Original Article
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Comparison of Pneumatic Lithotripter and Holmium-YAG Laser Lithotripter in Supine Mini Percutaneous Nephrolithotomy: A Single-Centre Experience

Supin Mini Perkütan Nefrolitotomide Pnömatik litotriptör ile Holmium-YAG Lazer Litotriptör Karşılaştırması: Tek Merkez Deneyimi

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ABSTRACT

Objective: The aim of this study was to compare the efficacy and safety of lithotripters used in supine mini percutaneous nephrolithotomy.

Material and Methods: Medical record of patients who underwent mini percutaneous nephrolithotomy in supine position between January 2023 and June 2024 due to kidney stone larger than 2 cm were evaluated. Thirty-nine patients were operated with Ho:YAG laser lithotripter (LL) and 54 patients were operated with pneumatic lithotripter (PL). Results of patients' demographics, stone size, stone density, operation time, stone-free rate (SFR), complications were compared.

Results: Mean age was 49.56±13.02 in LL group and 50.20±14.24 in PL group (p=0.825). Mean stone size was 3184±2117 mm^3 in LL group and 4117±2975 mm^3 in PL group and the results were similar between groups (p=0.097). Operation time was significantly higher in LL group than PL group (99.8±24.7 min, 85.7±28.1 min, respectively). SFR at postoperative 3rd month was similar between groups (92% in LL, 87% in PL) (p=0.512). Hemoglobin decrease rate (1.5±1.1 g/dL (IQR 1.5 g/dL) (LL) vs. 1.6±1.0 g/dL (IQR 1.6 g/dL) (PL), p=0.513) and overall complication rates (20% vs. 18%, p=0.897, respectively) were similar in the groups.

Conclusion: Both lithotripters can be preferred effectively in supine percutaneous lithotomy. Ballistic lithotripters are still a safe and effective option for mini-PNL with the advantage of reduced operation time.

Keywords: kidney stone, lithotripsy, supine percutaneous nephrolithotomy, laser, pneumatic

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ÖZET

Amaç: Bu çalışmanın amacı supin mini perkütan nefrolitotomide kullanılan litotriptörlerin etkinlik ve güvenilirliklerini karşılaştırmaktır.

Gereç ve Yöntemler: Ocak 2023 ile Haziran 2024 tarihleri arasında 2 cm'den büyük böbrek taşı nedeniyle supin pozisyonda mini perkütan nefrolitotomi uygulanan hastaların tıbbi kayıtları değerlendirildi. Otuzdokuz hasta Ho:YAG lazer litotriptör (LL) ve 54 hasta pnömatik litotriptör (PL) ile ameliyat edildi. Hastaların demografik özellikleri, taş boyutu, taş yoğunluğu, operasyon süresi, taşsızlık oranı; komplikasyon sonuçları karşılaştırıldı.

Bulgular: Ortalama yaş LL grubunda 49,56±13,02 ve PL grubunda 50,20±14,24 idi (p=0,825). Ortalama taş boyutu LL grubunda 3184±2117 mm^3 ve PL grubunda 4117±2975 mm^3 idi ve sonuçlar gruplar arasında benzerdi (p=0,097). Operasyon süresi LL grubunda PL grubuna göre istatistiksel olarak daha yüksekti (99,8±24,7 dak, 85,7±28,1 dak, sırasıyla). Ameliyat sonrası 3. ayda taşsızlık oranı gruplar arasında benzerdi (LL'de %92, PL'de %87) (p=0,512). Hemoglobin düşüş oranı (1,5±1,1 g/dL (IQR 1,5 g/dL) (LL) vs. 1,6±1,0 g/dL (IQR 1,6 g/dL) (PL), p=0,513) ve genel komplikasyon oranları (sırasıyla %20 vs. %18, p=0,897) gruplarda benzerdi.

Sonuç: Her iki litotriptör de supin perkütan litotomide etkili bir şekilde tercih edilebilir. Balistik litotriptörler, operasyon süresini kısaltma avantajıyla mini-PNL için hala güvenli ve etkili bir seçenektir.

Anahtar Kelimeler: böbrek taşı, taş kırma, lazer, pnömatik, supine perkütan nefrolitotomi

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) is the first-line treatment for kidney stones larger than 2 cm and the second-line treatment for kidney stones measuring between 1-2 cm (1). Standard PCNL (24-30 F) has higher stone-free rates (SFR) compared to shock wave lithotripsy (SWL) and retrograde intrarenal surgery (RIRS). However, PCNL has some disadvantages, such as a higher rates of hemorrhage, higher blood transfusion, and analgesic requirement (2,3). Mini-PCNL was described by Helal et al. to reduce these complications (4). Jackman et al. first used this technique on adults (5). While stone-free rates of mini-PCNL are similar to standard PCNL, mini-PCNL has advantages over standard PCNL such as lower transfusion and complication rates. However, mini-PCNL associated with longer operation time in patients with larger stones (1,6-7).

PCNL was initially performed in the oblique position, but the prone position later became the standard. The prone position provides easier access and a larger space for manipulation of the nephroscope (5). However, this position does not allow simultaneous retrograde access and poses challenges in patients with cardiovascular disease or obesity during the anesthesia (8). Supine position has become popular due to its advantages such as easier anesthetic intervention, less radiation exposure, retrograde access to the kidney, more efficient spontaneous evacuation of stone fragments, and shorter operation time (9).

After successful access to the collecting system, stones are fragmented using pneumatic, ultrasonic or laser lithotripters. The type of lithotripter can affect the operation time, complication rates, stone-free rate SFR and overall costs (10). Previous studies have investigated the outcomes of mini PCNL using holmium:yttrium-aluminum-garnet (Ho:YAG) lithotripter (LL) and pneumatic lithotripter (PL) in prone position. Sharma et al. compared the results of Ho:YAG and PL in prone mini-PCNL. In their study, SFR and complication rates were similar, while fragmentation time was significantly shorter in the LL group (11). In another study comparing LL and PL in prone mini-PCNL, operation times were similar between the groups (12).

There are several studies comparing laser lithotripters with pneumatic lithotripters in mini-PNL. However, there is still limited research comparing different lithotripters in the supine position. This study aims to evaluate the effects of low power LL (30 Watt) and PL on operational duration, SFR, and complication rates in supine mini-PCNL.

MATERIAL AND METHODS

This research was designed as a retrospective analysis. The study protocol was approved by the local ethics committee of our institution (Decision No:2024/0l0.99/6/3l, Decision Date:26.07.2024). Ninety-three patients who underwent supine mini-PCNL due to kidney stone larger than 2 cm between January 2023 and June 2024 were included in the study. Of these patients 54 underwent mini-PCNL using PL and 39 patients were operated on using LL. Patients' demographics, stone size, stone density, stone volume, operation time, hemoglobin decrease, complications, re-treatment and SFR were recorded. The diameter of the largest stone, stone volume, stone density, and degree of hydronephrosis were measured on CT. Stone volume was calculated with the following formula: V=0.523xAxBxC (13). All patients exhibited sterile urine cultures before the procedure. Patients were operated on in the Bart's flank-free position (14). After the placement of a 5 F open-ended ureteral catheter and a 16 F transurethral catheter, puncture of the collecting system was accomplished utilizing ultrasound and fluoroscopic imaging. An 18-gauge needle was placed into the renal collecting system, and the tract was dilated using Amplatz dilators (Amplatz Sheath, Boston Scientific, Natick, MA, USA), followed by the insertion of a 20 F Amplatz sheath.

A 12 F nephroscope (Richard Wolf, Knittlingen, Germany) was used in all procedures. Following fragmentation, stones were extracted using stone graspers. The stone fragmentation was performed with either 1.5 mm pneumatic lithotripter (Swiss Lithoclast, Nyon, Switzerland) or 30W-550 micron fiber Ho:YAG laser lithotripter (Quanta System Litho, Samarate, Italy). The insertion of the Double-j stent and nephrostomy catheter was conducted in accordance with the surgeon's preference. Double-j stent was placed in some patients. A re-entry nephrostomy catheter was not routinely used. The nephrostomy catheter was removed either postoperative first or second day. Kidney-Ureter-Bladder X-ray (KUB) was performed in all patients at postoperative first day. Double-j stent was removed at postoperative 3rd week. Residual control was performed with low-dose computed tomography (CT) at the postoperative 3rd month. Stone-free status was defined as <4 mm residual fragments. Postoperative complications were classified according to the Clavien Dindo classification system. Grade 1-2 complications were considered minor complications (postoperative fever, blood transfusion, additional pharmacological treatment), Grade 3 (requiring intervention under local or general anaesthesia) and above (Grade 4: sepsis, septic shock, organ failure, Grade 5: death) were considered major complications.

Statistical Analysis

Quantitative variables such as age and stone volume are presented as mean±standard deviation. Numbers and percentages were used for qualitative variables. Categorical variables were analysed using the chi-square test. Normality of distribution of variables was analysed using Kolmogorov and Smirnov test. The t-test was used for the comparison of continuous variables with a normal distribution. The Mann-Whitney U test was used for the comparison of continuous variables that had a skewed distribution. All analyses were performed using SPSS software version 23.0 (SPSS Inc., Chicago, IL, USA). Statistical tests were two-tailed and a p-value of 0.05 was considered significant.

RESULTS

Patients' mean age was 49.5±13.0 in the LL group and 50.2±14.2 in the PL group (p=0.825). The mean stone volume was 3184±2117 mm^3 (IQR 2667mm^3) in the LL group and 4117±2975 mm^3 (IQR 3090 mm^3) in the PL group, with no significant difference observed between the groups (p=0.097) (Table-1). Operation time was significantly shorter in the PL group (LL=99.8±24.7 min, PL=85.7±28.1 min; p=0.014). SFR in KUB on the postoperative first day was %84 (33/39) in the LL group and %79 (43/54) in the PL group (p=0.597). No statistically significant difference was noted between the groups regarding the stone-free rate at the third month postoperatively (LL=84%, PL=79%, p=0.512) (Table-2).

Table 1. Demographic data and stone characteristics

	LL (n=39)	PL (n=54)	P value
Age (mean±SD)	49.5±13.0	50.2±14.2	0.825
Gender (female/male)	11/28	15/39	0.964
Side (right/left)	22/17	23/31	0.212
Stone volume (mm^3) (mean±SD) **(IQR)**	3184±2117 2667	4117±2975 3090	0.097
Stone density (HU) (mean±SD)	969±300	978±320	0.889
Guy's stone score (mean±SD) **1** **2** **3**	1.3±0.6 28 7 4	1.4±0.6 38 10 6	0.874

Hemoglobin decrease rate (1.5±1.1 g/dL (IQR 1.5 g/dL) (LL) vs. 1.6±1.0 g/dL (IQR 1.6 g/dL) (PL), p=0.513) and overall complication rates (%20 vs. %18, p=0.897, respectively) were similar in the groups. Moreover, the rate of minor complications between the two groups did not differ significantly (15% (n=6) vs. 14% (n=8), P=0.940). Two patients in the LL group and one patient in the PL group received antibiotic therapy for postoperative infection, while one patient in the PL group required a blood transfusion. Double-j stent was placed under local anesthesia on 2 patients in each group due to residual fragments in the postoperative period. Grade 4 or 5 complications did not occur in both groups (Table-2).

Table 2. Intraoperative and postoperative data

	LL (n=39)	PL(n=54)	P value
Stone free rate **Postoperative first day, n (%)** **Postoperative 3 months, n (%)**	 33/6 (84) 36/3 (92)	 43/11 (79) 47/7 (87)	 0.597 0.512
Hemoglobin drop (g/dl) (mean±SD) **(IQR)**	1.5±1.1 **1.5**	1.6±1.0 **1.6**	0.513
Operation time (minutes)	99.8±24.7	85.7±28.1	**0.014**
Auxillary procedure **Dj insertion, n (%)**	 2 (5)	 2(3)	0.740
Clavien Dindo Complications, n (%) **Grade 1** **Grade 2** **Grade 3a**	8 (20) 5 1 2	10(18) 6 2 2	0.987

DISCUSSION

The present study investigated the perioperative outcome and complications of LL and PL in supine mini PNL. Both techniques demonstrated comparable stone-free rates and exhibited comparable complication rates. However, the PL technique was associated with reduced operative time.

Ho:YAG laser is the first-choice lithotripter in mini-PCNL. The reduced probe size facilitates compatibility with a smaller nephroscope and enhances irrigation efficiency. Another important advantage of LL is that it provides better fragmentation by changing energy and frequency values at different stone densities (10). Furthermore, it offers reduced retropulsion. This advantage enables for the fragmentation of stones into smaller fragments compared to PL (15). However, LLs are expensive devices, and the cost of laser fibers are also quite high. High-power holmium YAG lasers require a specific energy source. Concerning PL, retropulsion, particularly in hydronephrotic kidneys, represents the most significant disadvantage (16). Stone migration to other calyxes may cause difficulties in reaching the stone and lead to residual fragments. Besides that, PL can cause mucosal damage, bleeding or stone migration out of the collecting system. One of the most notable advantages of ballistic lithotripters is the relatively low financial burden associated with the initial assembly and maintenance expenses.

Mini-PCNL presents several advantages over conventional PCNL, including increased SFR and reduced complication rates (6). The duration of the procedure in mini-PCNL may be extended due to the reduced size of the sheath. The stone burden substantially impacts operational time (17,18). Research comparing LL and PL in mini-PCNL performed in the prone position yields inconsistent findings. Ganesamoni et al. conducted a prospective comparison of lithotripter types in mini-PCNL operations. Operation and fragmentation times were comparable in both the LL and PL groups, whereas the stone migration rate was higher in the PL group (12). Concordantly to this study, both types of lithotripters revealed equivalent stone-free rates in our research. Another prospective study indicated that, although operation times were comparable, fragmentation time was longer in the PL group (11). Similarly, İbis et al. conducted a comparison of high-power LL and PL in supine mini-PCNL, revealing that the operation time was greater in the PL group (10). They concluded that the high-power settings with the Ho:YAG laser provided a much more efficient lithotripsy and took out the possible advantage of the ballistic lithotripter. Liu et al. performed an evaluation of data from 100 patients to compare PL and 12W LL, finding that the operation time was shorter in the PL group. However, the study did not specify the position type (19).

In our investigation, the stone volume was greater in the PL group, however this difference was not statistically significant. (3184±2117 mm^3 vs. 4117±2975 mm^3, p=0.097). Nonetheless, the surgery duration was statistically considerably reduced in the PL group (99.8±24.7 min vs. 85.7±28.1 min, p=0.014). The differences in literature in outcomes can be explained by the variety of the power of Ho:YAG laser and variety in stone volume among the studies. Stone volume might be another factor effecting outcomes. We believe that the duration of the procedure may have been extended in the LL group due to the use of a 30 W Ho:YAG laser in our study.

Stone freeness is the most important factor reflecting surgical success. Studies examining the results from standard and mini-PCNL have indicated comparable outcomes. A review involving 1196 patients indicated that the SFR for mini-PCNL was 92.9%, which is comparable to that of standard PCNL(6). Tangal et al. conducted a retrospective evaluation of data from 312 patients who underwent supine PCNL. This study compared LL, PL, and their combination, revealing similar SFR statuses of 92.3%, 91.3%, and 91.3%, respectively (p=0.95) (20). A retrospective study comparing LL and PL in the supine position found that SFR status was similar between groups, with rates of 92.5% and 90.2%, respectively (p=0.23) (10). Our research revealed that, consistent with previous literature, the SFR status at three months postoperatively was 87% in the PL group and 92% in the LL group (p=0.512).

Abdelhafez et al. reported that the rates of bleeding and transfusion were higher in standard PCNL compared to mini-PCNL (21). When evaluating blood loss in mini PCNL for LL and PL, the outcomes appeared to be similar (11,12,19). In our research the rate of blood loss was comparable among the groups (p=0.513). Only one patient required a blood transfusion postoperatively. In our study, complication rates were similar in each group. This is likely attributed to the comparatively smaller size of renal calculi in this study and the relative safety associated with mini-PCNL.

The primary limitations of our study are the absence of randomization and the retrospective nature of the data analysis. Additionally, the present study's findings are derived from applying a 30 W laser. The use of high-power lasers, capable of reaching frequencies up to 100 Hz, significantly reduces operative times for laser lithotripsy. Besides that, we were unable to report our stone fragmentation time results. Instead, we collected data on total operative times.

CONCLUSION

Both technics provided similar outcomes in SFR and complications. Ballistic lithotripters are still a safe and effective option for mini-PNL with the advantage of reduced operation time. We believe that PL will continue to be preferred in mini-PNL because of their similar SFRs, similar complication rates, and their cost-effectiveness. More reliable results could be achieved with prospective randomized studies.

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