Ultra Mini PCNL

Satyendra Persaud, Ramandeep Chalokia, and Janak Desai

Abstract Mini percutaneous nephrolithotomy (mini-PCNL) has emerged as a promising technique in the field of kidney stone surgery, offering a minimally invasive approach for the management of renal calculi.Mini-PCNL involves the use of a smaller-caliber nephroscope compared to traditional percutaneous nephrolithotomy (PCNL). The miniaturized instruments allow for a less invasive procedure, resulting in reduced morbidity, shorter hospital stays, and faster recovery for patients with kidney stones. This technique combines the advantages of both PCNL and flexible ureteroscopy, enabling efficient stone fragmentation and removal.Procedural details of mini-PCNL, include patient selection criteria, renal access techniques, and the utilization of holmium laser lithotripsy for effective stone fragmentation. The advantages and limitations of mini-PCNL are discussed, providing valuable insights for urologists considering this approach for their patients.Mini-PCNL has demonstrated excellent stone clearance rates, particularly for medium-sized renal calculi and staghorn stones. The reduced risk of bleeding and potential for outpatient management further enhance its appeal in the management of urolithiasis.Mini percutaneous nephrolithotomy is a safe and effective alternative to conventional PCNL.

Keywords Mini percutaneous nephrolithotomy (mini-PCNL) · Kidney stone surgery · Urolithiasis · Nephrolithiasis · Percutaneous nephrolithotomy · Minimally invasive surgery · Renal calculi · Stone removal · Renal access · Small-caliber nephroscope · Flexible ureteroscopy · Renal anatomy · Stone fragmentation · Holmium laser lithotripsy · Endourology · Retrograde intrarenal surgery (RIRS) · Fluoroscopy · Postoperative care · Nephrostomy tube · Outpatient procedure

S. Persaud
Division of Clinical Surgical Sciences, University of the West Indies, West Indies, Trinidad and Tobago
e-mail: satyendra.persaud@sta.uwi.edu

R. Chalokia
Warrington and Halton Teaching Hospitals, NHS Foundation Trust, Warrington, UK

J. Desai (✉)
Samved Hospital, Ahmedabad, Gujarat, India
e-mail: drjanakddesai@gmail.com

J. D. Denstedt and E. N. Liatsikos (eds.), *Percutaneous Renal Surgery*,
https://doi.org/10.1007/978-3-031-40542-6_14

In 1941 Rupel and Brown removed a stone whole from an obstructed the kidney via a previously placed nephrostomy and percutaneous nephrolithotomy (PCNL) was born (Patel and Nakada 2015). Fernstrom and Johannson subsequently described the creation of a percutaneous access specifically to remove stones using a cystoscope and rigid graspers to remove the stone (Fernstrom 1976). In 1977, Alken would help create the percutaneous nephroscope and eventually Arthur Smith along with Kurt Amplatz created the 30Fr Amplatz sheath (Desai 2021). Eventually, 30Fr was described as the standard for PCNL at the time, being limited to this size by the availability of appropriately sized fibreoptic and lithotripsy devices. In the decades since, the procedure has evolved tremendously.

PCNL is now the procedure of choice for large kidney stones with stone free rates superior to shockwave lithotripsy or ureteroscopy (Assimos et al. 2016). The procedure has seen numerous innovations in instrumentation, radiology as well positioning and has entered an era of miniaturization. This was initially driven by the need to treat stones in the pediatric population and initially vascular access sheaths were repurposed and modified for this purpose, with Jackman and colleagues coining the term "mini-perc" in 1998 (Desai 2021). Subsequently, a number of minimally invasive PCNLs were developed, accompanied by purpose-built instruments. This has been possible with the concomitant development of fiberoptics and lasers which permitted lithotripsy through small calibre endoscopes.

One should be familiar with the terms describing the various categories of PCNL—these are described based on the outer diameter of the sheath and are as follows (Miernik 2019):

24–32Fr—Standard PCNL
14–22Fr—Mini PCNL
11–13Fr—Ultra-Mini PCNL
4.8–11Fr—Micro PCNL

1 Benefits of Miniaturization and the Development of Ultra-Mini PCNL

One dreaded complication of PCNL is bleeding and the risk of bleeding is directly related to tract size. In an analysis of over 5000 procedures in the Clinical Research Office of the Endourological Society (CROES) Global PCNL database, it was noted that transfusion risk varied between 1.1% with an 18fr tract to as high as 12.1% among patients whose tracts were over 30Fr (Yamaguchi et al. 2011) Table 1. Dr Desai and team in Ahmedabad similarly noted that bleeding seemed to increase significantly with tracts dilated beyond 14 to 16fr. They postulated that the elasticity of the kidney may be able to tolerate dilation up to this point, tearing once the tracts were dilated beyond this. This led the team to the development of the ultra-mini PCNL (UMP) with dilation to a maximum of 13Fr (Desai and Solanki 2013). This was first described in 2013 and since then has become an established option for the treatment of stones up

Table 1 Transfusion rate in relation to PCNL sheath size

	No of patients	% Blood transfusion
Small (18Fr or less)	271	1.1%
Medium (24Fr–26Fr)	1039	4.8%
Large (27Fr–30Fr)	3533	5.9%
Larger (>30Fr)	371	12.1%

Table 2 Comparisons of various miniaturized versions of PCNL

	Mini-PCNL	UMP	Micro-perc
Size of Sheath	18–22Fr	11Fr and 13Fr	4.8Fr
Stone removal	Forceps and ultrasonic disintegration with suction	Creating a fluid vortex	Leave for natural expulsion
Telescope size	3 mm	1 mm	0.9 mm
Resolution of telescope	30,000 pixels	17,000 pixels	10,000 pixels

to 2 cm. UMP falls on the miniaturization spectrum between traditional PCNL and micro-PCNL with several options lying in between (Table 2) (Smith et al. 2018)—the choice of procedure will depend on patient and stone characteristics as well as surgeon experience and comfort as well as availability of equipment. The technique, while it requires some experience, has proven to reproducible with authors reporting stone free rates as high as 99% with few or no complications (Agrawal et al. 2016).

2 Instruments and Technique

Instruments were specially created including a 3.5Fr 0-degree telescope (17,000 pixels) which fits into a 6Fr inner sheath with the latter having two ports, one for irrigation and the other permitting passage of a laser fiber. There is also an outer sheath, 11 or 13Fr in diameter with a small inner tube, 3fr in diameter, running along its length and connected to a side port (Figs. 1 and 2). The latter is a special feature—injection of fluid via this port creates a vortex within the collecting system with fluid moving from the high pressure renal pelvis into the outer sheath and allows evacuation of stone fragments.

The procedure is carried out under general anesthesia. Puncture is done in standard prone fashion following the cystoscopic placement of a ureteric catheter. This facilitates dilation of the tract under fluoroscopy using small Teflon dilators. The outer sheath, over an obturator, is inserted into the collecting system followed by the inner sheath with the attached camera. Under direct vision, stone disintegration is carried out via a 365-um laser fibre and fragments, which are less than 2mm. Following disintegration, the inner sheath is removed and saline is injected via the

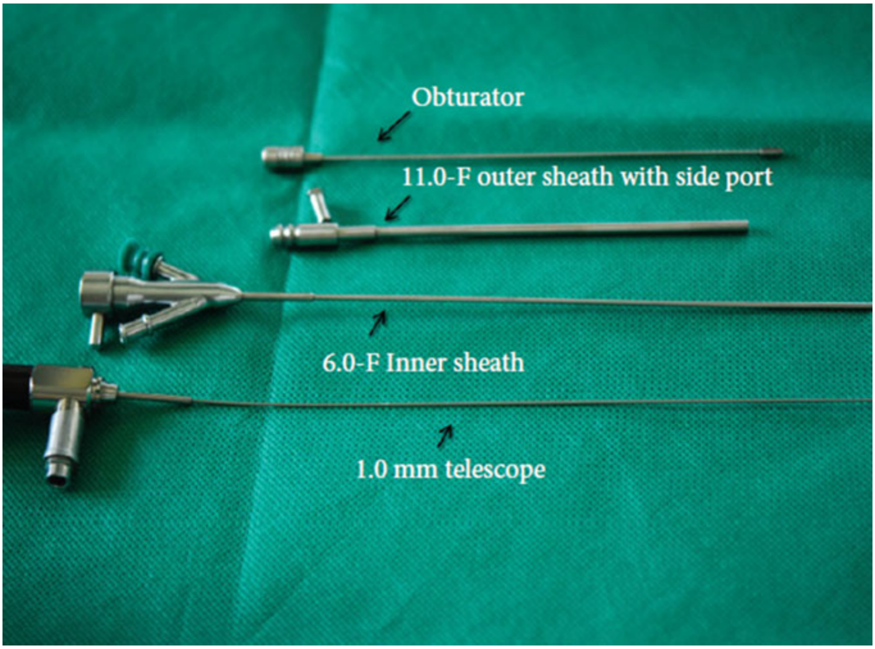

Fig. 1 UMP Instruments including telescope, inner sheath, and specially designed outer sheath (with obturator) which may be 11 or 13 Fr

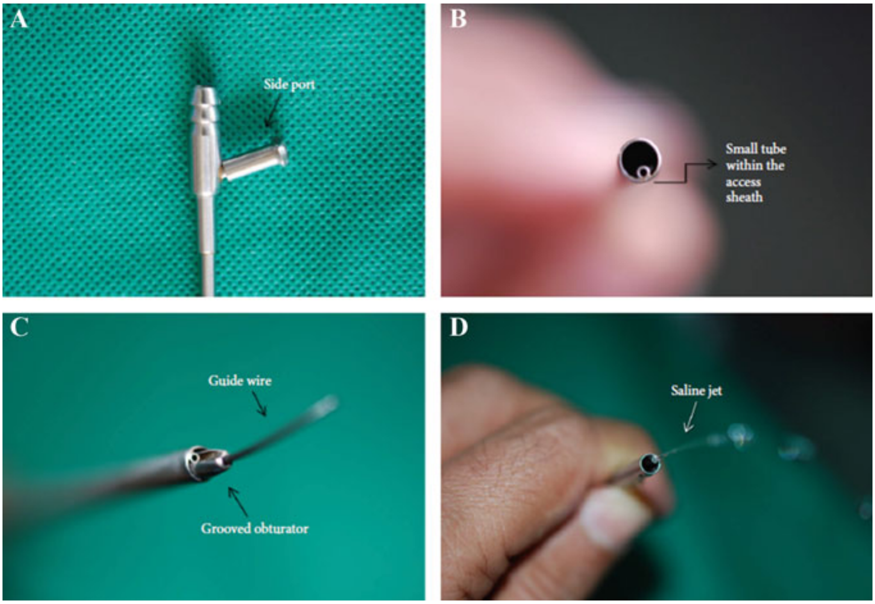

Fig. 2 (A) Outer sheath with side port for irrigation via water tube on the sheath (B). (C) Grooved obturator sliding over a guidewire. (D) Demonstration of waterjet function of the outer sheath

port on the outer sheath. The tiny fragments are agitated and are washed out via the vortex described above. This effect can also be created by flushing the ureteric catheter. Following this, the instruments are removed, and firm pressure is applied to the tract for a few moments. The ureteric catheter is kept for a few hours following surgery and barring no complications, this and the urinary catheter is removed and the patient is typically discharged within 24 h (Desai and Solanki 2013).

3 When Is UMP Appropriate?

UMP forms an important part of the stone treatment arsenal and falls along the spectrum of miniaturization between traditional PCNL and micro-PCNL—it is an option for stones up to 2 cm. One primary advantage of tract miniaturization is a decrease in blood loss. In an analysis of factors leading to bleeding during PCNL the authors noted that blood loss may be minimized via the utilization of smaller tracts in pediatric patients, those non hydronephrotic kidneys or narrow narrow infundibula as well as mopping up of smaller calyceal stones as part of a multi-puncture procedure (Kukreja et al. 2004). In the case of the latter, UMP is used as an adjunct to remove stones in a calyx which cannot be accessed by the primary PCNL tract—this avoids having to make larger secondary punctures. Apart from the blood loss related advantages, UMP offers a stent and nephrostomy-free option meaning that patient comfort is maximized, and hospital stay is minimized.

One of the key advantages in UMP over fURS (Flexible ureterorenoscopy) lies in the management of stones in lower pole calyces. In these cases, it is easier to access stones via UMP rather than fURS. This is well illustrated in a RCT by Datta and colleagues—almost a quarter of the patients had stones in their low poles with 100% clearance being achieved via UMP. This is contrasted with the fURS group where almost half of those with residual stones had lower pole stones pre intervention (Datta et al. 2016).

4 How Does Ultra Mini PCNL Compare to Ureteroscopy and Standard PCNL?

In a recent randomized trial, 98 patients with stones 10–30 mm were randomized to UMP and 46 to flexible ureteroscopy (fURS). Both mean laser time (41.17 min versus 73.58 min) and consumable costs ($45.73 versus 423.11) were significantly less in the UMP group. Additionally the stone free rate at 1 month of follow-up was 100% for UMP group and 73% for the fURS group. Grades I and II complications were 10% in the UMP group and 35% in the fURS group (Datta et al. 2016). In this study laser and evacuation times were significantly less for UMP and this may be due to quicker fragmentation and retrieval due to the vortex effect described above.

Schoenthaler and colleagues found similar stone free and complication rates between both procedures but cost of consumables was much less among patients undergoing UMP (Schoenthaler et al. 2015). In a Meta-Analysis, Jung found higher stone free rates, but similar complication rates, with UMP compared to fURS (Do et al. 2022).

Zhong and colleagues compared minimally invasive PCNL (16Fr) versus standard PCNL (26Fr) noting that miPCNL was associated with a higher stone clearance rate—89.7 versus 68%. There were similar complication rates between the two procedures but less chance of needing an adjunctive procedure with miPCNL (Zhong et al. 2011). The authors also noted that multiple mini tracts led to improved stone clearance for staghorn stones. While this study didn't use the kit as described by Desai, the data are nonetheless helpful. Adamou et al. compared standard, mini and ultra-mini PCNLs for single renal stones among 84 patients. They noted that while stone free rates were similar among different PCNL types, ultra-mini PCNL was associated with a shorter hospitalization and a smaller haemoglobin drop. They did note that operative time was longer in the ultra-mini group (Adamou et al. 2022).

5 Synopsis

In the era of miniaturization, there are several minimally invasive options to standard PCNL. The primary driver of the development of these options has been a reduction in blood loss that follows a smaller tract. One such option is the Ultra-mini PCNL. This has proven to be safe and efficacious and is an option for stones 2 cm or less. For these stones UMP may be used as the sole treatment modality and has the advantages of lower cost, faster operation times and being truly tube/stent free when compared to ureteroscopy. Additionally, for larger stones, UMP may be used as an adjunct to traditional PCNL for smaller stones which cannot be accessed with the primary tract and in this way avoids the bleeding risk that follows multiple large tracts. UMP also outperforms fURS when it comes to clearance of lower pole stones. One final advantage of UMP over fURS is the reduction in the cost of disposables. The financial and environmental benefits of this cannot be understated.

References

Adamou C, Evangelia Goulimi E, Pagonis K, Peteinari A, Tsaturyan A, Vagionis A, Lattarulo M, Giannitsas K Liatsikos EKP. Comparison between standard, mini and ultra-mini percutaneous nephrolithotomy for single renal stones: a prospective study. World J Urol. 2022;40(10):2543–8.

Agrawal M, Agarwal K, Jindal T, Sharma M. Ultra-mini-percutaneous nephrolithotomy: a minimally-invasive option for percutaneous stone removal. Indian J Urol [Internet]. 2016;32(2):132. Available from: http://www.indianjurol.com/text.asp?2016/32/2/132/174778

Assimos D, Krambeck A, Miller N. Kidney stones: surgical management guideline—American Urological Association. American Urological Association; 2016.

Datta SN, Solanki R, Desai J. Prospective outcomes of ultra mini percutaneous nephrolithotomy: a consecutive cohort study. J Urol. 2016;195(3):741–6.

Desai JSH. Mini percutaneous kidney stone removal applicable technologies. Urol Clin N Am. 2021.

Desai J, Solanki R. Ultra-mini percutaneous nephrolithotomy (UMP): one more armamentarium. BJU Int. 2013;n/a.

Fernstrom IJB. Percutaneous pyelolithotomy. A new extraction technique. Scand J Urol Nephrol. 1976.

Jung HDo, Chung DY, Kim DK, Lee MH, Lee SW, Paick S, et al. Comparison of ultra-mini percutaneous nephrolithotomy and retrograde intrarenal surgery for renal stones: a systematic review and meta-analysis from the KSER update series. J Clin Med [Internet]. 2022;11(6):1529. Available from: https://www.mdpi.com/2077-0383/11/6/1529

Kukreja R, Desai M, Patel S, Bapat S, Desai M. Factors affecting blood loss during percutaneous nephrolithotomy: prospective study. J Endourol. 2004;18(8):715–22.

Miernik ADJ. Small-caliber percutaneous nephrolithotomy: mini, UMP, and micro-perc. In: Smith A, Badlani G, Preminger GKL, editor. 4th ed. John Wiley and Sons; 2019. p. 301–309.

Patel SR, Nakada SY. The modern history and evolution of percutaneous nephrolithotomy. J Endourol. 2015.

Schoenthaler M, Wilhelm K, Hein S, Adams F, Schlager D, Wetterauer U, et al. Ultra-mini PCNL versus flexible ureteroscopy: a matched analysis of treatment costs (endoscopes and disposables) in patients with renal stones 10–20 mm. World J Urol [Internet]. 2015;33(10):1601–5. Available from: https://doi.org/10.1007/s00345-015-1489-4

Smith AD, Preminger G, Kavoussi L, Badlani GRA. Smith's textbook of endourology. 4th ed. Wiley; 2018.

Yamaguchi A, Skolarikos A, Buchholz N-PN, Chomón GB, Grasso M, Saba P, et al. Operating times and bleeding complications in percutaneous nephrolithotomy: a comparison of tract dilation methods in 5537 patients in the clinical research office of the endourological society percutaneous nephrolithotomy global study. J Endourol. 2011;25(6):933–9.

Zhong W, Zeng G, Wu W, Chen WWK. Minimally invasive percutaneous nephrolithotomy with multiple mini tracts in a single session in treating staghorn calculi. Urol Res. 2011;39(2):117–22.