The Surgical Management of Urolithiasis: A Review of the Literature

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ABSTRACT

The incidence of stone disease has increased significantly in the past 30 years, with a reported prevalence of 11% of the U.S. population in 2022, up from 9% in 2012 and 5.2% in 1994.[1] While prevention is a vital aspect of management, many patients present with symptomatic urolithiasis requiring surgical management. Emerging advances in endoscopy and technology has led to a dynamic shift in the surgical management of stone disease. This paper will serve as a comprehensive review to inform urologic and non-urologic medical professionals alike, as well as the layperson, on the surgical treatment of nephrolithiasis, starting from the initial evaluation, laboratory and radiographic studies, and various surgical options. Additionally, the nuances of managing the pediatric and pregnant patient with nephrolithiasis will be explored. Using the most up-to-date urologic data, our aim is to provide a comprehensive resource for readers who interact with patients experiencing acute episodes of urolithiasis.

KEYWORDS: nephrolithiasis, kidney stone, endourology, urology

INTRODUCTION

According to a 2012 National Health and Nutrition Examination Survey (NHANES) report, it is estimated that 19% of men and 9% of women will be diagnosed with a kidney stone by the age of 70.[2] This sharp increase in prevalence also reflects a nearly 50% increase in economic burden since 1994.[3] Given the rising incidence and costs, it is imperative for all clinicians to understand the presentation, evaluation, and treatment modalities for these patients. Kidney stones may be asymptomatic and incidentally found on imaging. However, they can also present with pain, obstruction, and infection.

Treating stones depends on many factors but most notably stone size and location. On average, asymptomatic stones <5mm have a 75% chance of spontaneous passage regardless of ureteral location. This rate decreases as stones increase in size and present more proximally.[4] In a select patient population not requiring emergent intervention, medical expulsion therapy (MET) can assist the passage process, allowing faster expulsion and fewer symptoms.[5] In contrast to these conservative treatment options, patients may also require surgical intervention in the form of extracorporeal shockwave lithotripsy (SWL), ureteroscopy, and percutaneous nephrolithotomy for stones not amenable to passage due to size and location. In addition, patients who present with acute obstruction, urinary tract infection, and sepsis – a true urologic emergency – may require urgent ureteral stent or nephrostomy tube placement for collecting system decompression.[6]

Kidney stones classically present with intermittent pain that radiates to the groin or lower abdomen. Patients may also experience dysuria, hematuria, odorous urine, frequency, nausea and vomiting, and fevers and chills.[7] When suspecting a stone, initial testing should include a thorough history and physical to assess for risk factors and history of stones, vitals, complete blood count (CBC), basic metabolic panel (BMP), and urinalysis. In addition, patients should have a non-contrast CT scan to evaluate for stones and hydronephrosis. If there is an obstructing stone, with concern for urosepsis or UTI, patients should be emergently taken to the OR for decompression via stent or nephrostomy tube placement and urine cultures should be sent. In addition, patients should be immediately started on broad spectrum intravenous antibiotics until urine cultures and antibiotic sensitivities result. The urgency of immediate intervention cannot be overstated as patients can acutely decompensate. According to Borofsky et al, patients not treated with surgical intervention had a 19% mortality rate, more than twice that of patients with decompression, necessitating immediate surgery.[8] Definitive stone removal should be delayed until patients clear the infection with a full course of antibiotics as manipulation may cause further systemic effects.[9]

Follow-up after surgical decompression varies by clinical experience and patient characteristics. However, the length of time to maintain an indwelling stent and the duration of antibiotics remains up for debate. One study by Shi et al showed that there was no significant difference in postoperative complication related to UTIs after seven days of an indwelling stent. Similarly, Orr et al concluded that the time between decompression and definitive stone treatment and the length of antibiotic treatment did not impact rates of postoperative urosepsis.[10] Reducing treatment duration will not only improve the rates of stent colic but also decrease the risk of antibiotic resistance in patients with prolonged stent and antibiotic treatment.

If there is a low degree of suspicion for obstruction or infection and depending on the size and location of the stone, patients can initially be managed with conservative measures. Patients with uncomplicated ureteral stones ≤10mm can be observed for spontaneous passage. If stones are more distal, patients can be prescribed MET to aid the passage process. Tamsulosin is the most well studied alpha-blocker that improves expulsion rates and renal colic; there is still a dearth of information regarding other modalities such as calcium channel blockers, phosphodiesterase-5 (PDE-5) inhibitors, and corticosteroids.[5] According to America Urologic Association guidelines, if spontaneous expulsion with or without MET is not successful after four to six weeks, patients may opt for surgical intervention. However, clinicians may wish to reimage patients to ensure the stone has not already passed to avoid unnecessary intervention.[11]

SURGICAL TREATMENT OF URETERAL AND RENAL STONES IN ADULTS

Shockwave lithotripsy (SWL)

Extracorporeal shockwave lithotripsy (SWL) is a non-invasive method for treating nephrolithiasis. Originally introduced in 1959, SWL uses precisely targeted ultrasonic sound waves to help disintegrate stones.[12] The latest technology utilizes electromagnetic energy to help reduce rates of retreatment.[13] SWL can be offered for patients who decline ureteroscopy and can be utilized in patients with total kidney stone burden ≤20 mm and ≤10 mm lower pole stone burden.[11] Contraindications to SWL are total stone burden >20mm, lower pole stone burden >10mm, pregnancy, and anatomic or functional obstruction of the ureter or distal collecting system, as well as cystine or uric acid stones due to harder stone composition.[11]

Ureteroscopy (URS) and SWL are the two most utilized methods for treating ureteral kidney stones with both showing similar rates of post-intervention infection, ureteral stricture or avulsion. URS, however, has a higher risk of ureteral avulsion due to the invasive nature of the intervention. Overall, comparative analyses have shown a lower risk of complication for SWL as compared to URS (RR 0.53, 95% CI 0.33–0.88, p <0.01).[14] Patients, however, should be counseled that treatment of ureteral stones with SWL carries a lower median stone free rate in a single procedures as compared to ureteral stones treated with URS (67% vs. 85%) while treatment of lower pole stone burden <10mm carries a comparable median stone free rate.[14] Most recent guidelines suggest URS should be offered as a first-line procedure; however, SWL is an acceptable alternative in properly selected patients. Specific risks of SWL that patients should be counseled on include hematuria, infection, ureteral stricture, and steinstrasse, or a lining of stone fragments in the ureter. Overall, SWL is a safe and non-invasive method for treating ureteral and kidney stones; however, due to lower median stone-free rates as compared to ureteroscopy, it is not always favored.

Ureteroscopy (URS)

URS uses a rigid or flexible scope to visualize the inside of the ureter and renal collecting system. Normal saline irrigation, often pressurized, is used throughout ureteroscopy to dilate the ureters and improve visibility.[15] URS is most commonly performed for stone treatment but can also be employed for obtaining biopsies, excising, or ablating abnormal tissue, making it an especially useful procedure when investigating unclear imaging findings.[16] Once a stone is located, a laser is used to break the stone into fragments that are then removed with a grasper, all through a working channel within the scope itself, or fragmented to dust that can passively exit through the urinary tract. While laser lithotripsy has become increasingly precise with technological advancement, the process of stone extraction creates potential for ureteral trauma.[11] Though shock-wave lithotripsy has the lowest complication rate and least morbidity,[14] URS has the highest sone-free rate, and it is considered first line therapy for mid or distal ureteral stones.[11] URS is considered a treatment option for intrarenal stones when the total non-lower pole renal stone burden is ≤20 mm.[17] Accessing the lower pole of the kidney with a ureteroscope can be challenging due to the sharp angle between the lower pole and renal pelvis,[18] but flexible ureteroscopes can also be used for treatment of lower pole renal stones in symptomatic patients whose lower pole stone burden is ≤10 mm in size.[19,20]

While some treatment options such as SWL require fluoroscopy for stone localization, URS allows for intracorporeal visualization. This makes URS and intracorporeal lithotripsy an effective treatment modality regardless of stone composition and radiolucency.[21] Patients on anticoagulation or at high risk of bleeding require special surgical precautions, and URS should be first line for stone treatment in these patients due to the minimally invasive nature of the procedure.[22] With URS, there is no need for incising tissue, and the procedure can often be performed with limited trauma to the kidneys and ureters.

Though life threatening complications are rare, URS complications can be serious when the do occur. Ureteral avulsion is a rare but devastating complication, with a reported incidence between 0.04 and 0.9%.[23] It is thought to most commonly be a consequence of excessive force on the ureter while trying to extract stones that have not been adequately broken into smaller fragments.[23] Ureteral wall injury is a much more common complication with some studies reporting superficial mucosal lesions after URS in up to 39.9% of patients and deep mucosal lesions in 17.6%.[24] There is also risk of creating a false passage or mucosal perforation during URS, and perforations have been estimated to occur in 0.3 to

7.4% of ureteroscopic procedures.[23] Using the smallest possible instruments and ensuring good visualization throughout the procedure can help to minimize ureteral injury.

Percutaneous Nephrolithotomy (PCNL)

During PCNL, a percutaneous tract is created from the patient's flank to access the kidney, generally via fluoroscopic needle localization into a targeted calyx. This can be done at the time of surgery by the urologist, or prior to surgery by an interventional radiologist where the patient is left with a percutaneous nephrostomy. That tract is then dilated and traversed with a working sheath through which instruments such as rigid nephroscopes are then passed directly into the collecting system to treat large volume stones. Flexible antegrade URS can also be performed through these sites. During PCNL, normal saline is also used as irrigation fluid, and it is considered best practice to visualize the entire kidney internally with a flexible nephroscope.[25]

PCNL is considered first-line therapy for symptomatic patients with a total renal stone burden >20 mm.[26,27] In cases of lower pole stones >10mm in size, PCNL has also been shown to have the highest stone-free rate.[28] When patients have failed management attempts with shock-wave lithotripsy and/or URS with laser stone treatment, PCNL is often the least invasive next step in management.[29] Since the late 1997, mini-PCNL has been another tool available to surgeons.[30] The mini PCNL uses a smaller sheath, and it has been shown to cause less tissue trauma during the percutaneous approach with a similar stone free rate to traditional PCNL.[30] Though the overall complication rates of mini-PCNL and PCNL have not been shown to be significantly different, mini-PCNL has demonstrated lower hemoglobin drop and shortened hospital stay.[30,31]

Although PCNL is a highly effective procedure, there is higher morbidity due to tissue trauma and increased risk of bleeding.[11] Additionally, obese or morbidly obese patients with large skin-to-stone distances as typically measured on pre-operative CT are not ideal candidates for PCN due to technical restraints. The most common complication of PCNL is bleeding, sometimes requiring blood transfusion postoperatively.[11] It has been estimates that 7% of patients require postoperative blood transfusion, and bleeding is often not fully discovered until completion of the procedure due to the tamponade effects of the nephrostomy sheath.[32,33] Due to the high risk of bleeding, PCNL may not be a feasible treatment option for patients at high risk of bleeding or those who are unable to discontinue anticoagulation prior to surgery.[34]

With an incidence rate of 10.8%, postoperative fever is another common complication of PCNL.[32] For patients with sterile urine preoperatively, development of postoperative fever has been linked with operative time and amount of irrigation fluid used during the procedure.[32] Prior to all urologic procedures, patients with bacteriuria should be identified and properly treated with antibiotics. Adequate management of preoperative bacteriuria has led to increasingly rare cases of urosepsis after PCNL. In addition to preoperative bacteriuria, renal anatomic abnormalities, neurogenic bladder, and long operative times, and high intrarenal pressure during the procedure have been identified as additional urosepsis risk factors. Injury to surrounding organs is always a risk of surgery, and sheath placement while gaining renal access is the highest risk portion of PCNL for damage to surrounding structures. Subcostal access has much lower risk of pleural injury than supracostal access, with hydrothorax being reported at 1.4% and 15.3% respectively.[35]

PCNL in itself is a form of pelvicalyceal rupture, and small tears in the collecting system are common during lithotripsy.[32] Pelvicalyceal tears often heal uneventfully and do not cause problems when drained adequately. Injury to the collecting system during PCNL has been reported at up to 5.2%, and urinoma formation is much more rare at 0.2%.[33,36] Nephrostomy tubes are often placed at the time of PCNL to ensure continued urine drainage and preserve kidney function but are considered optional in cases of uncomplicated and relatively atraumatic PCNL.[37]

SPECIAL POPULATIONS

Pediatric

There is an increasing incidence of kidney stones in pediatric populations, and more research is needed into stone treatment in this population.[38] A review of national database of pediatric nephrolithiasis found that of over 28,000 pediatric patients with stones, only about 2.5% underwent surgical treatment.[39] Management of kidney stones in children has similar principles to stone management in adults but there are a few special considerations. As described above, CT scan is considered the gold standard for diagnosis; however, to limit radiation in the pediatric population, ultrasonography can also be utilized. CT imaging provides the clinician with important information on the internal kidney anatomy, stone burden, and location of surrounding organ structures.[11] Children also should be queried for a personal or family history of kidney stones so evaluation for a metabolic disorder can be performed.[38] Children with asymptomatic and non-obstructing kidney stones may undergo active surveillance with routine ultrasonography. Children with uncomplicated ureteral stones <10mm can be offered observation or medical expulsion therapy. Patients who fail to pass their ureteral stone can be offered treatment including URS or ESWL. Patients with kidney stone burden ≤20mm can also be offered SWL or URS as first-line therapy and in patients with >20mm stone burden, PCNL or SWL may be offered for treatment.[11] A recent study of trends in treatment modality for pediatric kidney stones showed that SWL was the most commonly utilized modality (about 66% of patients). URS increased in frequency to about 31% of cases and PCNL showed a decreasing frequency of use.[39]

Pregnant patients

Pregnant patients are another population that require special consideration when treating nephrolithiasis, and the care and treatment of pregnant patients should always be approached collaboratively with the obstetrician. Symptomatic nephrolithiasis occurs in less than 1% of pregnancies and the presence of a kidney stone requires a multidisciplinary team during evaluation and treatment.[40] In patients with clinical suspicion for kidney stone, renal bladder ultrasound (RBUS) is the initial diagnostic modality which can be followed by non-contrast CT when US is non-diagnostic.[41] Many patients can be managed non-operatively; however, patients who present with a septic, obstructing kidney stone require urinary diversion with ureteral stent or percutaneous nephrostomy.[41] Patients with well-controlled symptoms can be offered observation as a first-line therapy.[11] For patients who fail observation and have intolerable symptoms, URS may be offered for more definitive treatment.[11] These decisions should be made in collaboration with the patient's obstetrician to ensure safety for both the mother and baby.

CONCLUSION

The incidence of stone disease has increased significantly in the past 30 years with a large proportion presenting in the acute phase of the condition requiring surgical management. Emerging advances in endoscopy and technology has led to a dynamic shift in the surgical management of stone disease, with options across levels in invasiveness from SWL to URS to PCNL, with new developments ongoing that will continue to improve technical efficacy and patient outcomes.

References

1. Hill AJ, Basourakos SP, Lewicki P, et al. Incidence of Kidney Stones in the United States: The Continuous National Health and Nutrition Examination Survey. Journal of Urology. 2022;207(4):851-856. doi:doi:10.1097/JU.0000000000002331
2. Scales CD, Smith AC, Hanley JM, Saigal CS. Prevalence of Kidney Stones in the United States. European Urology. 2012/07/01/ 2012;62(1):160-165. doi:https://doi.org/10.1016/j.eururo.2012.03.052
3. Pearle Margaret S, Calhoun Elizabeth A, Curhan Gary C, Null N. UROLOGIC DISEASES IN AMERICA PROJECT: UROLITHIASIS. Journal of Urology. 2005/03/01 2005;173(3):848-857. doi:10.1097/01.ju.0000152082.14384.d7
4. Coll DM, Varanelli MJ, Smith RC. Relationship of Spontaneous Passage of Ureteral Calculi to Stone Size and Location as Revealed by Unenhanced Helical CT. American Journal of Roentgenology. 2002;178(1):101-103. doi:10.2214/ajr.178.1.1780101
5. Bos D, Kapoor A. Update on medical expulsive therapy for distal ureteral stones: Beyond alpha-blockers. Can Urol Assoc J. Nov 2014;8(11-12):442-5. doi:10.5489/cuaj.2472
6. Swonke ML, Mahmoud AM, Farran EJ, et al. Early Stone Manipulation in Urinary Tract Infection Associated with Obstructing Nephrolithiasis. Case Reports in Urology. 2018/11/25 2018;2018:2303492. doi:10.1155/2018/2303492
7. MayoClinic. Kidney Stones. Accessed 9/10/2023, 2023. https://www.mayoclinic.org/diseases-conditions/kidney-stones/symptoms-causes/syc-20355755
8. Borofsky MS, Walter D, Shah O, Goldfarb DS, Mues AC, Makarov DV. Surgical Decompression is Associated with Decreased Mortality in Patients with Sepsis and Ureteral Calculi. Journal of Urology. 2013;189(3):946-951. doi:doi:10.1016/j.juro.2012.09.088
9. Pearle MS, Pierce HL, Miller GL, et al. Optimal Method of Urgent Decompression of the Collecting System for Obstruction and Infection Due to Ureteral Calculi. The Journal of Urology. 1998/10/01/ 1998;160(4):1260-1264. doi:https://doi.org/10.1016/S0022-5347(01)62511-4
10. Orr A, Awad M, Johnson N, Sternberg K. Obstructing Ureteral Calculi and Presumed Infection: Impact of Antimicrobial Duration and Time From Decompression to Stone Treatment in Developing Urosepsis. Urology. Feb 2023;172:55-60. doi:10.1016/j.urology.2022.10.010
11. Assimos D, Krambeck A, Miller NL, et al. Surgical Management of Stones: American Urological Association/Endourological Society Guideline, PART I. J Urol. Oct 2016;196(4):1153-60. doi:10.1016/j.juro.2016.05.090
12. Malinaric R, Mantica G, Martini M, et al. The Lifetime History of the First Italian Public Extra-Corporeal Shock Wave Lithotripsy (ESWL) Lithotripter as a Mirror of the Evolution of Endourology over the Last Decade. Int J Environ Res Public Health. Feb 25 2023;20(5)doi:10.3390/ijerph20054127
13. Desai M, Sun Y, Buchholz N, et al. Treatment selection for urolithiasis: percutaneous nephrolithomy, ureteroscopy, shock wave lithotripsy, and active monitoring. World J Urol. Sep 2017;35(9):1395-1399. doi:10.1007/s00345-017-2030-8
14. Aboumarzouk OM, Kata SG, Keeley FX, McClinton S, Nabi G. Extracorporeal shock wave lithotripsy (ESWL) versus ureteroscopic management for ureteric calculi. Cochrane Database Syst Rev. May 16 2012;(5):Cd006029. doi:10.1002/14651858.CD006029.pub4
15. Chen SS, Lin AT, Chen KK, Chang LS. Hemolysis in transurethral resection of the prostate using distilled water as the irrigant. J Chin Med Assoc. Jun 2006;69(6):270-5. doi:10.1016/s1726-4901(09)70255-2
16. Smentkowski KE, Bagley DH, Hubosky SG. Ureteroscopic biopsy of upper tract urothelial carcinoma and role of urinary biomarkers. Transl Androl Urol. Aug 2020;9(4):1809-1814. doi:10.21037/tau.2019.11.28
17. Srisubat A, Potisat S, Lojanapiwat B, Setthawong V, Laopaiboon M. Extracorporeal shock wave lithotripsy (ESWL) versus percutaneous nephrolithotomy (PCNL) or retrograde intrarenal surgery (RIRS) for kidney stones. Cochrane Database Syst Rev. Nov 24 2014;(11):Cd007044. doi:10.1002/14651858.CD007044.pub3
18. Cohen J, Cohen S, Grasso M. Ureteropyeloscopic treatment of large, complex intrarenal and proximal ureteral calculi. BJU Int. Mar 2013;111(3 Pt B):E127-31. doi:10.1111/j.1464-410X.2012.11352.x
19. Hyams ES, Munver R, Bird VG, Uberoi J, Shah O. Flexible ureterorenoscopy and holmium laser lithotripsy for the management of renal stone burdens that measure 2 to 3 cm: a multi-institutional experience. J Endourol. Oct 2010;24(10):1583-8. doi:10.1089/end.2009.0629
20. Perez Castro E, Osther PJ, Jinga V, et al. Differences in ureteroscopic stone treatment and outcomes for distal, mid-, proximal, or multiple ureteral locations: the Clinical Research Office of the Endourological Society ureteroscopy global study. Eur Urol. Jul 2014;66(1):102-9. doi:10.1016/j.eururo.2014.01.011
21. Lasser MS PG. Smith's Textbook of Endourology 3rd Edition. vol 273. Wiley-Blackwell,; 2012.
22. Turna B, Stein RJ, Smaldone MC, et al. Safety and efficacy of flexible ureterorenoscopy and holmium:YAG lithotripsy for intrarenal stones in anticoagulated cases. J Urol. Apr 2008;179(4):1415-9. doi:10.1016/j.juro.2007.11.076

23. De Coninck V, Keller EX, Somani B, et al. Complications of ureteroscopy: a complete overview. World Journal of Urology. 2020/09/01 2020;38(9):2147-2166. doi:10.1007/s00345-019-03012-1
24. Miernik A, Wilhelm K, Ardelt PU, Adams F, Kuehhas FE, Schoenthaler M. Standardized flexible ureteroscopic technique to improve stone-free rates. Urology. Dec 2012;80(6):1198-202. doi:10.1016/j.urology.2012.08.042
25. Masood Y, Iqbal N, Farooq RM, Iqbal S, Khan F. Intraoperative flexible nephroscopy during percutaneous nephrolithotomy: An 8 years' experience. Pak J Med Sci. May-Jun 2021;37(3):716-720. doi:10.12669/pjms.37.3.3565
26. Bryniarski P, Paradysz A, Zyczkowski M, Kupilas A, Nowakowski K, Bogacki R. A randomized controlled study to analyze the safety and efficacy of percutaneous nephrolithotripsy and retrograde intrarenal surgery in the management of renal stones more than 2 cm in diameter. J Endourol. Jan 2012;26(1):52-7. doi:10.1089/end.2011.0235
27. Karakoyunlu N, Goktug G, Şener NC, et al. A comparison of standard PCNL and staged retrograde FURS in pelvis stones over 2 cm in diameter: a prospective randomized study. Urolithiasis. Jun 2015;43(3):283-7. doi:10.1007/s00240-015-0768-2
28. Albala DM, Assimos DG, Clayman RV, et al. Lower pole I: a prospective randomized trial of extracorporeal shock wave lithotripsy and percutaneous nephrostolithotomy for lower pole nephrolithiasis-initial results. J Urol. Dec 2001;166(6):2072-80. doi:10.1016/s0022-5347(05)65508-5
29. Berczi C, Flasko T, Lorincz L, Farkas A, Toth C. Results of percutaneous endoscopic ureterolithotomy compared to that of ureteroscopy. J Laparoendosc Adv Surg Tech A. Jun 2007;17(3):285-9. doi:10.1089/lap.2006.0084
30. Thapa BB, Niranjan V. Mini PCNL Over Standard PCNL: What Makes it Better? Surg J (N Y). 2020/02/12 2020;06(01):e19-e23. doi:10.1055/s-0040-1701225
31. Mishra S, Sharma R, Garg C, Kurien A, Sabnis R, Desai M. Prospective comparative study of miniperc and standard PNL for treatment of 1 to 2 cm size renal stone. BJU Int. Sep 2011;108(6):896-9; discussion 899-900. doi:10.1111/j.1464-410X.2010.09936.x
32. Kyriazis I, Panagopoulos V, Kallidonis P, Özsoy M, Vasilas M, Liatsikos E. Complications in percutaneous nephrolithotomy. World Journal of Urology. 2015/08/01 2015;33(8):1069-1077. doi:10.1007/s00345-014-1400-8
33. Seitz C, Desai M, Häcker A, et al. Incidence, prevention, and management of complications following percutaneous nephrolitholapaxy. Eur Urol. Jan 2012;61(1):146-58. doi:10.1016/j.eururo.2011.09.016
34. Elkoushy MA, Violette PD, Andonian S. Ureteroscopy in patients with coagulopathies is associated with lower stone-free rate and increased risk of clinically significant hematuria. Int Braz J Urol. Mar-Apr 2012;38(2):195-202; discussion 202-3. doi:10.1590/s1677-55382012000200007
35. Lojanapiwat B, Prasopsuk S. Upper-pole access for percutaneous nephrolithotomy: comparison of supracostal and infracostal approaches. J Endourol. Jul 2006;20(7):491-4. doi:10.1089/end.2006.20.491
36. Mousavi-Bahar SH, Mehrabi S, Moslemi MK. Percutaneous nephrolithotomy complications in 671 consecutive patients: a single-center experience. Urol J. Fall 2011;8(4):271-6.
37. Zumstein V, Betschart P, Abt D, Schmid HP, Panje CM, Putora PM. Surgical management of urolithiasis - a systematic analysis of available guidelines. BMC Urol. Apr 10 2018;18(1):25. doi:10.1186/s12894-018-0332-9
38. Miah T, Kamat D. Pediatric Nephrolithiasis: A Review. Pediatr Ann. Jun 1 2017;46(6):e242-e244. doi:10.3928/19382359-20170517-02
39. Park HK, Kim JH, Min GE, et al. Change of Trends in the Treatment Modality for Pediatric Nephrolithiasis: Retrospective Analysis of a US-Based Insurance Claims Database. J Endourol. Jul 2019;33(7):614-618. doi:10.1089/end.2019.0154
40. Dai JC, Nicholson TM, Chang HC, et al. Nephrolithiasis in Pregnancy: Treating for Two. Urology. May 2021;151:44-53. doi:10.1016/j.urology.2020.06.097
41. Lee MS, Fenstermaker MA, Naoum EE, et al. Management of Nephrolithiasis in Pregnancy: Multi-Disciplinary Guidelines From an Academic Medical Center. Front Surg. 2021;8:796876. doi:10.3389/fsurg.2021.796876

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