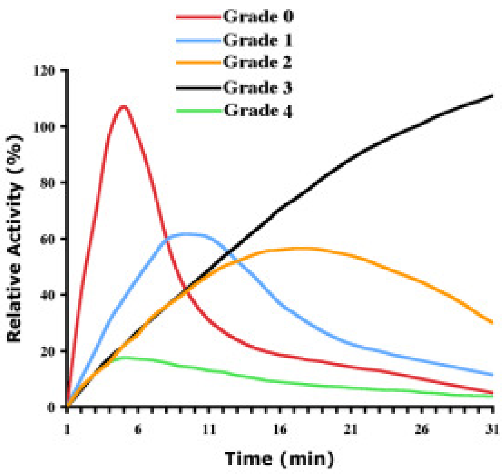
- -etiologies:
  - -renal artery stenosis (RAS)
    - -atherosclerosis (70%)
    - -fibromuscular dysplasia (FMD) (25%)
  - -less common
    - -renal artery dissection
    - -renal artery embolus/thrombus
    - -polyarteritis nodosa
    - -extrinsic effects on renal parenchyma (i.e. Page kidney, encircling neoplasia)

Nuclear medicine renogram: initial screening imaging examination of choice
- -imaging both prior to and after ACE-inhibitor (ACEI) administration (PO captopril)
- -comparison of renogram curves (with and without PO captopril)
- -worsening of renal function after PO captopril ('high probability' for RVH)
  - -delay in time to peak activity in the affected kidney of greater than 2 minutes (compared to baseline/contralateral kidney)
  - -retained cortical activity at 20 minutes differing from baseline/contralateral kidney by more than 20%
  - -change in differential renal function by greater than 10%

Note: TAC: time-activity curves



Captopril renogram in a patient with right renal artery stenosis. (A) Baseline study shows normal uptake and excretion of the tracer by both kidneys. (B) Post-captopril study, the left kidney continues to demonstrate normal uptake and transit of the tracer, the right kidney showed delayed uptake and poor transit of the tracer. [72]



TAC patterns in ACEI renography *depend on level of function and disease presence.*

Grade 0 is normal; grades 1-3 show progressively prolonged renal transit; grade 4 indicates some perfusion but no excretion. (Diagnostic Imaging: Nuclear Medicine)

Sonography: may also be used in initial screening for RVH (but is extremely user-dependent and prolonger examination)

-findings of RAS on US

-Direct: Increased peak systolic velocity (>180 cm/sec) at site of stenosis

Increased peak renal artery/peak aortic velocity ratios (>3.5)

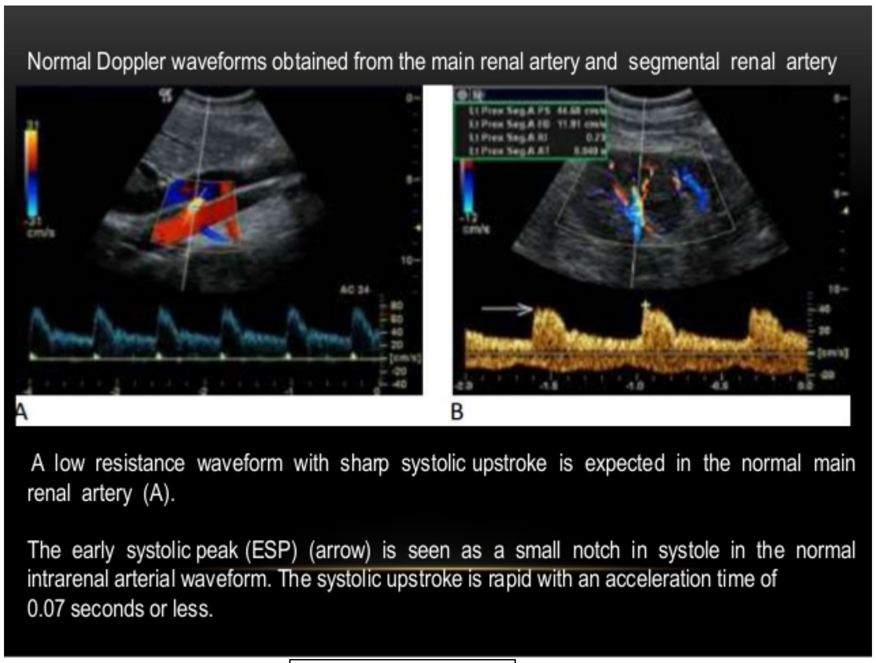
Indirect: Abnormal parenchymal vessel waveform ('parvus at tardus')

-slower rise/late arrival (tardus): acceleration time of >0.07 sec

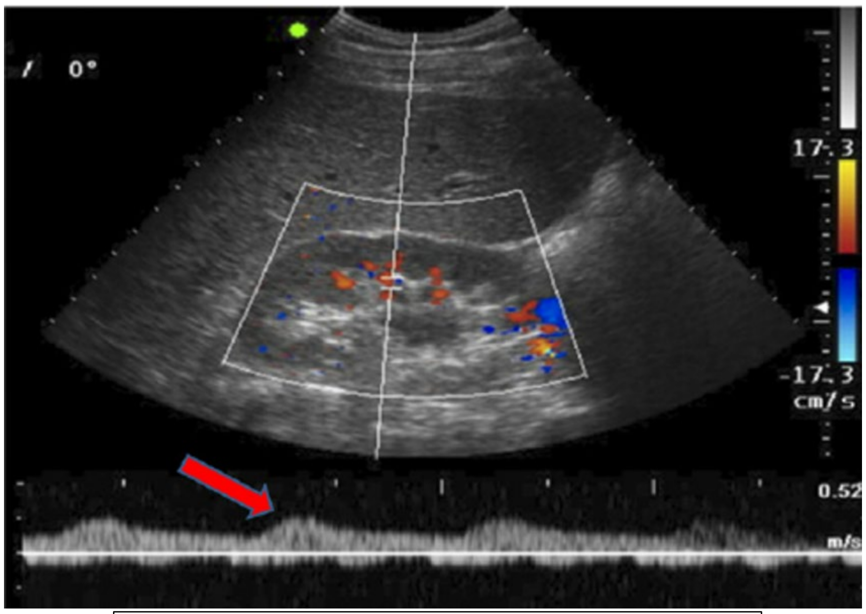
-lesser peak (parvus): <20-30 cm/sec

Decreased, RI, resistive index (distal to stenosis)

-RI: (PSV-EDV)/PSV, where PSV is peak systolic velocity and EDV is end diastolic velocity

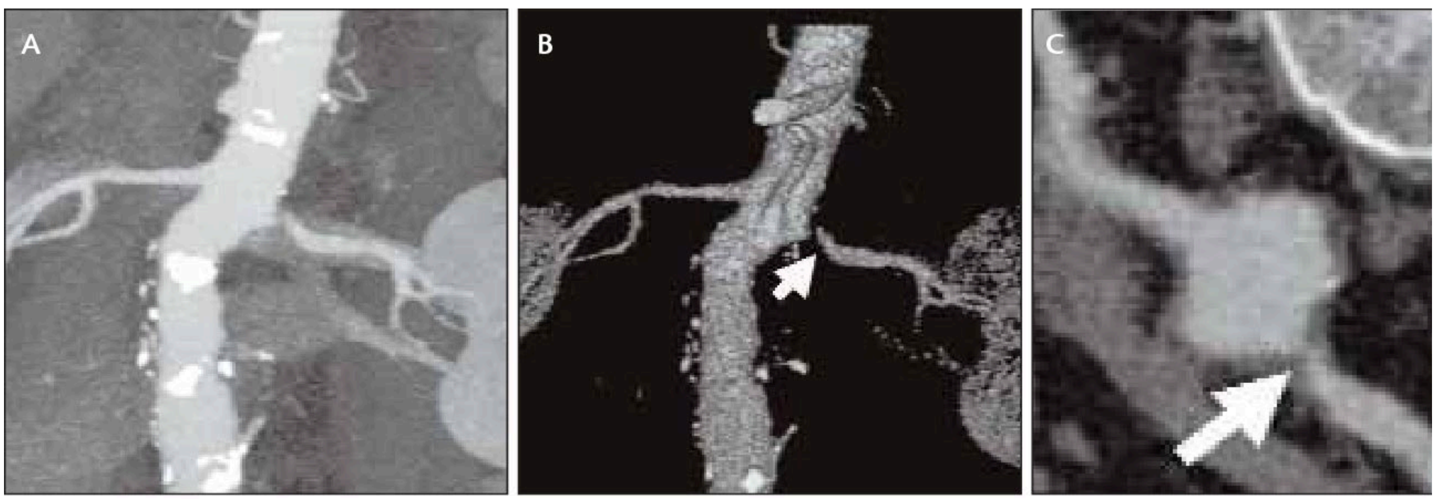


M. Goel, M.D.



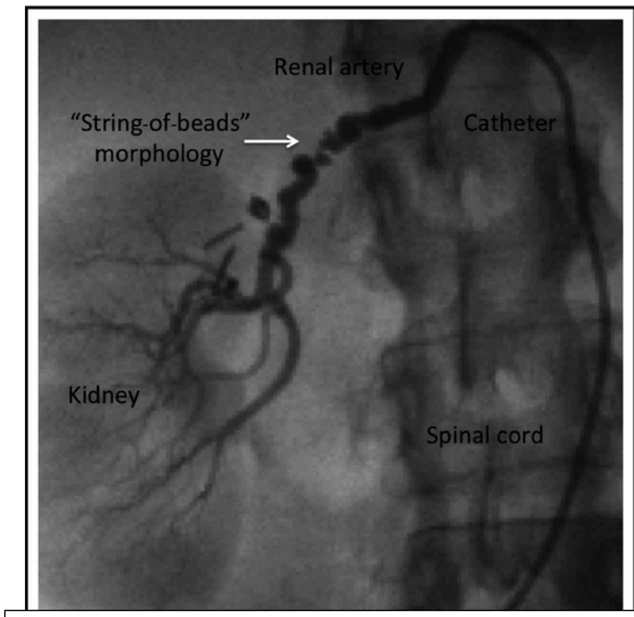
Parvus-tardus waveform (red arrow)
Compared to normal image 'B' at left
(Researchgate.net)

Note: CT-angiography and MR-angiography are available for structural assessment of renal arteries (in patients with normal renal function)



CTA of left RAS (white arrow): 'A' Coronal maximum intensity projection (MIP); 'B' Coronal 3D; 'C' Curve linear reconstruction. (Semantic scholar)

MRA of bilateral atheromatous RAS (white arrows)
(Researchgate.net)



Fibromuscular dysplasia (FMD): right renal artery
(onlinelibrary.wiley.com)

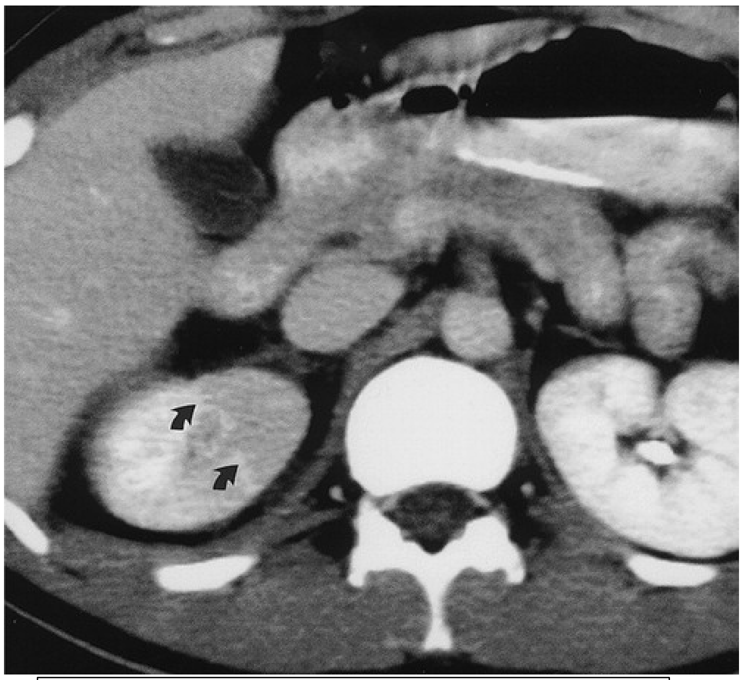
Note: Interventional radiology (i.e. conventional arteriography) is the 'gold standard' for assessment of renal artery stenosis
- allows for both assessment and potential treatment of RAS
- invasive procedure

Genitourinary trauma: Blunt and penetrating trauma may impact any level of the GU system.
- This discussion focuses on renal and urinary bladder trauma (with ureteral and urethral trauma assessment included in reference section)
- Enhanced CT imaging is the mainstay of assessment of *renal trauma*
    - multiphasic CT imaging allows for assessment of vascular injury, parenchymal injury, and collecting system injury
    - AAST (American Association for the Surgery of Trauma) renal injury scale allows for the grading of renal trauma

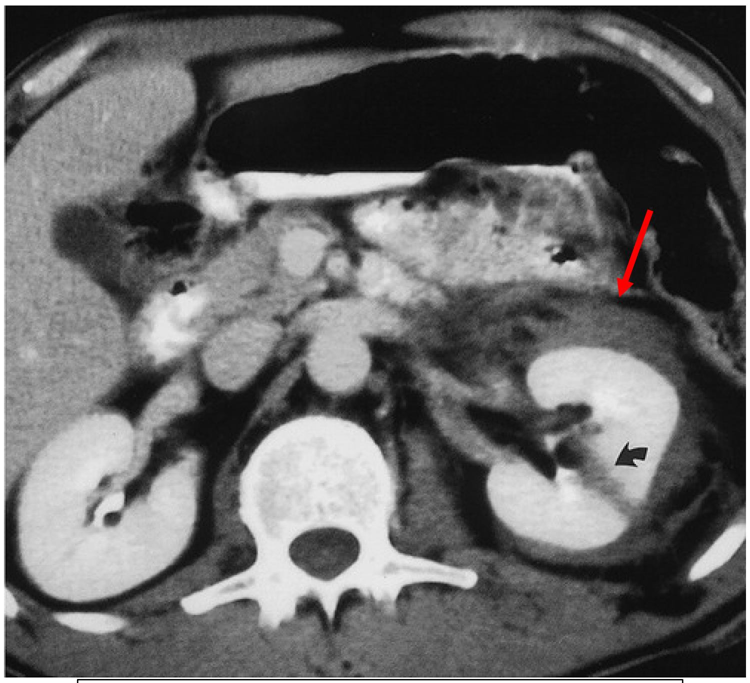
American Association for Surgery of Trauma Renal Injury Scale		
Grade	**Type**	**Description**
I	Contusion	Microscopic or gross haematuria. Urological studies normal.
	Haematoma	Subcapsular, non-expanding without parenchymal laceration.
II	Haematoma	Non-expanding peri-renal haematoma confined to renal retroperitoneum.
	Laceration	< 1.0cm parenchymal depth of renal cortex with no urinary extravasation.
III	Laceration	> 1.0cm parenchymal depth of renal cortex w/out collecting system rupture or urinary extravasation.
IV	Laceration	Parenchymal laceration extending through renal cortex, medulla & collecting system.
	Vascular	Main renal artery or vein injury with contained haemorrhage.
V	Laceration	Completely shattered kidney.
	Vascular	Avulsion of renal hilum that devascularises kidney.

Terminology:
- contusion: ill-defined areas of decreased renal enhancement
- laceration: irregular or linear parenchymal defect (potentially containing coagulated blood)
- hematoma: focal blood collection
    - *subcapsular perirenal*: located deep to renal capsular margins; cresentic shape
        - potential for pressure effects on renal parenchyma (i.e. Page kidney) and associated creation of potentially reversible form of secondary arterial hypertension
    - *extracapsular perirenal*: surrounding kidney within Gerota's fascia

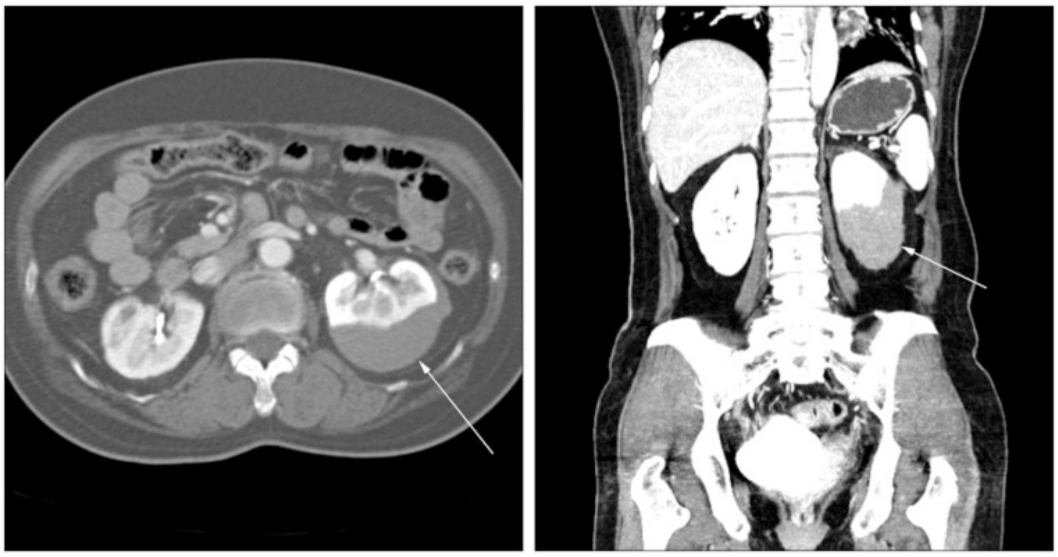
Note: CT density of acute coagulated blood ranges from 60-100 HU
- In GU trauma: Higher density collections may relate to active hemorrhage (i.e. extravasated blood) or collecting system injury (i.e. enhanced urine)



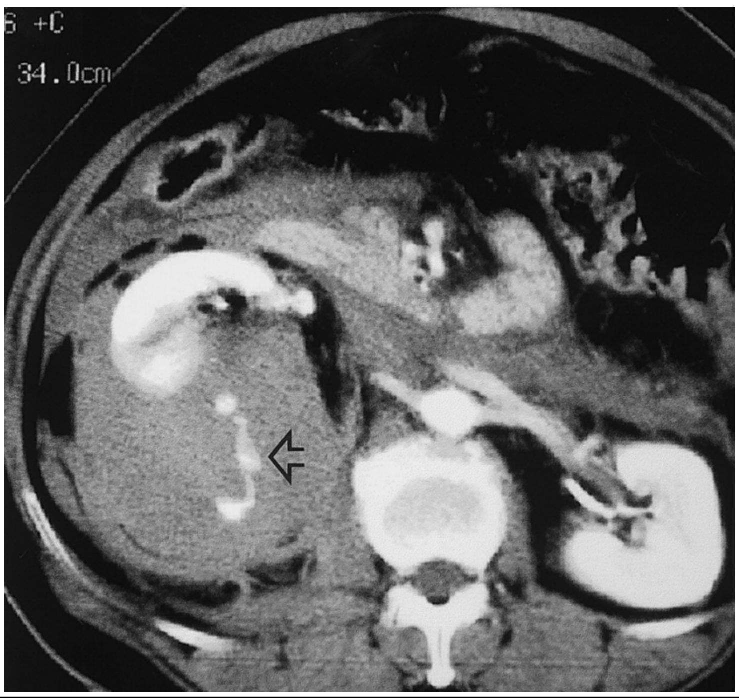
Right renal contusion (black arrows)
(RSNA RadioGraphics)



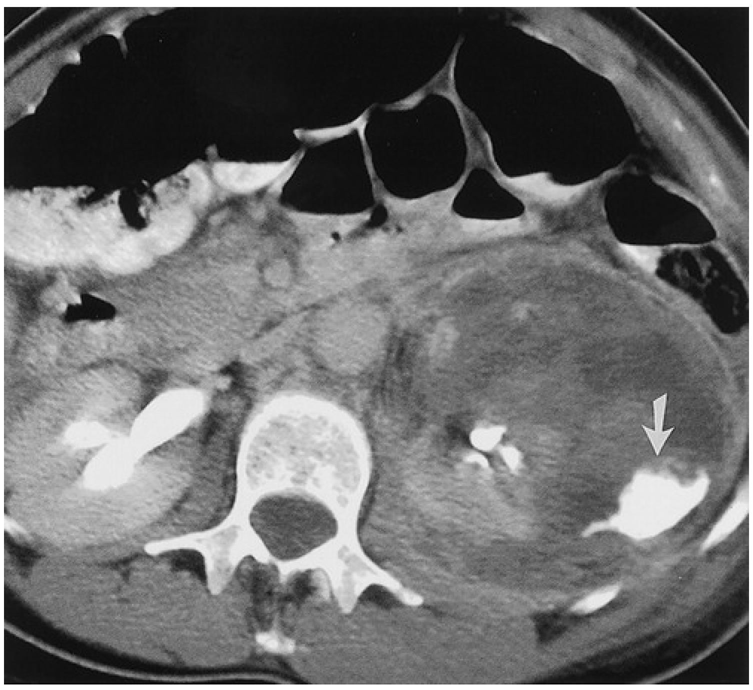
Deep left renal laceration (black arrow) with perinephric hematoma (red arrow)
(RSNA RadioGraphics)



Left-sided subcapsular hematoma, white arrows
(JKNS.com)



Active arterial hemorrhage (amidst perinephric hematoma), open arrow
(RSNA RadioGraphics)



Urine extravasation (amidst perinephric urinoma and hematoma), white arrow
(RSNA RadioGraphics)

Urinary bladder rupture:

-Imaging: Conventional cystogram (i.e. image of contrast-enhanced urinary bladder), CT-cystography

-Types:

-Intraperitoneal (45%): Caused by blunt trauma, penetrating trauma, invasive procedures

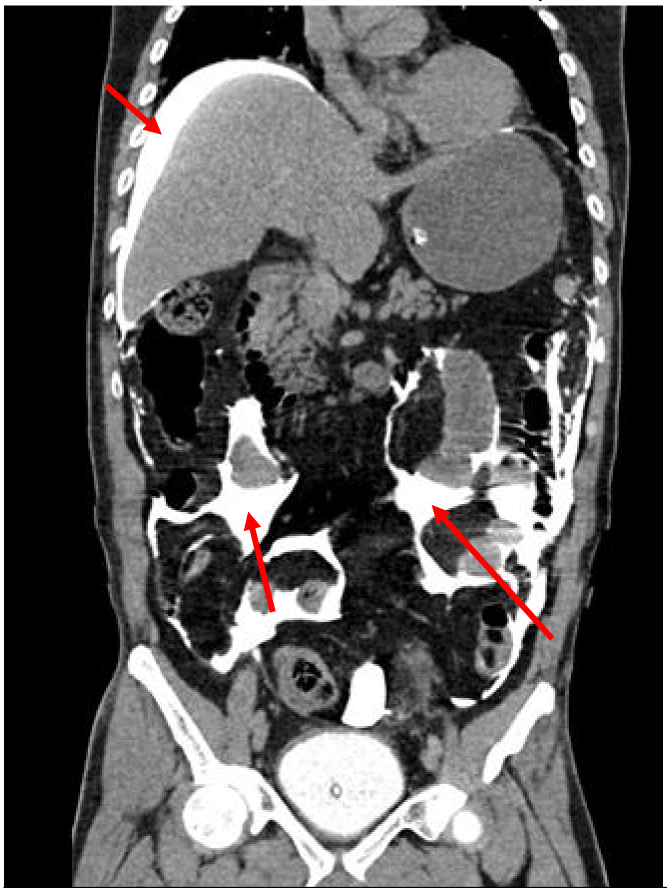
-location: at bladder dome

-visualized by presence of urine ascites

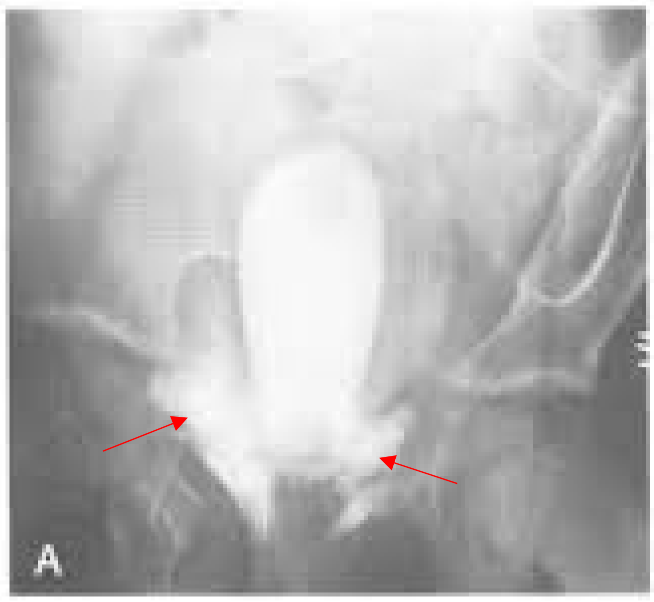
-Extraperitoneal (45%): Associated with pelvic fractures (spicules of bone), avulsion tears

-location: base of urinary bladder; anterolateral walls

-visualized by fluid around bladder; pear-shaped bladder



Intraperitoneal bladder rupture with enhanced urine ascites (red arrows)
(Radiopaedia.org)



Extraperitoneal bladder rupture, arrows
(Science direct.com)

References:

-Clinical Radiology: The Essentials. Daffner et al. 4th ed. (Chapter 9).

-Primer of Diagnostic Imaging. Weissleder et al. 4th ed. (Chapter 4).

-Genitourinary Radiology: The Requisites. Zagoria et al.

-American Journal of Roentgenology (AJR): Imaging of genitourinary trauma (Volume 192, Number 6)

-Note: Medical images are from anonymized patient data and online archives (as detailed)

OPTIONAL: Want to know more?

https://www.med-ed.virginia.edu/courses/rad/

www.auntminnie.com

www.acr.org

www.rsna.com