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Review

Multitract percutaneous nephrolithotomy in staghorn calculus

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Abstract Staghorn calculi are branched stones which occupy a majority portion of the pelvicaliceal system. An untreated staghorn calculus over time can damage the kidney and deteriorate its function and/or cause life threatening sepsis. Total stone clearance is an important goal in order to eradicate any infective focus, relieve obstruction, prevent recurrence and preserve the kidney function. Percutaneous nephrolithotomy (PCNL) is currently the accepted first-line treatment option for staghorn calculi. The options available are single-tract PCNL with an auxiliary procedure like shockwave lithotripsy, single-tract PCNL with flexible nephroscopy, or multitract PCNL. Each has its own pros and cons. But the ultimate goal of treatment for any patient with staghorn calculi should be safety, cost-effectiveness, and to achieve total stone clearance. With this article, we review the management of staghorn calculi with multiple percutaneous ("multitract") access, its advantages and disadvantages and its current position by studying the various published materials across the globe.

1. Introduction

The management of staghorn calculi continues to remain a challenge despite the advances in instrumentation and technology. The various options available in the treatment of staghorn calculi include percutaneous nephrolithotomy (PCNL) monotherapy, single-tract PCNL with flexible nephroscopy, multitract PCNL, combinations of PCNL and extra corporeal shock-wave lithotripsy (ESWL), ESWL monotherapy and open surgical options. The European Association of Urology and American Urological Association (AUA) guidelines recommend PCNL as the first

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line treatment for large burden stones (size >2 cm). PCNL is a safe and minimally invasive approach when compared to open surgery for patients with staghorn calculi [1]. Only a few studies in the literature report the advances and trends in the use of PCNL for large burden renal calculi.

The complete stone clearance is the cornerstone of the management of staghorn calculi. Percutaneous access for stone clearance has been modified, improvised and evolved into being a standard of care for treatment of renal stones. Jackman et al. [2] introduced the miniaturized percutaneous nephrolithotomy (mini-PCNL). It has been further modified as "minimally invasive PCNL (MIP)" with a continuous low-pressure irrigation system favouring faster stone clearance and avoiding nephrostomy tubes [3]. The safety and efficacy of MIP in treating patients with large complex staghorn stones have been questioned, mainly due to the smaller access sheath, leading to a comparatively reduced visibility, prolonged operative time and reduced stone-free rate (SFR) [4]. The debate continues over the use of single-tract versus multiple-tract PCNL in these large staghorn stones. With either method, the primary objectives would be complete clearance of the stone with minimal morbidity [5]. In this review, we want to bring out the use of multitract PCNL for staghorn stones.

2. Materials and methods

The initial literature database used for the analysis was developed using MEDLINE® and MeSH® headings search related to PCNL, staghorn calculi, multitract and bleeding in PCNL. Fifty-two citations were chosen on the basis of key words and recommendations by the authors, and thirty-four articles were ultimately shortlisted and included for the final review. In view of the paucity of manuscripts on staghorn calculus management in general and multi tract approach in particular, all the available articles with >100 cases and also the smaller but important and statistically significant studies were chosen for the review upon discussion among the authors. The authors concluded that the following points are to be studied and addressed with respect to the multi tract approach in the management of staghorn calculus (Table 1): Imaging modality, planning the procedure, access, stone-free rate, postoperative assessment, complications, and concerns regarding loss of renal function.

2.1. Imaging modality and planning

The distribution of staghorn stone burden in the pelvicaliceal system (PCS) is an important determinant of the complexity of PCNL. Appropriate blood investigations (complete blood count, coagulation profile and serum creatinine) and urinary microscopy with culture and sensitivity testing should be considered.

No direct evidence is available from the literature to support routine use of functional evaluation in all cases of renal calculi. Parenchymal bulk correlates well with differential and absolute function of the renal unit. Exact functional status information is needed only for cases where anatomical information suggests possibility of poorly functioning renal unit which might change the plan of action. Even in such cases it has been suggested that differential function can be fairly ascertained based on parenchymal bulk. Cases with medical renal disease need exact estimation of differential and absolute renal function using radionuclide scans as evidence is not clear about worth of parenchymal thickness in them. In the absence of intravenous pyelography/contrast enhanced CT (IVP/CECT) all efforts must be made to have good anatomic information by combining ultrasonography (USG)/X-ray kidney urinary bladder (KUB)/non contrast CT (NCCT)/magnetic resonance imaging (MRI)/magnetic resonance (MR) urogram/retrograde pyelography (RGP). IVP/CECT are still worthy and relatively safe modalities for obtaining good anatomic information from a single investigation and direct information about renal function from them is appreciable.

Non-contrast CT and contrast urography with three-dimensional (3D) reconstruction help in planning the percutaneous access for multi tract approach. However, for those with compromised renal function, a non-contrast 3D CT would help to assess the PCS, as well as the stone bulk and location [5]. Percutaneous nephrostomy (PCN) is performed in patients with renal insufficiency and severe infection to improve drainage and renal function. USG guided percutaneous drainage with patients under local anaesthesia in a predetermined calix will facilitate the stone removal later [6].

Various scoring systems exist in literature for predicting the complications and stone clearance during the preoperative planning stage. The S.T.O.N.E. nephrometry score was proposed by Okhunov et al. [7] for predicting the outcome of PCNL, with scores varying from 4 to 11. A preoperative CT scan analyzed the stone size (S), tract length

Table 1 Studies of multiple tract percutaneous nephrolithotomy.

Studies	No. of renal units	No. of tracts (most commonly)	Stone free rate (%)	Complications (major) (%)	Blood transfusion (%)	Hospital stay, mean (range), day
Singla et al. [23]	149	2–6 (3)	88.9	14	46	6.8 (3–28)
Aron et al. [14]	121	2–3 (2)	84	4.1	14.8	Not mentioned
Zeng et al. [25]	100	2–3	93	4	3	9.4 (6–13)
Liatsikos et al. [11]	100	2–6 (2)	87	10	45	4.6 (3–14)
Wong and Leveillee [13]	35	2–3	95	2.8	2.2	2 (1–10)
Hegarty and Desai [19]	20	2–6 (3)	95	10	20	4.25±1.74
Marguet et al. [16]	7	2–3	71.4	0	0	Not mentioned
Desai et al. [5]	500	2–3	84.1	5	12.4	11.1

(T), presence or absence of obstruction (O), number of involved calices (N) and stone essence/density (E). Increasing score positively correlated to higher blood loss, complication rate and hospital stay, whereas it inversely correlated to the clearance rate [7].

Mishra et al. [8] conducted a volumetric data assessment of stone burden, correlating the tract and stage requirement for complete clearance in PCNL done for staghorn calculi. The classification was made according to the total stone volume (TSV) and unfavorable calyx stone percentile volume (UFCSPV). CT scan volumetric assessment software, 3D-DOCTOR™ (Able Software Corp., Lexington, MA, USA) was used to assess the stone volume. The assessment of favorable and unfavorable calyx was performed on the image plane view of the software. A favorable calyx was defined as a calyx-containing stone that is at an obtuse angle to the entry calyx and has an infundibular width >8 mm. The stones were classified as: Type 1: <5 000 mm^3 TSV and <5% UFCSPV; Type 2a: 5 000–20 000 mm^3 TSV and <5% UFCSPV; Type 2b: <20 000 mm^3 TSV and >5% UFCSPV; Type 3: >20 000 mm^3 and any UFCSPV. In this study, the percentage of UFCSPV predicted the number of tract requirement while the TSV predicted the stage requirement in PCNL. The combination of TSV and UCSPV predicted the complexity of staghorn. The odds ratio increased adversely for multiple tracts as the UCSPV increased.

A significant proportion of staghorn stones require multiple PCN tracts and more than one stage of percutaneous procedure to achieve satisfactory result. Zhao et al. [9] remarked that multitract PCNL used either as intended one stage or as planned two stages procedure is a safe and effective modality in the treatment of staghorn stones. Their data suggested that it is more advantageous to employ the planned "two stages" approach than the intended "one stage" procedure due to the lower complication rates in the former.

2.2. Access

PCNL is varied with respect to different approaches for renal staghorn stones in terms of patient position, number of tracts, size of the tracts and intra-corporeal energy sources utilized, but the key to the success still remains a good access to the PCS which determines the ultimate success of the procedure—complete stone clearance with less morbidity. The basic procedure of multitract PCNL involves multiple punctures and tract establishment for total stone clearance. The basic principles of puncture, namely puncturing the centre of the papilla through the shortest possible skin entry should be followed. Desai et al. [10] suggested USG guided puncture into all required calyces and placement of guidewires in the desired calices, because it would become increasingly difficult as the procedure proceeds. The first tract to be used should be the one from wherein the majority of stone burden can be cleared. Subsequent punctures are done, if required depending on the remaining stone burden and the general condition of the patient. For supracostal access, the needle puncture will be placed immediately above the upper border of the lower rib to avoid damage to the intercostal vessels. As far as possible, punctures above the 11th rib should be avoided, since they are associated with higher (16-fold greater than supra-12th access) incidence of chest complications.

Liatisikos et al. [11] advocate a superior calyceal approach into the PCS for staghorn calculi. This is because the posterior upper pole calyx is in the most posterior portion of the kidney and hence it provides the most direct access to the renal pelvis, upper ureter, upper pole calyces, and also the lower pole calyces. In majority of the cases, the superior calyx is situated above the 12th rib because 80% of the right renal upper pole calyces and 85% of the left renal upper pole calyces are usually situated above the 12th rib in maximum expiration. Not all authors support an upper polar access for staghorn stones. Preminger et al. [12] demonstrated 2.2 cm cephalad movement of the kidney when patients were placed in prone position as viewed on intravenous pyelography. Hence the direct access to a superior calyx would require a supracostal puncture in more than 80% of patients. An intercostal puncture above the 12th rib carries a 2.8%–12% risk of pleural injury and chest complications [13]. Additional middle or lower pole calyceal punctures will require separate subcostal accesses either at the same setting or a different session and separate nephrostomy tubes for drainage through the different access routes.

Aron et al. [14] suggested fresh tracts to retrieve tenuous stones and larger fragments from peripheral calyces as reaching them from the primary access tract gave rise to "torquing" and subsequent bleeding. These punctures were usually made towards the end of the procedure, since anterior calyceal tracts tend to bleed more as a greater bulk of renal parenchyma is traversed by the dilators and sheath, since the entry into the calyx is side-on and not as end-on as a posterior calyx entry is in a prone patient. They believed that judiciously made multiple tracts do not significantly increase the intraoperative complications and transfusion requirements. In this series, as many as six percutaneous tracts (median three) were created in a single operative session to achieve complete stone clearance with 59.7% being supra-costal access. In a separate study done by Annes et al. [15] an intercostal approach was used in 43% of the single-tract accesses and 47% of the multi-tract accesses. The number of multiple tracts ranged from 2–3 per kidney, with 2 tracts being the most common.

Other authors have suggested ureteroscopy guided access wherein ureterorenoscopy was performed from below first to clear the stones in the peripheral calices, which would have needed a second or third nephrostomy access in the supine position. Once the remote calculi were cleared, then the patient was placed in the prone position and single access PCNL performed, but this procedure is not cost effective and has a steep learning curve [16].

Carefully chosen and planned access can also decrease the need for auxiliary procedures as shown by Lam et al. [17]. With substantial use of multiple tracts, they have been able to decrease ESWL requirement as an auxiliary procedure from 64.7% to 35.2% [17]. Nephrolithotripsy time is limited to around 90 min [5]. The procedure can be staged by placing a nephrostomy tube. If any of the punctures are not used in the first sitting because of restricted nephroscopy time, then the tract is dilated and a 14 Fr Malecot catheter is placed to allow tract maturation before the second stage.

The second stage is usually performed after 48 h, and residual stone burden is removed.

2.3. Postoperative assessment

Clearance during/after surgery can be assessed with intraoperative nephroscopy with or without fluoroscopy, plain KUB radiography with or without USG or plain CT KUB or check nephroscopy done at 24—48 h postoperatively before removing the tubes [18]. Plain CT KUB done within 48 h postoperatively shall also be considered to confirm the size of the residual fragments. If residual stone fragments are noted, a decision to proceed further depends on the size and location of the residual stone. A small fragment of size <5 mm might get expelled by a double-J stent with medical therapy. The authors advocated a second-look nephroscopy for larger stone fragments or in doubtful cases [5].

At their centre, Desai and colleagues [10] strictly follow a thorough surveillance plan, at 1 month after surgery with a plain abdominal film, renal USG, urine microscopy with culture analysis and a 24-h urinary metabolic evaluation (during which double-J stent would be removed), then every 3 months for first year, with X-ray KUB and USG at 1 year. Thereafter, a yearly clinical evaluation is used, with renal USG, plain X-ray KUB, blood and urine examinations [10]. Pearle et al. [18] has compared the use of non-contrast helical CT and plain X-ray KUB against the gold standard flexible nephroscopy on postoperative Day 2 or 3 to assess the accuracy of predicting the presence of residual fragments. They concluded a sensitivity and specificity of X-ray KUB and helical plain CT to be 46% *vs.* 100% and 82% *vs.* 62% respectively. Based on these findings, they suggested the elective use of flexible nephroscopy after PCNL based on CT findings, which avoided an unnecessary intervention in 20% of patients. Few have recommended the postoperative assessment on the basis of the density of the stone during the preoperative assessment. Hegarty and Desai [19] suggested the use of KUB films for radio-dense calculi such as calcium oxalate or a non-contrast helical CT scan for patients with lesser dense calculi such as struvite or other radiolucent stones.

2.4. SFR

The basic essence of treating any staghorn calculus is for maximum stone clearance with limited morbidity and preserved renal function. The AUA Nephrolithiasis guidelines panel on staghorn calculi [1] mention that there is 79% stone clearance rate with PCNL monotherapy. Guy's stone score is comprised of four grades which takes into account the anatomical distribution of the stone with PCS morphology and presence of spinal injury (Grade I: Single stone in mid/lower pole or single stone in the pelvis with simple anatomy; Grade II: Single stone in upper pole or multiple stones in a patient with simple anatomy or a single stone in a patient with abnormal anatomy; Grade III: Multiple stones with abnormal anatomy/calyceal diverticular stones/partial staghorn calculus; Grade IV: Staghorn calculus or any stone in patients with spina bifida/spinal injury) [20]. Guy's stone score, though not just limited to staghorn stones, is the only factor that significantly and independently predicted the SFR.

Risks of percutaneous procedures can be limited and higher single stage SFR can be achieved by constructing a 3D model of renal stones. Li et al. [21] performed PCNL with the assistance of the 3D model and found it to be effective in achieving a single-stage SFR of 93.3%. Rippel et al. [22] in their study defined residual fragments (RFs) as any ipsilateral renal or ureteral calculus greater than 2 mm on Plain CT performed between 1 and 3 months after surgery.

Singla et al. [23] studied a cohort of 164 renal units comprising 43 (26.2%) complete staghorn calculi, 85 (51.8%) partial staghorn calculi, and 36 (22.0%) with a borderline stone bulk. As many as six percutaneous tracts (median three) were created in a single operative session to achieve complete stone clearance. Complete stone clearance after a single session of PCNL was achieved in 116 renal units (70.7%), and 30 (18.3%) required a second look procedure. Of the 164 renal units, 146 (89.0%) were completely stone free after the second procedure. On the basis of these findings, they advocated the use of an additional tract for a larger stone bulk which enables complete clearance more efficiently and reliably than the use of a flexible nephroscopy which they found to be more tedious, time consuming and prone to leave some residual fragments behind.

Hegarty and Desai [19] in their study comparing the morbidity of multiple tracts when compared to the single tracts, observed that all single-tract and 95% of multiple-tract patients were rendered stone free. Liatsikos et al. [11] saw 87% SFR in a single session when the superior calyx was approached by a subcostal triangulation technique and the middle and lower calyces were approached by angular punctures, monitored by biplane fluoroscopy. Martin et al. [24] reported their results of PCNLs for 166 complete staghorn calculi. After one, two, three and four sessions, 45 (46%), 39 (40%), 9 (10%) and 4 (4%) patients respectively were rendered stone free. Stone clearance was 70% in patients who underwent clearance in a maximum of two sessions whereas those requiring more than two sessions still had a high residual rate of 61%. They further reported the requisite of more than one access in 58% of patients to a maximum of six tracts in their cohort. Their primary clearance rate decreased whenever they found the need for more than three tracts in total (68% stone free and 55% need for auxiliary ESWL *vs.* 52% stone free and 76% need for auxiliary ESWL).

Aron et al. [14] identified the need for fresh tracts to retrieve elusive stones whenever the stones were present in peripheral calyces. A multiple tract PCNL monotherapy and PCNL followed by SWL achieved a clearance rate of 84% and 94% respectively, with residual stone rate of 6% (seven units). The authors suggested a higher SFR achieved with a multi-tract percutaneous approach could possibly result in a lower stone recurrence rate, and lower incidence of recurrent UTI during long term follow-up. In their series, Desai et al. [5] also observed complete clearance in 84.1% of patients with the usage of multiple tracts in a single hospital stay (average 11.1 days) with minimal morbidity. Zeng and coworkers [25] limited the sizes of the multiple tracts to 14—18 Fr and were still able to achieve clearance

of 93% (100 renal units). Marguet et al. [16] compared combined ureteroscopic lasing of stone and PCNL to multiple access PCNL in clearing struvite staghorn stones; the former was associated with comparatively less blood loss and good stone clearance rate. Further, endoscopic combined intra renal surgery (ECIRS) is commonly performed in modified Valdivia position as it is more comfortable for the surgeon, has optimal cardiovascular and respiratory control especially in obese individuals, superior stone fragment washout and lower intra-pelvic pressure but carries the disadvantage of restricted space for renal puncture and nephroscope mobility, difficult lower pole puncture and also continuously collapsed collecting system. ECIRS is associated with improved SFR and reduced radiation exposure [26]. Hamamoto et al. [27] found the application of mini-ECIRS (RIRS and MiniPerc) for >3 cm stones and staghorn stones to have an excellent SFR of as high as 71.4% as against the miniperc which had poorer results (SFR of 38.9%)

Zhong et al. [28] described 54 patients with staghorn calculi who were prospectively randomized for multi-tract PCNL and single-tract PCNL. Multi-tract PCNL was associated with higher clearance rate, less need for adjunctive procedure, and the complication rates were comparable. Akman et al. [29] compared the early outcome of single-tract versus multiple-tract PCNL in the management of staghorn calculi. This retrospective study revealed a SFR of 70.1% and 81.1% in single-tract and multiple-tract groups, respectively. Maghsoudi et al. [30] achieved a SFR of 83%, but they claimed that the SFR and hospital stay were proportional to the stone size rather than the number of tracts. One of the prime concerns of the single-tract approach is the hindered vision secondary to bleeding, challenging the use of flexible nephroscopes. On the other hand, multitract PCNL has the ability to achieve stone clearance without increasing the cost of flexible instruments and the vision remains better with a good puncture. In the event of a patient requiring multi-tract PCNL, appropriate staging of the procedure, proper instrument selection and suitably timed multi miniperc procedure with USG access can achieve maximal stone clearance with minimal morbidity.

2.5. Complications

An unattended staghorn calculus can damage the kidney and can cause life threatening sepsis. Complete stone clearance is an important goal to eradicate the infection, relieve obstruction, prevent stone growth, and preserve kidney function. A concern with creating multiple percutaneous tracts is the possibility of higher bleeding and complication rates compared with procedures that require a single tract (Table 2). PCNL monotherapy with multiple tracts is associated with acute complication rates of 15% and transfusion rates of 18% [1]. Singla et al. [23] also observed a similar complication rates and transfusion rates (18.7% due to the procedure *per se*).

Martin et al. [24] reported their results of complete staghorn calculi ($n=166$), in which haemorrhage was reported in 20% of patients. The incidence of significant bleeding increased with the number of punctures, with 14% of cases with less than two punctures and 36% with greater than two tracts. The transfusion rates also differed significantly, with 20% and 41.6% requiring transfusion in patient with less than or more than two tracts for stone clearance. Lee et al. [31] with an average access tracts of two or more, reported a transfusion rate of 57%. Akman et al. [29] also observed that bleeding was significantly more common in the multiple-tract group.

Most other authors have not observed any difference in the complication rates between the single tract and multi-tract approaches. In their series, Desai et al. [10] observed that the overall hemoglobin drop was 1.4 g/dL and 2.1 g/dL in single tract and multi-tract PCNL respectively. However, the results were confounded by the presence of anemia and renal insufficiency in the multi-tract group. Hegarty and Desai [19] narrated a mean drop in haemoglobin to be similar in the two groups (2.3 g/dL for single tract *vs.* 2.1 g/dL for multiple tracts). They also observed that the need for transfusion correlated with lower preoperative haemoglobin and higher preoperative serum creatinine. There was a significant rise in serum creatinine (1.67 mg/dL to 1.91 mg/dL) and drop in creatinine clearance (76.9 mL/min to 67.2 mL/min) in the multi-tract group; this was more evident in patients with prior renal insufficiency. No major change in renal function was seen in the single-tract group. They found a positive correlation between a higher preoperative serum creatinine, low preoperative haemoglobin, and transfusion requirements.

Auge et al. [32] found no significant difference in blood loss, transfusion rates, complications, or length of surgery with increasing number of tracts. Annes et al. [15] reported a mean estimated blood loss, mean haemoglobin drop, mean operative time and drop in creatinine to be 92.0 mL per renal unit, 1.1 g/dL, 58.8 min and 0.02 mg/dL *vs.* 131.7 mL per renal unit, 1.5 g/dL, 56.2 min and 0.6 mg/dL in the single tract and multi-tract group respectively. There was no difference in the number of complications between the two groups.

The dreaded morbidity of bleeding, even after multi-tract approach is managed conservatively in majority of these series. Desai et al. [10] have shown the importance of the learning curve and use of USG guidance for reducing bleeding. It has been reported that the use of large-sized Amplatz sheath results in more blood loss and subsequent increased transfusion rates [4]. The measures taken to reduce the bleeding further are USG guided punctures, restricting the Amplatz sheath sizes to 26—28 Fr and dilation of the punctured tracts just before their usage. The same measures also brought down the incidence of other complications to bare minimum, namely, bowel injuries (0.35%). Zeng and coworkers [25] also restricted the multiple tracts to 14 Fr to 18 Fr and could achieve a blood transfusion rate of only 3%. Manohar et al. [33] studied the effectiveness of PCNL in children <5 years, wherein they witnessed more blood loss in patients requiring multiple tracts ($p=0.008$); nonetheless, staging the procedure did not increase the blood loss ($p=0.06$). They tackled the issues of hypothermia, blood transfusion, visceral injury and radiation exposure by the following modifications (staged multi mini-perc concept): Restricting the operative time to 1 h, appropriate staging of the procedure, wise selection of

Table 2 Complications (Clavien-Dindo classification).

Studies	Clavien Grade I	Clavien Grade II	Clavien Grade III	Clavien Grade IV
Hegarty and Desai [19] ($n=20$)	Fever 5%	—	—	—
Fei et al. [34] ($n=55$)	Nephrostomy tube displacement 1.89% Fever 16.98%	Blood transfusion 7.54% Non septic infections requiring additional antibiotics 3.78%	—	—
Desai et al. [10] ($n=773$)	Fever 24.9%	—	Clavien Grade IIIb: Bowel injury 0.35%	—
Zhao et al. [9][a] ($n=290$)	Fever Group 1: 13.1% Group 2: 7.9%	Blood transfusion Group 1: 3.4% Group 2: 9.7% SIRS Group 1: 12.4% Group 2: 6.2%	Angioembolization Group 1: 1.4% Group 2: 4.1%	Septic shock Group 1: four cases Group 2: two cases
Wong and Leveillee [13] ($n=49$)	Fever 12%	—	—	—
Singla et al. [23] ($n=149$)		Blood transfusion 30.8%	Hydrothorax 4.2% Angioembolization 2.4% Perinephric collection one case Hemothorax one case	Clavien Grade IVa: Urosepsis 5.3% Clavien Grade IVb: Second look PCNL 18.2% Double-J stenting 9.1%
Annes et al. [15] ($n=12$)	—	Blood transfusion 8.3%	—	—
Martin et al. [24] ($n=166$)	—	Blood transfusion <20% in <2 punctures 41.6% in >3 punctures	—	—
Hegarty and Desai [19] ($n=20$)	—	Blood transfusion 20%	—	—
Lee et al. [31] ($n=582$)	—	—	Clavien Grade IIIb: Colonic injury Urinary extravasation 7.2%	—
Aron et al. [14] ($n=121$)	—	—	—	Sepsis 0.97%

PCNL, percutaneous nephrolithotomy; SIRS, systemic inflammatory response syndrome; —, there were no reported complications in that particular grade of complication.

[a] $n=145$ pairs; Group 1: Two stage; Group 2: One stage.

the tract size and ultrasonographic puncture with fluoroscopic control.

The other complications were also not significantly different between the two groups, as reported in literature. Fei et al. [34] in their study found ten Clavien Grade 1 (nephrostomy tube displacement and transient fever <38 °C) (62.5%) and six Clavien Grade 2 (Bleeding requiring transfusion, Non-septic infections requiring additional antibiotics) (37.5%) complications; however, there were no complications above Clavien Grade 3. They inferred that total US-guided single-stage multiple-tract PCNL for treating staghorn calculi in selected cases was safe and feasible.

Zhao et al. [9] concluded in their retrospective study comprising 145 pairs (Group 1: Two stage and Group 2: One stage) that there was a considerably decrease in the mean number of total access tracts, infection complications, and blood transfusion rate in Group 1 than in Group 2. The infection and bleeding complications were similar in both groups. Their data suggested that the staged approach with the use of a single access tract in the initial procedure followed by additional tracts in the second stage may reduce the risk of infection complications.

Factors such as positive preoperative urine culture, infection stones, staghorn stones, stone size, diabetes, multiple punctures, and length of operative time are all important predictors for postoperative infection complications. Viprakasit et al. [35] reported 65% positive urine culture for staghorn stones and 38% for metabolic stones. Maghsoudi et al. [30] in their study also found that postoperative fever correlated with stone size and number of tracts.

2.6. Concerns regarding loss of renal function

The ultimate aim of any stone clearance surgery is to preserve the renal function. The multiple tracts with multiple

nephrostomy tubes, besides adding to increased postoperative patient discomfort and hospital stay, also lead to multiple skin scar formation. Clayman et al. [36] found the mean scar volume to be 0.294—0.430 mm^3 in animal models, and its ratio to total kidney volume to be 0.13%—0.16%. The results given above revealed that injury of the percutaneous tract to renal parenchyma is minimal, and the idea of performing multiple-tract PCNL for large complete staghorn calculi is completely safe and feasible. Hegarty and Desai [19] showed no significant impact of PCNL on renal function in patients requiring single-tract or multiple tract access. As a group, patients requiring multiple tracts had a significant postoperative increase in serum creatinine; however, an increase 0.5 mg/dL was seen only in patients with a high baseline serum creatinine of 1.4 mg/dL.

3. Conclusion

PCNL using multiple tracts is reasonably safe and effective, and should be the first option for massive renal staghorn calculi. Complete clearance of staghorn calculi with a multitract PCNL approach is definitely feasible and more importantly is cost-effective. Multiple-tract PCNL exhibits a similar safety profile to single-tract access and the dreaded morbidity is bleeding, most of which is managed conservatively. There was a modest trend towards shorter operative times in the multi-tract cohort, despite a larger average stone burden.

Author contributions

Study concept and design: Arvind P. Ganpule.
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Conflicts of interest

The authors declare no conflict of interest.

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