Kark and Muehrcke [5] in 1954. The kidneys were localized using landmark distances between the vertebral spinous processes and the 11th and 12th ribs and palpation of the kidney movement with the patient in a prone position. With the evolution of imaging tools, varying imaging techniques have been used to guide renal biopsies including fluoroscopy [6], renal scans [7], ultrasound [8, 9], and CT [10, 11].

### Indications and Rationale

The current accepted indications for renal biopsy include biopsy of a focal solid lesion or a suspicious cystic lesion to establish the diagnosis or nonfocal biopsy to evaluate for nephropathy or renal transplant rejection.

### Solid Renal Mass

With the increasing utilization of cross-sectional imaging, the number of incidentally discovered renal masses is increasing [12, 13], and many small lesions present as diagnostic dilemmas [14, 15] (Fig. 1). Historically, solid renal masses were not biopsied because if the lesion could not be characterized as a benign cyst or angiomyolipoma, it must be surgically removed [14] and there was a small reported risk of tumor seeding [16–23]. In addition, older histologic techniques had higher false-negative results and had difficulty distinguishing low-grade renal cell carcinoma (RCC) from benign oncocytoma [24]. However, improvements in biopsy techniques and histologic analysis with immunohistochemistry stains have increased the...
positive predictive value to 95–100% for the diagnosis of RCC [25–30]. In addition, the risk of tumor seeding is extremely low, with only seven reported cases in the literature [17–23].

With the increase in the use of percutaneous ablation, during which a renal mass is not surgically removed and pathologically analyzed, a biopsy confirms malignancy before treatment [31]. In one institution, approximately 37% of solid renal masses referred for ablation turned out to be benign renal masses [32]. A biopsy also allows oncologists to tailor future treatments and surveillance on the basis of the specific tumor subtype and grade [33].

Cystic Renal Lesion

Cystic renal lesions can be a simple cyst, a complicated benign renal cyst, or a cystic RCC. Features of a nonsimple cystic renal mass on CT include calcifications, high attenuation (> 20 HU), septations, enhancement, wall thickening, and nodularity [34] (Fig. 2). Approximately 10% of RCCs can present as a cystic mass [35]. In 1986, Bosniak [36] proposed a classification system to characterize renal cysts: category I, simple benign cysts; category II, benign cystic lesions that are minimally complicated; category III, more complicated cystic lesions; and category IV, lesions that are clearly malignant cystic carcinomas. In 1993, he revised the classification to include category II to allow follow-up of minimally complicated cysts that are more complex than category II lesions [37]. Although some individuals do not biopsy cystic renal lesions because of the potential for false-negative results and risk for tumor seeding [38], at our institution we biopsy all Bosniak type III lesions because up to 39% of lesions categorized as category III can be benign [39].

Nonfocal Renal Biopsy

A nonfocal biopsy samples any portion of the renal cortex [40]. Nonfocal biopsies are performed to evaluate for nephropathies [41], as part of the workup in a patient presenting with a renal transplant rejection [42], or to evaluate myriad systemic diseases that can affect the kidneys including HIV [43, 44] and systemic lupus erythematosus [45].

Approach

At our institution, imaging-guided percutaneous renal biopsies are usually outpatient procedures. They are performed with conscious sedation under ultrasound or CT guidance [45, 46]. In the following sections of this article, we describe our rationale for patient positioning and sedation and detail the steps of how we perform renal biopsies.

Preprocedure Workup

Before any renal biopsy, a patient’s medical history and medications are reviewed for the ability to tolerate a procedure under conscious sedation.

Review of medical history and medications—Medical records are reviewed for any history of cardiac disease or respiratory issues. Significant history of heart disease, such as a recent myocardial infarction, angina, congestive heart failure, or respiratory illnesses such as emphysema or obstructive sleep apnea, may require the aid of an anesthesiologist to monitor the sedation for the case.

Medications are reviewed to address any cross reactivity with the sedatives administered for conscious sedation and to withhold any anticoagulation drugs. A recent article provides guidance as to types and time intervals that anticoagulation medications should be withheld for percutaneous biopsies [47].

Laboratory values—Laboratory data are reviewed with particular attention to coagulation profile and creatinine level.

Coagulation—For all biopsies we prefer an international normalized ratio (INR) of 1.5 and platelet count of ≥ 50,000 th/cumm. Recent articles have suggested that an INR of < 2.0 and platelet counts as low as > 25,000 th/cumm are acceptable [47]. Blood products are administered to correct the coagulopathy. Occasionally, we are asked to perform renal biopsies for patients with renal failure who can present with uremic-induced platelet dysfunction. The platelet dysfunction may be corrected with the administration of desmopressin (1-desamino-8-D-arginine vasopressin).

Glomerular filtration rate—Serum creatinine values allow us to assess the estimated glomerular filtration rate and an opportunity to administer IV contrast material if needed for focal renal biopsies for which the lesion can be localized only on contrast-enhanced CT.

Equipment

Core Aspirate, Fine-Needle Aspirate, or Both

For focal renal biopsies, we obtain both fine-needle aspirates and core biopsy samples. In a review of 369 focal renal biopsies performed at our institution, we found that a combination of core biopsy and fine-needle aspiration produces the greatest diagnostic yield of malignant tissue (Samir AE, et al. Presented at the 2005 annual meeting of the Radiological Society of North America). All our focal renal biopsies are performed using a 17-gauge coaxial needle through which we obtain 20- to 22-gauge fine-needle aspirates and 18-gauge core samples.

For nonfocal renal biopsies, we typically use a 15-gauge core. In some institutions, pathology departments prefer larger cores, but many institutions use 18-gauge needles successfully, although more passes may be needed. The internal diameter of the 18-gauge needle (300–400 μm) [2, 48] is only barely larger than the adult glomeruli (200–250 μm) [2]. The advantage of a 14-gauge needle
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Fig. 3—Image of core biopsy equipment used. Photograph shows 18-gauge biopsy needle (top) compared with 14-gauge needle (bottom).

Fig. 4—42-year-old man who presented for biopsy of solid right renal mass. Axial planning CT scan obtained with patient in ipsilateral side–down position allows kidney to be splinted from respiratory motion.

Fig. 5—69-year-old man who presented for right renal biopsy. Axial planning CT scan obtained with patient in prone position allows most direct access to kidney.

is that it can obtain samples that are 900–1,000 μm [48] (Fig. 3).

Number of Passes
The number of samples obtained can not only determine the success of the biopsy but also increase the risk for bleeding and other complications [49].

For focal renal biopsies, we insert a coaxial needle and through it we obtain two or three core samples and four to six fine-needle aspirates. Because we typically obtain enough adequate samples for focal biopsies, we do not have a pathologist available during the biopsy to confirm adequacy.

For nonfocal renal biopsies, we pass a 15-gauge needle into the renal cortex one or two times and obtain samples that are evaluated for adequacy by a pathologist.

Ultrasound Versus CT Guidance
Although studies have shown that ultrasound guidance is superior to blinded nonfocal renal biopsies [50], no study to our knowledge has directly compared CT-guided renal biopsies with ultrasound-guided renal biopsies.

Ultrasound—Ultrasound has the advantages of real-time needle placement and no radiation and is therefore well suited for most nonfocal renal biopsies in thin patients and in biopsies of some focal solid masses or cystic masses that can be seen on ultrasound.

CT—CT has the advantage of better resolution and tissue contrast and is better able to localize the lesion and identify the surrounding critical structures. The use of each technique is dependent on the experience of the operator and the resources of the institution. At our institution, we perform most nonfocal renal biopsies using ultrasound guidance and focal renal biopsies using CT guidance.

Positioning
Ipsilateral Side Down
Whenever possible for focal renal biopsies under CT guidance, we prefer positioning the patient ipsilateral side down to splint the normal motion of the kidney due to respiration. The needle is inserted from a posterior approach in a trajectory that avoids the lungs, adjacent organs, and central renal collecting system (Fig. 4).

Prone
Native kidneys are most easily biopsied with the patient in a prone position. Both focal and nonfocal biopsies may be performed with the patient in a prone position (Fig. 5). Lesions along the lateral edge of the kidney may be difficult to access via an ipsilateral side–down approach.

Ipsilateral Side Up
The ipsilateral side–up position is occasionally chosen for patients undergoing nonfocal renal biopsies of the native kidneys under ultrasound. Because motion is compensated by real-time visualization and targeting with ultrasound, the ipsilateral side–up position allows the interventional radiologist to directly access the kidney while standing beside the patient.

Supine
A supine position of the patient is chosen for nonfocal ultrasound-guided biopsies of a transplanted kidney. Typically, a transplanted kidney is positioned in the right or left lower pelvis and the most direct access is via an anterior approach. A supine anterolateral approach may also be used in obese patients [51]. A supine transhepatic approach is occasionally used to reach anterior renal lesions.

Conscious Sedation Versus Local Anesthetic Only
The use of conscious sedation versus local anesthetic only is dependent on institutional policies. At our institution, most patients receive conscious sedation with midazolam hydrochloride (Versed, Roche Laboratories) and fentanyl and vital signs including blood pressure, pulse, and oxygen saturation are monitored. Occasionally we perform ultrasound-guided nonfocal biopsies using only local lidocaine.

Detailed Steps of the Biopsy Procedure
When patients present to our department for renal biopsy, they have not eaten for 8 hours to allow the administration of conscious sedation. An IV line is started and fluids are administered.

Focal Renal Biopsy
For focal renal biopsies, patients are brought to our interventional CT suite, consented, and placed ipsilateral side down. After all conscious sedation monitoring equipment is attached to the patient, including blood pressure, pulse, and pulse oximetry, a localizing grid is placed and preliminary CT images at 5-mm axial slices covering the entire length of the kidney
are obtained. The lesion is then identified and an approach is chosen.

The ideal approach to a focal renal mass is the shortest route to the lesion that passes through some normal renal cortex and avoids adjacent organs, lung, and the central renal collecting system (Fig. 6). Once the target and entrance site are chosen, the patient’s back is then prepared, draped, and anesthetized with 1% lidocaine. A coaxial needle is then inserted into the lesion and the position of the needle tip is confirmed on CT. Subsequently, fine-needle aspirates and core samples are obtained. We typically obtain six fine-needle aspirates: two samples placed on slides and four samples placed in a fixative solution. We then obtain three core biopsy samples that are placed in saline.

Once all samples are acquired, the needle is removed and postprocedure images are obtained to assess for perinephric hemorrhage.

Patients are monitored in our recovery suite for 2–3 hours after the procedure. As the sedation wears off, the patient is asked to urinate to ensure no hematuria and is then discharged with printed instructions.

Cystic Renal Lesion Biopsy

Cystic renal lesions represent a special subset of focal renal mass biopsies. The primary goal in biopsying a cystic lesion is to sample the nodular component of the cyst. Toward that end, when a cystic lesion is biopsied at our institution, we first target the nodular component with the coaxial needle. If the nodular component is not well identified, then any portion of the cyst is targeted, the fluid is aspirated, and then air or contrast material is injected to identify the nodular component (Fig. 7). The fluid is then sent for cytology evaluation, and fine-needle aspirates and core biopsies are obtained from the targeted nodular component.

Nonfocal Renal Biopsy

Nonfocal renal biopsies are typically performed under ultrasound guidance. Patients are brought into our ultrasound suite, given a consent form to sign, and placed in a lateral decubitus position. After conscious sedation, monitoring equipment is attached, and sedation is started, the nearest kidney is imaged. A trajectory that passes from the midpole renal cortex to the lower pole cortex—avoiding the central echogenic hilum—is chosen (Fig. 8). Once the entrance site is identified, the skin is then prepared, draped, and anesthetized with 1% lidocaine. Subsequently, a 15-gauge core biopsy gun is advanced into the renal cortex and samples are obtained. At our institution, we typically have a pathologist present at the biopsy to confirm the adequacy of our samples for nonfocal renal biopsies.

Success Rate

The overall success rate of all renal biopsies varies from a sensitivity of 70–100% and a specificity of 100% [27, 28, 52–60]. In the biopsy of focal renal masses, the sensitivity and negative predictive value can vary on the basis of the size of the mass [58]. Lesions between 4 and 6 cm had the greatest sensitivity and negative predictive value at 97% (95% CI, 83–100%) and 89% (95% CI, 51–99%), respectively. For patients with a cystic mass with no known malignancy, the sensitivity and negative predictive value were 33% (95% CI, 2–87%) and 87% (95% CI, 58–98%), respectively [59].

In performing solid renal mass biopsies, a constant dilemma that arises is a “negative” renal biopsy in the setting of a solid enhancing renal mass with no features to suggest angiomylipoma. Depending on the degree of suspicion, a repeat biopsy may be performed. In a recent study of 119 core biopsies, in 25 patients (21%) no accurate diagnosis was possible pathologically. Of these 21 patients, 13 underwent a repeat biopsy and 11 malignant lesions were identified [61]. Another option in small renal lesions (< 3 cm) is watchful waiting with follow-up CT to confirm stability. Another dilemma we occasionally face is a pathologic diagnosis of a mass with “oncocytic elements.” In such cases unless a pathologist can make a definitive diagnosis of an oncocytoma, we

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manage solid renal masses with oncocytic elements as malignant renal neoplasms.

Complications

Renal biopsies are very safe procedures. The overall mortality rate in a review of more than 16,000 abdominal fine-needle biopsies was 0.031% [26]. Complications include hemorrhage, infection, pneumothorax, adjacent organ injury, and tumor seeding.

Hemorrhage

Hemorrhage from percutaneous renal biopsy can be perinephric or into the collecting system. Hemorrhage may occur because of

Fig. 9—47-year-old man who underwent biopsy of renal mass. Axial unenhanced CT scan obtained after biopsy shows minimal perinephric hemorrhage (arrow).

Fig. 10—52-year-old man who underwent biopsy of renal mass. Axial unenhanced CT scan obtained after biopsy shows slightly hyperdense subcapsular hemorrhage (arrow).

Fig. 11—67-year-old woman with persistent bleeding after nonfocal renal biopsy. Arteriogram shows small pseudoaneurysm (arrow). This pseudoaneurysm was embolized with coil.

The neovascularity of RCCs or from normal cortical vascularity.

Neovascularity from RCCs can almost always lead to perinephric hemorrhage; in the past, perinephric hemorrhage has been reported in up to 91% of biopsies [62]. A more recent review showed mild perinephric hemorrhage in 44% [54].

For nonfocal renal biopsies, hematuria can be seen in approximately 35% of patients and perirenal hematoma in 65% of patients [2]. Less than 1% of patients require blood transfusion. Renal loss is seen in less than 0.1% of cases [2].

In most cases, minimal perinephric hemorrhage is seen and poses no risk to the patient (Fig. 9). If there is a large amount of perinephric hemorrhage and it extends into the pelvis, patients are monitored closely; if there is evidence of hemodynamic instability, they are given IV fluid boluses and blood products.

Typically, pressure from the surrounding Gerota capsule tamponades most hemorrhage (Fig. 10). If persistent nonpulsatile hemorrhage was present...
rhage is seen from the coaxial needle during a biopsy, we can inject gelatin particles (Gelfoam, Upjohn) to attempt to coagulate the bleeding. On rare occasions, hemorrhage is persistent and patients are transferred for angiography and embolization of a pseudoaneurysm (Fig. 11).

Infection
Infection as a complication of a renal biopsy is very rare. All biopsies are performed under sterile conditions. If patients have a urinary tract infection before the biopsy, the elective biopsy is delayed until the infection has cleared.

Pneumothorax
Upper pole renal tumors are at risk for causing a pneumothorax (Fig. 12). Placement of the patient in the ipsilateral side–down position minimizes the amount of pleura one may have to traverse to reach the lesion. A small pneumothorax is monitored with a follow-up chest radiograph in 1–2 hours. If the patient is asymptomatic or if there is a progressive increase in the size of the pneumothorax, a small-bore chest tube can be placed and set to suction overnight and can be removed within 24 hours.

Adjacent Organ Injury
Potential injury to adjacent organs can occur including injuries to the liver, spleen, pancreas, and colon.

Tumor Seeding
Seeding of the biopsy tract secondary to percutaneous biopsy is extremely rare, with only seven cases reported in the literature [17–23].

Special Circumstances Nonvisible Renal Mass on Unenhanced CT
Many times, a focal renal mass is visible on only a nephrographic phase diagnostic CT scan and is not visible on unenhanced CT. In such cases, we use intrarenal landmarks and contour markings to identify the location of the mass on a localizing CT scan (Fig. 13). If we are not confident of the location of the lesion, we can first insert the biopsy needle to the presumed location and then administer contrast material and image in a nephrographic phase. If the targeted needle position is accurate, we proceed with obtaining samples. If the targeted needle position is not accurate, we insert a second biopsy needle into the lesion using the first needle as a relative guide.

Renal Biopsy in Patients With Uncorrectable Coagulopathy
For patients with uncorrectable coagulopathy, two potential solutions exist for renal sampling. For nonfocal renal biopsy, a transperitoneal approach has been described in the literature [63–67]. Any bleeding that occurs extends into the vessels directly. Another option is a laparoscopic renal biopsy with direct coagulation of the bleeding site [68–70].

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