

Contemporary best practice in the management of staghorn calculi

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Abstract: Staghorn calculi are complex renal stones that occupy the majority of the renal collecting system. These stones are associated with high morbidity and can lead to recurrent urinary tract infections, urosepsis, renal deterioration, and death if left untreated. Managing patients with staghorn calculi can be challenging. Fortunately, advances in technology and endourology techniques have enabled urologists to effectively treat these stones with minimal morbidity to the patient. This article describes the contemporary best practices in the initial evaluation, management, and follow up of patients with staghorn calculi to help the practicing urologist navigate this complex condition.

Keywords: kidney stone, renal stone, staghorn calculi

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Introduction

Staghorn calculi are complex renal stones that occupy the majority of the renal collecting system and are of particular importance to urologists as they often carry high morbidity and mortality rates. Treatment is often complicated but necessary given that untreated stones can lead to recurrent urinary tract infections, urosepsis, renal deterioration, and death.^{1–5} Staghorn calculi were historically thought to be primarily struvite, but modern investigations reveal they can be one of many compositions.⁶ These stones are still often associated with infection and urea-splitting organisms.⁷ The treatment goal for most patients is complete stone removal to prevent regrowth on persistent stone debris. However, achieving a stone-free state can be difficult, requiring staged or combined approaches.

While surgical treatment of these stones is the standard of care in many patients, early series on treatments such as percutaneous nephrolithotomy quote complication rates up to 50%, including sepsis, bleeding, cardiothoracic events, and even death.^{6,8,9} Fortunately, technology, science, and the field of endourology have continued to evolve and advancements have led to safer and more effective treatments. New technology continues to

drive us to an operating room table with high definition, superior endoscopes and advanced intra- and extracorporeal lithotripsy technology.¹⁰ These advancements assist providers in achieving more effective stone removal and better patient care. Though there is undeniable progress, we have not been able to minimize all risk. We have evolved also by considering conservative management in some select candidates, especially those at high risk for surgery.^{11–13} This contrasts with traditional thinking about the management of this condition and stems partly from our developing understanding of this disease process. Our knowledge of metabolic disturbances, stone compositions, and overall natural history of the disease has grown.

We aim to describe the contemporary best practices in the initial evaluation, treatment, and follow up of patients with staghorn calculi to help the practicing urologist navigate this complex condition.

Initial evaluation

History and physical exam

Obtaining a thorough and complete history and performing a physical exam is imperative when

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evaluating patients presenting with kidney stone disease. A thorough history of present illness is the first step to determine the onset of symptoms, evolution of discovery, and current condition of the patient. The presence of previous bladder infections, pyelonephritis, hematuria, or pain are clinically important. It is essential to know whether the stone was discovered incidentally, since an asymptomatic status may help guide shared decision-making.

Next, clinicians should review all past medical and surgical history. Medical comorbidities and frailty affect outcomes and are paramount when making treatment decisions.¹⁴ Some studies have suggested a calculation of Charlson Comorbidity Index (CCI) or a similar tool can be predictive of outcomes.^{9,15,16} Medical history related to the urinary tract must be delineated, such as a history of dysfunctional voiding, lower urinary tract symptoms, benign prostatic hyperplasia, or neurogenic bladder. Any previous surgical history is important for surgical planning, such as prior bladder reconstruction, prior ureteral or urethral procedures, prior kidney surgeries, and prior stone surgeries. Review of all applicable operative reports is recommended. Any prior stone episode and management should be fully investigated. Review of all medications is also critical to identify drugs that cause stones or coagulopathies. Records should also be reviewed for any prior stone analysis or 24-h urine collections. This allows for careful consideration of preoperative medical therapy such as dissolution of nonstruvite stones or more aggressive prophylactic antibiotic therapy for calcium carbonate apatite stone formers.

While there is some evidence that pure struvite/calcium carbonate apatite stones do not require a full metabolic workup, recent literature has shown that some of these patients do have a definable metabolic abnormality that can be targeted for future prevention.^{17,18} A metabolic workup including blood and urine laboratory tests are indicated. Each patient should have a complete blood count (CBC), basic metabolic panel (BMP), prothrombin time, international normalized ratio index, magnesium, and parathyroid hormone (PTH) level. CBC will identify patients with anemia, thrombocytopenia, or infection. Serum electrolytes and creatinine should be obtained to assess renal function and identify any metabolic derangements. Serum calcium and PTH levels may reveal hyperparathyroidism. If PTH is elevated in the absence of hypercalcemia,

a vitamin D level can help to identify secondary hyperparathyroidism.

Urinalysis and urine culture must be obtained when an intervention is planned. Urine culture should include speciation and antibiotic sensitivity data to guide perioperative antibiotic treatment. Additionally, 24-h urine studies are important to consider when evaluating patients with staghorn calculi. This can be done before or after treatment at the discretion of the urologist. The authors prefer preoperative metabolic evaluation, if feasible, so plans to prevent stone recurrence are in place before stone removal. There has been some controversy over the utility of a single 24-h urine collection and many providers feel that a second 24-h urinalysis is critical and may capture derangements missed on the first analysis.¹⁹

Imaging

Imaging is a critical step in the evaluation of patients with staghorn calculi. Computed tomography (CT) scan without intravenous contrast is the imaging modality of choice when evaluating a patient for renal calculi that may need intervention. Preoperative imaging is imperative for surgical planning and can aid in choosing what intervention is most appropriate. CT imaging allows for accurate assessment of stone morphology and location, which helps guide percutaneous access when percutaneous nephrolithotomy (PCNL) is planned. The American Urological Association (AUA) guidelines state that clinicians should obtain a non-contrast CT scan on a patient prior to performing PCNL.²⁰ Characteristics of the stone on CT imaging such as the attenuation, or Hounsfield measurement, may be helpful when determining stone fragility and stone composition.²¹ Staghorn calculi branch into multiple calyces and are often designated as 'partial' or 'complete' depending on the size of the stone and number of calyces occupied. There is no clear consensus on what defines a partial *versus* a complete staghorn calculus, such as volume criteria or number of calyces occupied. However, a staghorn calculus is generally considered a branching renal stone that occupies multiple portions of the renal collecting system.²²

In patients with large staghorn calculi, it is important to assess renal function quantitatively with a renal scintigraphy scan. This is performed using common radiotracers such as technetium-99m diethylenetriamine pentaacetic acid (DTPA) or technetium-99m mercaptoacetyl triglycerine

(MAG-3). In accordance with AUA guidelines, if the involved kidney has negligible function (<10%), nephrectomy may be the best treatment option.²⁰ Currently, nuclear renal scans are considered the gold standard imaging study to evaluate differential renal function. While some studies have shown a correlation between renal parenchymal thickness measured on CT imaging and differential renal function, this is only an estimate and is not always accurate.^{23,24} Therefore, the authors recommend performance of a nuclear renal scan in all patients with staghorn calculi.

Antibiotics

Struvite or calcium carbonate apatite stones which constitute many staghorn calculi form in the presence of urease-producing bacteria including *Proteus*, *Staphylococcus*, *Pseudomonas*, *Providencia*, and *Klebsiella*.²⁵ However, these stones only account for approximately 25% of all staghorn calculi.²⁶ *E. coli* is not typically known to produce urease but has been implicated in secondarily infected nonstruvite stones. Patients with staghorn calculi are at high risk of infection and infection-related complications. Sepsis after PCNL is a serious complication and has been reported to occur in 0.3–4.7% of cases.²⁷ Left untreated, sepsis rates are even higher in this population.^{28–30}

While lower urinary tract urine culture (clean catch or catheterized specimen) is mandatory preoperatively, these cultures do not always correlate with stone or renal pelvis culture. Patients undergoing PCNL who have a negative urine culture preoperatively may still develop sepsis and other infectious complications.³¹ Shafi and colleagues found that the bacteria identified in stone cultures only matched the bacteria identified in urine cultures in 43.5% of cases.³² Bacteria within the stone may be the underlying cause of infectious complications after stone treatment. Mariappan and colleagues demonstrated that patients with a negative urine culture prior to PCNL had a significant reduction in the risk of urosepsis if given a 1-week course of ciprofloxacin prior to surgery.³³ Similarly, Bag and colleagues performed a prospective randomized trial that demonstrated a reduced risk of urosepsis in patients treated with a 1-week course of nitrofurantoin despite a sterile pre-operative urine culture, supporting the theory that a culture from the urine in the bladder may not capture stone colonization.³⁴ In contrast, a recent report from the EDGE consortium showed that preoperative

antibiotics in 86 patients with a negative urine culture preoperatively did not change sepsis, intensive care unit admission or complication rates.³⁵ It is important to note that the patients in this study were considered a low risk for infection. The current AUA guidelines recommend perioperative antibiotic prophylaxis for PCNL procedures using a single oral or intravenous (IV) dose of an antibiotic that covers gram positive and negative uropathogens. The panel did not feel there was strong enough evidence to endorse the practice of administering a 1-week course of antibiotic therapy for patients with negative cultures prior to PCNL.²⁰ Those patients with positive preoperative urine cultures should be treated for 5–7 days with culture-specific antibiotics before surgery even if they are asymptomatic. It should be noted that because the stone often harbors bacteria, a negative urine culture will often not be able to be achieved preoperatively even with multiple courses of antibiotics; the goal of the preoperative coverage is to decrease colony counts to lower the risk of infectious complications. Surgery can proceed after a full course of antibiotics with additional, unique, culture-specific antibiotics provided in the operating room. For high-risk patients, culture-specific antibiotics are often continued for 5–7 days postoperatively. Stone cultures are always obtained intraoperatively to help guide antibiotic therapy adjustments should the patient have signs of an inflammatory response postoperatively. Stone cultures are best obtained by crushing the stone in saline and sending the fluid for testing.

For patients with a high risk of infectious complications, establishing preoperative nephrostomy drainage may improve patient outcomes. Benson and colleagues hypothesized that preoperative nephrostomy drainage allows for removal of infected or stagnant urine from the collecting system, provides means to obtain renal pelvis urine culture for better targeted antibiotic coverage, and decreases post-PCNL infectious complications.³⁶ Access obtained preoperatively may or may not be used during PCNL. It is important to discuss the preferred access site with interventional radiology colleagues on each individual patient if preoperative access is to be performed.

Active versus conservative management

Untreated staghorn calculi can lead to recurrent urinary tract infections, urosepsis, renal deterioration, and death.^{1–5} In patients with chronic kidney disease or those with deranged renal

function tests, early and aggressive intervention aimed at complete stone clearance may improve or stabilize renal function. Management of staghorn calculi in patients with chronic kidney disease can be challenging. These patients often have multiple medical comorbidities in addition to renal insufficiency, which is a recognized risk factor for higher morbidity and mortality during stone treatment.³⁷

Conservative management of staghorn calculi is controversial but sometimes necessary in select groups. Achieving a stone-free state often involves multistage or percutaneous procedures, which can be dangerous in the poor surgical candidate or simply unwanted by some patients. Morbidity and mortality for stone treatment is low overall, but higher in patients with significant comorbidities. Given that the mechanism for renal decline begins with inflammation from recurrent infections, management of known infection stones requires closer consideration.³⁸

While the mainstay of the treatment of all staghorn stones has been surgical, three recent studies have concluded that conservative management could be safe in select patients with appropriate monitoring.^{11,12,39} Surgical management of staghorn calculi is advised in all eligible patients due to risks of recurrent infection and kidney failure, however, some patients do not develop these symptoms and may be better managed with conservative management. In high-risk patients it is paramount to analyze the costs and benefits of treatment with procedural risks in mind such as sepsis, bleeding, renal colic, cardiothoracic events, and even death.^{6,8,16} Surgical interventions are often long and require multiple procedures, with early complication rates up to 50% in some series, especially in patients with a high CCI score.^{8,16} As always, a patient must be informed about the risks and benefits associated with both active and conservative management options. Shared decision-making remains important in these clinical situations.

Based on a recent study by our group, Morgan and colleagues evaluated a cohort of 29 patients managed conservatively.¹³ Patient histories, symptoms, CCI scores, renal function, and outcomes were calculated. Few patients had a decline in renal function (14%) and less than one-third of patients endorsed symptoms such as urinary tract infection, gross hematuria or flank pain. There was only one related hospital admission in this group. By and large, this small cohort was

managed nonoperatively with few complications or readmissions.

At our institution, those patients managed conservatively are followed up every 6–12 months with imaging, an office visit with a full history and physical, as well as a serum creatinine level to monitor renal function. Patients undergo routine renal scintigraphy scans to follow differential function as well as plain X-ray and ultrasound to assess for hydronephrosis and evaluate stone burden including contralateral investigation. Those patients with declining renal function, or those who have become symptomatic with pain, hematuria, or infections are then reconsidered for operative intervention where the risks and benefits are reevaluated.

Operative management: what surgery when

Complete removal of staghorn calculi should remain the goal in patients whose comorbidities do not preclude treatment.^{40,41} Treatment options for staghorn calculi include PCNL, shock wave lithotripsy (SWL), ureteroscopy, or a combination of two or more of these treatments. Less commonly, invasive open or laparoscopic/robotic-assisted stone surgery is indicated. Irrigation of the collecting system with agents to dissolve stones, such as Renacidin[®], with or without surgery has also been evaluated but is not commonly used. Important considerations when determining the ideal treatment for staghorn calculi include stone-free rates, number of required procedures, and complication rates. PCNL remains the gold standard first-line treatment for the majority of staghorn calculi.²⁰ With the advent of less invasive procedures, miniaturized equipment, and better fragmentation and extraction devices, surgical management of these complex stones continues to improve.

Anatrophic nephrolithotomy is a surgical procedure in which a parenchymal incision is made in an intersegmental plane, allowing for the removal of large renal calculi directly from the collecting system. This open technique is associated with high morbidity, higher transfusion rates, and need for re-exploration secondary to bleeding.⁴² In 2005, Al-Kohlany and colleagues performed a prospective randomized trial comparing PCNL with open surgery. This study showed comparable stone clearance rates, however, the PCNL group was shown to have less bleeding, shorter operative time, less operative complications, and

Table 1. Stone-free rates and complication rates of the various treatment modalities for staghorn calculi.

Treatment modality	PCNL	SWL	PCNL + ureteroscopy	PCNL + SWL	Open surgery	Ureteroscopy + laser lithotripsy (stones > 2cm)
Stone-free rates	78% ²²	54% ²²	78% ⁵⁴	66% ²²	82% ²²	94% ⁴⁹
	57% ⁵¹	60% ⁵⁰	71% ⁵⁵	72% ⁵¹	97% ⁵⁹	
	59% ⁵⁸		88% ⁵⁸	73% ⁵²		
	76% ⁵⁹			67% ⁵⁶		
Complications	22% ⁵¹	13% ⁵⁰	44% ⁵⁴	21% ⁵⁶	45% ⁵⁹	10% ⁴⁹
	27% ⁵²					
	21% ⁵³					
	23% ⁵⁷					
	41% ⁵⁹					

PCNL, percutaneous nephrolithotomy; SWL, shock wave lithotripsy.

a shorter hospital stay.⁴³ With the high morbidity of open anatomic nephrolithotomy and the evolution of minimally invasive endourological therapies, open stone surgery is no longer the treatment of choice for staghorn calculi. Nephrectomy should be considered when the involved kidney has negligible function, usually <10%, in patients requiring treatment.²⁰ The combination of stones and recurrent infections results in xanthogranulomatous pyelonephritis in a subset of these patients, and nephrectomy is often indicated.^{5,44}

Robotic and laparoscopic approaches have been adapted from open surgical techniques for the removal of large renal stones. These approaches require renal hilum exposure, renal vessel clamping, nephrotomy, collecting system closure, and parenchymal closure. Laparoscopic ultrasound may be used for intraoperative assessment of remaining stone fragments, since fluoroscopy is not feasible during robotic surgery. While these techniques have been shown to be feasible with relatively good stone-free rates, they remain second-line therapies when compared with less invasive endourological techniques secondary to cost and lack of outcomes demonstrating superiority.^{42,45}

SWL was generally thought to be an adjunct treatment to minimize the number of access points required during PCNL but is not recommended as a monotherapy due to lower stone-free rates.⁴⁶ When comparing PCNL with SWL, the AUA meta-analysis in 2005 showed that PCNL alone had the highest stone-free rate at 78%, while combination therapy of PCNL plus SWL and SWL monotherapy resulted in stone-free rates of 66% and 54% respectively.²² While SWL had been historically used as a PCNL

adjunct, improved PCNL techniques, including the incorporation of flexible nephroscopy, have provided complete or nearly complete clearance of stone material which decreased the need of SWL treatment.²² Also, if combination therapy is undertaken, PCNL should be the last procedure to maximize stone fragment removal.^{47,48} Ureteroscopy can also be used as a second-stage procedure if minimal burden remains. Stone-free rates and complication rates of the various treatment modalities for staghorn calculi are noted in Table 1.^{22,49–59}

Staged ureteroscopy is a viable treatment offered to patients who are poor candidates for PCNL, such as a patient on lifelong anticoagulation that cannot be safely interrupted. However, as a monotherapy, multiple procedures are required, even for lower volume stones.^{60,61} In 2015, Karakoyunlu and colleagues compared staged flexible ureteroscopy with PCNL for renal pelvic stones >2 cm and found no significant difference in stone-free rates, however, they concluded that PCNL had an advantage over staged flexible ureteroscopy due to the need for multiple treatments and longer treatment time for staged flexible ureteroscopy.⁶² Thus, PCNL has emerged as the superior treatment option and should be offered as first-line therapy for patients with a total renal stone burden >20 mm as stated in the AUA guidelines.²⁰

PCNL remains the gold standard treatment for staghorn calculi due to high stone-free rates and lowest complication rates.²⁰ Optimal access to the kidney is imperative to successfully clear the collecting system of stone. Gaining access through the upper or lower pole calyces appears to be the best approach because it provides a straight tract

along the axis of the kidney and allows for access to the upper pole, lower pole, and the renal pelvis without excessive torquing of the rigid instruments. Access should be gained below the level of the 11th rib and access should be obtained when the patient is kept under full expiration to minimize the risk of hydrothorax or injury to the lung. Multiple percutaneous access tracts may be utilized when treating large or complex stones. When used judiciously, multiple access tracts are safe and effective at achieving stone clearance with similar complication rates when compared with single-tract PCNL.^{63,64}

AUA guidelines recommend that flexible nephroscopy should be a routine part of standard PCNL.²⁰ A randomized prospective study in which patients underwent rigid nephroscopy during PCNL with or without concomitant flexible nephroscopy showed that the stone-free rate was higher (92.5% versus 70%) in patients who had concomitant flexible nephroscopy.⁶⁵ In addition, antegrade flexible ureteroscopy should be performed when migration of stone fragments down the ureter is suspected.²⁰

The introduction of miniaturized instruments and sheaths have expanded the arsenal of tools that urologists may utilize when treating staghorn calculi. Standard PCNL access tracts are 24–30Fr. In 1998, Jackman and colleagues reported the first series of ‘mini-perc’ PCNL performed on adults using a 13Fr access sheath with good stone clearance and the potential advantages of a reduced length of hospital stay and reduced bleeding.⁶⁶ Wright and colleagues aimed to standardize the nomenclature of these smaller access tracts as they have become increasingly used. This group identified mini-perc (14–20Fr), ultra mini-perc (11–13Fr), and micro-perc (4.85Fr) as the standard terminology.⁶⁷ Advantages of mini-perc over standard PCNL also include a potentially reduced analgesic requirement.⁶⁸

Nephrostomy tube drainage after a PCNL procedure is often recommended and serves multiple purposes. It can provide hemostatic tamponade of the tract, provide reliable drainage of the collecting system, and maintain access for future percutaneous procedures. Large bore nephrostomy drainage (>20Fr) may be reserved for patients who have significant bleeding or for patients with a high concern for infection. Small bore (9–12Fr) nephrostomy drainage is more

traditionally used. Tubeless PCNL is an option in uncomplicated cases and is associated with less postoperative pain and decreased hospital stay.⁶⁹

Postoperative follow up

Generally, a chest X-ray is obtained in the post-recovery unit to rule out pneumothorax or hydrothorax. CBC and BMP are also obtained postoperatively to identify any electrolyte abnormalities and follow hemoglobin and white blood cell count given the risks of bleeding and infection. In the immediate postoperative period, obtaining a low-dose CT scan without contrast may be utilized to identify any remaining stone fragments and direct future second-look procedures.

Renal ultrasound and abdominal radiograph (KUB) may be obtained 4–6 weeks postoperatively to establish a baseline study and again around 6 months. If these studies suggest no stone recurrence, patients may be followed with KUB or renal ultrasound every 6 months for the first 1–2 years and thereafter annually if stable. Very select patients may benefit from a single daily low-dose prophylactic antibiotic for 3–6 months postoperatively, but further study is needed before this is recommended. All patients with history of staghorn calculi should have a full metabolic evaluation with bloodwork and a 24-h urine study performed either pre or postoperatively to guide future stone prevention therapy.

Conclusion

Staghorn calculi are complex renal stones associated with high morbidity and mortality. Fortunately, advances in technology in endourology have enabled urologists to effectively treat these stones with minimal morbidity to the patient. We have also realized that there is a small group of asymptomatic patients with high frailty who can be more safely managed nonoperatively. PCNL has remained the gold standard when treating these complex stones and the advent of smaller instruments and sheaths have broadened the arsenal of tools urologists have to completely clear these stones from the collecting system.

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Conflict of interest statement

The authors declare that there is no conflict of interest.

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