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Developments in technique and technology: the effect on the results of percutaneous nephrolithotomy for staghorn calculi

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OBJECTIVE

To review the development of the technique of percutaneous nephrolithotomy (PCNL), for ease of learning and development of instrumentation for staghorn calculi at our centre since 1991, and to assess the results and outcomes.

PATIENTS AND METHODS

We retrospectively analysed the hospital records of 773 patients (632 males and 141 females, 834 renal units) who underwent PCNL for staghorn calculi at our centre from January 1991 to August 2008. We divided the patients into three groups depending on the changes in treatment policy, global trends and advances in equipment as follows: the first 200 cases (group I) from January 1991 to December 1996 (216 renal units); the next 200 (group II) from January 1997 to December 2001 (212 renal units); and the last 373 (group III) from January 2002 to August 2008 (406 renal units).

RESULTS

The mean (SD, range) operative duration in groups I, II and III, respectively, were 138.2 (52.7, 60–310), 121.4 (42.8, 70–250) and 112.5 (51.5, 55–310) min; the decrease in haemoglobin level was 3.2, 2.6 and 1.6 g/dL, respectively, and continued to decrease with improvements in technique. With increasing experience, the number of stages required for stone clearance and the number of tracts required decreased exponentially. Most of the severe complications occurred early in our experience. The stone clearance rate in groups I, II and III was 81%, 86% and 93%, respectively, after completing the procedure; the overall clearance rate with observation/auxiliary procedures was 86%, 89% and 96%, respectively. The mean hospital stay for groups I, II and III was 11.1 (3.9, 7–25), 9.5 (3.4, 5–22) and 7.1 (3.6, 4–28) days, respectively.

CONCLUSION

The percutaneous management of staghorn calculi requires considerable expertise. Our data suggest that 'multiperc' PCNL is difficult to learn and requires experience. Although over the years our results improved, complete clearance remains a challenge. A constant review and application of newer techniques and results will improve the overall clearance rates further.

KEYWORDS

staghorn, calculus, percutaneous nephrolithotomy, outcome, technique

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) monotherapy is the standard recommendation for staghorn calculi [1]. Staghorn calculi represent advanced calculogenesis. The management strategy for treating staghorn calculi depends on total stone burden, location and distribution of the stone in relation to the collecting system. The other major factors that might have an impact are the status of renal function, degree of hydronephrosis and infection. Patient compliance is of paramount importance, particularly in patients from developing countries.

The current AUA guidelines recommend PCNL as the first treatment option for managing staghorn calculi [1]. The other recommended options are initial percutaneous removal followed by ESWL. This treatment option constitutes percutaneous debulking through a single tract with high reliance on ESWL for residual stones; obviously the final result depends on residual stone burden and renal anatomy. Among the various strategies used for improving the efficacy of combined therapy is the use of flexible nephroscopy for reducing the number of tracts and improving stone clearance [2].

At our centre we have been using PCNL since 1986, and we have been constantly changing our treatment philosophy and strategies by adapting to newer technologies and guidelines to improve the clearance rates and reduce complications. In the era of open surgery, the standard was anatrophic nephrolithotomy, with success rates of ≈95% with a minimal blood transfusion rate and preservation of renal function. In the early 1980s, technological development resulted in the emergence of ESWL, PCNL and ureteroscopy, with various energy sources for stone disintegration. Over the years we have adapted to newer developments and as our experience increased with PCNL for simple stones, we extended our indications to staghorn and complex calculi. To improve the results we incorporated newer ancillary procedures such as flexible nephroscopy and 'minipercs' for clearance. The aim of this study was to review the developments in the technique of PCNL for staghorn calculus at

TABLE 1 The conditions for PCNL in the three groups

Group/period	N patients (renal units)	Details
I/ January 1991–December 1996	200 (216)	Storz nephroscope with sheath (28 F) Ultrasonic lithotripsy Tract 28–30 F Unplanned multiple tracts
II/ January 1997–December 2001	200 (212)	Wolf nephroscopes with no sheath, 24, 22, 18 F Lithoclast with Lithovac Tract size according to infundibulum
III/ January 2002–August 2008	373 (406)	Use of slender nephroscopes, 12 and 18 F Flexible nephroscope and ureteroscope Pre-planned multiple ultrasonic access Lithoclast Master (ultrasound + Lithoclast + suction) Planning on three-dimensional CT urography

our centre since 1991, and to assess the results and outcomes.

PATIENTS AND METHODS

We retrospectively analysed the hospital records of 773 patients (632 males and 141 females, 834 renal units) who underwent PCNL for staghorn calculi at our centre from January 1991 to August 2008. We divided the patients into three groups depending on the changes in treatment policy, global trends and advances in equipment. In this analysis we arbitrarily divided the groups depending on the changes and developments in instrumentation and strategies, as shown in Table 1. A complete staghorn stone was defined as one that either totally filled all calyces and renal pelvis, or filled ≥80% of the renal collecting system. A partial staghorn stone was defined as one that filled the renal pelvis and at least two or more calyces.

The evaluation before surgery included adequate imaging for stone size, renal anatomy and function. Intrarenal anatomy was assessed on anteroposterior and oblique plain films of the abdomen and IVU. Later, non-contrast CT and contrast urography with three-dimensional (3D) reconstruction proved to be very useful in planning the percutaneous access and were used in the management of patients in group III. However, we limit the use of preoperative CT urography to those patients with a serum creatinine level of ≤1.5 mg/dL. For those with compromised renal function, we obtain a non-contrast-enhanced 3D CT, which helps us to assess the pelvicalyceal system, as well as the stone bulk and location.

In addition, all patients had appropriate blood investigations (complete blood count, coagulation profile and serum creatinine) and urinary microscopy with culture and sensitivity testing. All patients received appropriate culture-sensitive antibiotics if deemed necessary. Patients were also evaluated for any associated comorbidity, e.g. diabetes, hypertension, infection, renal insufficiency and most importantly, anaemia.

A percutaneous nephrostomy (PCN) was placed in patients with renal insufficiency and obstruction, to improve drainage and renal function. If necessary, preoperative dialysis was done before PCNL to improve the safety of the procedure. Similarly, patients with severe infection were initially managed with preoperative PCN to improve drainage and function. We have found internal JJ stenting inadequate for renal decompression. It is our policy to establish ultrasonography (US)-guided percutaneous drainage under local anaesthesia in a predetermined desired calyx, which will facilitate stone removal later in such situations.

All PCNL was done under general anaesthesia, with a standard PCNL procedure. After cystoscopy a 5 F ureteric catheter was placed on the desired side with the patient in the lithotomy position; the bladder was drained with a 16 F Foley catheter and a prone position adopted, with support under the chest and pelvis with padded bolsters.

Renal access was predetermined after studying the stone configuration and intrarenal anatomy of collecting system. First, the numbers of calyces to be approached were counted and the number of punctures ascertained. One of the punctures was planned to be the main one through which the maximum stone burden would be cleared. Remaining ones were secondary-access punctures, which were used to clear residual peripheral calyceal stones. We prefer multiple peripheral tracts to clear residual calyceal stones which had not been cleared easily through the main tract. Secondary punctures were aimed at clearing the calyceal stones.

All initial punctures were made by operating urologist using US guidance. Subsequent punctures were made under fluoroscopy and each one was stabilized by passing a guidewire in either the ureter or in another calyx. Except the main one, all other guidewires were secured outside. The tract was dilated using a screw dilator which allows a single-step dilatation to 14 F; thereafter the tract was dilated with serial telescopic Alken dilators (up to 24 F). The main tract was dilated to facilitate placement of a 26 or 28 F Amplatz sheath, while secondary tracts if necessary were dilated until they could accommodate a 20 or 24 F Amplatz sheath. In first 200 cases we used ultrasonic lithotripsy to disintegrate the stones. We adopted the policy of an aggressive approach by creating 'multiperc' for complete clearance. Our major concern was bleeding and the blood transfusion rate. We studied the factors affecting the blood loss and then modified the technique accordingly so as to reduce the blood loss [3].

We limited our lithotripsy time to 90 min. We started using pneumatic energy for stone disintegration, which was easy to maintain and efficient. The procedure was terminated by placing a nephrostomy tube if the vision was obscured by bleeding. If any of the punctures were not used in the first sitting, and we felt a need to dilate the tract in a subsequent sitting, a 14 F Malecot catheter was placed for tract maturation.

A 20 or 22 F Nelaton catheter was placed as a nephrostomy tube at the end of the procedure. In multiple tract procedures, the secondary tracts were drained by 12 or 14 F tubes.

A second stage, if necessary, was scheduled after 72 h. The exact position of residual fragments was determined by a plain abdominal X-ray taken on second day after initial surgery.

TABLE 2 The demographic data, operative variables, clearance rates and complications

Variable	Group I	Group II	Group III	P I vs II	P II vs III	P I vs III
N (%) of patients	200 (25.9)	200 (25.9)	373 (48.2)			
N (%) of renal units	216 (25.9)	212 (25.4)	406 (48.7)			
Side (R : L) (ratio)	114:102 (1.12:1)	113:99 (1.13:1)	214:192 (1.10:1)			
Gender (M : F) (ratio)	166:34 (4.88:1)	162:38 (4.26:1)	304:69 (4.42:1)			
Mean (SD, range) age, years	42.7 (14.1, 9–76)	42.8 (14.5, 4–72)	38.8 (15.1, 1–79)			
Partial staghorn, *n*	116	112	211			
Complete staghorn, *n*	100	100	195			
Mean (SD, range) stone size, mm^2	795.3 (527.5, 194–3550)	1058.1 (604.6, 211–4560)	1100 (580.1, 110–5725)			
Operative statistics and clearance rates % (*n*)						
Required single tract	31.0 (67)	38.6 (82)	42.1 (171)	0.11	0.41	<0.001
Required multiple tracts	68.9 (149)	61.3 (130)	57.8 (235)	0.27	0.40	<0.001
CC in 1 stage	38.4 (83)	39.6 (84)	54.2 (220)	0.47	<0.001	<0.001
CC more than one stage	42.6 (92)	46.7 (99)	39.2 (159)	0.31	<0.001	<0.001
Clearance rate after PCNL, %	81.0 (175)	86.3 (183)	93.3 (379)	0.20	<0.001	<0.001
CC after observation/auxiliary procedures	86.1 (186)	89.1 (189)	96.3 (391)	0.42	0.05	<0.001
Operative statistics, blood loss and hospital stay Mean (SD, range)						
Operative duration, min	138.2 (52.7, 60–310)	121.4 (42.8, 70–250)	112.5 (51.5, 55–310)	0.30	0.16	<0.001
Hospital stay, days	11.1 (3.9, 7–25)	9.5 (3.4, 5–22)	7.1 (3.6, 4–28)	0.28	0.12	0.080
Decrease in haemoglobin, g/dL	3.2 (0.84, 1.7–6)	2.6 (0.88, 1.2–6.5)	1.6 (1.05, 0.4–6)	0.24	0.01	<0.001
Perioperative complications, % (*n*)						
Perforation of PCS	8.3 (18)	7.5 (16)	4.5 (18)			
Migration of fragments outside PCS	1.8 (4)	1.4 (3)	0.05% (2)			
Perinephric collection	6.5 (14)	5.2 (11)	2.7 (11)			
Pneumothorax	1.5 (3)	0.5 (1)	0.25 (1)			
Colonic injury	–	0.9 (2)	0.25 (1)			
Per-operative bleeding requiring termination of procedure	4.2 (9)	2.8 (6)	3.2 (13)			
Per-operative transfusion rate (severe anaemia)	6 (13)	7.5 (16)	4.7 (19)			
Postoperative complications						
Fever (≥37.8 °C)	34.5 (69)	28.0 (56)	24.9 (93)	0.20	0.12	0.01
UTI (culture-positive)	20.0 (40)	10.6 (21)	6.2 (23)	0.009	0.35	0.01
Perinephric collection requiring aspiration	1.9 (4)	1.4 (3)	0.5 (2)			
Angio-embolization	0.9 (2)	–	–	–	–	–
Nephrectomy	0.5 (1)	–	–	–	–	–
Postoperative transfusion rate	11.9 (8/67)	10.9 (9/82)	7.0 (12/171)	0.92	0.39	0.31
One tract	11.9 (8/67)	10.9 (9/82)	7.0 (12/171)	0.92	0.39	0.31
>1 tract	18.7 (28/149)	16.1 (21/130)	11.9 (28/235)	0.52	0.36	0.68

CC, complete clearance of stones; PCS, pelvicalyceal system. P values of <0.05 indicate significance.

The stone-free status was decided after X-ray evaluation with an anteroposterior and oblique plain film. Patients were followed as outpatients in the first month and then every 3 months for the first year, and thereafter by a yearly clinical evaluation with renal US, plain abdominal films, blood and urine examinations.

In children all punctures were made with US guidance. The tract was dilated under fluoroscopy control with Alken telescopic dilators. The tract calibre was limited to a minimum size depending on the size of the targeted calyx, width of infundibulum and age of the patient. In our initial cases ultrasonic disintegration was used. Later we designed a slender (0.8 mm) lithoclast probe with suction cannula that could be passed through a paediatric nephroscope (18 F). This newly designed probe was specially manufactured for our centre.

Patient groups were evaluated for the mean number of tracts and stage requirement, mean operative time, haemoglobin decrease, complications during and after surgery, requirement for auxiliary procedures, stone clearance rates and hospital stay. The three groups were also compared to ascertain any significant change in the planning, management and results over time.

RESULTS

The demographic data of the three groups of patients are shown in Table 2, with the operative statistics and clearance rates. The mean operative time and decrease in haemoglobin level continued to decline as our experience increased, as did the number of stages required for stone clearance, and the number of tracts decreased exponentially. In group I, 40 (20%) patients had a serum creatinine level of >1.5 mg/dL, which was similar in group II and III (39, 19.5% and 65, 17.4%, respectively); the number of patients with a serum creatinine level of >3 mg/dL was 23 (10%), 20 (11.5%) and 25 (7.2%) in groups I, II and III, respectively.

The most common complication after surgery was fever (≥38 °C). Complications were graded using the Clavien system [4], with grade I in 34.5%, 28% and 24.9% of group I, II and III, respectively; 20% of group I had a culture-positive UTI after surgery (Clavien grade II), for which sensitive antibiotics were required to control the fever. In group II and III, 10.6% and 6.2% of patients, respectively, were found to have a culture-positive UTI and were managed according to the sensitivity. Most of the severe complications (Clavien grade IIIb), i.e. bleeding requiring angioembolization (two), bleeding requiring nephrectomy (one), colonic injury (two), and pneumothorax (four) occurred early in our experience. The stone clearance rate in groups I, II and III was 81.0%, 86.3% and 93.3%, respectively, after completing the procedure; the overall clearance rate with observation/auxiliary procedures was 86.1%, 89.1% and 96.3%, respectively. The mean hospital stay for groups I, II and III were declined with increasing experience from ≈11 to ≈7 days (Table 2).

DISCUSSION

Wickham and Kellett [5] in 1981 concluded that small mobile stones in the major renal collecting system can be extracted through a percutaneous tract. Subsequent reports established PCNL as a routine technique to treat patients with large or otherwise complex calculi [6,7]. Advances in surgical technique and technology later allowed the urologist to remove calculi percutaneously with increasing efficiency, and the first report of the percutaneous management of staghorn calculus was by Clayman *et al.* in 1983 [8]. Since then, several reports have been published describing experience with managing staghorn calculi [9–11]. The AUA guidelines (1994) recommended combined therapy consisting of initial percutaneous removal through a single tract and ESWL for residual stone. The results depends on residual burden and renal anatomy/function [12]. Streem *et al.* [13] described a combined technique in 1997 termed 'sandwich therapy', which consisted of primary percutaneous stone debulking followed by ESWL of any inaccessible, residual infundibulocalyceal stone extensions or fragments. After ESWL, a secondary percutaneous procedure was done. These various stages are usually separated by 1 or 2 days. However, improved PCNL techniques, incorporating the increasing use of flexible nephroscopy and providing complete or nearly complete clearance of stone material at the time of the primary procedure, have decreased or eliminated the need for additional ESWL treatment [14]. The negative effect of an increasing stone burden (size and number) on the results of ESWL was reported by many groups using a variety of lithotripters [15]. In our experience, sandwich therapy for the management of staghorn calculi leads to higher morbidity in terms of increased bleeding and associated sepsis. The AUA Nephrolithiasis guidelines panel on staghorn calculi (2004) altered its previous guidelines (1994) and recommended PCNL monotherapy as the first treatment option in the management of staghorn calculi.

Tubeless PCNL has been offered as an option for treating staghorn calculi, although no clearly defined algorithm exists for selecting patients suitable for tubeless PCNL. Malcolm *et al.* [16] recently retrospectively analysed their experience with tubeless PCNL to evaluate its safety and efficacy for 42 cases of complex renal calculi, including 25 total/partial staghorn stones, and reported a single-procedure stone-free rate of 74.5%, and a two-procedure stone-free rate of 91.5%. They concluded that tubeless PCNL is safe and effective and can be used in cases of complex renal stone disease. However, data supporting the tubeless PCNL in the management of staghorn calculi are limited.

The prime objective in PCNL is complete stone clearance with minimum morbidity and morbidity. Since 1991 we used PCNL for staghorn calculi to achieve that objective. We improvised over the technique described by Wickham and Kellett [5]. Over the past 18 years we have developed this technique further.

The management policy for staghorn calculi at our centre has closely followed those of the AUA guidelines for managing staghorn stones. Thus it is not surprising that the stone-free rates have steadily improved over the years. The AUA Nephrolithiasis guidelines panel on staghorn calculi [1] suggested that percutaneous monotherapy with multiple tracts is associated with a 79% stone-clearance rate, acute complication rates of 15%, and transfusion rates of 18%. It is evident from our analysis that the stone-clearance rate improved, with a decrease in associated morbidity (fewer complications and blood loss) as our experience increased.

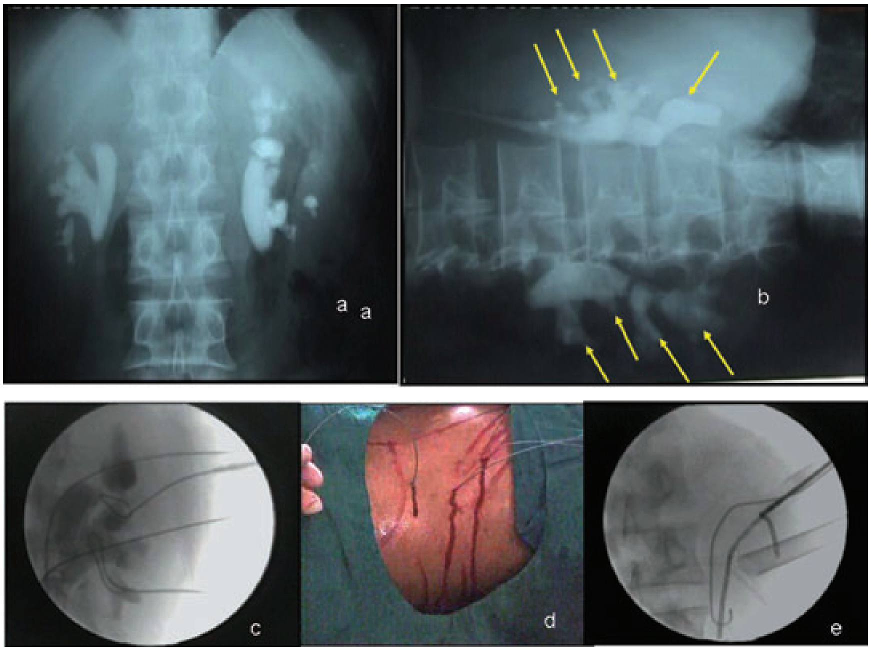
In the first group, the Storz 27 F nephroscope was used with the sheath, but over the years we realized that a sheathed nephroscope adds to the operating time and reduces the size of the fragments retrieved. Similarly, the energy source in this group was an ultrasonic burr, which was accompanied by problems such as overheating and instrument failure. In the same period we were in the initial phase of our experience, and hence the number and type of punctures were unplanned. We feel that the instrument design and the energy source used added to the number of stages required for stone clearance.

In the second group, we used the more slender Wolf (24 F) nephroscope, with pneumatic energy, which resulted in faster disintegration. Similarly, as our experience increased the number of punctures decreased. The newer nephroscope had no sheath, and hence the Amplatz sheath enabled retrieval of larger fragments, simultaneously keeping the intrapelvic pressure low.

In the last group we had an array of instruments along with flexible nephroscopes. We added ultrasonic energy to pneumatic energy (Lithoclast master) as options. This helped to improve the clearance rates, simultaneously decreasing the number of tracts and the stages. As we gained experience over the years, we followed the policy of judicious pre- and intraoperative management in diabetic and hypertensive patients, planning and pre-placing the guidewires (Fig. 1), restricting the nephroscopy time to 90 min, and staging the procedure in cases of renal insufficiency, infection and intraoperative poor visibility [17]. All these strategies helped to reduce the morbidity (complications) and simultaneously improve the clearance rates.

To summarize, we feel that the following strategies have helped during the development of the technique, and in improving the results at our centre: First, renal access is achieved by the operating urologists, as we feel the operating surgeon is the most familiar with the intrarenal anatomy and the surgical procedure, and thus is the most suitable person for making a puncture into the appropriate calyx. It is essential to be familiar with intrarenal pelvicalyceal anatomy and the relative position of the stone in it. Earlier we did that by studying anteroposterior and lateral plain X-rays and IVU. Later, non-contrast CT and contrast urography with 3D reconstruction have been very useful in planning the percutaneous access. The advantages of US-guided puncture are a straight, short tract that passes through the cup of the calyx. In addition, the US-guided puncture decreases the chance of visceral injury and causes less exposure of radiation to the patient and surgeon. US-guided punctures by urologists have been advocated by us and various others [17–19] and advantages of such guided access in reducing the complication rates were reported by Osman *et al.* [20].

FIG. 1. The technique of PCNL: a, bilateral staghorn calculi; b, planning the punctures on IVU; c, pre-placed guidewires in the desired calyces (right side); d, surface view of pre-placed guidewires (right side); e, complete clearance of right staghorn calculi.



The second policy was the improvement and miniaturization of endourological equipment. Stone disintegration was initially by ultrasonic burr (group I) which required longer, and subsequent staging of the procedure. With the advent of pneumatic lithotripsy, the fragmentation was faster and the clearance better (group II). The combination of pneumatic and ultrasonic energy with suction helped in clearing fragments faster, thus reducing the number of stages (group III). Hofmann *et al.* [21] found that the ultrasonic and Lithoclast combination for percutaneous litholapaxy was a very effective instrument, producing smaller stone particles and thus fewer residual stone fragments after PCNL than with the Lithoclast or ultrasonic fragmentation alone, which supports our results.

The third policy has been the use of flexible endoscopy as an adjunct to rigid endoscopy, as in group III. Beaghler *et al.* [14] concluded that liberal use of the flexible endoscopes as an adjunct to rigid instruments during primary PCNL or in a second procedure to remove residual renal calculi might increase the stone-free rate and decrease the need for additional access tracts and procedures. Flexible endoscopy helps the surgeon to inspect the entire collecting system, which facilitates the removal of residual fragments. In our experience, flexible nephroscopy has been of use mainly for residual stones in the inaccessible calyces with an associated large pelvis, while flexible ureteroscopy as an adjuvant was useful with a smaller pelvis. Newer instruments, e.g. stone-retrieval baskets, graspers, wires, high-pressure irrigants, etc. help in perfecting the procedure.

The fourth policy was the use 'multiperc, multitract' PCNL. The perceived concerns about multiple tracts, which include greater bleeding and higher complication rates, were addressed in previous studies [17]. Hegarty *et al.* [22], in their study, noted that the mean decrease in haemoglobin level in patients having multiple tracts was similar to that in patients needing a solitary tract; the use of multiple tracts did not lead to a higher incidence of complications. Complete clearance was achieved in 95% of their cases. Liatsikos *et al.* [23] described multiple angular punctures to approach the superior, middle and lower pole of the kidney for managing staghorn calculi, with 87% stone clearance rates in a single session. Auge *et al.* [24] found no significant difference in blood loss, transfusions, complications or length of surgery as the number of tracts increased. Aron *et al.* [25] found PCNL monotherapy to achieve an 84% complete clearance rate that improved to 94% with ESWL in eight renal units with small residual fragments. They concluded that aggressive PCNL monotherapy using multiple tracts is safe and effective, and should be the first option for massive renal staghorn calculi. Our data suggest that although more stages were required in group I, the same results could be achieved in group II and III with fewer tracts and stages. This change was due to better preoperative planning, increased surgical expertise after experience with increased use of the 'multiperc, multitract' strategy. We now feel that although flexible endoscopy decreases the incidence of residual stones, it requires considerable training and experience; moreover, it cannot be done in patients with bleeding and subsequent poor vision in the operating field.

There was a reduction in the complication rates over time in the present series, mainly of fever and culture-positive UTI. This is attributed to our policy of drainage of the infected system before PCNL, limiting the lithotripsy time and implementing the latest plasma sterilization techniques (Sterrad NX®, Johnson & Johnson Ltd) for sterilizing the instruments.

The fifth policy was aggressive prevention, surveillance and treatment of residual stones, which helped to improve the overall clearance rates. Better and faster disintegration of stones lead to smaller fragments and residual stones, as seen in group II and III. Whenever residual fragments were suspected during surgery, a JJ stent was placed. This is evident in our results, where the clearance rates improved in group III in conjunction with the introduction of a policy of placing JJ stents. In the recent years, the use of non-contrast CT helped to detect small residual fragments more effectively [26]. At our centre, we strictly follow a thorough surveillance plan, at 1 month after surgery with a plain abdominal film, renal US, urine microscopy with culture analysis and a 24-h urinary metabolic evaluation, then every 3 months for first year, with IVU at 1 year. Thereafter, a yearly clinical evaluation is used, with renal US, plain abdominal film, blood and urine examinations. Importantly, staghorn calculi comprise ≈20% of our workload, contrary to the situation in the western world. The hospital stay appears to be longer in the present series than in western reports, but that merely reflects the differences in healthcare services of different countries.

We firmly believe that the following strategies, when used, help to improve the results of PCNL: (i) 3D CT assessment of renal anatomy for planning the site(s) of puncture and size of the tract; (ii) US-guided punctures made by the urologist; (iii) multi-tract, multi-stage PCNL in large-volume staghorn stones with pre-placed guidewires in desired calyces; (iv) the optimal use of flexible endoscopy; and (v) aggressive treatment of residual stones.

In conclusion, the percutaneous management of staghorn calculi requires considerable expertise. Our data suggest that 'multiperc' PCNL requires considerable training and experience. The technique can be perfected and results improved with the miniaturization of instruments, as well as judicious use of flexible endoscopy. Although our results have improved significantly over the years, complete clearance remains a challenge. A constant review of results and application of newer techniques will improve the overall clearance rates further. In this regard, the newer methods, e.g. flexible endoscopes and 3D CT, are the key factors.

CONFLICT OF INTEREST

None declared.

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Abbreviations: **PCNL**, percutaneous nephrolithotomy; **3D**, three-dimensional; **US**, ultrasonography; **PCN**, percutaneous nephrostomy.

EDITORIAL COMMENT

We congratulate the authors on their excellent results. Undoubtedly most procedures improve with experience and we believe that these results reflect this rather than their changes in approach and technique. This explains why the 'learning curve' is , as it should be, always emphasized with new technology. We appreciate the complexities of different health systems. However, an initial stone free-rate of only 54% is rather lower than in other series. The stone-free rate primarily depends on the determination of the surgeon and the complexity of the anatomy. We agree that flexible nephroscopy and ureteroscopy, either concomitant with or subsequent to the initial surgery, has increased the stone-free rate and decreased the morbidity of percutaneous renal surgery. Residual stones should only be left within the kidney if they are inaccessible with flexible instruments and the fragments are too small to warrant an additional percutaneous puncture.

The authors advocate the use of US guidance for the initial puncture and then go on to use fluoroscopy. Although ultrasound equipment is inexpensive and there is no contraindication to its use, we find it to be redundant. Interestingly, even with the use of US to gain access, colonic injury is not preventable, albeit at a very small rate of 0.25%, indicating that there is a 'learning curve' associated with the use of US guidance.

The authors indicate that on preoperative review of the CT they plan the number of necessary punctures, and place them at the onset of the case. We have found that the anatomy changes dramatically during the procedure, and if one uses an upper calyceal approach, most calyces become accessible as the stone load is removed from the renal pelvis and some of the adjoining calyces.

There are many intracorporeal lithotripters available on the market and success depends on how well each one functions at the requisite time. The authors recommend the combination of pneumatic and ultrasonic lithotripter, and when that particular instrument was tested at our institution and compared with our ultrasonic lithotripter the accompanying representatives agreed that we should keep our existing equipment. Pietrow *et al.* [1], in a randomized clinical trial, showed that the combined lithotripter is better than ultrasonic lithotripter. However, the choice of a particular lithotripter remains with the surgeon, the maintenance agreement with the company and the institution. Furthermore, lithotripters vary in their performance, depending on how well they are tuned and whether they are free of any debris.

Overall, we congratulate the authors for their perseverance to improve their results over time, as PCNL has continued to be the standard for staghorn calculi in the last 25 years.

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