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Review

Contemporary role of multi-tract percutaneous nephrolithotomy in the treatment of complex renal calculi

Sudharsan Balaji ^a, Arvind Ganpule ^{a,*}, Thomas Herrmann ^b,
Ravindra Sabnis ^a, Mahesh Desai ^a

^a Department of Urology, Muljhibhai Patel Urological Hospital, Nadiad, Gujarat, India

^b Department of Urology, Spital Thurgau AG STGAG Kantonspital Frauenfeld and Kantonspital Münsterlingen, Thurgau, Switzerland

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Abstract Complex renal calculi remain to be a challenge for the treating urologist due to sheer bulk and the technicalities involved. Percutaneous nephrolithotomy (PCNL) remains the treatment modality of choice in dealing with these large and complex stones. The limiting factor in their treatment continues to be the need for using additional tracts or the use of flexible nephroscopy for complete stone clearance. This systematic review focuses on the need for multi-tract PCNL for complex renal calculi. The literature review was performed using PubMed database using the keywords “multiple tract PCNL” or “multiperc”. We identified original articles published on the usage of multiple tracts for stone clearance in renal calculi between January 2000 to October 2018, and the search was restricted to available literature in English language only. Ten studies with $n > 20$ were included for the final analysis. We analyzed the technical efficacy with respect to the number of tracts and stages that were required for stone clearance, outcomes and complications, especially, procedural bleeding and post-procedure infective complications of multiple-tract PCNL for large burden renal stones. Multiperc is found to be safe, feasible and effective for the management of large burden complex renal calculi with respect to stone clearance and morbidity associated with the procedure. It is cost effective and complete stone clearance as a single procedure is higher in comparison to flexible ureteroscopy and shockwave lithotripsy.

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* Corresponding author.

E-mail address: doctorarvind1@gmail.com (A. Ganpule).

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1. Introduction

The American Urological Association (AUA) guidelines recommend percutaneous nephrolithotomy (PCNL) as the first-line treatment for staghorn calculi and the European Association of Urology (EAU) guidelines recommend PCNL for the treatment of renal stones of size more than 2 cm and lower pole stones more than 1.5 cm [1,2]. The PCNL has clearly shown superior stone clearance rates for complex renal calculi than flexible ureteroscopy (FURS) and shock-wave lithotripsy (SWL), albeit with higher complication rates [3,4]. Rassweiler et al. [4] defined complex renal calculi based on stone burden and distribution, renal function and associated infection. In case of complex calculi, the number of accesses is defined by the overall size and volume of the stone, anatomy of the pelvi-calyceal system (PCS), stone distribution, general health of the patient and the experience of the operating surgeon.

Multiperc or multiple tract PCNL has been well established in the management of complex renal calculi [3,5]. Despite the proven advantages of this technique, it still remains under-utilized for the fear of complications involved with multiple punctures at the same time. We systematically reviewed the available literature on this topic to assess the safety and efficacy of multiple tract PCNL in the clearance of large burden renal calculi.

1.1. Evidence acquisition

The literature review was performed using PubMed database. We identified original articles on the usage of multiple tracts for stone clearance in renal calculi and the search was restricted to available literature in English language only. Inclusion criteria were articles published from January 2000 to October 2018, discussing the technical efficacy, outcomes and complications of multiple tract standard or mini-PCNL for complex large renal stones. The study was restricted to human adult population for the purpose of this review. Only those studies with $n > 20$ were included for the final analysis. Case reports, small case series, comments and editorials were excluded for part of this study. The search was conducted in PubMed database by the first author using the keywords "Multiple tract PCNL" or "Multiperc". The search recognized 103 studies in total, and was narrowed down to 72 studies after excluding duplicates and inclusion of five from the references. The abstracts of these 69 articles were screened and 10 articles (eight standard PCNL and two Mini-PCNL) were identified for full text eligibility into the study [6–15]. There were two authors who were retrieving the information independently and an agreement was touched upon the final inclusion articles. The likely shortcomings of a single database review system, heterogeneity of the included study population and selection bias are admitted.

1.2. Evidence synthesis

PCNL is the gold standard in the management of staghorn stones and complex renal calculi according to the AUA and EAU guidelines from stone management [1,2]. In the treatment of complex renal calculi, the limiting factor is

the morbidity associated with the establishment of multiple tracts. We decided to review the available literature on this topic and analyzed the 10 studies.

1.3. Study population

A total of 10 studies reporting PCNL for complex renal calculi were reviewed for this study (Fig. 1, Tables 1–3).

1.4. Number of tracts for stone clearance

Complex staghorn stones may require more than one tract for complete stone clearance. Single tract clearance has lesser morbidity, but gives suboptimal stone clearance and is advocated only for small burden staghorn stones [8,16]. In comparison to single tract approach, multiple tracts provide superior stone clearance [4,17]. The morbidity is directly proportional to the number of tracts used for the stone clearance, especially the bleeding. A concern of renal parenchymal damage and functional loss with multiple tracts exists, but available small scale studies suggest similar parenchymal damage in multiple versus single tract PCNL [18,19].

In this review, the number of tracts used for stone clearance varied from two to seven. Aron et al. [6] suggested that the commonest cause of bleeding has been persistence with a single tract to completely clear the stone. The prolonged intra-renal manipulation with the rigid nephroscope causes significant "torquing" effect against the PCS which results in bleeding. They promoted a wider indication for the use of multiple tracts and utilized two to seven tracts to clear the stone and they have found it to be safe. Hegarty and Desai [8] observed that the primary tract establishment by an urologist and routine upper polar access gave maximal stone clearance and minimized the number of secondary tracts. Mishra et al. [12] proposed the staghorn morphometry to estimate the number of tracts for stone clearance. They stratified the stone according to the total stone volume, favourable (obtuse angle to entry calyx with an infundibular width more than 8 mm) and unfavourable calyx (acute angle to entry calyx or infundibular width less than 8 mm) stone volume which could predict the entry calyx and the possible need for secondary tract placement for stone clearance.

1.5. Number of stages for stone clearance

A longer operative time is detrimental to the patient in terms of more fluid absorption and blood loss. The concept of staging the procedure, which is effective in dividing the surgery into two halves is not new [8,11,20,21]. With the establishment of more tracts and dividing the surgery into two stages, the concept of pre-placed tract stone clearance comes into the mainstay. The advantages are manifold: First, the patient has minimal hemodynamic alterations which is especially true for the elderly. The fluid absorption through the previously placed tract is less in comparison to the freshly placed tract. Secondly, the preplaced tract is more mature and bleeds less than the freshly placed tract. This decreases the blood loss during the procedure [22,23]. Thirdly, our experience shows that continuous irrigation of fluid masks the smaller fragments in the intraoperative

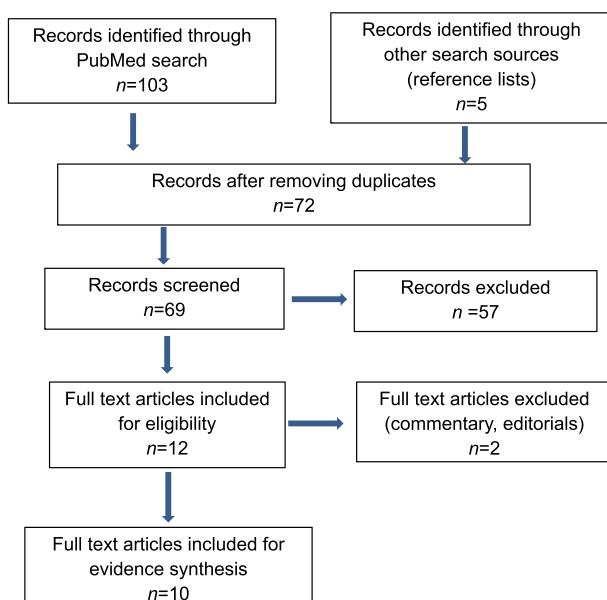


Figure 1 Consort flow chart of included studies.

period which becomes more visible on the plain X-ray kidney ureter bladder (KUB)/ultrasonography performed at 48 h after absorption of the extravasated fluid. Thus, a second stage or a check nephroscopy performed as a second stage definitely improves the stone clearance rate and minimizes the clinically insignificant residual fragments (CIRF) rate.

Maximal stone clearance with the primary tract within the stipulated time, which is usually 75–90 min of nephroscopy time, followed by placement of secondary tracts before completion of the first stage procedure is the optimal strategy [23]. Certain authors have advocated for calyceal puncture at the beginning before any stone removal as this allows an optimal distension of the system with dye seen fluoroscopically, or an ultra-sonographic access, both of which are difficult after dilation and partial stone clearance [6].

Preoperative prediction to stage the stone clearance using staghorn morphometry as suggested by Mishra et al. [12] helps in better patient understanding and compliance. They suggested that the decision to stage the disease depends on the total stone volume and the anatomic complexity of the pelvi-calyceal system.

1.6. Stone clearance

An untreated complex renal stone is likely to cause parenchymal destruction and ultimate deterioration of renal function. Every effort should be made for complete stone clearance as there are enough evidence to suggest higher likelihood for continuing stone growth and infection with incomplete stone clearance [24,25]. Overall, the rates of stone clearance in the different studies range from 78% to 95%. Various maneuvers have been suggested for complete stone clearance in these studies. Mishra et al. [12] suggested puncture of the entry calyx bearing the maximal stone and from where the rest of the stone could be accessed. Although it varied, in majority of these stones,

the calyx of entry was lower or middle calyces. This is in contradiction to the study by Aron et al. [6] and Zeng et al. [9], who preferred the superior calyx and middle calyx, respectively, to clear the majority of stones.

After clearing majority of stones through primary access tract, the bulk of the residual stone dictates the further course of management. Small volume of stone requires usage of flexible nephroscope to identify and manipulate the stone into the main calyx or pelvis from where it can be retrieved out [3,26]. Various baskets and newer stone expulsion devices help in getting the stone out of the adjacent calyces. *In situ* lasing is done if the stone cannot be moved out of the calyx. This is suitable only for small volume stones as a larger bulk prolongs the duration of surgery. Larger stones and stones in calyces parallel to the entry calyx mandate placement of second tract for complete clearance [3,6,7,9–11].

Any bleeding or prolonged duration of surgery mandates staging the procedure. Second stage PCNL for stone clearance varied from 12% to 35% in various studies. Staging the disease definitely improves the ultimate stone clearance. It remains to be seen if this helps in decreasing the stone recurrence in that particular renal unit. Need for auxiliary procedures for successful stone clearance varies from 8% to 20%. All types of procedures, namely SWL and flexible ureteroscopy (FURS) have been used by different authors for clearing the stones [27–31]. Size and location of the residual fragment and surgeon preference dictate the type of modality used for clearance of the residual fragment.

1.7. Complications of multi-tract PCNL

Complication of multitract PCNL is simply not an addition of the number of tracts used for the procedure. Without doubt, it is higher than a simple uncomplicated PCNL, however, it is a procedure which is done in select centres of excellence across the globe and hence this gets nullified to a certain extent. In this meta-analysis, the complications varied from 5% to 44% overall [6–15]. Here we describe the common and dreaded complications of PCNL, namely, bleeding and infection/sepsis (Table 2).

1.8. Post PCNL bleeding

The average Hemoglobin drop in these studies varies from 1.8 gm% to 8.3 gm%. Liu et al. [14] reported a Hemoglobin drop of 2.2 gm% in multiple tract approach versus 1.2 gm% in single tract PCNL. They observed that the reasons for the higher blood loss were due to the multiple punctures and dilations required in the multi-tract group and longer operative time. Desai et al. [10] published the largest series of multiple tract PCNL consisting of 500 patients with a mean hemoglobin drop of 2.1 gm% [10]. In the series by Fei et al. [13], the hemoglobin drop was 8.1 gm%, despite the fact that nearly 83% of patients had only two tracts for stone clearance.

Although all studies have been unanimous in mentioning the higher blood loss and hemoglobin drop associated with multiple tract PCNL, data on requirement of blood transfusion after multiperc are diverse. The blood transfusion

Table 1 Ten studies reporting PCNL for complex renal calculi were reviewed.

References	Renal units (n)	Male: Female	Mean age (year)	Stone burden*(as available in various studies)	No. of tracts	Operative time (min)	Stone clearance rate	Auxiliary procedure
Aron et al., 2005 [6]	121	88:15	43	3 089–6 012 (mean 4 800) mm ²	2 (n=11) 3 (n=68) 4 (n=39) 5 (n=3)	146 (100–180)	84%	Stage II PCNL:19 SWL: 8 (6.6%)
Liatsikos et al., 2005 [7]	100	NA	49 (24–72)	Complete staghorn: 90% Partial staghorn: 10%	2.4 (2–6)	110 (90–180)	87%	13% (3 URS, 5 SWL, 3 DJS)
Hegarty et al., 2006 [8]	20	4:16	54.4±12.4 (34–77)	MSA: 2 156.6±1 441.2 (55–4 720) mm ²	2.9 (2–6)	NA	95%	4 (20%) Stage II: 3
Zeng et al., 2007 [9]	100	69:31	46.6 (22–73)	2 274.63 (1 573.64–3 482.12) mm ²	2 (92) 3 (7) 4 (1)	107 (43–130)	93%	Stage II PCNL: 28 SWL: 2 URS: 2
Desai et al., 2008 [10]	500	400:100	NA	MSA>3 000 mm ²	2–7	88.7±22.6	84.1%	NA
Singla et al., 2008 [11]	164	118:31	39.8 (12–65)	Borderline: 36 Partial: 85 Complete: 43	2–47 3–73 4–41 5–2 6–1	NA	I stage–70.7% II stage–89%	Stage II PCNL: 30 (18.2%) SWL: 16 (9.7%) URS: 2 (1.2%)
Mishra et al., 2012 [12]	53	15:38	47.5±8.9	MSV: 18 835±17 924 mm ³	2 (n=7) >2 (n=21)	NA	92.9%	NA
Fei et al., 2014 [13]	55	28:27	52.23±7.37	MSA<3 000 mm ²	2 (46, 83.6%) 3 (8, 14.6%) 4 (1, 1.8%)	84.87±24.98	78.1%	2 SWL (3.6%)
Liu et al., 2016 [14]	34	19:15	54.3±6.43	MSA: 2 103 mm ² (1 404–5 660 mm ²)	2.38±0.70	86.62±26.82 (40–195)	27 (79.4%)	15 (44.1%) PCNL: 12 (35.3%) SWL: 3 (8.8%)
Liang et al., 2017 [15]	54	24:30	47.8 (41–63)	Largest size: 2.5–8.6 cm	3.6 (2–7)	78.7 (26–124)	24 (88.9%)	Stage II PCNL: 13 Stage III PCNL: 7

DJS, double J stenting; MSA, mean surface area; NA, not available; PCNL, percutaneous nephrolithotomy; SWL, shock wave lithotripsy (extracorporeal); TSV, total stone volume; URS, ureterorenoscopy.

Table 2 The common and dreaded complications of PCNL, namely, bleeding and infection/sepsis.

	Complication	Hb drop/blood loss	Blood transfusion rates	Hospital stay (day)	Infection/sepsis
Aron et al., 2005 [6]	NA	NA	18 (14.9%)	4 (2–16)	Grade II–22 (21.0%) Grade III–1 (0.8%)
Liatsikos et al., 2005 [7]	Minor: 17% Major: 7%	450 mL	45%	4.6 (3–14)	Grade I–12.0%
Hegarty and Desai, 2006 [8]	Minor: 30% Major: None	2.3 gm%	4 (20%)	4.25±1.74	Grade II–2 (10.0%)
Zeng et al., 2007 [9]	Minor–9 Major–6	112 mL (64–483 mL)	3 (3%)	9.4 (6–13)	7 (7.0%)
Desai et al., 2008 [10]	23 (5%)	2.1 gm%	62 (12. %)	11.1	NA
Singla et al., 2008 [11]	Minor–33.5% Major–15.9%	NA	46 (30.8%)	6.8 (3–28)	8 (5.3%)
Mishra et al., 2012 [12]	16 (30.1%)	1.85±1.7 gm%	NA	8.7±4.5	Grade I: 10 Grade II: 4 Grade III: 2
Fei et al., 2014 [13]	16 (30.1%)	8.23±2.39	4 (7.4%)	5.20±1.31	Grade I: 9 (17.0%) Grade II: 2 (3.8%)
Liu et al., 2016 [14]	15 (44.1%)	2.2±1.6 gm%	6 (17.6%)	9.1 (4–21)	Grade I: 6 (17.6%) Grade II: 2 (5.9%)
Liang et al., 2017 [15]	10 (18.5%)	97.3 (30–250) mL	None	18 (10–31)	Grade I: 4 (7.4%) Grade II: 6 (11.1%)

NA, not available; PCNL, percutaneous nephrolithotomy; Hb, hemoglobin.

requirement ranged from 7% to 20% in the included set of studies. Despite larger hemoglobin drop of 8 gm%, Fei et al. [13] had a transfusion requirement of only 7%. The authors acknowledged that the need for transfusion was subjective and influenced by the general condition of the patient, pre-operative absolute hemoglobin values, hemodynamic instability during surgery and the hemoglobin drop due to surgery. More anemic patients will necessitate apparently more blood transfusions, as against a well prepared patient, who might not require a transfusion even with a larger drop of hemoglobin. Liu et al. [14] and Desai et al. [10] observed that the multiple tract approach had a larger need for blood transfusion as against the single tract approach, but the difference was not statistically significant.

Zeng et al. [9] observed that the bleeding risk was higher with the larger sized tracts used with clearance of large sized stones and hence recommended minimizing the tract size to only 18 Fr in clearing large stones as well. Ganpule et al. [3] and Desai et al. [10] also observed similar findings and restricted the tract sizes to 26–28 Fr and avoided standard amplatz dilation up to 30 Fr or 32 Fr. For reasonably smaller of the larger sized stones, multi-miniperc is ideal to decrease the blood loss. Manohar et al. [5] utilized smaller tracts in children to minimize the blood loss with comparable stone clearance rates. Another measure suggested to decrease the blood loss was the usage of ultrasonography for puncture, which resulted in more perfect angle of entry into the target calyces. It is also helpful to puncture the different calyces at the beginning of the case with a guidewire left *in situ* and leave the tract dilation to be performed at the time of usage of the tract as pre-emptive dilation leads to more blood loss for the entire duration of surgery [3,4,10,32–34].

1.9. Infection and sepsis related complications

Complications encountered during the postoperative period, graded according to the Clavien Dindo Grading was analyzed [35,36]. In total, majority were Grade I complications (7.4%–17.6%) and others were Grade II (3.8%–21.0%). There were very few Grade III septic complications reported in few studies amounting to 0.8%–1.0% [6,12]. The literature has been divided with respect to infectious complications post multiple tract PCNL. In a study by Sharma et al. [37] wherein they identified the factors predicting infection following PCNL, multiple tract usage increased the risk of infection. Korets et al. [38] used urine culture and pelvic urine culture to prospectively identify patients who develop systemic inflammatory response following PCNL. Multiple tract PCNL predisposed to more infectious complications in this study as well. The factors responsible for more infection could be increased number of tubes serving as a portal of entry, vascular damage leading to ischemic milieu for propagating infection and opened vascular channels which serve as a route of entry of bacteria into the blood stream leading to systemic response [37–39].

Contemporary literature suggests that establishing multiple tracts might as well be protective against infectious risk or at the minimum; it is no different from standard PCNL. The proponents of this hypothesis suggest that the predominant factor causing infection and sepsis after PCNL is secondary to increased pelvic pressure causing pyelo-venous backflow [39]. The normal pelvic pressure ranges from 1.47 mmHg to 4.41 mmHg and can increase manifolds according to the irrigation inflow, volume of the pelvicalyceal system (PCS), nephroscope size, presence or absence of Amplatz sheath, combined

Table 3

References	Clavien Dindo Grade I	Clavien Dindo Grade II	Clavien Dindo Grade III A	Clavien Dindo Grade III B	Clavien Dindo Grade IV and V
Aron et al., 2005 [6]	None	22 UTI antibiotic change (21%) 18 blood transfusion (14.9%)	5 DJS for prolonged PCN site leak 2 angioembolization 3 chest drain placement (7.1%)	None	1 sepsis (0.8%) 2 ileus
Liatsikos et al., 2005 [7]	12 UTI 1 hydrothorax	3 pneumonia (antibiotic change) 1 DVT	3 DJS for prolonged PCN site leak 1 angioembolization	None	1 paralytic ileus
Hegarty and Desai 2006 [8]	NA	2 antibiotic change (10%) 4 blood transfusion (20%)	None	None	None
Zeng et al., 2007 [9]	2 hydrothorax observation	4 antibiotic change 3 blood transfusion	2 (change in DJ/PCN) 1 angioembolization 1 chest drain placement	2 (URS)	None
Desai et al., 2008 [10]	NA	19 blood transfusion (8.4%)	None	None	Not available
Singla et al., 2008 [11]	3 hydrothorax observation	6 antibiotic change 46 blood transfusion (30.8%)	15 DJS (9.1%) 4 angioembolization (2.4%) 4 chest drain insertion (2.4%) 1 aspiration of peri-nephric collection	None	2 septic shock
Mishra et al., 2012 [12]	10 (18.9%)	4 (7.5%)	2 (3.8%)	None	None
Fei et al., 2014 [13]	10 (18.9%) 9 transient fever 1 PCN tube displacement	6 (11.3%) 2 antibiotic change 4 blood transfusion	None	None	None
Liu et al., 2016 [14]	6 fever (17.6%)	2 antibiotic change (5.9%) 6 blood transfusion (17.6%) 1 prolonged leak	None	None	None
Liang et al., 2017 [15]	2 self limited bleeding (3.7%)	6 antibiotic change (11.1%)	None	None	None

DJS, double J stenting; DVT, deep vein thrombosis; NA, not available; PCN, percutaneous nephrostomy; URS, ureterorenoscopy; UTI, urinary tract infection; DJ, double J stent; PCN, percutaneous nephrostomy.

suction usage during intra-corporeal lithotripsy in PCNL and the size of the ureteric catheter used and the egress of outflow fluid from the PCS [40,41]. Zhong et al. [42] identified postoperative fever in patients who had a high renal pelvic pressure (RPP) of more than 30 mmHg and more than 50 s during surgery [42]. Infected system might be more susceptible to this damage at a lower pressure threshold. Abourbih et al. [39] studied the effect of multiple tract PCNL on RPP wherein the pressures were significantly low during multiple tract PCNL (9.35 mm Hg without suction) as against single tract PCNL (31.35 mm Hg without suction). It remains to be seen if this translates in to lesser pyelovenous backflow with multiple tracts, but it is logical that an additional portal of egress of fluid out of the PCS when the second tract is kept open definitely decreases the intra-pelvic pressure [39,42].

1.10. Safety of multiperc approach

Akman et al. [43] compared the effect of multiple-tract PCNL in 413 patients and found no significant difference in the mean changes in the creatinine values between the multiple tract and single tract approaches. Fayad and coworkers [44] estimated the effect of multiperc PCNL on renal function and established that patients with baseline renal impairment (serum creatinine level ≥ 1.4 mg/dL) experienced worsening of serum creatinine and deterioration of glomerular filtration rate (GFR). Liu and colleagues [14] showed in their retrospective analysis that the mean change of serum creatinine was not statistically significant between the two groups. Studies using cystatin C for renal functional estimation have also showed no significant difference between preoperative and postoperative values [13].

PCNL definitely damages renal parenchymal tissue leading to a permanent scar at the site of the nephrostomy tract. The amount of renal damage has been estimated by Clayman et al. [45] and Traxer et al. [46] in animal models, wherein they found the mean scar volume to be 0.294–0.43 mm³ amounting to 0.13%–0.16% of the total kidney volume. This miniscule loss of renal tissue from a single-tract PCNL procedure appears to have little impact on long-term renal function as gauged by Krambeck et al. [47] in their longitudinal follow-up study of PCNL treated patients over 19 years, wherein the subjects had no increased associations with hypertension, diabetes or chronic renal damage.

We have presented the best available evidence from the literature on this topic, but the authors would like to point out the demerits of this study. The study population from these 10 studies is heterogeneous and the sample size of eight of these studies was found to be less than 100. The conclusion drawn out of this systematic review needs to be confirmed with large scale multi-centric randomized controlled trials. Meta-analysis could not be performed as the data analyzed from the studies are diverse with the different studies using varied number of tracts and the results of the studies are heterogeneous with different summarization and results.

2. Conclusion

Multiperc appears to be a safe and feasible option for the management of complex renal calculi with respect to stone clearance and morbidity associated with the procedure. It is effective and the chance of complete stone clearance as a single procedure is high as against flexible ureteroscopy or SWL.

Author contributions

Study design: Sudharsan Balaji, Arvind Ganpule.

Data acquisition: Sudharsan Balaji.

Data analysis: Sudharsan Balaji.

Drafting of manuscript: Sudharsan Balaji, Arvind Ganpule.

Critical revision of the manuscript: Thomas Herrman, Ravindra Sabnis, Mahesh Desai.

Conflicts of interest

The authors declare no conflict of interest.

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