This chapter reviews commonly encountered renal symptoms. The four main points of this chapter are:

1. Computed tomography, performed both without and with contrast material, is the imaging study of choice for hematuria.
2. Computed tomography performed without contrast (CT-KUB) is the initial imaging study of choice for evaluating acute flank pain.
3. CT-angiography, MR-angiography, and nuclear medicine studies may be used for evaluating suspected renovascular hypertension.
4. Ultrasound is the study of choice for evaluating new onset renal failure.

**COMPUTED TOMOGRAPHY IS THE IMAGING STUDY OF CHOICE FOR HEMATURIA**

Computed tomography (CT), performed both without and with contrast material, is the imaging study of choice for the evaluation of hematuria. In addition to CT, patients will also need to undergo cystoscopy, because mucosal bladder processes invisible on CT frequently cause bleeding. Prior to discussing and illustrating CT, however, note that evaluation of hematuria generally follows an algorithm (for example, see the American Academy of Family Physician’s web page) that specifically excludes many patients with hematuria from imaging and cystoscopy.

The algorithms exclude many patients from imaging and cystoscopy because hematuria is a common problem which is frequently transient. Froom et al. found microscopic hematuria on at least one occasion in 39% of 1,000 young men who had annual urinalyses between the ages of 18 and 33; 16% had hematuria on two or more occasions. In a different study, Mohr et al. found hematuria in 13% of men and postmenopausal women.

Most of the algorithms in evaluation of hematuria sequentially identify and exclude those who do not need imaging, typically those with exercise induced hematuria, bleeding associated with urinary tract infections, medication induced hematuria, hematuria associated with dehydration, myocardial infarction, or hypertension, and glomerular hypertension.

A variety of sports (both contact and noncontact) may result in exercise induced hematuria, with the degree of hematuria related to the intensity and duration of exercise. Exercise induced hematuria is typically microscopic, asymptomatic, and almost always resolves within 72 hours, but if hematuria persists, further evaluation may be necessary.

Urinary tract infections may be asymptomatic and still cause hematuria. Most algorithms call for clearing a urinary tract infection and retesting for hematuria before proceeding with imaging.

Multiple medications cause hematuria by a variety of processes, including interstitial nephritis (e.g. captopril, furosemide, NSAIDs) papillary necrosis (e.g. aspirin, NSAIDs), hemorrhagic cystitis...
(e.g. Cytoxan, Ifosfamide (Ifex), Mitotane (Lysodren)), and urolithiasis (e.g. indinavir, and NSAIDs once more). One notable exception to medications associated with hematuria: anticoagulation does not offer an adequate explanation for hematuria, and these patients typically need to be worked up.

In addition to infection and drugs, hematuria has also been related to a number of additional conditions, including dehydration, myocardial infarction, atrial fibrillation, and hypertension. Presence of any of these conditions may explain hematuria, and retesting for hematuria after treating the underlying condition should probably precede imaging.

Finally, patients with glomerular hematuria, diagnosed by the presence of red cell casts in the urine, do not need to undergo imaging, but likely need to be referred to a nephrologist. Additional signs of glomerular hematuria include protein excretion exceeding 500 mg/day when there is no bleeding, a dysmorphic appearance of most red cells, and brown, cola-colored urine with gross hematuria.

After the exclusion of hematuria caused by exercise, infection, medications, other known medical conditions, and glomerular hematuria, further work-up should diagnose causative lesions of the kidneys, collecting system, and bladder. The likelihood of finding (or not finding) abnormalities has been studied several times, including a large study of 4,023 patients summarized in this table:

<table>
<thead>
<tr>
<th>Cause</th>
<th>Microhematuria</th>
<th>Macrohematuria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculi</td>
<td>7.8% (153)</td>
<td>8.8% (183)</td>
</tr>
<tr>
<td>Renal cell cancer</td>
<td>1.0% (19)</td>
<td>2.0% (41)</td>
</tr>
<tr>
<td>Upper tract TCC</td>
<td>0.2% (3)</td>
<td>0.5% (10)</td>
</tr>
<tr>
<td>Bladder TCC</td>
<td>3.7% (73)</td>
<td>16.5% (342)</td>
</tr>
<tr>
<td>No cause identified</td>
<td>87.3% (1702)</td>
<td>72.2% (1497)</td>
</tr>
</tbody>
</table>


Given the diseases listed in the table, the evaluation of hematuria should target calculi and tumors of the kidneys and collecting system (including the bladder). As noted above, algorithms typically call for both CT, to evaluate for stone disease and renal and upper tract tumors, and cystoscopy, to evaluate for bladder mucosal lesions not visible with CT. CT is a good test, because it not only detects renal calculi which cause hematuria, but it also detects renal cell cancer (and other parenchymal tumors) as well as rare causes of hematuria.

With respect to renal stone disease, note that patients may have hematuria, not have flank pain, and still have calculi as the cause of their disease (Figure 1). The widespread use of CT in the evaluation of patients with hematuria has resulted in a greater recognition of this situation. Also note that a combined unenhanced/enhanced study is necessary to study patients with hematuria, because the contrast material may obscure nonobstructing stones (Figure 2).

One of the main reasons to perform imaging in patients with hematuria is to discover otherwise asymptomatic renal cell cancer (Figure 3). Renal cell cancer, seen more frequently with increasing age, usually manifests as an exophytic contrast enhancing mass. Such lesions are usually not biopsied, but taken directly to surgery where the urologist will typically remove at least a portion of the kidney, and often the entire kidney. In elderly patients or those with multiple medical problems who cannot tolerate surgery, percutaneous thermal ablation forms an alternative therapy.

In some instances, CT may allow a specific histologic diagnosis of a renal tumor other than renal cell cancer. The presence of at least some fat in the lesion indicates an angiomyolipoma (Figure 4), a lesion that does not need to be biopsied. Some authorities advocate removing angiomyolipomas larger than 4 cm on the grounds that they may hemorrhage.

CT allows detection of several additional, rare causes of hematuria including a retroaortic renal vein, renal arteriovenous malformations, and renal artery aneurysms.
Figure 1. Renal stone in a 51 year old woman with asymptomatic hematuria. A. Noncontrast axial CT study shows a stone (arrow) at the left ureteropelvic junction. B. Noncontrast reformatted coronal CT (right) also demonstrates the stone (arrow). Incidentally noted is a cyst of the contralateral kidney.

Figure 2. Renal stone associated in a 50 year old woman with hematuria. A. Precontrast (unenhanced) CT clearly shows a nonobstructing right renal stone (arrow). B. On the postcontrast CT, contrast material largely obscures the stone. If only the postcontrast CT had been performed, the stone would be very difficult (if not impossible) to recognize.

CT also demonstrates transitional cell tumors of the renal collecting system, including within the renal pelvis, within the ureter (figure 5), and within the bladder (Figure 6). Note that not all bladder lesions will be visible on CT, which is why CT and cystoscopy are recommended in the evaluation of patients with hematuria.
Figure 3. Renal cancer in a 76 year old man with hematuria. A. Unenhanced CT shows an exophytic mass (arrows) of the left kidney. B. Enhanced CT shows heterogeneous enhancement of the mass (arrow). Renal cell cancer was found at surgery.

Figure 4. Renal angiomyolipoma in a 73 year old man with unrelated abdominal pain. A. Early, nephrographic phase CT shows a circumscribed, fat density mass of the right kidney (arrow), demonstrating the same density as the perinephric fat. B. Delayed examination shows the same lesion (arrow), which again demonstrates fat density. This lesion was unchanged five years later.

In the evaluation of hematuria, CT is superior to other methods of imaging. While, historically, intravenous pylograms (IVPs) were the imaging study of choice for evaluation of hematuria, these studies are virtually never performed when CT is available. Gray-Seas et al found that CT had a sensitivity of 100% and a specificity of 97% in the evaluation of renal tumors, versus a sensitivity of 61% and a specificity of 91% for IVPs. Regarding ultrasound for evaluation of renal tumors, Warshauer et al found US was only 60% sensitive.

Note, however, that CT should not be used in pregnant patients with hematuria. Ultrasound is the study of choice in these patients (Figure 7). If the ultrasound is normal, it is usually reasonable to wait until the pregnancy is completed and then, if hematuria persists, perform a CT at that time.
Figure 5. Transitional cell carcinoma of the ureter in a 78 year old man with hematuria. A, B, and C. Sequential axial delayed CT studies show a normal left ureter (in cross section, a small white circle) and an abnormal right ureter with a tumor distorting the ureter, which is peripherally displaced along the tumor margin. D. Delayed reformatted coronal CT shows the tumor (arrow) along the lower margin of the visualized right ureter.

Figure 6. Transitional cell cancer of the bladder in a 79 year old man with hematuria. A. Unenhanced CT shows a subtle filling defect within the bladder (arrow). B. The portal venous phase image (taken two minutes following contrast injection) shows a contrast-enhancing lesion (arrow). C. On the delayed image (taken 10 minutes after contrast injection) the filling defect (arrow) is much more conspicuous against the background of the opacified urine. Less dense, unopacified urine is seen along the anterior bladder.
Figure 7. Medullary sponge kidney in a 30 year old pregnant woman with hematuria. A. Renal ultrasound of the patient shows marked increase in renal echogenicity extending through the renal cortex (arrows), indicating medullary sponge kidney. B. A normal kidney for comparison. Note the increased echoes are confined to the central portion of the kidney in the renal pelvis.

**CT-KUB IS THE STUDY OF CHOICE FOR EVALUATING ACUTE FLANK PAIN**

Decades ago, plain films of the abdomen showed stones of the “Kidneys, Ureter, and Bladder”. Those films were therefore called “KUB” studies. The analogous unenhanced CT of the abdomen and pelvis has come to be called the “CT-KUB”. In patients with a clinical history suspicious for renal stone disease, the CT-KUB has supplanted all other imaging modalities. CT-KUB allows detection not only of stone disease, but also other causes of abdominal or flank pain. Ha and MacDonald found significant alternate pathology in 33% of patients with suspected nephrolithiasis. Overlap exists between this and the prior indication, as patients with stone disease (and other genitourinary diseases) may have either hematuria, flank pain or both. If the CT-KUB does not demonstrate a cause of flank pain, it makes sense to consider adding contrast-enhanced images to the exam.

Typical algorithms for evaluation of renal colic recommend CT-KUB, with the exception of pregnant patients (evaluated with ultrasound) and patients with known renal stone disease where prior plain films have documented the stones. Certain indications, such as patients with urosepsis, acute renal failure, anuria, and/or unyielding pain, nausea, or vomiting, require urgent urologic consultation. The reason these algorithms support CT-KUB is that CT-KUB can demonstrate and characterize renal stones (Figure 8) as well as alternative causes of pain. Portis et al found that stones less than 5 mm in diameter had a significantly higher likelihood of passage than stones 5 mm or greater, and that stones that had made it to the distal ureter by the time of diagnosis were more likely to pass without intervention than those discovered in the proximal ureter (74% versus 53%). This work was done in 1991 and was based on plain film or IVP data. Coll et al, using CT data, found a similar relationship between the likelihood of stone passage and stone size: 87% of stones 1 mm or less passed, 76% of stones 2 to 4 mm passed, 48% of 7 to 9 mm stones passed, and only 25% of stones > 9 mm passed. These findings support the general maxim that small stones will often pass, but large stones usually don’t. CT-KUB is an excellent method of locating and sizing all stones. Furthermore, it can demonstrate which stones cause hydronephrosis. Renal distension, perinephric stranding (Figure 8) and hydronephrosis (Figure 9) indicate that the stone is obstructing the collecting system and likely symptomatic.
CT-KUB also allows diagnosis of any of several alternative causes in patients with acute flank pain with or without hematuria, including dissecting aortic aneurysm (see chapter 12), diverticulitis (Figure 10; see also chapter 7), and appendicitis (see chapter 7).

CT-KUB is superior to other methods of evaluation in patients with acute renal pain. When directly compared with plain films, CT-KUB shows greater sensitivity (95% - 100% versus 45% - 59%) and specificity (94% - 96% versus 71 – 77%)\(^6\).

Plain films may represent a reasonable imaging study in patients who have a history of radio-opaque calculi (that may be seen on plain films) and acute flank pain that is similar to previous episodes. A CT-KUB will still likely be necessary if the plain film does not completely elucidate the size and location of the obstructing calculus\(^1\).

CT-KUB has also supplanted IVPs in the evaluation of stone disease. Compared to IVPs, CT-KUB shows greater sensitivity (95 - 100% versus 64 – 87%) and specificity (94 - 96% versus 92 – 94%)\(^6\). Smith et al studied 20 patients with acute flank pain, 12 of whom had stone disease, CT detected 11 and IVP 5. In addition to inferior diagnostic performance, IVPs require contrast injection, take longer to perform, and involve greater radiation exposure.

As in the case of plain films and IVP, CT-KUB outperforms US, which has a sensitivity of only 19% and a specificity of 97\(^%\)\(^6\). As noted above, US is the study of choice in pregnant women (Figure 7).

Figure 8. Renal stone disease in an 82 year old man with acute right flank pain. A. CT-KUB at the level of the kidneys shows perinephric stranding (arrow). B. CT-KUB at the level of the proximal ureter shows a calcified stone (arrow).
Figure 9. Renal stone disease and hydronephrosis in a 62 year old man with known stone disease and new onset left flank pain. A. CT-KUB at the level of the left collecting system shows hydronephrosis. Note contralateral, nonobstructing calculus. B. CT-KUB at the level of the uteropelvic junction shows an obstructing renal stone.

Figure 10. Diverticulitis in a 73 year old woman with flank pain and hematuria. CT-KUB shows typical fat stranding along the descending colon diagnostic of diverticulitis.
CT-ANGIOGRAPHY, MR-ANGIOGRAPHY, AND NUCLEAR MEDICINE STUDIES MAY BE USED FOR EVALUATING SUSPECTED RENOVASCULAR HYPERTENSION

Most cases of hypertension either have an obvious cause or are idiopathic, and respond to appropriate treatment. Imaging should be performed when there is a suspicion of renal artery stenosis, which arises in the following clinical scenarios:

1. Severe or refractory hypertension (e.g., not controlled with three drug regimen).
2. An acute rise in blood pressure over a previously stable value.
3. Proven age of onset before puberty.
4. Age less than 30 years in non-obese patients with a confirmed negative family history of hypertension.\(^1\)

CT angiography

CT angiography demonstrates the abdominal arterial tree including the renal arteries, and allows diagnosis of renal artery stenosis (Figure 12). It requires IV contrast material and therefore elevated creatinine or decreased creatinine clearance is a relative contraindication to the study (see Chapter 16).

MR angiography

MR angiography also demonstrates the abdominal arterial tree including the renal arteries, and allows diagnosis of renal artery stenosis. It may be done either with or without gadolinium containing IV contrast, although studies done without IV contrast are technically more demanding. The contrast given for magnetic resonance imaging was once thought to be considerably safer than the contrast material given for CT studies, and at one point MR angiography was the study of choice in patients with renal insufficiency. The discovery that MR contrast material may provoke nephrogenic systemic fibrosis in patients with renal insufficiency, however, has all but eliminated use of such contrast in these patients (see Chapter 16). Nephrogenic systemic fibrosis is an uncommon side effect of MR contrast, which is occasionally fatal.

Figure 12. Renal artery stenosis treated with angioplasty in a 54 year old with hypertension. A. Initial CT angiogram (left) shows stenosis of the left renal artery (arrow). B. Follow-up CT following angioplasty shows decreased stenosis (arrow). The patient’s hypertension was under better control with fewer medications following angioplasty.
Renal scintigraphy

Another method to screen patients with renal insufficiency and possible renovascular hypertension is with a nuclear medicine study. In these studies, an intravenous radiotracer (Tc-99m DTPA) is injected followed by scans of both kidneys. This usually yields a normal study with bilateral, symmetric function of the kidneys resulting in normal time-activity curves: the amount of radioactivity shows an early spike and then later declines. The test is then repeated with an angiotensin-I converting enzyme (ACE) inhibitor, typically 25 mg of oral captopril. The abnormal kidney (downstream from the level of renal artery stenosis) will show much less activity and a flattened peak on the time-activity curve compared to the normal kidney.

ULTRASOUND IS THE STUDY OF CHOICE FOR EVALUATING NEW ONSET RENAL FAILURE

Patients with renal failure may present with decreased urine, flank pain, edema, hypertension, weakness and fatigue, anorexia, vomiting, mental status changes, or fever, but many patients are asymptomatic and are simply found on a screening study to have an elevated plasma creatinine or an abnormal urinalysis (such as microscopic hematuria or proteinuria). Since obstruction of renal outflow is a treatable disease, and since ultrasound will make this diagnosis, these patients should undergo an ultrasound study. Of course, these patients by definition have renal insufficiency, a relative contraindication to contrast-enhanced CT and MRI (see Chapter 16). Ultrasound is fast, relatively cheap, and involves no ionizing radiation or contrast material, all great advantages compared to other methods of evaluating acute renal insufficiency.

Renal obstruction will be accompanied by distention of the renal collecting system. Most frequently, this is secondary to either prostatic hypertrophy or tumors of the pelvis. These patients need referral to urology for drainage with expected return of renal function.

Ultrasound examination of patients with any of several “medical renal diseases” (for example, chronic glomerulonephritis), may show small, echogenic kidneys consistent with chronic disease, with the ultrasound appearance secondary to loss of renal parenchyma and increased interstitial fibrosis. However, the ultrasound study may also be normal in chronic disease, and these patients typically require referral to a nephrologist for possible biopsy and diagnosis, with appropriate treatment and counseling.

Polycystic kidney disease may present with renal failure in an adult, and in these cases the ultrasound is usually diagnostic, demonstrating enlarged kidneys with multiple cysts (Figure 11).

SUMMARY

Imaging often plays a critical role in the evaluation of renal symptoms. In patients with hematuria, combined unenhanced/enhanced CT allows diagnosis of such common causes as renal stones, renal cell cancer and transitional cell carcinoma of the collecting system, ureters, and bladder. In patients with flank pain suspected to be of renal origin, CT-KUB can evaluate the size and position of obstructing stones as well as diagnose alternative causes of flank pain. In patients with suspected renovascular hypertension, CTA, MRA, and renal scintigraphy all offer noninvasive methods of screening for renal artery stenosis. In patients with acute renal failure US allows a rapid diagnosis of obstruction.
Figure 11. Polycystic kidney disease in a 63 year old with hematuria. A. Ultrasound study of the left kidney shows two cysts (arrows). B. Ultrasound study of the right kidney shows an additional cyst (arrow). C. Coronal reformatted image from a CT-KUB shows multiple, variably sized cysts (arrows).

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