SECTION 8

Renal Histopathology in Acute Kidney Injury

CHAPTER 31

Practical Considerations of Renal Biopsies in Critical Care Patients

Jwalant R. Modi, Helen Liapis, Bruce A. Molitoris, and Michael T. Eadon

OBJECTIVES

This chapter will:

1. Discuss the indications and contraindications of a renal biopsy in critically ill patients. Understand the difference between performing a renal biopsy as an outpatient as opposed to the critical care setting.
2. Address the risks of a renal biopsy, including their prevalence, practical strategies for prevention, and clinical management of complications.
3. Evaluate the benefits of performing a renal biopsy in the critical care setting and its impact on management strategies.

A kidney biopsy is considered the gold standard for the diagnosis of a wide array of kidney diseases and systemic illnesses. This chapter focuses on the indications, complications, and periprocedural management of nontargeted native kidney biopsies, with a special emphasis on considerations relevant to the critically ill patient. Targeted kidney biopsies for renal masses and protocol kidney transplant biopsies are beyond the scope of this discussion. In the critical care setting, acute kidney injury is a common phenomenon[1]; however, the cause is often multifactorial or uncertain.[2] A kidney biopsy may provide important diagnostic and prognostic information necessary to determine whether a specific therapeutic intervention is indicated or whether such therapy is futile. The decision to biopsy critically ill patients portends added complexity as compared to commonly performed outpatient renal biopsies. This chapter outlines valid indications and contraindications, as well as providing practical suggestions to optimize timing, biopsy modality selection, and prevention of complications for patients at higher risk.

The first renal biopsies were performed in 1923 using an open surgical approach.[3] The percutaneous approach was first adopted as routine practice in the 1950s using a modified Vim-Silverman needle.[4] The technique has been refined further through the concomitant use of either ultrasound or computed tomography guidance as well as the use of a spring-loaded needle. These advances have improved biopsy adequacy and complication rates.[5] However, despite these improvements in safety, risks remain. Selecting patients with a proper indication for a biopsy is paramount. Furthermore, the threshold to embark upon a renal biopsy in the intensive care unit (ICU) is different than in an outpatient nephrologist's office.

INDICATIONS AND CONTRAINDICATIONS FOR RENAL BIOPSY

The general indications to pursue a renal biopsy include unexplained proteinuria, glomerular hematuria, progression of chronic kidney disease, or acute kidney injury (AKI). A kidney biopsy should be considered in any patient with reduced kidney function and either unexplained microscopic hematuria or significant proteinuria. Table 31.1 illustrates the contrast in thresholds for renal biopsy between stable outpatients and inpatients in the ICU. Certain common sense prerequisites for a kidney biopsy are applicable to inpatients and outpatients. These requisites are the following:

1. The differential diagnosis includes diseases associated with significant morbidity, mortality, or a decrement in quality of life.
2. A diagnosis will change management and guide therapy.
3. The differential diagnoses have divergent therapeutic strategies that may be entertained only after a tissue diagnosis.
4. The potential adverse effects of such therapeutic measures and the risks of the procedure are acceptable for the patient's current health status.[6]

For example, a kidney biopsy is recommended infrequently in a patient with a terminal illness.

In contrast to outpatient indications, the most common indication for renal biopsy in the ICU is AKI, which may be

TABLE 31.1

Indications for Renal Biopsy

GENERAL OUTPATIENT INDICATIONS	CRITICAL CARE INDICATIONS
Unexplained renal impairment or progression of chronic kidney disease	Unexplained renal impairment or progression of chronic kidney disease with both: Glomerular hematuria and Proteinuria > 1 g/day
Significant proteinuria (>1 g/day)	
Unexplained microscopic hematuria of glomerular cause	
Renal manifestations of a systemic disease[a]	Renal manifestations of a life-threatening systemic disease[a]
Suspected acute or chronic rejection of a transplanted kidney	Suspected acute or chronic rejection of a transplanted kidney

[a]Systemic diseases include but are not limited to pulmonary renal syndromes (granulomatous polyangiitis, Goodpasture's disease, systemic lupus erythematosus), anti-neutrophil cytoplasmic antibody vasculitis, multiple myeloma, amyloidosis, lymphoma, light chain deposition, thrombotic thrombocytopenic purpura, hemolytic uremic syndrome, antiphospholipid syndrome, systemic scleroderma, inferior vena cava, or renal vein thrombosis).

TABLE 31.2

Contraindications to Renal Biopsy

ABSOLUTE CONTRAINDICATIONS	RELATIVE CONTRAINDICATIONS
• Uncontrolled hypertension	• Solitary kidney
• Bleeding diathesis or inability to hold periprocedural anticoagulation	• Antiplatelet agents
• Widespread cystic disease or renal malignancy	• Anatomic abnormalities, including a horseshoe kidney
• Hydronephrosis	• Small kidneys or cortical thinning
• Inability of the patient to cooperate or provide consent	• Inability to tolerate blood loss or blood transfusion
• Active urinary sepsis	• Hypotension on vasopressors
• Platelet count < 50,000/mm^3	• Platelet count < 150,000/mm^3

From Chen TK, Estrella MM, Fine DM. Predictors of kidney biopsy complication among patients with systemic lupus erythematosus. *Lupus.* 2012;21(8):848-854.

classified as incident AKI while hospitalized, AKI exacerbating chronic kidney disease (CKD) or another systemic illness, or unresolved AKI present on initial presentation. Acute tubular necrosis (ATN) is the most frequently encountered diagnosis among hospitalized patients with AKI, accounting for 45% to 88% of all AKI.[1,7,8] Often the diagnosis of ATN is made clinically, and therapy consists of identifying and correcting any underlying insults from sepsis, hypotension, or nephrotoxicity.[9] Given the prevalence of ATN and the lack of targeted intervention for this condition, it is easy to overlook alternative diagnoses such as glomerulonephritis, acute interstitial nephritis, thrombotic microangiopathy, and nephrotic syndrome. These conditions require prompt and specific targeted therapy.[8] Therefore, all patients with AKI should be evaluated for proteinuria and hematuria. The presence of proteinuria and hematuria is associated with mortality in critically ill patients independent of other baseline conditions.[10]

The evaluations of proteinuria and hematuria are complicated by several factors in critically ill patients. First, ATN may result in albuminuria or tubular proteinuria secondary to diminished reabsorption by injured proximal tubules.[11,12] In patients with AKI, proteinuria of less than 1.0 g/day is insufficient to warrant a renal biopsy without the presence of systemic disease or microscopic hematuria. The evaluation of hematuria frequently is confounded by nonglomerular hematuria, because many patients have Foley catheters, urinary tract infections, or urologic comorbidities. The nephrologist's assessment of the urinary sediment can assist in determination of which patients would benefit from a renal biopsy. The laboratory urinalysis may miss vital clues such as red blood cell (RBC) or white blood cell casts, dysmorphic RBCs, acanthocytes, schistocytes, and crystals.[13]

In patients with a systemic disease, such as lupus nephritis or granulomatous polyangiitis, a pathologic diagnosis from the kidney is instrumental in dictating therapy. The biopsy provides valuable information about disease activity and chronicity (inflammation, fibrosis) within the kidney or may prove useful in the absence of reduced renal function, because the pathologic information can guide therapy for other involved organ systems.[5] However, given the invasive nature of the procedure and the risks associated with it, it is necessary to identify the patients who are most likely to benefit from this procedure. Absolute and relative contraindications to a kidney biopsy are detailed in Table 31.2.

Special Considerations in the Elderly and During Pregnancy

Elderly

Elderly (≥65 years) and very elderly (≥80 years) patients account for a small proportion (3%–13%) of procedures in kidney biopsy registries. The perception that these patients have increased procedural risk and treatment-associated adverse events (related to immunosuppression) is thought to outweigh the clinical benefit in this population.[14,15] However, these perceptions are not supported by the literature. None of the large biopsy series nor a meta-analysis by Corapi et al. identified age as an independent risk factor for complications.[16]

Pregnancy

In pregnancy, there is concern that patients have higher complication rates related to increased renal blood flow during gestation. Although minimal prospective data are available, one series of renal biopsies in pregnant women revealed that complication rates were low and not significantly different than the general population.[17] Because a gravid uterus may affect a patient's ability to lie prone, alternate positioning (sitting upright or lying in the lateral decubitus position) for kidney biopsy may be preferred.[18]

BIOPSY TECHNIQUE AND MODALITIES

A percutaneous ultrasound-guided kidney biopsy is the present standard of care to obtain pathologic tissue for

diagnosis. The procedure usually is performed by trained nephrologists or interventional radiologists. The technique for native and transplant kidney biopsy is similar except for positioning of the patient. An ultrasound-guided kidney biopsy is performed under local anesthesia with a disposable, automatic, spring-loaded device using 14-, 16-, or 18-gauge needles (outer diameter of 2.11, 1.65, and 1.27 mm, respectively). The diagnostic yield is determined by different factors, including adequacy of tissue, operator experience, size of the kidneys, and a patient's ability to cooperate. The criterion for adequate biopsy tissue typically is considered to be 15 to 20 glomeruli. Adequate tissue is obtained in 95% to 99% of biopsies performed using 14- or 16-gauge needles.[19] Computed tomography (CT) may be used as an alternate primary imaging modality and may be preferred in obese patients, those with complicated anatomies (e.g., cysts or a horseshoe kidney), and those for whom kidney visualization with ultrasound is difficult.[20] Other means of obtaining renal tissue include open biopsy, laparoscopic biopsy, and transjugular biopsy. Each of these methodologies is associated with specific risks but hold particular merits depending on the clinical scenario (Table 31.3).

In the presence of a solitary kidney, there is concern that a percutaneous biopsy may result in marked bleeding, which in turn may require a nephrectomy and render the patient anephric. Selected case series have revealed this risk may be less than the risk of general anesthesia.[6] There are not enough data or experience with this practice to safely recommend it as a standard of care, and the percutaneous renal biopsy of a solitary kidney is a relative contraindication. Other nonpercutaneous techniques, such as the open or laparoscopic approaches, are preferred.

In intensive care patients on mechanical ventilation, the traditional modality of choice for native kidney biopsies is an open surgical approach.[21,22] However, critically ill patients on mechanical ventilation are often at too high a risk for surgery. It is possible to perform a percutaneous renal biopsy with portable ultrasonographic guidance by placing the patient prone and ventilating manually with a self-inflating (Ambu) bag.[23] Conlon PJ et al. performed a study comparing percutaneous kidney biopsies to open surgical biopsies in a group of ICU patients on mechanical ventilation in whom pulmonary renal syndrome was among the possible differential diagnoses.[23] They performed percutaneous biopsy on seven patients and obtained adequate renal tissue in all cases. The complication rate was similar to the open biopsies performed during the same period.

TABLE 31.3

Alternative Methods for Obtaining Renal Tissue and Their Risks and Benefits Compared With a Percutaneous Approach

METHOD	ADVANTAGE(S)	DISADVANTAGE(S)
Transjugular[45]	Suggested for patients with a bleeding diathesis or platelet count < 100,000/mm^3	Potential of capsular perforation Contrast-induced nephropathy Deficient sampling with inadequate glomeruli in up to 24% of cases
Open[46]	High yield of adequate tissue Better hemostasis control	Requires general or spinal anesthesia
Laparoscopic[47]	High yield of adequate tissue Better hemostasis control	Requires general or spinal anesthesia

Bleeding Complications in Percutaneous Kidney Biopsies

The most common complications of a percutaneous kidney biopsy are bleeding, arteriovenous fistula, and infection.[24] Injury or perforation to other organs is a rare complication of ultrasound- or CT-guided kidney biopsies with preprocedural visualization of the anatomic structures in the vicinity of the kidney.

Bleeding is the most common and clinically relevant complication of a kidney biopsy. An insignificant drop in hemoglobin after a kidney biopsy is very common. It is also important to be aware of the effects of postural changes on hemoglobin levels, which are observed commonly after a variety of procedures requiring bed rest.[25] Major bleeding events that result in alteration of management, extended hospital stay, blood transfusion, intervention, surgery, or death are uncommon. A systematic review and meta-analysis of all adult percutaneous renal biopsy studies from 1980 to 2011 (34 studies with 9474 biopsies meeting inclusion criteria) was done by Corapi et al.,[16] which found the rates of complications as listed in Table 31.4. A schema of the approach to postbiopsy bleeding is shown in Fig. 31.1.

Imaging

Postbiopsy imaging by routine ultrasonography or computed tomography after biopsy holds minimal utility in predicting

TABLE 31.4

Bleeding Complications After Percutaneous Native Renal Biopsy

COMPLICATION	NO. OF STUDIES	NO. OF PROCEDURES	NO. OF COMPLICATIONS	COMPLICATION RATE[a]
Macroscopic hematuria	30	8042	342	3.5 (2.2–5.1)
Blood transfusion	32	9456	144	0.9 (0.4–1.5)
Angiographic intervention	24	8445	30	0.6 (0.4–0.8)
Nephrectomy	29	8941	1	0.01
Bladder obstruction	6	2416	7	0.3
Death	29	8971	2	0.02

[a]Percentage; values in parentheses, when shown, are 95% confidence intervals.
From: Corapi KM, Chen JL, Balk EM, et al. Bleeding complications of native kidney biopsy: a systematic review and meta-analysis. *Am J Kidney Dis.* 2012;60(1):62-73.

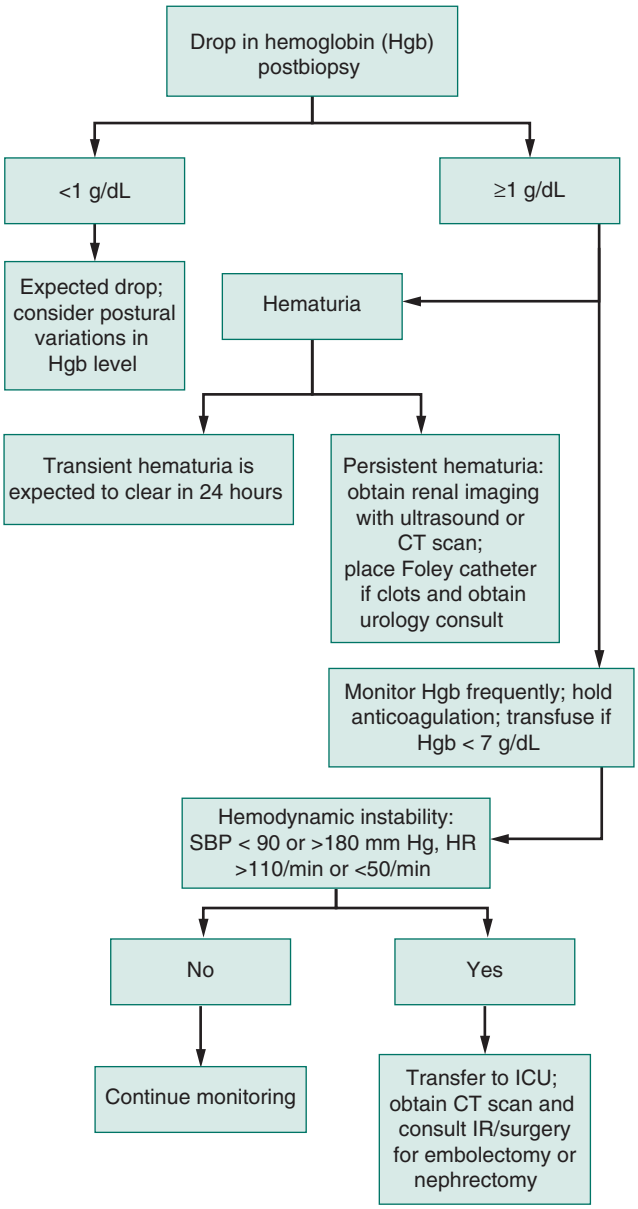

FIGURE 31.1 Management guide for bleeding after renal biopsy.

relevant clinical complications or altering management. A retrospective single center study of 317 percutaneous kidney biopsies with an immediate postbiopsy ultrasound found that 86% of patients had a detectable hematoma, but only 13% had a hematoma larger than 2 cm.[26] Although the presence of a hematoma larger than 2 cm was associated with a greater absolute decrease in hemoglobin (6.9% when >2 cm vs. 2.9% for <2 cm and 2.0% when no hematoma) as well as a hemoglobin decrease of more than 10%, it was not associated with higher rates of transfusion or intervention.[26] Similar results were found in an analysis of 162 patients with percutaneous native kidney biopsies who had an ultrasound 1 hour postprocedure.[27] In the study, 69% of patients with minor complications and 87% of patients with major complications had a detectable hematoma. The size of the hematoma did not predict the complication rate, although there was a trend toward association with a hematoma size greater than 3 cm (55% vs. 26%; p = .06). The absence of a hematoma was a more useful predictor, because the negative predictive value for developing a complication was 95%.[27] These studies suggest that the presence of hematoma on postbiopsy imaging does not predict clinically relevant complications, but the absence of hematoma has a high negative predictive value for complications and may be used to determine which patients can be discharged with a shorter observation period.

Peribiopsy Anticoagulation

Patients who require chronic anticoagulation with warfarin or low-molecular-weight heparin (LMWH) often can undergo a renal biopsy with a brief interval off anticoagulation. In patients at lower risk for venous thromboembolism, our practice is to hold warfarin for 5 days before the procedure and administer LMWH until 24 hours before the procedure. We resume warfarin and LMWH 72 hours after the procedure if no bleeding complications were observed. No data are available on the complication rates after renal biopsy with the novel oral anticoagulants (NOACs). NOACs such as rivaroxaban, apixaban, and dabigatran have half-lives ranging from 9 to 17 hours. We typically hold these drugs for 48 hours before a renal biopsy and resume 72 hours after. Alternatively, the use of a heparin bridge in the peribiopsy period may be used in patients who cannot safely remain off anticoagulation for multiple days. Platelet transfusions should be given for any patient with a platelet count less than 50,000/mm^3. Consider fresh frozen plasma administration for an international normalized ratio (INR) ≥ 1.4.

Antiplatelet Agents

Mackinnon et al. retrospectively compared complication rates after native renal biopsy between centers where antiplatelet agents were stopped 5 days before biopsy (n = 75) or continued (n = 60).[28] Patients were not biopsied if they had a BP greater than 160/90 mm Hg, INR > 1.4, or platelet count < 100×10^9/L. Continuation of antiplatelet agents was associated with a greater absolute decrease in hemoglobin as well as the percentage of patients with a >1 g/dL drop. However, no difference in major complications (requirement for transfusion or radiologic or surgical intervention) was observed between patients undergoing elective (1.3% vs. 0; p = .56) or urgent (5.2% vs. 3.4%; p = .17) biopsy. A second study by Atwell et al. described a single-center experience of 15,181 percutaneous biopsies of multiple organs, including 5832 native and allograft kidney biopsies between 2002 and 2008 and found no difference in bleeding between patients who did or did not take aspirin within 10 days of biopsy (1% vs. 0.6%; p = .53).[29] In the meta-analysis by Corapi et al., the rate of transfusion did not differ between patients in whom antiplatelet agents were held for at least 7 days (nine studies, 2116 biopsies) and patients in whom antiplatelet agents were held for less than 7 days (seven studies; n = 4009; 0.5% vs. 0.7%, p = 0.7).[16] However, given the limited data exploring this question and that most kidney biopsies are elective procedures, we recommend holding antiplatelet agents for 7 days before the procedure when possible. Our practice is to hold antiplatelet agents for a minimum of 3 days in the inpatient setting. However, if the procedure cannot be delayed and antiplatelet agents have been administered recently, a transjugular approach should be used. This approach also is indicated if the absolute platelet count is less than 100×10^9/L.

Desmopressin

The use of a desmopressin acetate infusion (0.3 μg/kg) 1 hour before a renal biopsy has been associated with smaller and fewer (13.7% vs. 31%) hematomas in patients with a creatinine less than 1.5 mg/dL and normal coagulation parameters. However, desmopressin administration did not result in fewer transfusions or interventions in these patients.[30] In patients with more significant renal dysfunction, the population in which it is most often considered, desmopressin has been found to correct bleeding time abnormalities in patients with renal biopsy indications.[31] Although there have been no controlled studies exploring the effect of desmopressin on adverse events in these patients with severe renal dysfunction, a case series of 1055 patients did reveal that a prolonged bleeding time was associated with more frequent adverse bleeding complications.[32] Many institutions no longer offer a bleeding time analysis because it is labor intensive for the laboratory. The platelet function assay, or PFA-100, has been found to correlate well with a bleeding time analysis.[33] Several small studies involving renal biopsies have failed to show a benefit of the PFA-100 assay in the prediction of bleeding complications.[34–36] Nonetheless, given the small size of these studies, the practice at our institution is to obtain a PFA-100 before a renal biopsy as a surrogate for the bleeding time. If the adenosine diphosphate (ADP) and epinephrine closures are abnormal in a patient with elevated blood urea nitrogen, we administer desmopressin prophylactically before a renal biopsy.

Additional Complications of Percutaneous Renal Biopsies

Arteriovenous Fistula

Arteriovenous fistulas are often asymptomatic and self-resolving; however, they can result in AKI because of a vascular steal syndrome compromising blood flow to the rest of the kidney.[24] This complication is diagnosed by renal Doppler ultrasonography in patients who develop AKI after biopsy. Transcatheter embolization is required to stop the shunting.

Infection

With the use of sterile technique, disposable needles, and careful preprocedural evaluation with ultrasonography, the risk of infection with a percutaneous kidney biopsy is exceedingly rare.[6]

Page Kidney

A Page kidney is a rare phenomenon characterized by an acute rise in blood pressure secondary to continued external compression of the renal parenchyma resulting in a form of secondary hypertension. The compressive force is usually a subcapsular hematoma, which causes a decrease in renal perfusion and activation of renin-angiotensin-aldosterone system, leading to hypertension.[37] Deterioration of kidney function is seen more commonly in patients with a solitary kidney or bilateral page kidneys. The first-line treatment for a Page kidney involves angiotensin-converting enzyme (ACE) inhibitor and angiotensin receptor blocker use, which is not used conventionally in the control of hypertension with AKI. When pharmacologic management does not suffice, there are more invasive options available such as percutaneous drainage of the offending collections, surgical decompression with removal of the fibrocollagenous shell, or even complete nephrectomy.[38]

PRE- AND POSTBIOPSY MANAGEMENT

The following checklists are intended to be a practical set of steps to reduce complications rates before and after a renal biopsy.

A checklist of prebiopsy evaluation follows:

- Obtain a complete blood count (CBC), INR/prothrombin time, activated partial thromboplastin time, serum creatinine, urinalysis, and a type and screen. Consider a preprocedural platelet function assay or bleeding time if available at your institution.
- Medications should be reviewed for agents that may increase a patient's bleeding risk. The patient or provider should discontinue anticoagulants, antiplatelet agents, and nonsteroidal antiinflammatory drugs (NSAIDs) 1 week before a renal biopsy if possible. Most anticoagulants or antiplatelet agents are held for 72 hours after a renal biopsy, unless a compelling cardiac or vascular indication requires earlier reinitiation. Arrangements should be made for intravenous heparin infusions, platelet transfusions, fresh frozen plasma transfusions, and desmopressin administration as required.
- If the patient's platelet count is less than 100,000/mm^3, or recent antiplatelet agents have been administered, a transjugular renal biopsy is the modality of choice.
- Place ventilated patients in the prone position. A respiratory therapist should assist with manual ventilation or ventilator pauses as required.
- Ensure adequate blood pressure control (<140/90 mm Hg). Patients should be treated with short-acting oral or intravenous antihypertensive agents.
- Secure an appropriate informed consent.
- Obtain adequate intravenous access because anxiolytics or anesthetic agents may be required for anxious, uncooperative, and/or pediatric patients as well as for intravenous resuscitation fluids in case blood pressure drops during or after the procedure.

Postbiopsy checklist and orders include the following:

- Enforce strict bed rest for 6 hours.
- Administer acetaminophen or opiate analgesia for pain, but avoid NSAID use. Provide antiemetics as needed.
- Monitor vital signs every 15 minutes for 2 hours, every 30 minutes for 4 hours, and then hourly for the next 18 hours the first day postbiopsy.
- Obtain a repeat CBC the next morning (or sooner if hemodynamic changes are present); save serial urine specimens postbiopsy for gross hematuria and clots.

DIAGNOSIS AND THERAPY

As mentioned earlier, ATN is the most frequently encountered type of renal injury in the critical care setting.[1,7,8] Because the presence of proteinuria or hematuria in the critical care setting frequently is confounded, a renal biopsy may be important to guide therapy. A retrospective study of 56 patients in five ICUs determined the impact of a kidney biopsy on renal management as well as the frequency of procedure-related complications. From 54 analyzed kidney

biopsies, ATN (n = 26), glomerulonephritis (n = 14), acute vascular nephritis (n = 11), acute interstitial nephritis (AIN, n = 6), and deposit disease (n = 3) were all diagnosed. Management of 40 (71%) patients was affected by the renal biopsy. In 23 patients, new treatments were initiated. In 13 patients, ongoing treatments were stopped, including four life-sustaining therapies. In 13 patients, chronic renal replacement was started. Seven patients had a severe bleeding event, and there was one fatality.[39]

Fig. 31.2 illustrates pathologic features of commonly seen renal diseases in a critical care unit. Fig. 31.2A demonstrates ATN, often managed by supportive measures and correction of the contributing factors (sepsis, hypotension, nephrotoxic drugs). The recovery rates vary depending upon whether the ATN is purely ischemic (74%) or multifactorial (30%).[40] AKI resulting from renal atheroemboli (Fig. 31.2B) can be mistaken easily for ATN because of its similar clinical presentation. In contrast to ATN, this diagnosis is associated with a poor overall prognosis[41] and does not require specific therapy other than the supportive measures. Fig. 31.2C displays the pathologic hallmarks of AIN. Although this condition may recover spontaneously with removal of the offending drug, many practitioners elect to treat aggressively with glucocorticoids because such treatment has been associated with a more complete renal recovery.[42,43] Crescentic glomerulonephritis or rapidly progressive glomerulonephritis (RPGN, Fig. 31.2D) emphasizes the impact of a tissue diagnosis on the management strategy. In the critical care setting, pulmonary renal syndromes (e.g., anti-neutrophil cytoplasmic antibody [ANCA], Goodpasture's disease, and systemic lupus erythematosus [SLE]) require a prompt diagnosis and therapy because of their associated mortality. The management includes aggressive treatment with high-dose glucocorticoids, immunosuppressive therapy with cyclophosphamide and/or rituximab, and therapeutic plasma exchange (TPE) in cases with diffuse alveolar hemorrhage. Another renal emergency is thrombotic microangiopathy (TMA), which includes thrombotic thrombocytopenic purpura (TTP), hemolytic uremic syndrome, complement-mediated TMA, and drug-induced TMA (Fig. 31.2E). Immediate management of TMA should be initiated with plasma exchange (PEX) based on clinical suspicion and should not be delayed for a kidney biopsy confirmation. Fig. 31.2F demonstrates the histopathology of cast nephropathy secondary to multiple myeloma. In this condition, light chains within the tubules form casts as a result of binding with Tamm-Horsfall protein. Management of AKI resulting from myeloma cast nephropathy includes initiation of bortezomib-based chemotherapy in combination with dexamethasone to rapidly decrease the production of light chains. Plasmapheresis to rapidly lower the circulating free light chains may be indicated for patients with myeloma cast nephropathy.

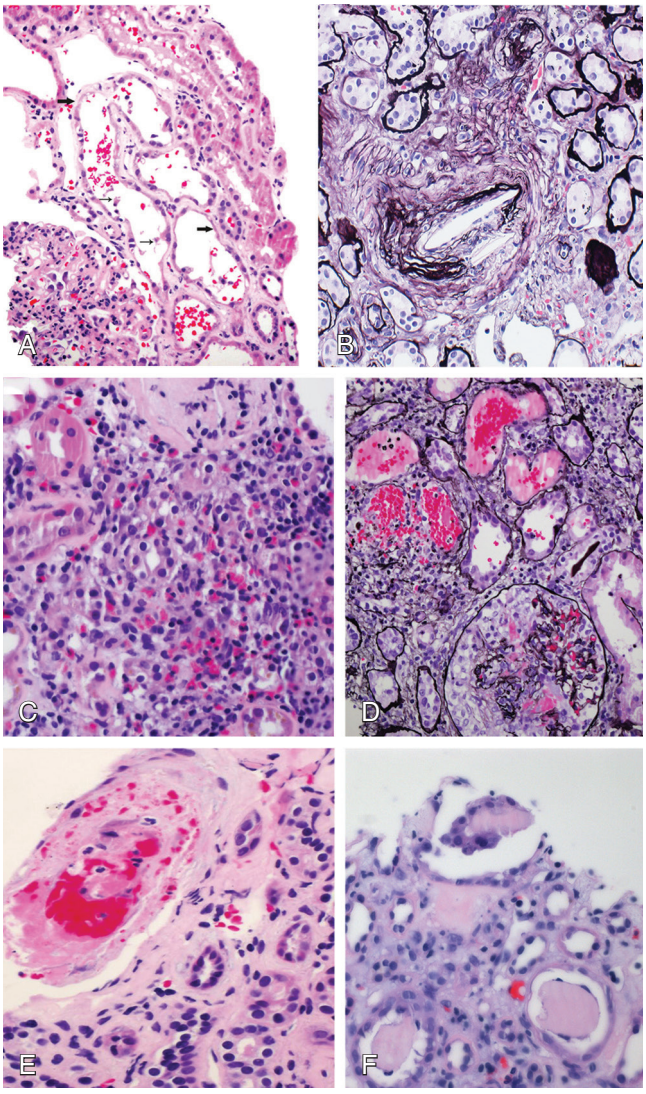

FIGURE 31.2 See also color plates. Pathologic features of common acute kidney injury diagnoses in the critical care setting. A, Acute tubular necrosis with proximal tubules showing flattening of the lining epithelial cells and loss of brush border *(thick arrow).* The *thin arrows* point to fragmented, detached epithelial cells floating into tubular lumens. Also present are numerous luminal red blood cells (RBCs) (H&E stain ×100); B, Renal atheroemboli evidenced by colorless, spindle-shaped cholesterol clefts within small arteries. Cholesterol crystals dissolve with formalin fixation. Crystals often are phagocytosed by immune cells forming giant cells (Silver stain ×100). C, Acute interstitial nephritis with diffuse chronic interstitial inflammation and prominent eosinophils. Eosinophils can be few, plentiful, or absent because their half-life is approximately 2 weeks. D, Crescentic or rapidly progressive glomerulonephritis illustrated by ANCA vasculitis. The renal biopsy shows a glomerulus containing an epithelial crescent with focal necrosis. Tubules are dilated and contain lysed RBCs. E, Thrombotic microangiopathy evidenced by an arteriole with luminal fibrin thrombus and fragmented mural RBCs. F, Cast nephropathy resulting from multiple myeloma with numerous pale tubular casts. *Arrows* point to a cellular reaction engulfing paraprotein casts.

CONCLUSION

A kidney biopsy can differentiate a wide range of clinical entities and help direct management. Given the prevalence of ATN as the cause of AKI in critical care patients, a higher pretest probability is required to entertain a renal biopsy. To evaluate for diseases other than ATN, a nephrology consultation is quintessential to examine the urinary sediment and determine the utility of a biopsy. Percutaneous kidney biopsies may be performed safely in critically ill patients with careful candidate selection and attentive preprocedural preparation of patients.

Key Points

1. Patient selection for a renal biopsy is important because the threshold to perform a renal biopsy in the intensive care unit is generally higher than the outpatient setting. Examination of the urinary sediment is important in determining the utility of a biopsy.
2. Acute tubular necrosis is the most common diagnosis of acute kidney injury among hospitalized patients. Thus it is easy to overlook an alternative diagnosis such as glomerulonephritis, interstitial nephritis, thrombotic microangiopathy, or nephrotic syndrome. A kidney biopsy provides important diagnostic and prognostic information to determine whether a specific therapeutic intervention is indicated.
3. The most common complication of a percutaneous kidney biopsy is bleeding. Proper preparation, biopsy modality, and patient selection can reduce complication rates.

Key References

6. Hogan JJ, Mocanu M, Berns JS. The Native Kidney Biopsy: Update and Evidence for Best Practice. *Clin J Am Soc Nephrol*. 2016;11:354.
11. Dickson LE, Wagner MC, Sandoval RM, et al. The proximal tubule and albuminuria: really! *J Am Soc Nephrol*. 2014; 25(3):443-453.
16. Corapi KM, Chen JL, Balk EM, et al. Bleeding complications of native kidney biopsy: A systematic review and metaanalysis. *Am J Kidney Dis*. 2012;60:62-73.
32. Korbet SM, Volpini KC, Whittier WL. Percutaneous renal biopsy of native kidneys: a single-center experience of 1,055 biopsies. *Am J Nephrol*. 2014;39(2):153-162.
39. Philipponnet C, Guerin C, Canet E, et al. Kidney biopsy in the critically ill patient, results of a multicentre retrospective case series. *Minerva Anestesiol*. 2013;79(1):53-61.

A complete reference list can be found online at ExpertConsult.com.

References

1. Mehta RL, Pascual MT, Soroko S, et al. Spectrum of acute renal failure in the intensive care unit: the PICARD experience. *Kidney Int*. 2004;66(4):1613-1621.
2. Chertow GM, Burdick E, Honour M, et al. Acute kidney injury, mortality, length of stay, and costs in hospitalized patients. *J Am Soc Nephrol*. 2005;16(11):3365-3370.
3. Gwyn NB. Biopsies and the Completion of certain Surgical Procedures. *Can Med Assoc J*. 1923;13(11):820-823.
4. Kark RM, Muehrcke RC. Biopsy of kidney in prone position. *Lancet*. 1954;266(6821):1047-1049.
5. Madaio MP. Renal biopsy. *Kidney Int*. 1990;38(3):529-543.
6. Hogan JJ, Mocanu M, Berns JS. The Native Kidney Biopsy: Update and Evidence for Best Practice. *Clin J Am Soc Nephrol*. 2016;11(2):354-362.
7. Santos WJ, Zanetta DM, Pires AC, et al. Patients with ischaemic, mixed and nephrotoxic acute tubular necrosis in the intensive care unit–a homogeneous population? *Crit Care*. 2006;10(2):R68.
8. Liano F, Pascual J. Epidemiology of acute renal failure: a prospective, multicenter, community-based study. Madrid Acute Renal Failure Study Group. *Kidney Int*. 1996;50(3):811-818.
9. Lerolle N, Nochy D, Guerot E, et al. Histopathology of septic shock induced acute kidney injury: apoptosis and leukocytic infiltration. *Intensive Care Med*. 2010;36(3):471-478.
10. Han SS, Ahn SY, Ryu J, et al. Proteinuria and hematuria are associated with acute kidney injury and mortality in critically ill patients: a retrospective observational study. *BMC Nephrol*. 2014;15:93.
11. Dickson LE, Wagner MC, Sandoval RM, et al. The proximal tubule and albuminuria: really! *J Am Soc Nephrol*. 2014; 25(3):443-453.
12. Parikh CR, Lu JC, Coca SG, et al. Tubular proteinuria in acute kidney injury: a critical evaluation of current status and future promise. *Ann Clin Biochem*. 2010;47(Pt 4):301-312.
13. Tsai JJ, Yeun JY, Kumar VA, et al. Comparison and interpretation of urinalysis performed by a nephrologist versus a hospital-based clinical laboratory. *Am J Kidney Dis*. 2005;46(5):820-829.
14. Moutzouris DA, Herlitz L, Appel GB, et al. Renal biopsy in the very elderly. *Clin J Am Soc Nephrol*. 2009;4(6):1073-1082.
15. Rivera F, Lopez-Gomez JM, Perez-Garcia R, et al. Clinicopathologic correlations of renal pathology in Spain. *Kidney Int*. 2004;66(3):898-904.
16. Corapi KM, Chen JL, Balk EM, et al. Bleeding complications of native kidney biopsy: a systematic review and meta-analysis. *Am J Kidney Dis*. 2012;60(1):62-73.
17. Packham D, Fairley KF. Renal biopsy: indications and complications in pregnancy. *Br J Obstet Gynaecol*. 1987;94(10):935-939.
18. Lindheimer MD, Davison JM. Renal biopsy during pregnancy: 'to b (or not to b (?'. *Br J Obstet Gynaecol*. 1987;94(10):932-934.
19. Burstein DM, Korbet SM, Schwartz MM. The use of the automatic core biopsy system in percutaneous renal biopsies: a comparative study. *Am J Kidney Dis*. 1993;22(4):545-552.
20. Sateriale M, Cronan JJ, Savadler LD. A 5-year experience with 307 CT-guided renal biopsies: results and complications. *J Vasc Interv Radiol*. 1991;2(3):401-407.
21. Gupta M, Haluck RS, Yang HC, et al. Laparoscopic-assisted renal biopsy: an alternative to open approach. *Am J Kidney Dis*. 2000;36(3):636-639.
22. Whittier WL, Korbet SM. Renal biopsy: update. *Curr Opin Nephrol Hypertens*. 2004;13(6):661-665.
23. Conlon PJ, Kovalik E, Schwab SJ. Percutaneous renal biopsy of ventilated intensive care unit patients. *Clin Nephrol*. 1995; 43(5):309-311.
24. Preda A, Van Dijk LC, Van Oostaijen JA, et al. Complication rate and diagnostic yield of 515 consecutive ultrasound-guided biopsies of renal allografts and native kidneys using a 14-gauge Biopty gun. *Eur Radiol*. 2003;13(3):527-530.
25. Lippi G, Salvagno GL, Lima-Oliveira G, et al. Postural change during venous blood collection is a major source of bias in clinical chemistry testing. *Clin Chim Acta*. 2015;440:164-168.
26. Ishikawa E, Nomura S, Hamaguchi T, et al. Ultrasonography as a predictor of overt bleeding after renal biopsy. *Clin Exp Nephrol*. 2009;13(4):325-331.
27. Waldo B, Korbet SM, Freimanis MG, et al. The value of post-biopsy ultrasound in predicting complications after percutaneous renal biopsy of native kidneys. *Nephrol Dial Transplant*. 2009;24(8):2433-2439.
28. Mackinnon B, Fraser E, Simpson K, et al. Is it necessary to stop antiplatelet agents before a native renal biopsy? *Nephrol Dial Transplant*. 2008;23(11):3566-3570.
29. Atwell TD, Smith RL, Hesley GK, et al. Incidence of bleeding after 15,181 percutaneous biopsies and the role of aspirin. *AJR Am J Roentgenol*. 2010;194(3):784-789.
30. Manno C, Bonifati C, Torres DD, et al. Desmopressin acetate in percutaneous ultrasound-guided kidney biopsy: a randomized controlled trial. *Am J Kidney Dis*. 2011;57(6):850-855.
31. Gotti E, Mecca G, Valentino C, et al. Renal biopsy in patients with acute renal failure and prolonged bleeding time. *Lancet*. 1984;2(8409):978-979.
32. Korbet SM, Volpini KC, Whittier WL. Percutaneous renal biopsy of native kidneys: a single-center experience of 1,055 biopsies. *Am J Nephrol*. 2014;39(2):153-162.
33. Francis J, Francis D, Larson L, et al. Can the Platelet Function Analyzer (PFA)-100 test substitute for the template bleeding time in routine clinical practice? *Platelets*. 1999;10(2-3):132-136.
34. Ranghino A, Mella A, Borchiellini A, et al. Assessment of platelet function analyzer (PFA-100) in kidney transplant patients before renal allograft biopsy: a retrospective single-center analysis. *Transplant Proc*. 2014;46(7):2259-2262.
35. Islam N, Fulop T, Zsom L, et al. Do platelet function analyzer-100 testing results correlate with bleeding events after percutaneous renal biopsy? *Clin Nephrol*. 2010;73(3):229-237.
36. Ho SJ, Gemmell R, Brighton TA. Platelet function testing in uraemic patients. *Hematology*. 2008;13(1):49-58.
37. Wahdat R, Schwartz C, Espinosa J, et al. Page kidney: taking a page from history. *Am J Emerg Med*. 2016.
38. Davies MC, Perry MJ. Urological management of 'page kidney'. *BJU Int*. 2006;98(5):943-944.
39. Philipponnet C, Guerin C, Canet E, et al. Kidney biopsy in the critically ill patient, results of a multicentre retrospective case series. *Minerva Anestesiol*. 2013;79(1):53-61.
40. Schiffl H, Fischer R. Clinical cause of presumed acute tubular necrosis requiring renal replacement therapy and outcome of critically ill patients: post hoc analysis of a prospective 7-year cohort study. *Int Urol Nephrol*. 2012;44(6):1779-1789.
41. Scolari F, Ravani P, Gaggi R, et al. The challenge of diagnosing atheroembolic renal disease: clinical features and prognostic factors. *Circulation*. 2007;116(3):298-304.
42. Galpin JE, Shinaberger JH, Stanley TM, et al. Acute interstitial nephritis due to methicillin. *Am J Med*. 1978;65(5):756-765.
43. Gonzalez E, Gutierrez E, Galeano C, et al. Early steroid treatment improves the recovery of renal function in patients with drug-induced acute interstitial nephritis. *Kidney Int*. 2008;73(8):940-946.
44. Chen TK, Estrella MM, Fine DM. Predictors of kidney biopsy complication among patients with systemic lupus erythematosus. *Lupus*. 2012;21(8):848-854.
45. Mal F, Meyrier A, Callard P, et al. Transjugular renal biopsy. *Lancet*. 1990;335(8704):1512-1513.
46. Nomoto Y, Tomino Y, Endoh M, et al. Modified open renal biopsy: results in 934 patients. *Nephron*. 1987;45(3):224-228.
47. Shetye KR, Kavoussi LR, Ramakumar S, et al. Laparoscopic renal biopsy: a 9-year experience. *BJU Int*. 2003;91(9):817-820.