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Preoperative Indications for Percutaneous Nephrolithotripsy in 2009

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Abstract

Since the first description of percutaneous nephrolithotripsy (PNL) over 30 years ago, the indications for this procedure in the management of upper tract urinary stones has greatly expanded. Despite recent advances in shock wave lithotripsy and ureteroscopic technologies, PNL maintains a dominant role in the management of complex and large volume upper tract stones. The contemporary indications for PNL are reviewed herein.

Introduction

Urinary stone disease is a highly prevalent condition that has affected mankind since the earliest recorded times. Multiple management modalities have been developed, broadly parallel to the evolution of surgery. At first, stone burden clearance was the main aim; more recently, minimal invasiveness has become a prominent goal of treatment. Initially performed during the 1940s and later perfected by Fernström and Johansson,[1] percutaneous nephrolithotripsy (PNL) was the first major step in this direction. After more than 30 years of refinements, PNL has become a safe and highly effective treatment for patients with urinary stones.

As with any other surgical technique, the indications and contraindications for PNL are not immutable. Increasing experience, technologic evolution, patient preference, economic pressures, and alternative treatments have, over time, led to changes in indications. In this review, we provide the contemporary indications (Table 1) for the use of PNL for upper tract urinary stone disease.

Stone Size and Location

Stone burden is one of the most important clinical factors that influence treatment decisions,[2] because it is closely related to stone-free rates (SFRs), need for secondary procedures, and complications. The most widely proposed cutoff for a large stone has been set at >2 cm, but this is only weakly evidence based.[3]

The European Association of Urology through their updated guidelines, recommends the use of PNL for any stone that exceeds 20 mm in diameter. Currently, this is the most commonly used indication for PNL.[3]

In 2005, the American Urological Association published guidelines for the management of staghorn calculi and, according to their analysis, PNL resulted in a 78% SFR *vs* 71% for open surgery, 66% in combined (PNL-shockwave lithotripsy [SWL]-PNL) therapy, and 54% with SWL only. With respect to the mean number of procedures, 1.9 were necessary in the PNL group, 3.3 in combination therapy, 3.6 in the SWL arm, and 1.4 for open surgery.[4]

Al-Kohlany and associates[5] compared PNL with open surgery and reported that SFR was slightly higher in open surgery (82% *vs* 74%) but with greater morbidity (37% *vs* 16%), and increased length of hospital stay (6 *vs* 4 days). The panel recommended that PNL be the initial treatment option for most patients who harbor staghorn calculi, either as the sole modality or for very large stone burdens and complex cases as the initial approach of combined therapy.

SFRs with PNL can be improved with the use of flexible nephroscopy and laser energy, as shown by the 95% SFR reported by Wong and Leveillee.[6] PNL is also superior to retrograde ureteroscopy (URS) for the management of stones in the 1 to 2 cm range. This population was prospectively investigated by Chung and colleagues,[7] who report a SFR of 87% *vs* 67%, with minimal blood loss and only a 10-minute difference in the median operative time when comparing PNL *vs* URS. The complication rate was higher in the PNL group with two cases of urinary leakage as well as a 48-hour difference in length of hospital stay.[7] On the other hand, URS carries the morbidity of almost universal ureteral stent placement and secondary stent removal, which when balanced, might offset its perceived benefits as the least invasive procedure.

Stone location is an important determinant of treatment success and is most notable when considering therapy of a lower pole caliceal stone. In retrospective studies, SWL,

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Table 1. Summary of Indications for Percutaneous Nephrolithotripsy as First-Line Treatment

Indications	
Stone size and location	>20 mm, staghorn, lower calix, upper ureter
Composition	Hard: Cystine, brushite, calcium monohydrate Soft: Matrix, uric acid
Anatomic anomalies	Horseshoe, ectopic, crossed or fused kidneys, posteriorly located caliceal diverticulum, transplanted kidney
Patient factors	A- Occupation: Aviators, divers, special forces B- Obesity C- Previous renal surgery D- Skeletal anomalies: Scoliosis, contractures E- Encrusted foreign objects F- Urinary diversion: Conduits, antireflux

although less invasive, yields a lower SFR (50%–56%) than PNL (85%–90%).[8–11] Albala and coworkers[12] investigated this in a randomized controlled trial in which only 37% of the SWL patients were SFR *vs* 95% of PNL cases, without a significant difference in complications between groups. When the stone size exceeded the 10-mm threshold, the SFR with SWL dropped to only 21%.

Furthermore, Carr and colleagues[10] have shown that patients who were treated and rendered stone free with SWL for lower pole calculi have a greater recurrence rate (22%) than with PNL (4%) at 1 year after the procedure; the recurrence in the SWL group was predominantly in the lower and interpolar calices irrespective of the original stone location.[10] Fragments less than 4 mm after SWL double the chance of a symptomatic stone event or the need for intervention within 2 years of treatment.[10] The management of calculi less than 10 mm in the lower pole calix by PNL is controversial in spite of a reported SFR of 97% to 100% (67% with SWL),[13] because of the invasiveness and the longer hospitalization needed.

PNL is also an alternative to URS or SWL for very large proximal ureteral stones. Several series have reported SFR of 85% to 100%.[14–16] Juan and associates[17] compared PNL with URS in this situation and reported SFR of 95% and 58%, respectively. The authors also calculated treatment efficiency quotients (EQ), a tool that enables clinicians to compare the performance of a variety of procedures in regard to retreatment and ancillary procedures.[18] With an EQ of 100 as the most efficient, the calculated EQs for PNL and SWL in their study were 95 and 67, respectively.[17]

Stone Composition

The chemical composition of the calculus determines the hardness of the stone. This has a direct effect on the SWL fragmentation ability,[19] up to the point of making some stones SWL resistant, either because of their extreme hardness or softness. The preoperative determination of stone composition may be suspected in some persons by clinical means (stone analysis from previous episodes, recurrent urinary tract infection, or comorbidities, medications), urinalysis (pH, crystals),[20–25] and imaging (radiolucent stones, staghorns). Stone Hounsfield unit (HU) values in noncontrast CT can also be used as a surrogate for stone hardness and have been shown to predict SFR after SWL. Perks and associates[26] showed that SWL of stones with HU <900 was associated with a 85% fragmentation rate. Unfortunately, the wide overlap in HU values and the mixed composition of many stones make accurate identification of stone composition difficult.[19,26]

The hard stone category comprises cystine, brushite, and calcium monohydrate stones.[27] At the other end of the spectrum, very soft stones pose two problems for SWL. First, they may be radiolucent, thus making fluoroscopic targeting for SWL difficult and necessitating intravenous or retrograde contrast to define the filling defect. The best example is uric acid calculi. Second, although relatively rare, are matrix stones that, because of their gelatinous nature and sparse crystalline structure, are relatively resistant to SWL.

Struvite renal stones are typically associated with the chronic presence of urea-splitting micro-organisms in the urinary tract, the presence of foreign bodies, and often concurrent urinary stasis. The only way to eradicate the bacteria, prevent stone growth, and recurrent urinary tract infection is by complete elimination of the stone burden. PNL provides the greatest opportunity to do this and should be considered the treatment of first choice.

Anatomic Anomalies

Urinary tract anomalies can be accompanied by impaired urine drainage and stone formation. Experiences in managing calculi in horseshoe kidneys with PNL in a multicenter setting were reported by Raj and coworkers.[28] The mean stone surface area was 448 mm^2; SFR was 87.5%, with a major complication rate of 12.5%. Because of the increased length of the tract, rigid nephroscopy was seldom sufficient by itself for complete stone clearance, highlighting the importance of flexible instruments and the availability of intracorporeal lithotripsy devices using flexible probes, such as laser or electrohydraulic. Other investigators reported SFR of 71% to 84%,[29–31] depending on the series, and 53% to 79% when SWL is the management modality.[32–35]

PNL of urinary calculi in ectopic and fused kidneys has been reported using either the standard approach or using a laparoscopic-assisted transabdominal puncture. Matlaga and associates[36] reported on eight patients and noted a 100% SFR with primary and second-look PNL without complications. Mosavi-Bahar and coworkers[37] describe the same SFR after PNL in three patients. They reported a SFR of 25% for SWL of crossed fused ectopic kidneys and an 81.8% SFR when treating patients with nonfused ectopic kidneys. This SFR, however, was achieved through multiple sessions in 35% of the patients (2–6 treatments).

Caliceal diverticula are associated with stone formation in up to 50% of patients and can represent a therapeutic challenge.[38] Auge and associates,[39] retrospectively compared the outcomes of PNL *vs* URS and found that PNL was far superior with symptomatic resolution in 86% *vs* 35% for URS, SFR of 78% *vs* 19%, and diverticula resolution in 61% *vs* 18% for PNL and URS, respectively. Furthermore, 41% of the URS patients needed salvage PNL either because of an unidentifiable ostium or retained stone fragments. This resulted in an 18%

complication rate in the PNL group and a longer hospital stay. Others have reported SFR with PNL in up to 84% to 100% of cases with 64% to 100% obliteration of the diverticulum, with <10% complication rate.[40–44]

Some series have evaluated SWL as monotherapy in caliceal diverticula harboring stones; however, results have been disappointing, with a SFR of 20% to 60% with no diverticula obliteration.[45,46] Turna and colleagues[47] reported their long-term follow-up experience with SWL (<1 cm stones) *vs* PNL (>1 cm stones). Overall, 21% *vs* 83% of patients were stone free, the complication rate was 16% *vs* 17%, and the recurrence rate was12% *vs* 13%, respectively. Thirty-nine percent of patients in the SWL cohort needed either salvage PNL or URS. When subdivided by stone location, the SFR of mid and lower caliceal stones were only 19% and 0%, respectively, once again outlining the importance of location for stone clearance.

Urolithiasis is a rare complication of renal transplantation that affects approximately 0.23% to 6.3% of grafted kidneys.[48] Most reports are of small case series; thus, definitive management is controversial. Because of the unique anatomic location and the ureteroneocystotomy potentially complicating retrograde access, PNL for these patients is a safe and effective option (SFR 100%), even for ureteral stones.[49]

Challacombe and coworkers[50] reported on 13 patients who were treated with SWL at their institution; 61% needed multiple SWL sessions (2–6), there were no lost grafts, and all patients except one were stone free (97% SFR).

Patient Factors

Occupation

In some high-risk occupations, such as civilian and military pilots, the diagnosis of urinary calculi is accompanied by immediate cancellation of active duty, even when the person is asymptomatic. In this group of patients, the most expeditious form of treatment—albeit the most invasive—could be justified to ensure SFR in the most efficient manner. Zheng and colleagues[51] reviewed the experience of four endourology centers in which aircraft pilots with renal stones were treated and concluded that SWL was the least likely to render the patient stone free (35%) and led to the longest work-lost interval (4.7 weeks). PNL was associated with a higher maximized SFR (100%) and minimized the work-loss interval (2.6 weeks).

Obesity

Any interventional procedure is considerably more challenging as the body mass index (BMI) increases above 30 kg/m^2. Unfortunately, obesity is a common trend in many western countries, thus limiting SWL for technical issues (gantry weight limits, imaging resolution, F2 positioning) and by outcomes because of increased skin to stone distance, which some authors have shown diminishes the success rate of SWL from 79% to 57% when this distance is greater than 9 cm.[26]

In multiple studies, PNL appears not to be affected by BMI with regard to SFR, complications, length of hospital stay, or cost,[52–54] although some minor modifications to the working instruments or technique may be necessary for morbidly obese patients. PNL has also been successfully performed under conscious sedation with local anesthesia, thus minimizing the cardiovascular and pulmonary impact of the prone position in morbidly obese patients.[55]

Previous surgery

Inflammation and scarring after renal surgery may distort the normal pelvicaliceal anatomy, theoretically reducing stone clearance after SWL and ultimately affecting SFR. PNL after either open/laparoscopic renal surgery or previous PNL is potentially technically more difficult but retains a high SFR (77%–95%) and safety (6%–12% complication rate) when compared with patients with no previous renal surgery.[56–69] PNL may be the treatment of choice in patients with smaller stones or ureteral stones when previous ureteral or bladder surgery precludes retrograde access, such as crossed trigonal ureteral reimplantation for vesicoureteral reflux or ureteral stricture, especially when the patient has a preexisting nephrostomy tube *in situ*.[61]

Skeletal anomalies

In some patients with skeletal anomalies, such as severe scoliosis or with body contractures, SWL positioning and effective coupling with the shockwave head may be limited; thus, this subgroup of patients may be better served with PNL.[62] PNL, however, may be similarly limited by such orthopedic anomalies.

Encrusted foreign objects

Troy and associates[63] and Leroy and coworkers[64] have reported on their experience with upper urinary tract foreign bodies (ureteral stent fragments, nonabsorbable sutures, and dilation balloon fragments), some of which had stone encrustation. This infrequent condition can only be managed by removal of the foreign body, because it serves as a nidus for stone formation; if retrograde instrumentation fails, PNL is typically indicated.

Urinary diversion

Ten percent to 12% of ileal and 4% of colonic conduits are complicated by urinary calculi formation.[65] Retrograde access can be challenging; however, PNL in this setting has been reported to have a 75%–100% SFR and a complication rate of 12%, mainly because of urinary leak and urosepsis.[66–69] The commonality of struvite stones in this population necessitating complete stone clearance also often encourages a percutaneous approach.

Conclusions

Although SWL and ureteroscopy have prominent roles to play in the surgical management of upper tract stone disease, there are a number of clinical situations that mandate a more definitive approach. In 2009, PNL maintains its position as the most effective treatment option for patients with large stone burdens, in situations associated with complex renal anatomy, and when attempting to achieve an immediate stone-free state is a high priority.

Disclosure Statement

No competing financial interests exist.

References

1. Fernström I, Johansson B. Percutaneous pyelolithotomy. A new extraction technique. Scand J Urol Nephrol 1976;10:257–259.
2. Duvdevani M, Razvi H, Sofer M, Beiko DT, Nott L, Chew BH, Denstedt JD. Contemporary percutaneous nephrolithotripsy: 1585 procedures in 1338 consecutive patients. J Endourol 2007;21:824–829.
3. Tiselius HG, Alken P, Buck C, Gallucci M, Knoll T, Sarica K, Turk C. Guidelines on urolithiasis. European Urological Association, 2008. Available at: www.uroweb.org/fileadmin/tx_eauguidelines/Urolithiasis.pdf. Accessed July 2, 2009.
4. Preminger GM, Assimos DG, Lingeman JE, Nakada SY, Pearle MS, Wolf JS Jr; AUA Nephrolithiasis Guideline Panel. Chapter 1: AUA guideline on management of staghorn calculi: Diagnosis and treatment recommendations. J Urol 2005;173:1991–2000.
5. Al-Kohlany KM, Shokeir AA, Mosbah A, Mohsen T, Shoma AM, Eraky I, El-Kenawy M, El-Kappany HA. Treatment of complete staghorn stones: A prospective randomized comparison of open surgery versus percutaneous nephrolithotomy. J Urol 2005;173:469–473.
6. Wong C, Leveillee RJ. Single upper-pole percutaneous access for treatment of > or = 5-cm complex branched staghorn calculi: Is shockwave lithotripsy necessary? J Endourol 2002;16:477–481.
7. Chung BI, Aron M, Hegarty NJ, Desai MM. Ureteroscopic versus percutaneous treatment for medium-size (1–2 cm) renal calculi. J Endourol 2008;22:343–346.
8. McDougall EM, Denstedt JD, Clayman RV, Preminger G, Brown RD, McClennan BL. Comparison of extracorporeal shock wave lithotripsy and percutaneous nephrolithotomy for the treatment of renal calculi in the lower pole calices. J Endourol 1989;3:265–271.
9. Lingeman JE, Siegel YI, Steele B, Nyhuis AW, Woods JR. Management of lower pole nephrolithiasis: A critical analysis. J Urol 1994;151:663–667.
10. Carr LK, D'A Honey J, Jewett MA, Ibanez D, Ryan M, Bombardier C. New stone formation: A comparison of extracorporeal shock wave lithotripsy and percutaneous nephrolithotomy. J Urol 1996;155:1565–1567.
11. Chen RN, Streem SB. Extracorporeal shock wave lithotripsy for lower pole calculi: Long-term radiographic and clinical outcome. J Urol 1996;156:1572–1575.
12. 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 2001;166:2072–2080.
13. Preminger GM. Management of lower pole renal calculi: Shock wave lithotripsy versus percutaneous nephrolithotomy versus flexible ureteroscopy. Urol Res 2006;34:108–111.
14. Karami H, Arbab AH, Hosseini SJ, Razzaghi MR, Simaei NR. Impacted upper-ureteral calculi >1 cm: Blind access and totally tubeless percutaneous antegrade removal or retrograde approach? J Endourol 2006;20:616–619.
15. Maheshwari PN, Oswal AT, Andankar M, Nanjappa KM, Bansal M. Is antegrade ureteroscopy better than retrograde ureteroscopy for impacted large upper ureteral calculi? J Endourol 1999;13:441–444.
16. Kumar V, Ahlawat R, Banjeree GK, Bhaduria RP, Elhence A, Bhandari M. Percutaneous ureterolitholapaxy: The best bet to clear large bulk impacted upper ureteral calculi. Arch Esp Urol 1996;49:86–91.
17. Juan YS, Shen JT, Li CC, Wang CJ, Chuang SM, Huang CH, Wu WJ. Comparison of percutaneous nephrolithotomy and ureteroscopic lithotripsy in the management of impacted, large, proximal ureteral stones. Kaohsiung J Med Sci 2008;24:204–209.
18. Clayman RV, McClennan BL, Garvin TJ, Denstedt JD, Andriole GL. Lithostar: An electromagnetic acoustic shock wave unit for extracorporeal lithotripsy. J Endourol 1989;3:307.
19. Dretler SP, Spencer BA. CT and stone fragility. J Endourol 2001;15:31–36.
20. Gagnon RF, Alli AI, Watters AK, Tsoukas CM. Indinavir crystalluria. Kidney Int 2006;70:2047.
21. Go T. Effect of antiepileptic drug polytherapy on crystalluria. Pediatr Neurol 2005;32:113–115.
22. Alarcón-Martínez H, Casas-Fernández C, Escudero-Rodríguez N, Cao-Avellaneda E, Domingo-Jiménez R, Puche-Mira A, Rodríguez-Costa T. [Nephrolithiasis and topiramate.] (Spa) Rev Neurol 2006;42:91–94.
23. Matlaga BR, Shah OD, Assimos DG. Drug-induced urinary calculi. Rev Urol 2003;5:227–231.
24. Fogazzi GB, Garigali G. The clinical art and science of urine microscopy. Curr Opin Nephrol Hypertens 2003;12:625–632.
25. Fogazzi GB. Crystalluria: A neglected aspect of urinary sediment analysis. Nephrol Dial Transplant 1996;11:379–387.
26. Perks AE, Schuler TD, Lee J, Ghiculete D, Chung DG, D'A Honey RJ, Pace KT. Stone attenuation and skin-to-stone distance on computed tomography predicts for stone fragmentation by shock wave lithotripsy. Urology 2008;72:765–769.
27. Al-Bareeq R, Wignall GR, Denstedt JD. Percutaneous nephrolithotomy: Indications and techniques. In: Urolithiasis. Nakada S, Pearle MS, eds. In press.
28. Raj GV, Auge BK, Weizer AZ, Denstedt JD, Watterson JD, Beiko DT, Assimos DG, Preminger GM. Percutaneous management of calculi within horseshoe kidneys. J Urol 2003;170:48–51.
29. Jones DJ, Wickham JE, Kellett MJ. Percutaneous nephrolithotomy for calculi in horseshoe kidneys. J Urol 1991;145:481–483.
30. Lampel A, Hohenfellner M, Schultz-Lampel D, Lazica M, Bohnen K, Thürof JW. Urolithiasis in horseshoe kidneys: Therapeutic management. Urology 1996;47:182–186.
31. Al-Otaibi K, Hosking DH. Percutaneous stone removal in horseshoe kidneys. J Urol 1999;162:674–677.
32. Serrate R, Regué R, Prats J, Rius G. ESWL as the treatment for lithiasis in horseshoe kidney. Eur Urol 1991;20:122–125.
33. Kirkali Z, Esen AA, Mungan MU. Effectiveness of extracorporeal shockwave lithotripsy in the management of stone-bearing horseshoe kidneys. J Endourol 1996;10:13–15.
34. Clayman RV. Effectiveness of extracorporeal shockwave lithotripsy in the management of stone-bearing horseshoe kidneys. J Urol 1998;160:1949.
35. Gallucci M, Vincenzoni A, Schettini M, Fortunato P, Cassanelli A, Zaccara A. Extracorporeal shock wave lithotripsy in ureteral and kidney malformations. Urol Int 2001;66:61–65.
36. Matlaga BR, Kim SC, Watkins SL, Kuo RL, Munch LC, Lingeman JE. Percutaneous nephrolithotomy for ectopic kidneys: Over, around, or through. Urology 2006;67:513–517.
37. Mosavi-Bahar SH, Amirzargar MA, Rahnavardi M, Moghaddam SM, Babbolhavaeji H, Amirhasani S. Percutaneous nephrolithotomy in patients with kidney malformations. J Endourol 2007;21:520–524.

38. Middleton AW Jr, Pfister RC. Stone-containing pyelocaliceal diverticulum: Embryogenic, anatomic, radiologic and clinical characteristics. J Urol 1974;111:2–6.
39. Auge BK, Munver R, Kourambas J, Newman GE, Preminger GM. Endoscopic management of symptomatic caliceal diverticula: A retrospective comparison of percutaneous nephrolithotripsy and ureteroscopy. J Endourol 2002;16:557–563.
40. Shalhav AL, Soble JJ, Nakada SY, Wolf JS Jr, McClennan BL, Clayman RV. Long-term outcome of caliceal diverticula following percutaneous endosurgical management. J Urol 1998;160:1635–1639.
41. Monga M, Smith R, Ferral H, Thomas R. Percutaneous ablation of caliceal diverticulum: Long-term followup. J Urol 2000;163:28–32.
42. Canales B, Monga M. Surgical management of the calyceal diverticulum. Curr Opin Urol 2003;13:255–260.
43. Landry JL, Colombel M, Rouviere O, Lezrek M, Gelet A, Dubernard JM, Martin X. Long term results of percutaneous treatment of caliceal diverticular calculi. Eur Urol 2002;41:474–477.
44. Al-Basam S, Bennett JD, Layton ZA, Denstedt JD, Razvi H. Treatment of caliceal diverticular stones: Transdiverticular percutaneous nephrolithotomy with creation of a neoinfundibulum. J Vasc Interv Radiol 2000;11:885–889.
45. Streem SB, Yost A. Treatment of caliceal diverticular calculi with extracorporeal shock wave lithotripsy: Patient selection and extended followup. J Urol 1992;148:1043–1046.
46. Ritchie AW, Parr NJ, Moussa SA, Tolley DA. Lithotripsy for calculi in caliceal diverticula? Br J Urol 1990;66:6–8.
47. Turna B, Raza A, Moussa S, Smith G, Tolley DA. Management of calyceal diverticular stones with extracorporeal shock wave lithotripsy and percutaneous nephrolithotomy: Long-term outcome. BJU Int. 2007;100:151–156.
48. He Z, Li X, Chen L, Zeng G, Yuan J. Minimally invasive percutaneous nephrolithotomy for upper urinary tract calculi in transplanted kidneys. BJU Int 2007;99:1467–1471.
49. Lu HF, Shekarriz B, Stoller ML. Donor-gifted allograft urolithiasis: Early percutaneous management. Urology 2002;59:25–27.
50. Challacombe B, Dasgupta P, Tiptaft R, Glass J, Koffman G, Goldsmith D, Khan MS. Multimodal management of urolithiasis in renal transplantation. BJU Int 2005;96:385–389.
51. Zheng W, Beiko DT, Segura JW, Preminger GM, Albala DM, Denstedt JD. Urinary calculi in aviation pilots: What is the best therapeutic approach? J Urol. 2002;168:1341–1343.
52. Bagrodia A, Gupta A, Raman JD, Bensalah K, Pearle MS, Lotan Y. Impact of body mass index on cost and clinical outcomes after percutaneous nephrostolithotomy. J Urol 2008;72:756–760.
53. Pearle MS, Nakada SY, Womack JS, Kryger JV. Outcomes of contemporary percutaneous nephrostolithotomy in morbidly obese patients. J Urol 1998;160:669–673.
54. Koo BC, Burtt G, Burgess NA. Percutaneous stone surgery in the obese: Outcome stratified according to body mass index. BJU Int 2004;93:1296–1299.
55. Kanaroglou A, Razvi H. Percutaneous nephrolithotomy under conscious sedation in morbidly obese patients. Can J Urol 2006;13:3153–3155.
56. Margel D, Lifshitz DA, Kugel V, Dorfmann D, Lask D, Livne PM. Percutaneous nephrolithotomy in patients who previously underwent open nephrolithotomy. J Endourol 2005;19:1161–1164.
57. Sofikerim M, Demirci D, Gülmez I, Karacagil M. Does previous open nephrolithotomy affect the outcome of percutaneous nephrolithotomy? J Endourol 2007;21:401–403.
58. Lojanapiwat B. Previous open nephrolithotomy: Does it affect percutaneous nephrolithotomy techniques and outcome? J Endourol 2006;20:17–20.
59. Basiri A, Karrami H, Moghaddam SM, Shadpour P. Percutaneous nephrolithotomy in patients with or without a history of open nephrolithotomy. J Endourol 2003;17:213–216.
60. Kurtulus FO, Fazlioglu A, Tandogdu Z, Aydin M, Karaca S, Cek M. Percutaneous nephrolithotomy: Primary patients versus patients with history of open renal surgery J Endourol 2008;22:2671–2675.
61. Kane J, Anast JW, Stoller ML. Percutaneous treatment of ureteral stones. In: Smith's Textbook of Endourology. 2nd ed. Hamilton, BC Decker Inc, 2006, pp 143–148.
62. Streem SB. Percutaneous stone extraction. In: Smith's Textbook of Endourology. 2nd ed. Hamilton, BC Decker Inc, 2006, pp 127–141.
63. Troy RB, Streem SB, Zelch MG. Percutaneous management of upper tract foreign bodies. J Endourol 1994;8:43–47.
64. LeRoy AJ, Williams HJ Jr, Segura JW, Patterson DE, Benson RC Jr. Indwelling ureteral stents: Percutaneous management of complications. Radiology 1986;158:219–222.
65. de la Rosette JJ, Conort P, Desai M, et al. Treatment of renal stone. In: Stone Disease. 2nd International Consultation on Stone Disease. Paris, Health Publication, 2008, pp 139–238.
66. Cass AS, Lee JY, Aliabadi H. Extracorporeal shock wave lithotripsy and endoscopic management of renal calculi with urinary diversions. J Urol 1992;148:1123–1125.
67. Wolf JS Jr, Stoller ML. Management of upper tract calculi in patients with tubularized urinary diversions. J Urol 1991;145:266–269.
68. Cohen TD, Streem SB, Lammert GK. Selective minimally invasive management of calculi in patients with urinary diversions. J Urol 1994;152:1091–1094.
69. el-Nahas AR, Eraky I, el-Assmy AM, et al. Percutaneous treatment of large upper tract stones after urinary diversion. Urology 2006;68:500–504.

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Abbreviations Used

BMI = body mass index
CT = computed tomography
EQ = efficiency quotients
HU = Hounsfield units
PNL = percutaneous nephrolithotripsy
SFR = stone-free rate
SWL = shockwave lithotripsy
URS = ureteroscopy