Every physician needs a basic understanding of diagnostic imaging to understand how to order the appropriate studies and to understand the resulting radiologist's report.
What is the difference between a urologist and a nephrologist?

• Urologists and nephrologists both treat kidney problems. **Urologists** are surgical specialists who focus on anatomical or structural disorders of the kidneys and urinary tract. They treat problems such as kidney stones, kidney blockages, and kidney cancer. Urologists are qualified to perform surgery and outpatient medical procedures to correct such conditions.

• **Nephrologists** are medical specialists who focus on disorders that affect the way the kidneys work such as diabetes and chronic kidney disease. Nephrologists prescribe nonsurgical medical treatments for these disorders.
Science has given urologists a bevy of tools to probe the most private parts of the body in diagnosing urinary and renal disease. Every modern imaging technology, from conventional X-rays to radionuclide imaging, has found its way into urologic radiology's arsenal. The good news for physicians is that they have many options to explore the kidneys, ureters, bladder and surrounding structures. The better news for patients is that today's tests are thorough, relatively pain-free and often quick.
What problems could require imaging of the urinary tract?

Imaging can help the health care provider find the cause of
1. urinary retention—the inability to empty the bladder completely
2. urinary frequency—urination eight or more times a day
3. urinary urgency—the inability to delay urination
4. urinary incontinence—the accidental loss of urine
5. blockage of urine
6. abdominal mass
7. pain in the groin or lower back
8. blood in the urine
9. high blood pressure
10. kidney failure
METHODS OF INVESTIGATION

- ULTRASONOGRAPHY
- RADIOLOGY
  - Simple abdominal X-ray
  - Intravenous urography
  - Retrograde pieloureteterography
  - Cystography
  - Uretrography
- NUCLEAR MEDICINE
  - Static studies: static renal scintigraphy
  - Dynamic studies: renogram
- CT (without, with contrast, Angio)
- MRI (without, with contrast, Angio)
In imaging the urinary tract, the modality of choice for the initial examination will almost universally be ultrasound (US). US is inexpensive, immediate, painless, requires no sedation or anesthetic, is widely available, and is radiation free. US can be used to scan in any plane at the discretion of the operator, and whereas the technique is entirely operator dependent, most centers have staff with a high level of skill.
ULTRASOUND

- Doppler USG

- High frequency - high resolution but low penetration depth

- Renal - parenchyma
  - evaluate hematuria, solid mass, cysts
  - congenital abnormalities, stones

- Adrenal - CT/MRI better
  - Nodules, cysts, hemorrhage, location, tumors

- Bladder - examine wall, lesions
  - Transvaginal, transabdominal, transrectal
  - Normal wall >= 6 mm
  - bladder volume

- Prostate - transrectal, access for biopsy
ULTRASOUND

- Scrotal-
  - Evaluate: mass, pain, torsion, orchitis, epididymitis, hydrocele, hernia, varicoceles
  - Testicle: 4 x 3 cm
  - Veins: >2mm = varicocele - evaluate in erect position
Doppler Ultrasound
The kidneys-ureters-bladder is often the first imaging study performed to visualize the abdomen and urinary tract.

- The film is taken with the patient supine and should include the entire abdomen from the base of the sternum to the pubic symphysis.
- Can show bony abnormalities, calcification and large soft tissue masses.
Indications

- Plain urinary tract (PUT) film = Kidney Ureter Bladder (KUB) film
- Plain films are widely used in the management of stone diseases.

1. To be a preliminary film in anticipation of contrast administration.
2. To assess renal calculus disease before and after treatment.
3. To assess the presence of residual contrast from a previous imaging procedure.
4. To assess the position of drains and stents.
5. To help the investigation of blunt or penetrating trauma to the urinary tract.
Limitations

1. Bowl gases or stools may obscure small stones.
2. Stones may be obscured by other structures such as bones or ribs.
3. Calcifications in pelvic veins or vascular structures may be confused with ureteral calculi.
4. Stones that are poorly calcified or composed of uric acid may be radiolucent.
1. Spinal and bony pelvis abnormalities → spina bifida, sacral agenesis, fractures, metastases.

2. Organ outlines → liver, spleen, kidneys, bladder and Displacement of normal structures

3. Soft tissue
   a. Psoas muscle: absence may indicate mass/fluid in retroperitoneum
   b. Soft tissue masses

4. Radio-opaque shadows (stones vs phlebolii vs calcifications).

5. Stomach and bowel gas (colonic distension or I.O.)
CONTRAST FILMS

- Rapidly concentrated by kidneys and opacifies urinary tract
- Low osmolar iodine nonionic contrast material less osmolar load - fewer complications than high osmolar

Reactions:
  - Allergic, renal toxicity, shock
UROGRAPHY

- Involves instillation of contrast material to better visualize the collecting or lumenal structures of the kidneys, ureters, bladder, and urethra.
  - This can be done after i/v injection or direct instillation into the urinary tract.
    1) Intravenous urography
    2) Cystourethrography
    3) Retrograde urethrography
**INTRAVENOUS UROGRAPHY**

- IVU/ intravenous pyelogram is the classic modality of imaging the entire urethelial tract from pyelocalyceal system through the ureters and bladder.
  - Excellent for identifying small urethelial lesions as well as the severity of obstruction from calculi.
  - Provides anatomical and qualitative functional information about the kidneys.
1. Demonstrate the renal collecting systems and ureters.

2. Investigate the level of ureteral obstruction in renal units displaying delayed function.

3. Demonstrate intraoperative opacification of collecting system during ESWL or Per-cutaneous access to the collecting system.

4. Demonstrate renal function during emergent evaluation of unstable patients.

5. Demonstrate renal and ureteral anatomy in special circumstances (e.g., ptosis, after transureteroureterostomy, after urinary diversion).
Contraindications

1. Renal insufficiency for worsening of their renal function (contrast induced nephrotoxicity).

2. Multiple consecutive contrast studies – less than 48 hours (increased possibility for CIN).

3. Documented allergic reaction to contrast such as urticaria, angioedema, laryngeal edema, bronchospasm, and hypotension with tachycardia.

4. Cardiac disease as contrast administration can cause worsening of congestive heart failure, due to the osmotic load.

5. Patients who are on metformin must stop the drug 48 hours before contrast injection as it can cause lactic acidosis which may be fatal.
Fig. 4. Normal excretion phase of an intravenous urogram. The kidneys, collecting systems, ureters, and bladder appear normal. Bowel catharsis before the study is to prevent obscuring bowel gas (arrows). S, spine; B, bladder. (From ref. 3.)
Fig. 5. Coned-down image of the IVU in Fig. 2 showing normal nephrogram and sharply defined calyces (solid arrows), which drain to the renal pelvis (symbols) by way of the infundibula (open arrows). The ureteropelvic junctions and proximal ureters are normal. (From ref. 3.)
CYSTOGRAPHY

- Permits imaging of an opacified urinary bladder after retrograde instillation of contrast media through a urethral or suprapubic catheter
  - Imaging is performed to demonstrate a suspected urine leak, either from traumatic bladder rupture or after bladder surgery
  - Can also demonstrate a presence of a fistula between the bladder and vagina or to characterize bladder diverticuli
NORMAL MALE CYSTOGRAM
Complete evaluation of the urethra includes both antegrade and retrograde urethrography

- Allows visualization of the anterior male urethra
- Used for evaluating a suspected traumatic urethral injury or urethral stricture
- Can also be useful for diagnosis of a urethral diverticulum in females
- Evaluate anterior and posterior urethra- strictures, trauma
- 8-16 F foley in fossa navicularis, fill balloon with 1-2 mL and inject 30-50% contrast while filming obliquely
NORMAL RUG

 NORMAL RUG using Foley technique

Balloon

Normal cone of bulbar urethra

Foley catheter

RUG - digital

Bladder

Prostatic

Membranous

Normal "cone" of bulbar urethra

Penile urethra

Bulbar urethra

Normal Retrograde Urethrogram
Multi-Detector Computed Tomography (MDCT)
CT + ANGIO CT SCAN

- Often used to examine structures in the abdomen and pelvis (liver, pancreas, gallbladder, spleen and intestines).

- CT Scans are a diagnostic tool that urologists use to detect and diagnose: recurrent urinary tract infections, sources of blood in the urine (hematuria), kidney stones, renal cysts and masses. It can help urologists rule out prostate, bladder and renal cancers.
CT + ANGIO CT

- Contrast- parenchyma, adrenals
- 3-D to evaluate vascular abnormality
- 100-150 mL i/v bolus injection
- Renal- stages:
  - Precontrast- stones, parenchyma, vascular calcifications, renal contour
  - 30 sec- cortex vs medulla
  - Nephrographic- 100 sec- uniform enhancement of parencyma (masses)
  - Pyelographic- excretory- collecting system
CONTRAST CT
MRI

- No iodinated contrast
- Soft tissue resolution better than CT
- Contraindications - pacemaker, aneurysm clips
- T1 - fluid dark, fat bright
- T2 - fluid bright, fat dark
MRI
MRI

- **Renal** - will not evaluate stones, determine tumor
- **Adrenal** - contain more fat than cancers, bright on T2, isodense with liver
- **Bladder** - to determine invasion of wall by cell cancer or other pelvic neoplasms (on T2)
- **Prostate** - evaluate prostate cancer for capsular invasion. T1-distinct from surrounding fat/seminal vesicles (intermediate intensity), T2-peripheral zone (high intensity), central (intermediate), neurovascular bundles bright, seminal vesicles (high)
### Table 1
Comparison of advantages and disadvantages between computed tomography (CT) and magnetic resonance (MR) imaging modalities

<table>
<thead>
<tr>
<th>CT</th>
<th>MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses ionizing radiation, high-dose procedure</td>
<td>Uses magnetic resonance, no ionizing radiation</td>
</tr>
<tr>
<td>Excellent spatial resolution</td>
<td>Excellent contrast resolution</td>
</tr>
<tr>
<td>Actual scanning time measured in seconds (typically &lt;10 s)</td>
<td>Actual scanning time measured in minutes (typically 45 min)</td>
</tr>
<tr>
<td>Rarely requires general anesthetic in children</td>
<td>Frequently requires general anesthetic in children, depending on age</td>
</tr>
<tr>
<td>Excellent at showing calcification</td>
<td>Poor at showing calcification (signal void)</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>Poor at showing edema or pathological changes in specific tissue types</td>
<td>Excellent at showing edema and pathological changes in specific tissue types</td>
</tr>
<tr>
<td>Usually requires intravenous contrast (unless looking for calcification when not required)</td>
<td>Usually requires intravenous administration of contrast (but certain sequences can be tailored if this is contraindicated)</td>
</tr>
<tr>
<td>No known risk of nephrogenic systemic fibrosis (NSF)</td>
<td>Risk of NSF (rare, but renal patients believed to be at increased risk)</td>
</tr>
<tr>
<td><strong>Less expensive</strong></td>
<td><strong>Expensive</strong></td>
</tr>
<tr>
<td>Usually available as an emergency imaging technique</td>
<td>Not routinely available as an emergency technique</td>
</tr>
<tr>
<td><strong>No significant contraindications</strong></td>
<td>Contraindicated in patients with any internal ferrous objects (pacemakers, defibrillators, recent orthopedic metalware, other implanted metallic devices, metallic foreign bodies)</td>
</tr>
<tr>
<td><strong>Open-style scanners</strong></td>
<td>Generally quite enclosed scanners – risk of claustrophobia</td>
</tr>
</tbody>
</table>
NUCLEAR MEDICINE

- Uses the radiation released by radionuclides (called nuclear decay) to produce images.

- A radionuclide, usually technetium-99m, is combined with different stable, metabolically active compounds to form a radiopharmaceutical that localizes to a particular anatomic or diseased structure (target tissue).

- Tracer goes to the target organ and can then be imaged with a gamma camera, which takes pictures of the radiation photons emitted by the radioactive tracer.

- Physiologic and anatomic info...
AORTOGRAPHY: LEFT RENAL ARTERY THROMBOSIS
MR ANGIOGRAPHY

- Left renal artery stenosis
## Imagistic Criteria for Hematuria

<table>
<thead>
<tr>
<th>Radiologic Examination Procedure</th>
<th>Appropriateness Rating</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multidetector CT urography</td>
<td>8</td>
<td>This is becoming the method of choice for hematuria, supplanting intravenous pyelography</td>
</tr>
<tr>
<td>Radiography, intravenous urography (intravenous pyelogram, excretory urography)</td>
<td>8</td>
<td>—</td>
</tr>
<tr>
<td>Ultrasonography, kidney and bladder, transabdominal</td>
<td>6</td>
<td>May miss ureteral and urothelial lesions; abdominal radiography, retrograde pyelography, and cystoscopy are useful adjuncts</td>
</tr>
<tr>
<td>Radiography, retrograde urography</td>
<td>5</td>
<td>—</td>
</tr>
<tr>
<td>MRI urography</td>
<td>4</td>
<td>—</td>
</tr>
<tr>
<td>CT, abdomen and pelvis</td>
<td>4</td>
<td>CT may follow intravenous pyelogram or ultrasonography if initial findings are ambiguous</td>
</tr>
<tr>
<td>Kidney, angiography</td>
<td>4</td>
<td>Rarely, vascular malformations may cause hematuria and require angiography for diagnosis</td>
</tr>
<tr>
<td>Radiography, abdomen, KUB</td>
<td>2</td>
<td>It is assumed that a plain film of the abdomen will be part of the indicated intravenous pyelogram; if an intravenous pyelogram is not performed, KUB may be performed with ultrasonography</td>
</tr>
<tr>
<td>MRI, abdomen, and pelvis</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>Urinary tract scintigraphy</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>Virtual cystoscopy</td>
<td>2</td>
<td>—</td>
</tr>
</tbody>
</table>
US testes was performed which demonstrate the left testicle assuming an abnormal orientation and lack normal color and power Doppler flow with maintained testicular normal echogenicity, consistent with acute testicular torsion. The right testicle is within normal.
Ultrasound - stones
Nephrocalcinosis

Calcification which appears medullary over the left renal shadow.
PLAIN FILM-
LEFT DISTAL URETERAL CALCULUS

A

B
Intravenous urography
Figure 4-4. A, Right ureteral calculus (arrow) overlying the sacrum is difficult to visualize on the plain film. B, The right posterior oblique study fails to confirm the location of the ureteral calculus. C, Computed tomography confirms this 6-mm calculus in the right ureter at the level of the third sacral vertebra.
20mm stricture in the bulbous urethra.
Anatomy of the normal ureter on ascending urethrogram.

Urethral stricture
Horseshoe kidney.
Examples

Bilateral Duplication of ureter
Renal hypoplasia
Renal hypoplasia
Ectopic kidney
Ectopic kidney
Ectopic kidney
Ectopic kidney
Ectopic kidney
Tumors
Tumors
Tumor
Hypervascular process left kidney
Hypervascular process left kidney
Hypervascular process left kidney
Hypervascular process left kidney
renal carcinoma
PARAPELVICAL CYST
**Bosniak renal cyst classification**

The **Bosniak classification system** for CT evaluation of renal cysts is helpful in determining both malignant risk and required follow-up and/or treatment.

**Bosniak 1**

simple cyst, imperceptible wall, rounded

work up: nil

% malignant: ~ 0%

**Bosniak 2**

minimally complex, a few thin (< 1mm) septa, thin Ca++; non-enhancing high-attenuation (due to proteinaceous or haemorrhagic fluid) renal lesions of less than 3 cm are also included in this category; these lesions are generally well margined.

work up: nil

% malignant: ~ 0%

**Bosniak 2F**

minimally complex but requiring follow up.

increased number of septa, minimally thickened or enhancing septa or wall thick Ca++,

hyperdense cyst that is:

  > 3 cm diameter, mostly intrarenal (less than 25% of wall visible); no enhancement

work up: needs ultrasound / CT follow up

% malignant: ~ 25%
Bosniak 3
indeterminate, thick or multiple septations, mural nodule, hyperdense on CT (see 2F)
treatment / work up: partial nephrectomy or RF ablation in elderly / poor surgical risk
% malignant: ~54% 

Bosniak 4
clearly malignant, solid mass with large cystic or necrotic component
treatment: partial / total nephrectomy
% malignant: ~100%
Extrarenal renal cyst expansion
Extrarenal renal cyst expansion
Extrarenal renal cyst expansion
Polycystic kidney disease:

CT vs MRI
Polytrauma

extensive skin emphysema kidney contusion.
CT

TRAUMA
Normal prostate gland
Figure 43-3. Normal prostate. A, Contrast-enhanced CT scan at the level of the prostate gland. The peripheral zone (yellow arrow) and central gland (red arrow) can occasionally be differentiated. The obturator internus (OI) forms the lateral border of the ischiorectal fossa. The psoas muscle (Ps) and gluteal muscles (G) can also be seen. B, Axial T2-weighted MR image shows better differentiation between the peripheral zone (yellow arrow) and the central gland (red arrow). C, Sagittal T2-weighted MR image shows...
NORMAL MRI APPEARANCE OF PROSTATE

- Normal prostate has homogenous low signal on T1WI
- Zonal anatomy is best demonstrated on T2WI
- Comprise of low signal central zone and higher signal peripheral zone
Ill-defined hypointense lesions in the peripheral zone of the prostate gland - this appearance is highly likely of prostatic carcinoma.