Lasers in Medical Science (2020) 35:1765–1768
https://doi.org/10.1007/s10103-020-02971-x

ORIGINAL ARTICLE

What is the optimum lithotripsy method for high density stones during mini-PNL? Laser, ballistic or combination of both

Semih Tangal[1] · Adem Sancı[2] · Utku Baklacı[2] · Muammer Babayiğit[2] · Murat Can Karaburun[2] · Eralp Kubilay[2] · Mehmet İlker Gökce[2]

Received: 20 November 2019 / Accepted: 22 January 2020 / Published online: 30 January 2020

Abstract

Percutaneous nephrolithotomy (PNL) is the primary treatment option for renal stones > 20 mm in diameter. Mini-PNL gained popularity with its minimally invasive nature. The aim of this study was to compare the efficiency of ballistic and laser lithotripsy with the combined use of both techniques. Data of 312 patients underwent mini-PNL for renal stones with Hounsfield Unit > 1000 was investigated retrospectively. We identified 104 patients underwent combined ballistic and laser lithotripsy. Propensity score technique was used to create the laser and ballistic lithotripsy groups. Groups were matched on stone size, stone density, and Guy's stone score. Primary end point of the study was to compare the stone free rate (SFR), complication rates, and duration of surgery. Mean age of the population was 49.4 ± 6.1, stone size was 24.6 ± 6.3 mm, and stone density was 1215 ± 89 HU. The groups were similar for age, stone size, stone density, and Guy's stone score. The SFR and the complication rates of the 3 groups were similar ($p = 0.67$). The duration of the surgery was shorter in the combined group (46.1 ± 6.3 min) compared to the laser lithotripsy (54.5 ± 6.6 min) and ballistic lithotripsy (57.2 ± 6.9 min) groups. Both laser and ballistic lithotripsy are effective methods for stone fragmentation during mini-PNL. Combined use of both methods has the potential to improve the fragmentation rates and diminish the operative times in case of high density stones.

Keywords Kidney stone · Percutaneous nephrolithotomy · Laser lithotripsy · Ballistic lithotripsy · Mini-PNL

Introduction

Percutaneous nephrolithotomy (PNL) is the primary treatment modality for renal stones > 20 mm [1, 2]. Due to the nature of this surgery, there is significant risk of complications and to reduce the morbidity of the procedure, miniaturization of the PNL procedure was of interest. Jackman et al. reported the first mini-PNL technique [3]. Following this, dedicated instruments for mini-PNL were produced [4–8] and took their place in routine clinical practice [9].

Fragmentation of the stones in to smaller particles is an important step of PNL procedure, and currently ballistic, ultrasonic, and laser lithotripters are the most commonly used devices for this purpose. The miniaturized PNL systems such as micro-PNL, ultra-mini-PNL, and super-mini-PNL methods mainly rely on use of holmium laser lithotripsy [9]. Therefore, comparison of lithotripsy methods for mini-PNL has not been studied extensively in clinical studies previously.

Ganesamoni et al. conducted a prospective randomized study to compare the laser and ballistic lithotripsy during mini-PNL and concluded that both methods are safe and effective. But authors also mentioned that laser lithotripsy provides less stone migration and easier fragment removal [10]. However, combined use of laser and ballistic lithotripsy has not been subjected to any studies in the current existing literature. The aim of this study was to compare the efficiency of laser and ballistic lithotripsy with the combined use of both lithotripsy methods.

✉ Mehmet İlker Gökce
migokce@yahoo.com

1 Department of Urology, Ufuk University School of Medicine, Ankara, Turkey

2 Department of Urology, Ankara University School of Medicine, Ankara, Turkey

Materials and methods

In this study, the prospectively collected data of 733 patients underwent mini-PNL at our institution by a single experienced surgeon between January 2015 and April 2019 was investigated retrospectively. We identified 104 patients who underwent combined laser and ballistic lithotripsy for stones with density > 1000 Hounsfield Units (HU), and propensity score technique was used to create the laser lithotripsy (n = 104) and ballistic lithotripsy (n = 104) groups. The groups were matched on stone size, stone density, and Guy's stone score (GSS). Cases with anatomic abnormalities and those underwent endoscopy combined intrarenal surgery were excluded. The study was approved by the institutional ethical committee of our institution (Approval number: 05-299-18).

The parameters analyzed were, age, gender, stone size (sum of largest diameter of all stones in case of multiple stones), stone density (HU), GSS, duration of operation, complication rates, stone free rates (SFR), and duration of hospitalization. Postoperative imaging was performed with KUB and/or ultrasonography, and non-contrast CT scan was performed in case of suspicion of any residual fragments prior to JJ stent extraction at postoperative day 7–15. SFR was defined as absence of any size of residual fragments.

Surgical method

Patients were placed in Galdakao modified supine Valdivia (GMSV) position and a 6Fr ureteral catheter was placed and retrograde pyelogram was performed. Percutaneous access was performed under fluoroscopy and ultrasound guidance. After creation of the access, a hydrophilic guidewire was placed in the collecting system. The MIP-M kit (Karl Storz, Tuttlingen, Germany) was used to create percutaneous tract. Fifteen Fr metallic dilator was inserted over the guidewire, and 16 Fr metallic sheath was placed. Twelve Fr nephroscope was introduced and laser lithotripsy (Dornier Medilas H Solvo, Wessling, Germany) was performed with fragmentation settings of 1.5–2.0 J and 10 Hz. Ballistic litotripsy (Vibrolith Plus, Elmed, Ankara, Turkey) was performed with a 4 Fr probe with 6–10 Hz frequency. The fragments were extracted with the vacuum cleaner effect and with the help of a basket when necessary. A JJ stent was placed in all cases and nephrostomy tube was not placed in any of the cases. For combined ballistic and laser lithotripsy, the main strategy was initial fragmentation to pieces less than 10 mm with ballistic lithotripsy and continue with laser lithotripsy to produce smaller fragments and apply vacuum cleaner effect. Fragmentation to pieces less than 5 mm with the ballistic lithotripter was avoided as it may lead to migration of the fragments to other calices.

Statistical analysis

Continuous data were expressed as mean–standard deviation and categorical data were expressed as number and standard deviation. One-way analysıs of variance (ANOVA) was used to compare the continuous variables and chi-square test was used to compare the categorical variables between the three groups. A p value < 0.05 was considered as significant.

Results

Total data of 312 patients were analyzed and there were 104 patients in each group with respect to the propensity score technique. The mean age of the population was 49.4 ± 6.1 years, mean stone size was 24.6 ± 6.3 mm, and mean stone density was 1215 ± 89 HU. The groups were similar for age, gender, stone size, stone density, and Guy's stone score. Results are summarized in Table 1.

The SFRs of the laser lithotripsy, ballistic lithotripsy, and the combined lithotripsy groups were 92.3%, 91.3%, and 91.3% respectively and there was no statistically significant difference ($p = 0.95$). The SFRs of the patients underwent non-contrast CT scan for postoperative imaging were also similar among the groups (87.1% vs. 84.6% vs. 85.7%, $p = 0.95$). The complication rates of the 3 groups were also similar ($p = 0.67$). All of the complications observed were Calvien-Dindo grade I and II. Transfusion was needed in one patient in the laser lithotripsy group and in one patient in the combined lithotripsy group. Rest of the grade II complications were recorded for antibiotic therapy postoperatively (Table 2).

The duration of the surgery was significantly shorter in the combined lithotripsy group (46.1 ± 6.3 min) compared with the laser lithotripsy (54.5 ± 6.6 min) and ballistic lithotripsy (57.2 ± 6.9 min) groups. The median postoperative hospital stay was 1 day for all three groups ($p = 0.88$). Results are summarized in Table 2.

Discussion

Mini-PNL established its role in the management of renal stones with diminished complication rates and similar success rates compared with the large-bore PNL [9, 11]. Both laser and ballistic lithotripsy can be applied during mini-PNL and results of our study also indicates that both lithotripsy methods are valid options. However, we found out that combination of both lithotripsy methods maintains shorter operative times with similar success and complication rates compared with the use of either method individually.

Holmium laser lithotripsy is the main lithotripsy method for miniaturized PNL systems due to the advantage of being applied with a thin fiber that can fit through the narrow working channels of the optical systems and producing small fragments that can be extracted from the small caliber sheaths. With the increased use of high power laser systems, larger stones can also be fragmented successfully with minimal complications. Also, the surgeon can adjust the laser parameters

Table 1 Demographic and patient related characteristics of the groups

Parameter	Laser lithotripsy ($n = 104$)	Ballistic lithotripsy ($n = 104$)	Combined lithotripsy ($n = 104$)	p value
Age (mean ± SD)	49.5 ± 6.2	48.8 ± 6.6	49.8 ± 6.5	0.77
Gender, n (%)				0.69
Male	61	57	63	
Female	43	47	41	
Stone size, mm (mean ± SD)	24.6 ± 6.3	24.6 ± 6.3	24.6 ± 6.3	1
Stone density, HU, (mean ± SD)	1215 ± 89	1215 ± 89	1215 ± 89	1
Guys stone score (GSS), n (%)				1
GSS-1	68 (65.4)	68 (65.4)	68 (65.4)	
GSS-2	27 (25.9)	27 (25.9)	27 (25.9)	
GSS-3	9 (8.7)	9 (8.7)	9 (8.7)	
GSS-4	-	-	-	

with respect to the stone characteristics and perform the lithotripsy in the most efficient way. However, in case of large and harder stones, efficacy of laser lithotripsy may decrease and the laser fibers can be damaged due to the use of high energy settings and burn-back effect.

Ballistic lithotripsy has been shown to be an effective and safe option for PNL. It needs direct contact and can fragment the stone effectively regardless of the hardness of the stone. However, the main disadvantage is stone retropulsion especially in case of dilated collecting systems [12, 13]. During mini-PNL use of a forceps for fragment extraction is usually not necessary as the fragments can be taken out effectively with the help of Bernoulli's principle so called vacuum-cleaner effect [14]. To apply this technique, laser lithotripsy is the best method as the surgeon can produce appropriate sized fragments that can be taken out efficiently and the thin laser fiber does not alter the water inflow which is crucial for the vacuum-cleaner effect. The role of ballistic lithotripsy during mini-PNL has not been studied extensively in the current existing literature and there is no study evaluating the role of combined laser and ballistic lithotripsy.

In a prospective randomized study, Ganesamoni et al. compared the laser and ballistic lithotripsy for mini-PNL in a population of 60 patients and they used the same mini-PNL system with our study. The primary outcome of the study was the total operative time and there were no significant differences between the groups. Also, the groups were similar for stone fragmentation time, success, and complication rates. However, the authors reported higher stone migration rate, more difficulty in fragment retrieval, and higher need for use of a basket or forceps in the ballistic lithotripsy group [10]. Similarly, we did not find a significant difference between the groups in terms of SFR and complication rates. However, operative times were shorter in the combined lithotripsy group compared with both laser and ballistic lithotripsy groups.

In our study, the mean stone size was greater than the study by Ganesamoni et al. [10] (24.6 mm vs. 17.5 mm). We believe that when the stone diameter is > 2 cm and the stone density is > 1000 HU, initial stone fragmentation with ballistic lithotripsy to produce fragments of less than 1 cm and further fragmentation with laser to make these fragments smaller and take them out with vacuum-cleaner effect is an effective method. In our study, the total operative time was shorter in the combined lithotripsy group but success and complication rates and the duration of hospital stay were similar among the groups. Therefore, the cost-effectiveness of combined use of laser and ballistic lithotripsy is questionable.

Ganesamoni et al. also reported higher risk of stone migration to other calices during ballistic lithotripsy and this is a significant problem especially in case of a lower pole puncture in prone PNL. However, this is a less significant problem for supine PNL as it is easier to access the upper pole calices from

Table 2 Comparison of groups for surgical outcomes

Parameter	Laser lithotoripsy ($n = 104$)	Ballistic lithotripsy ($n = 104$)	Combined lithotripsy ($n = 104$)	p value
Stone free rate, n (%)	96 (92.3)	95 (91.3)	95 (91.3)	0.95
Complication rate, n (%)	12 (11.5)	9 (8.6)	10 (9.6)	0.77
Grade I	10	8	7	
Grade II	2	1	3	
Duration of surgery, minutes (mean ± SD)	54.5 ± 6.6	57.2 ± 6.9	46.1 ± 6.3	0.03
Hospital stay, days (median and range)	1 (1–3)	1 (1–3)	1 (1–4)	0.88

a lower pole access [15]. Additionally, upper pole calices may be accessed retrogradely with a flexible ureteroscope in supine position to clear any migrated fragment [16]. In our series, all patients were operated in GMSV position and therefore, stone migration related to use ballistic lithotripter did not have any effect of SFR.

The most important drawbacks of our study are the lack randomization and retrospective analysis of the data. Besides, the results of the current study are based on use of a 30 W laser device and with the use of currently available high power lasers that can reach up 100 Hz frequency, the operative times for laser lithotripsy can be much shorter. Additionally, we did not record the time for fragmentation individually, rather had data on total operative times. However, the groups were matched on stone size and stone density; therefore, we believe that there would not be a selection bias effecting the fragmentation times.

Conclusions

Our study shows that both laser and ballistic lithotripsy are effective and safe options for stone fragmentation during mini-PNL. Combined use of both laser and ballistic lithotripsy in case of high density stones provides high SFR without increased complication rates and has the potential to shorten the operative times.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study was approved by the institutional review board. Approval number: 05-299-18.

References

1. Assimos D, Krambeck A, Miller NL, Monga M, Murad MH, Nelson CP, Pace KT, Pais VM Jr, Pearle MS, Preminger GM, Razvi H, Shah O, Matlaga BR (2016) Surgical management of stones: American urological association/endourological society guideline, PART I. J Urol 196(4):1153–1160. https://doi.org/10.1016/j.juro.2016.05.090
2. Turk C, Petrik A, Sarica K, Seitz C, Skolarikos A, Straub M, Knoll T (2016) EAU guidelines on interventional treatment for urolithiasis. Eur Urol 69(3):475–482. https://doi.org/10.1016/j.eururo.2015.07.041
3. Jackman SV, Docimo SG, Cadeddu JA, Bishoff JT, Kavoussi LR, Jarrett TW (1998) The "mini-perc" technique: a less invasive alternative to percutaneous nephrolithotomy. World J Urol 16(6):371–374
4. Lahme S, Bichler KH, Strohmaier WL, Gotz T (2001) Minimally invasive PCNL in patients with renal pelvic and calyceal stones. Eur Urol 40(6):619–624
5. Nagele U, Schilling D, Anastasiadis AG, Walcher U, Sievert KD, Merseburger AS, Kuczyk M, Stenzl A (2008) [Minimally invasive percutaneous nephrolitholapaxy (MIP)]. Urologe A 47 (9):1066, 1068-1073. doi:https://doi.org/10.1007/s00120-008-1814-2
6. Bader MJ, Gratzke C, Seitz M, Sharma R, Stief CG, Desai M (2011) The "all-seeing needle": initial results of an optical puncture system confirming access in percutaneous nephrolithotomy. Eur Urol 59(6):1054–1059. https://doi.org/10.1016/j.eururo.2011.03.026
7. Desai J, Solanki R (2013) Ultra-mini percutaneous nephrolithotomy (UMP): one more armamentarium. BJU Int 112(7):1046–1049. https://doi.org/10.1111/bju.12193
8. Zeng G, Wan S, Zhao Z, Zhu J, Tuerxun A, Song C, Zhong L, Liu M, Xu K, Li H, Jiang Z, Khadgi S, Pal SK, Liu J, Zhang G, Liu Y, Wu W, Chen W, Sarica K (2016) Super-mini percutaneous nephrolithotomy (SMP): a new concept in technique and instrumentation. BJU Int 117(4):655–661. https://doi.org/10.1111/bju.13242
9. Lahme S (2018) Miniaturisation of PCNL. Urolithiasis 46(1):99–106. https://doi.org/10.1007/s00240-017-1029-3
10. Ganesamoni R, Sabnis RB, Mishra S, Parekh N, Ganpule A, Vyas JB, Jagtap J, Desai M (2013) Prospective randomized controlled trial comparing laser lithotripsy with pneumatic lithotripsy in miniperc for renal calculi. J Endourol 27(12):1444–1449. https://doi.org/10.1089/end.2013.0177
11. Yamaguchi A, Skolarikos A, Buchholz NP, Chomon GB, Grasso M, Saba P, Nakada S, de la Rosette J, Clinical Research Office Of The Endourological Society Percutaneous Nephrolithotomy Study G (2011) Operating times and bleeding complications in percutaneous nephrolithotomy: a comparison of tract dilation methods in 5,537 patients in the Clinical Research Office of the Endourological Society Percutaneous Nephrolithotomy Global Study. J Endourol 25(6):933–939. https://doi.org/10.1089/end.2010.0606
12. Haupt G, van Ophoven A, Pannek J, Herde T, Senge T (1996) In vitro comparison of two ballistic systems for endoscopic stone disintegration. J Endourol 10(5):417–420. https://doi.org/10.1089/end.1996.10.417
13. Piergiovanni M, Desgrandchamps F, Cochand-Priollet B, Janssen T, Colomer S, Teillac P, Le Duc A (1994) Ureteral and bladder lesions after ballistic, ultrasonic, electrohydraulic, or laser lithotripsy. J Endourol 8(4):293–299. https://doi.org/10.1089/end.1994.8.293
14. Mager R, Balzereit C, Gust K, Husch T, Herrmann T, Nagele U, Haferkamp A, Schilling D (2016) The hydrodynamic basis of the vacuum cleaner effect in continuous-flow PCNL instruments: an empiric approach and mathematical model. World J Urol 34(5):717–724. https://doi.org/10.1007/s00345-015-1682-5
15. Sofer M, Giusti G, Proietti S, Mintz I, Kabha M, Matzkin H, Aviram G (2016) Upper calyx approachability through a lower calyx access for prone versus supine percutaneous nephrolithotomy. J Urol 195(2):377–382. https://doi.org/10.1016/j.juro.2015.07.101
16. Scoffone CM, Cracco CM, Cossu M, Grande S, Poggio M, Scarpa RM (2008) Endoscopic combined intrarenal surgery in Galdakao-modified supine Valdivia position: a new standard for percutaneous nephrolithotomy? Eur Urol 54(6):1393–1403. https://doi.org/10.1016/j.eururo.2008.07.073