The Efficacy of Percutaneous Nephrolithotomy Using Pneumatic Lithotripsy vs. the Holmium Laser: a Randomized Study

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Abstract The objective of the study is to compare the efficacy of percutaneous nephrolithotomy using holmium laser vs pneumatic lithotripsy. From August 2010 to March 2014, 200 patients with double kidney and single kidney stones without previous operations or other diseases were randomized into two groups according to the type of lithotripter used: pneumatic ($n = 100$) and laser ($n = 100$). The preoperative, intraoperative, and post-operative follow-up findings were analyzed and compared. The average stone size was similar in both the pneumatic and holmium laser lithotripsy groups ($202.8 \pm 52.6 \text{ mm}^2$ vs. $200.3 \pm 50.8 \text{ mm}^2$). No significant difference was found between the operation time for the two groups ($55.9 \pm 16.5 \text{ min}$ vs. $62.4 \pm 17.6 \text{ min}$). The concentrations of creatinine in both groups increased 2–24 h after the operation and decreased to a normal level 1–4 days after the operation in both groups. Renal diuretic scan revealed that the peak and the renal index were both abnormal after the operation but became normal 4 days after the operation in both groups. No significant difference of creatinine concentration or the diuresis renogram was observed between the two groups. However, two cases in the holmium laser group had almost lost the renal function of the operated kidney 1 year later. Both pneumatic and holmium laser lithotripsy can be associated with acute renal injury in some patients after the operation without any

significant difference. However, some infrequent severe renal function damage in laser lithotripsy should be noted.

Keywords Percutaneous nephrolithotomy · Renal function · Holmium laser lithotripsy · Pneumatic lithotripsy · Urinary stones

Introduction

Urolithiasis affects 5–15 % of the population worldwide [1, 2]. Recurrence rates are close to 50 % [3], and the cost of urolithiasis to individuals and society is high. Since its introduction in 1976, percutaneous nephrolithotomy (PCNL) has been considered the golden standard for renal and upper urinary tract stones. In view of the fact that the minimally invasive approach of PCNL allows stone removal with lower morbidity, higher postoperative patient comfort, shorter convalescence, and lower cost than open techniques, PCNL has prominent advantages [4–6]. However, PCNL may entail some complications [7, 8].

Combined with energy producers, including the holmium: yttrium–aluminum–garnet (Ho:YAG) laser and pneumatic lithotripter, PCNL has evolved into a safer and more efficacious modality for treating stones in almost all locations of the kidney and has become the first-line therapy for kidney stones [9]. However, based on the potential advantages of flexible nephroscopy, PCNL has encountered new challenges, and its value to urinary stone treatments still requires further evaluation [10, 11].

In recent years, much light has been shed on the damage of PCNL to renal function [12]. Despite the enormous clinical knowledge of the PCNL technique and its outcomes, the impact of this technique on renal function and possible mechanism still has not been well clarified. To some degree, this may

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be due to the masking of the contralateral kidney. Hence, the effect of PCNL on the lateral kidney still needs to be investigated, especially by a long follow-up and contrast evaluation. In this study, our prospective randomized study was aimed at comparing the efficacy of PCNL using pneumatic lithotripsy vs. the Holmium laser.

Materials and Methods

This study was approved by the research council committee of our university. We enrolled 640 patients in our center from August 2010 to March 2014. A total of 200 patients were included in the study with the inclusion criteria: age between 18 and 70 years old, normal serum creatinine and uric acid, and bilateral functional kidney with solitary kidney stone. Other exclusion criteria included: combined diseases not suitable for PCNL, severe diabetes or hypertension, and anticoagulation administration. Patients were randomized into the pneumatic and holmium laser groups. Randomization was carried out using computer-generated simple random tables in a 1:1 ratio and the informed consent was obtained. The necessary preoperative preparation included laboratory tests, intravenous urograms (IVU) for normal lateral renal function, ultrasonography, and computed tomography scanning (CT-scan) for all the patients to contrast the hydronephrosis. Before PCNL, a urine culture was obtained, and, if positive, appropriate antibiotics were administered.

All procedures were performed by a single skilled urologist. After general anesthesia, a 5 F retrograde transurethral ureteral catheter was preoperatively implanted. Under ultrasound introduction, a carefully selected calyceal puncture was made with an 18 gage Skinny Needle (Cook Medical, Bloomington, IN, USA). The success of the puncture was verified by the free passage of saline injected through the preoperatively implanted ureteral catheter. A flexible 0.035-in. Zebra guidewire (Boston Scientific Miami Corporation, FL, USA) was then introduced into the renal collecting system, followed by a stepwise dilation from 6 to 16 F. Then, a ureteroscope (Lahme, Richard Wolf, Knittlingen, Germany) was introduced through a sheath to the urinary stone.

All the patients in both groups had received PCNL with single tract. Stone fragmentation was performed with a pneumatic lithotripter (Vibrolith, Elmed, Turkey, with the parameter at five bars and 10 Hz) in group I or a Ho:YAG laser (Stone Light 12 W, 550-nm laser fiber with the energy at 1–1.5 J per pulse and 5–12 Hz) in group II. Lithotripsy was performed, with a USG for preliminary confirmation for stone clearance during the surgery, followed by an implant of a ureteral double-pigtail stent (5 F for 1 month), post-operative nephrostomy drainage (14 F for 4 days) and foley catheter drainage (16 F for 5 days) according to the guideline of Chinese Urological Association. The blood creatinine and

urea nitrogen were recorded at 1 day before, right after, 1 day after, 4 days after, 1 month after, and 1 year after the operation. Additionally, the time until the peak and the changes in the split renal function by renal diuretic scan were recorded at 1 day before, 4 days after, 1 month after, and 1 year after the operation.

Comparisons of the outcomes between the two groups were performed. The data are presented as the mean $\pm$ SD. Student's *t* test was used for comparison (SPSS 13.0 software), with $p < 0.05$ considered significant.

Results

The patients' mean age, mean body weight, gender ratio, and stone sizes measured through the KUB analysis were calculated as formula: $S = l \times w \times \pi \times 0.25$ (where l = length, w = width, $\pi = 3.14$), which were all similar between the pneumatic and the laser groups (Table 1). The intra-operative and post-operative findings, such as auxiliary treatment, complications (including pelvic perforation, bleeding requiring transfusion and high fever), and hospital stay, were not significantly different. However, the stone-free rates of the two groups were significantly different (Table 2). The mean concentrations of serum creatinine, time to peak, and split renal function (pre-op and post-op) are shown in Fig. 1. No significant change was found in renal function at each peri-operative stage between the two methods of lithotripsy. Unfortunately, there are two cases in the holmium laser group who had almost lost the renal function of the operated kidney 1 year later. One patient suffered from a proximal left ureteral stone (example as in Fig 2) and the other from a staghorn stone in the left kidney pelvis.

Discussion

The treatment of large renal calculi has been revolutionized over the past two decades, and minimally invasive techniques

Table 1 Stone parameters and demographics of the patients

	Pneumatic	Holmium laser	<i>P</i>
Number of patients	100	100	
Mean age (years) $\pm$ SD	54.4 $\pm$ 12.3	53.2 $\pm$ 15.2	0.73
Gender (male : female)	64:36	58:42	0.38
Body weight (kg)	70.1 $\pm$ 10.6	69.7 $\pm$ 11.1	
Stone size (mm ²)	202.8 $\pm$ 52.6	200.3 $\pm$ 50.8	0.63
Stone location			
Pelvis	16	9	
Upper calyx	27	35	
Middle calyx	31	34	
Lower calyx	26	22	

Table 2 Intra-operative and post-operative findings

	Pneumatic	Holmium laser (%)	P
Operation time (min)	55.9 ± 16.5	62.4 ± 17.6	0.07
Stone-free rate (%)	86	92	0.03
Auxiliary treatment	13	9	0.01
Re-PNCL	8	6	
Receiving post-operative ESWL	4	2	
Post-operative complication	15	16	0.85
ureteral perforation	2	2	
Bleeding requiring transfusion	2	4	
High fever (≥39 °C)	11	10	
Hb decrease (post- minus pre-operation, g/l)	10.5 ± 4.8	9.8 ± 5.3	0.84
Hospital stay post-operatively (days)	8.2 ± 1.1	8.5 ± 1.5	0.04

have mostly replaced open surgeries. Small upper urinary tract calculi are preferentially managed with extracorporeal shock wave lithotripsy (SWL), and larger or more complex stones can be removed via PCNL [13]. The most commonly used PCNLs are pneumatic and Ho:YAG laser lithotripters. Both pneumatic and laser lithotripsy are promising therapeutic methods for energy production that have been used in recent years [14–16]. However, the side effects of the two methods still need to be clarified.

Renal function impairment is a major concern during PCNL, especially in the treatment of large renal calculi. However, the effect of PCNL on renal function remains unclear. Although an enormous clinical knowledge of the PCNL technique and its outcomes is available, quantitative data concerning the effect of this technique on renal function are insufficient. There are few literatures assessing the renal function of patients who have undergone PCNL, as well as of data specifically measuring the effect of pneumatic lithotripsy and holmium laser lithotripsy on renal function [17]. Thus, a further investigation of lithotripsy methods for PCNL is mandatory.

Cass et al. found an 8 % decrease in the mean split function of the treated side by a ^{99m}Tc-DMSA renal scan 7 days after the operation; this decrease was 4.8 % 1 month later, reflecting the largely reversible nature of the functional changes [18]. Long-term effects of PCNL on renal function have been evaluated in another study by assessing the estimated glomerular filtration rates (GFR) during the first few days after PCNL in 94 patients. Renal GFR decreased immediately after PCNL, reaching a minimum 48 h after operation before slowly increasing. Avoiding factors that can negatively affect renal function during the early postoperative period, such as nephrotoxic drugs, contrast agents, shock wave lithotripsy, and re-PCNL, seems to be advisable [19]. When the serum creatinine increases immediately, the GFR always decreases by more than 50 %. Lojanapiwat et al. assessed the short-term and long-term effects of PCNL on 17 patients with a solitary

Fig. 1 Changes in renal function as a result of PCNL. **a** Serum concentration of creatinine. **b** Serum concentration of uric acid. **c** Time to peak in diuresis renography. **d** Split renal function in diuresis renography

a

Amount (cpm)

Time (min)

LK

RK

b

SOUTHWEST HOSPITAL C5-2 Abd/Gen 08 Apr 09 10:49:42 115.6/2 Mr L2 Fr #101 19.9cm

Map 3 170dB/C2 Persist Off 2D Opt/FSCVT Fr Rate:Surv SonoCT™

BW Pg Col Pg

c

Amount (cpm)

Time (min)

RK

LK

In this study, we found that both pneumatic and Ho:YAG laser lithotripters in PCNL can be associated with acute renal function injury. The mean serum creatinine increased significantly right after the operation in the patients of both groups but became normal approximately 7 days afterward. Renal diuretic scan showed that the peak time decreased significantly right after the operation, but the recovery had begun 7 days to 1 month afterward and completely finished 1 year later. The split renal function also increased significantly after PCNL, indicating that the renal function was impaired acutely and temporarily after the adoption of both pneumatic and Ho:YAG laser lithotripters, as well as that each type of lithotripter was effective in improving the renal function.

So far, no causative relation is established or even proposed for the energy source to be causing renal injury. Our comparative study has shown that both pneumatic and holmium laser

lithotripsy can be associated with acute renal injury in some patients after the operation, with no significant difference. This might be caused by the lithotripsy or even by PCNL. However, some infrequent severe renal function damage in laser lithotripsy should be noted.

Compliance with Ethical Standards

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

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