Surgical outcomes of high-power holmium laser versus pneumatic lithotripsy during multitract percutaneous nephrolithotomy for the management of staghorn renal stones: a randomized comparative study

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Aim

To evaluate early perioperative surgical outcomes of high-power holmium laser lithotripsy (HP-HLL) versus pneumatic lithotripsy (PL) in patients with staghorn stones undergoing multitract percutaneous nephrolithotomy (PCNL).

Patients and methods

From January 2021 till April 2022, 43 patients with staghorn stones, candidates for PCNL were enrolled in this randomized comparative study. Patients with simple renal stones, ipsilateral renal anomalies, not fit for PCNL or refusing randomization were excluded. After successful access to targeted calices, 21 and 22 patients were randomized to PL (group A) and HP-HLL (group B), respectively. Surgical outcomes were assessed in both groups.

Results

Both groups were matched as regards preoperative patients' and stones' characteristics (P>0.05). We did not find statistically significant differences between HP-HLL and PL as regards operative time (P=0.513), fragmentation time (P=0.289), or duration of hospital stay (P=0.721). Stone-free rate was higher but not statistically significant with HP-HLL (81.8 vs. 71.4%, P=0.42). HP-HLL was associated with less intraoperative extravastion/perforation (4.5 vs. 19.1%), less perioperative blood transfusion (9.1 vs. 14.3%), and less need for intraoperative double J (DJ) indwelling stenting (9.1 vs. 28.6%) but without statistical significant differences (P=0.185, 0.664, 0.101, respectively). HP-HLL was associated with less persistent leakage after removal of the nephrostomy tube without statistical significance (14.3 vs. 4.5%, P=0.272). Perioperative need for DJ application was statistically significantly higher with PL (47.6 vs. 13.6%, P=0.015).

Conclusion

HP-HLL is safe and effective during multitract PCNL for the management of staghorn stones. HP-HLL is associated with comparable stone-free rate and perioperative complications, but less need for perioperative DJ stenting.

Keywords:
high-power laser lithotripsy, multitract percutaneous nephrolithotomy, pneumatic lithotripsy, staghorn stones, surgical outcomes

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Introduction

Percutaneous nephrolithotomy (PCNL) is the standard treatment for large renal stones more than or equal to 2 cm, lower calyceal stones more than 1 cm, and staghorn stones [1]. During PCNL, various forms of energy are used to disintegrate large stones into small fragments [2]. Few prospective comparative studies evaluated their use during PCNL [3–6], but all these studies did not include staghorn stones. Only one retrospective study compared pneumatic versus laser lithotripsy during PCNL for the management of complex Guy's stone score grade IV renal stones [7]. Our current randomized comparative study aimed at evaluating the performance of high-power holmium laser lithotripsy (HP-HLL) versus pneumatic lithotripsy (PL) during multitract PCNL for staghorn stones.

Patients and methods

The sample size was calculated using STATA program setting alpha error at 5% and power of 80%. At least 15 cases in each group were required based on results from Malik *et al*. [3], reporting a mean operative time of 125.7 ± 31.1 min in the laser group compared with 98.5 ± 18.7 min in the pneumatic group.

Patients with partial staghorn stones (filling renal pelvis and only two major calyces) as well as complete

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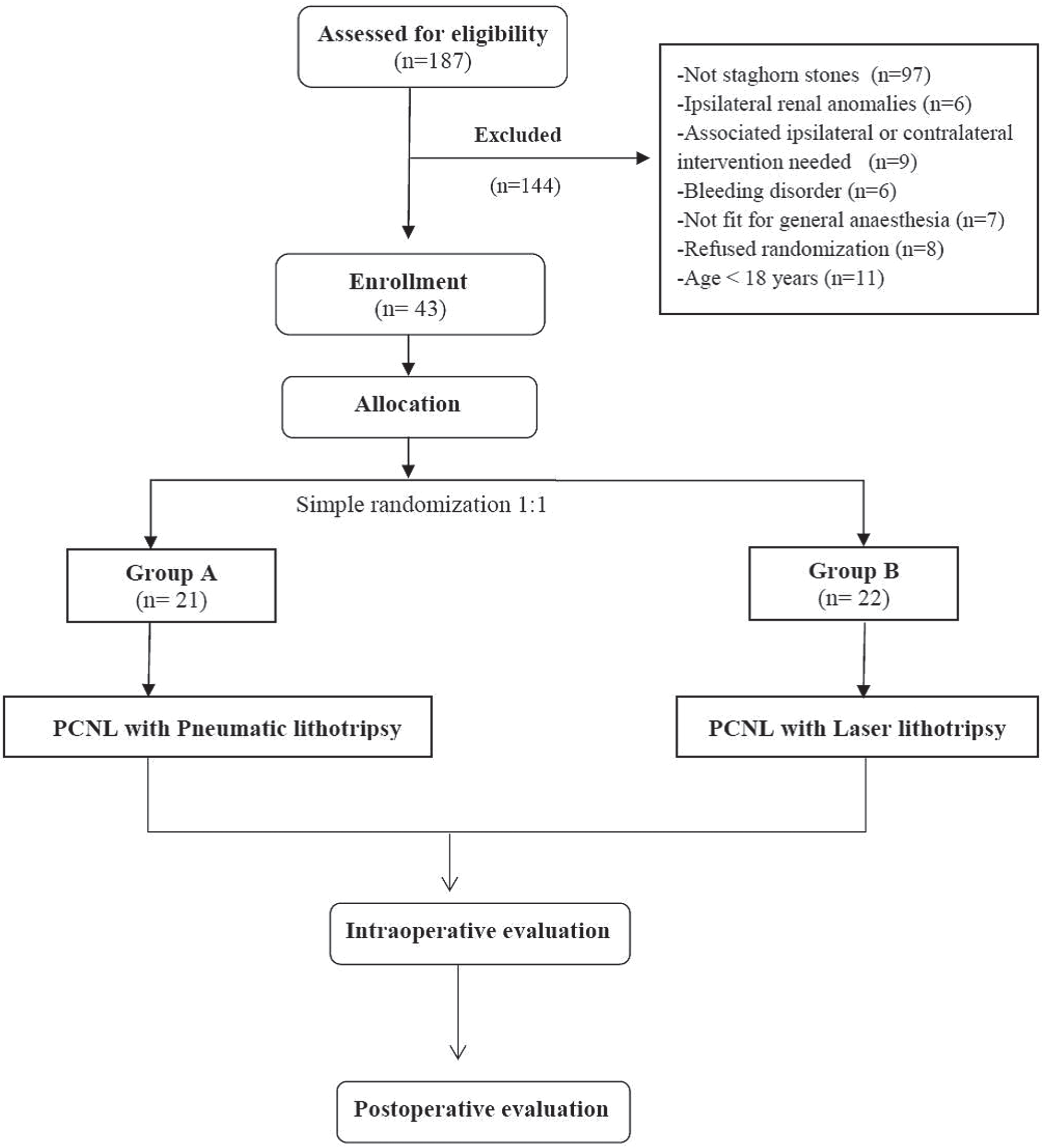
staghorn stones (filling renal pelvis and three major calyces) [8], who were candidates for PCNL were randomized into two groups through simple randomization using a computer-generated list and closed envelopes. Patients in group A underwent PL, whereas patients in group B underwent HP-HLL. Patients less than 18 years or having renal stones not occuping renal pelvis and at least two major calyces, bleeding coagulopathies, ipsilateral renal anomalies, ureteral or renal pathology requiring simultaneous intervention, and not fit for PCNL or refusing randomization were excluded.

In all, 43 adult patients out of 187 patients with nephrolithiasis were included in our study from January 2021 to March 2022 (Fig. 1).

Preoperative evaluation included comprehensive history, careful local and general examination, urine culture and sensitivity, plain radiograph of kidney, ureter, and bladder, pelvi-abdominal ultrasonography, and noncontrast computer tomography of the urinary tract. Patients with positive urine culture were temporarily excluded till resolution of urinary tract infection.

All patients underwent multitract PCNL in prone position under fluoroscopic guidance after obtaining local ethics committee approval and written informed consents. All patients were requested to fast 8 h before intervention. All procedures were done by the same team of experienced endourologists. After induction of general anesthesia, an intravenous third-generation cephalosporin antibiotic was administrated and the

Figure 1



CONSORT chart of the clinical study.

patients were placed in lithotomy position to apply a 6 Fr ureteral catheter. Patients were placed in prone position and two or three percutaneous tracts were established under fluoroscopic guidance to achieve good stone clearance for staghorn stones. Supracostal puncture was done just above the upper border of the twelfth rib during maximum expiration to access complex stones at the upper calyx, if required.

After successful puncture of the targeted calyx and insertion of curved guidewires into the collecting system; central Alken rod and 30-Fr Amplatz dilator were placed over the guidewire. Amplatz sheath was applied and the collecting system was accessed through a 26-Fr Karl Storz nephroscope. Stone fragmentation was achieved with a PL in group A and a high-power holmium-Yag laser system (Lumenis PULSE 120W; Moses Technology, Boston Scientific, Marlborough, USA) using a 200 μm laser fiber in group B. Laser settings for stone fragmentation and stone dusting during PCNL were adjusted to 1.2 J×6 Hz and 0.3 J×70 Hz long pulse, respectively.

Intraoperative evaluation included fragmentation time (time required for lithotripsy and stone extraction), total operative time (from insertion of the ureteral catheter till the end of procedure), extravasation/perforation of the collecting system, need for blood transfusion, need for insertion of indwelling double J (DJ) stent, and intraoperative complications. Postoperative chest radiograph was done routinely in patients with supracostal puncture to assess for hydrothorax. Intraoperative DJ stents were placed in case of injuries to the pelvicalyceal system or presence of large residual fragments. Postoperative evaluation included assessment of stone-free rate (SFR; defined as the presence of no renal stones or stone fragments <4 mm) by the noncontrast computer tomography of the urinary tract done on the first postoperative day, postoperative fever, persistent urinary leakge (>24 h) after removal of the nephrostomy tube, length of hospital stay, and the need for further intervention after initial PCNL.

Statistical analysis

Data were collected, coded, and analyzed by the Statistical Package for the Social Sciences (SPSS, Armonk, New York, USA), version 20. Quantitative variables were presented as mean±SD, while categorical variables were presented as number and percentages. χ^2 test and/or Fisher's exact tests were used to evaluate the association between categorical variables. Independent *t* test was used to evaluate the correlation between two independent groups with quantitative data. The *P* value was considered statistically significant if less than 0.05.

Results

In all, 43 patients with a mean age of 50.51 ± 10.41 years were included in our study. Sixteen (37.2%) patients had recurrent ipsilateral renal stones; 26 (60.5%) patients had partial staghorn stone, whereas 17 (39.5%) patients had complete staghorn stones. Overall SFR for all patients was 76.7%. Mean operative time and fragmentation time were 86.47 ± 15.49 and 65.16 ± 16.91 min, respectively. Mean hospital stay was 3.16 ± 1.17 days. Postoperative fever was the most common complication in 14% and blood transfusion was required in 11.6%.

Both PL and HP-HLL groups were matched as regards age, sex, comorbidities as well as all stone characteristics (*P*>0.05) (Table 1).

Number of access tracts needed was not statistically significantly different between both groups (*P*=0.864). Our study demonstrated that HP-HLL and PL were associated with comparable mean operative time and fragmentation (*P*=0.513 and 0.289, respectively). HP-HLL was associated with statistically nonsignificant less intraoperative extravastion/perforation (4.5 vs. 19.1%), less perioperative blood transfusion (9.1 vs. 14.3%), and less need for intraoperative DJ indwelling stenting (*P*=0.185, 0.664, 0.101, respectively). Only one patient in HP-HLL had colonic injury and was detected during retrograde pyelography at completion of procedure, so DJ stent was applied and nephrostomy tube was placed as a drain (Table 2).

SFR was higher with HP-HLL compared with PL (81.8 vs. 71.4%,), but this difference was not statistically significant (*P*=0.42). Mean hospital stay was comparable between both groups (3.2 and 3.1 days for HP-HLL and PL, respectively, *P*=0.721). Further management of residual stones through second-look PCNL and extracorporeal shock wave lithotripsy with or without DJ stenting were not statistically significant different in both groups (*P*<0.05). However, perioperative need for DJ application was statistically significant higher with PL (47.6 vs. 13.6%, *P*=0.015) (Table 3).

HP-HLL was associated with nonsignificant more postoperative fever (18.2 vs. 9.5 vs. 18.2%, *P*=0.413), but less persistent leakage (>24 h) after removal of the nephrostomy tube (4.5 vs. 14.3%, *P*=0.272). Cardiovascular events and ICU admission were not statistically significant different between both groups (*P*>0.05). Supracostal puncture was needed in nine (42.9%) patients in the PL group as well as nine (40.9%) patients in the HP-HLL group. None of

Table 1 Preoperative demographic data

	Group A (*N*=21) (pneumatic lithotripsy) [*n* (%)]	Group B (*N*=22) (laser lithotripsy) [*n* (%)]	*P* value
Age			
Mean±SD	51.76±10.24	49.32±10.68	0.449[T]
Sex			
Female	7 (33.3)	6 (27.3)	0.665[C]
Male	14 (66.7)	16 (72.7)	
Comorbidities			
Diabetes mellitus	5 (23.8)	3 (13.6)	
Hypertension	4 (19.1)	5 (22.7)	0.776[C]
Cardiac disease	2 (9.5)	3 (13.6)	
Chest disease	1 (4.8)	2 (9.1)	
Previous ipsilateral intervention for nephrolithasis			
Pyelolithotomy	4 (19.1)	4 (18.2)	
PCNL/RIRS	5 (23.8)	6 (27.3)	0.961[C]
SWL	3 (14.3)	4 (18.2)	
Stone type			
Complete staghorn	8 (38.1)	9 (40.9)	0.850[C]
Partial staghorn	13 (61.9)	13 (59.1)	
Side			
Right	13 (61.9)	10 (45.5)	0.280[C]
Left	8 (38.1)	12 (54.5)	
Diameter			
Mean±SD	5.23±0.71	5.30±0.62	0.732[T]
Hounsfield			
Mean±SD	996.52±379.60	1110.09±417.37	0.357[T]
Ipsilateral recurrent nephrolithiasis			
No	13 (61.9)	14 (63.6)	0.906[C]
Yes	8 (38.1)	8 (36.4)	

[C], χ^2 test; PCNL, percutaneous nephrolithotomy; RIRS, retrograde intrarenal surgery; SWL, extracorpoeral shock wave lithotripsy; [T], independent *t* test.

Table 2 Intraoperative evaluation

	Group A (*N*=21) (pneumatic lithotripsy) [*n* (%)]	Group B (*N*=22) (laser lithotripsy) [*n* (%)]	*P* value
Number of tracts			
Two tracts	12 (57.1)	12 (54.5)	0.864[C]
Three tracts	9 (42.9)	10 (45.5)	
Total operative time			
Mean±SD	84.86±11.46	88.0±18.70	0.513[T]
Fragmentation time			
Mean±SD	62.33±16.17	67.86±17.53	0.289[T]
Perforation/extravasation			
No	17 (81)	21 (95.5)	0.185[F]
Yes	4 (19)	1 (4.5)	
Blood transfusion			
No	18 (85.7)	20 (90.9)	0.664[F]
Yes	3 (14.3)	2 (9.1)	
Intraoperative DJ application			
No	15 (71.4)	20 (90.9)	0.101[C]
Yes	6 (28.6)	2 (9.1)	
Colonic injury			
No	21 (100)	21 (95.5)	1.000[F]
Yes	0	1 (4.5)	

[C], χ^2 test; DJ, double J; [F], Fisher's exact test; [T], independent *t* test.

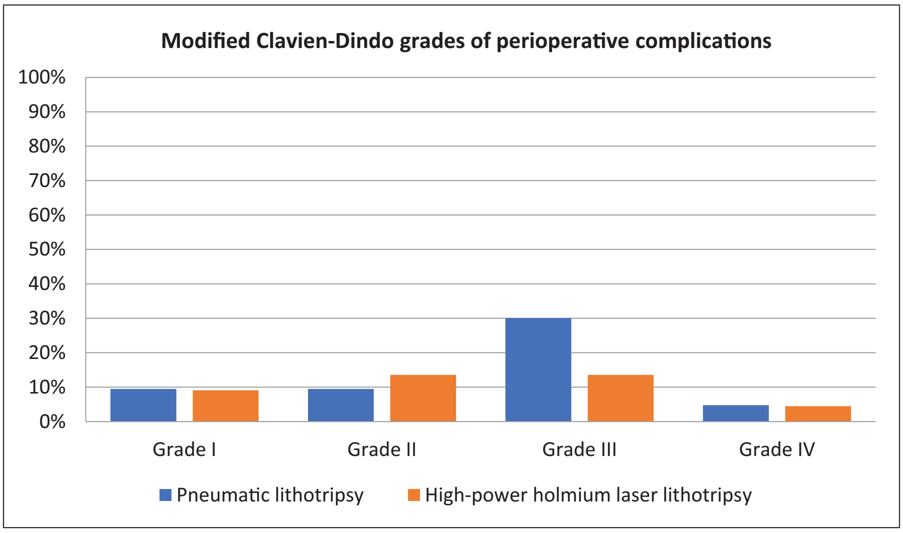
these patients developed postoperative hydrothorax or required chest tube placement. No mortality was reported in either group. In all, 13 (59.1%) patients in HP-HLL had no perioperative complications, whereas (38.1%) in PL had perioperative complications. However, our study did not demonstrate statistically significant differences as regards perioperative complications (0.457). Perioperative complications

Table 3 Postoperative surgical outcomes

	Group A (N=21) (pneumatic lithotripsy) [n (%)]	Group B (N=22) (laser lithotripsy) [n (%)]	P value
Stone free			
No	6 (28.6)	4 (18.2)	0.420^{C}
Yes	15 (71.4)	18 (81.8)	
Hospital stay (days)			
Mean±SD	3.10±0.89	3.23±1.41	0.721^{T}
Postoperative DJ application			
No	17 (81)	21 (95.5)	0.185^{F}
Yes	4 (19)	1 (4.5)	
Postoperative SWL			
No	16 (76.2)	20 (90.9)	0.191^{C}
Yes	5 (23.8)	2 (9.1)	
Second-look PCNL			
No	20 (95.2)	21 (95.5)	1.000^{F}
Yes	1 (4.8)	0	
Perioperative DJ stenting			
No	11 (52.4)	19 (86.4)	0.015^{C*}
Yes	10 (47.6)	3 (13.6)	

C, χ^2 test; DJ, double J; F, Fisher's exact test; PCNL, percutaneous nephrolithotomy; SWL, extracorporeal shock wave lithotripsy; T, independent t test. *Statistically significant.

Figure 2



Modified Clavien–Dindo grades of perioperative complications.

were classified according to the modified Clavien–Dindo grading. Grade I complications included patients with postoperative fever more than 38°C managed without change of antibiotic and patients with minimal urine leakage after removal of nephrostomy tube managed with watchful waiting. Grade II complications compromised patients with perioperative bleeding requiring blood transfusion, patients with supraventricular tachycardia requiring antiarrhythmic medications in the ward as well as patients with postoperative pneumonia managed with change of antibiotics. Grade III complications involved patients who required postoperative DJ stenting, second-look PCNL, and patients with colonic injury managed with controlled colocutaneous fistula. Grade IV complications included patients who required postoperative ICU admission due to hyposaturation or severe bleeding leading to hypovolemic shock. Our study demonstrated no statistically significant differences between HP-HLL and PL as regards modified Clavien–Dindo grades of complications (P=0.399) (Fig. 2).

Discussion

The main objectives in treating renal stones are rendering patients stone free and avoiding major perioperative complications after single intervention. PCNL can achieve high SFRs, however may be associated with various perioperative morbidities [1].

Few randomized trials compared the safety and efficacy of pneumatic and laser lithotripsy during PCNL. However, all these studies included simple stones less than 3 cm with single percutaneous tract and excluded staghorn and complex stones [3–6]. Only one retrospective study reported by Hong *et al.* [7] compared outcomes of pneumatic versus laser lithotripsy in Guy's stone score grade IV renal stones.

A recent meta-analysis [9] compared laser with nonlaser lithotripsy during PCNL included three randomized comparative studies comparing pneumatic to laser lithotripsy [3–5] for renal stones less than cm, single study compared laser, pneumatic and shock pulse lithotripsy [6], and a single randomized study comparing ultrasonic versus HP-HLL lithotripsy in staghorn stones [10].

In our study, we prospectively compared perioperative outcomes between HP-HLL versus PL during PCNL for the treatment of staghorn renal stones. This high-power laser lithotripter (120 W) utilizes the 'Moses technology' allowing less energy loss and higher fragmentation efficacy in a shorter operative time [9]. Moses technology modulates laser energy into two adjacent pulse waves; initial wave separates water and makes a bubble, whereas the following wave penetrates this bubble to hit the targeted stones. This allows minimal loss of energy and more efficient fragmentation in a shorter time [11].

In our study, we did not find statistically significant difference between both groups as regards operative time (P=0.513), and this was consistent with many studies comparing laser to PL in less complex renal stones [4–6] and retrospective study including staghorn stones by Hong *et al.* [7]. Only Malik *et al.* [3] demonstrated statistically significantly longer operative time with the laser group compared with the pneumatic group (P<0.001). Our operative time for PL and HP-HLL was 84.86 versus 88 min for PL and HP-HLL, respectively. This operative time was shorter than that reported by Malik and colleagues (125.7 and 98.5 min for HLL and PL, respectively) as well as Hong and colleagues (137.7 vs. 134.27 min for PL and HLL, respectively, P=0.744) [3], but longer than the operative time reported by Liu *et al.* [5] (55.9 vs. 62.4 for PL vs. HLL, respectively) and Ganesamoni *et al.* [4] (60.7 vs. 57.2 for HLL vs. PL, respectively).

Meta-analysis comparing laser lithotripsy versus the nonlaser group [9] demonstrated a shorter operative time in the nonlaser group (P=0.002); however, most of these studies included patients with renal stones less than 3 cm. Differences in operative time may be related to the power of laser lithotripter, stone complexity and density, number of percutaneous access tracts, and surgical experience.

We did not find statistically significant differences as regards SFR between laser and PL (P=0.42), and this was consistent with most comparative studies [3,4,7]. Only Liu *et al.* [5] reported statistically significantly higher SFR with laser lithotripsy (P=0.03). In corcordance with our study, Hong *et al.* [7] demonstrated higher nonstatistically significant SFR with HLL compared with PL (59.09 vs. 48.15%, P=0.363). Meta-analysis comparing laser to nonlaser lithotripsy [9] demonstrated statistically significantly higher SFR with nonlaser lithotripsy (P=0.03).

We did not find statistically significant difference between both groups regarding complication rate, which was relatively close to complication rates reported by Malik *et al.* [3] (13.3% in laser and 23.3% in pneumatic) as well as Liu *et al.* [5] (16% vs. in laser and 15% in laser and pneumatic groups, respectively).

In concordance with all comparative studies [3–7] and meta-analysis [9], we did not find statistically significant differences between PL and HLL as regards overall perioperative complications, postoperative fever, need for blood transfusion, or urine extravasation.

Perioperative complications were classified according to the modified Clavien–Dindo grades, and we found that no statistically significant differences between laser and PL grades of perioperative complications (P=0.399). This was also consistent with other studies [4,7].

In our study, perioperative need for DJ application was statistically significantly less with HP-HLL compared with PL. 10 (47.6%) patients in the pneumatic group (28.6 and 19% for intraoperative and postoperative stenting, respectively), whereas only three (13.6%) patients in the laser group (9.1 and 4.5% for intraoperative and postoperative stenting, respectively) needed perioperative indwelling DJ stenting. In the literature, there was inconsistency for DJ applications during PCNL, where Ganesamoni *et al.* [4] applied DJ according to surgeon's preference, whereas other authors applied indwelling DJ stents for all patients undergoing PCNL [5].

In agreement with Malik *et al.* [3], we did not find statistically significant difference between the two groups according to hospital stay (P=0.721). However, other studies have found statistically significant shorter hospital stay in the laser group compared with the pneumatic group [5,7]. Mean postoperative hospital stay reported in our study was 3.1 ± 0.89 days in PL and 3.23 ± 1.41 days in HP-HLL, and this was comparable to Malik *et al*. [3] reporting 3–4 days after PCNL after pneumatic and laser lithotripsy. However, other colleagues have reported a longer postoperative hospital stay, 7–8 days [5,7]. Meta-analysis comparing nonlaser to laser lithotripsy [9] demonstrated statistically nonsignificant shorter duration of hospital stay with laser lithotripsy (P=0.25).

To our knowledge, no previous comparative randomized study evaluated the outcomes of pneumatic and laser lithotripsy during PCNL for staghorn stones. It is also worth mentioning that our study is the first to compare pneumatic to high-power laser lithotripsy utilizing the Moses technology during PCNL. Main limitations of our study were a single-center analysis and the relatively small sample size. Large multicentric randomized studies are encouraged to evaluate the safety and efficacy of various fragmentation methods to improve surgical outcomes of PCNL.

Conclusion

Both pneumatic and laser lithotripsy are effective for staghorn stone fragmentation during PCNL. HP-HLL can achieve relatively higher SFR and relatively less perioperative complications and reduce the need for perioperative DJ application during PCNL for staghorn renal stones.

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Conflicts of interest

There are no conflicts of interest.

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