High- vs Low-power Holmium Laser Lithotripsy: A Prospective, Randomized Study in Patients Undergoing Multitract Minipercutaneous Nephrolithotomy

Shushang Chen, Lingfeng Zhu, Shunliang Yang, Weizhen Wu, Lianming Liao, and Jianming Tan

OBJECTIVE
To determine the efficacy and safety of high-power holmium: yttrium aluminum-garnet (Ho:YAG) laser lithotripsy for multitract modified minimally invasive percutaneous nephrolithotomy (MPCNL) in the treatment of patients with large staghorn renal calculi.

METHODS
A randomized, prospective study was conducted. Two-hundred seventy-three consecutive patients (291 renal units) with large staghorn renal calculi were randomized to undergo multitract MPCNL with 30-W low-power or 70-W high-power Ho:YAG laser lithotripsy. Both groups were compared in terms of perioperative findings and postoperative outcomes, including procedure time, stone-free rate, length of hospital stay, transfusion rates, renal function recovery, and other complications.

RESULTS
The average patient age was 49.2 years (range 22-73) and mean stone size was 5.54 ± 0.7 cm. The 2 groups had some comparable perioperative findings and outcome, including tracts required per operated renal unit (n), blood loss, postoperative fever, postoperative hospital stay, stone-free rate, and improvement of operated renal function. The operation time in the high-power group was significantly shorter than that in the low-power group (129.20 ± 17.2 vs 105.18 ± 14.2, P < .01).

CONCLUSION
A combination of multitract MPCNL and high-power Ho:YAG laser lithotripsy can greatly decrease the operative time without increasing the intraoperative complications or delaying postoperative renal function recovery when compared with low-power Ho:YAG laser lithotripsy. UROLOGY 79: 293–297, 2012. © 2012 Elsevier Inc.

Although percutaneous nephrolithotomy (PCNL) has been widely used for treating large renal calculi, complete renal staghorn calculi often present a formidable challenge to the endourologist. Results from recent studies showed PCNL with multiple tracts yielded a greater stone clearance rate than single-tract PCNL in the treatment of renal staghorn calculi. Some urologists, however, may hesitate to place multiple tracts during PCNL because of the apprehension that this may increase complications. It has been demonstrated that minimally invasive PCNL (MPCNL), with small percutaneous tracts and minimized instruments, can decrease the complications, which has encouraged the application of multitract MPCNL. However, another problem emerges that the limited percutaneous working sheath may increase the operating time.

Holmium: yttrium aluminum-garnet (Ho:YAG) laser has proved to be an effective modality in the treatment of distal and proximal ureteral stones and even renal stones. The advantage of the Ho:YAG compared with other intracorporeal lithotripter devices mainly lies in the miniaturization of instruments and excellent fragmentation of all stones, regardless of their composition, and yields smaller fragments than lithoclast, pulsed dye laser, or electrohydraulic lithotripsy. However, the typical power setting of Ho:YAG laser for lithotripsy is usually ≤20 W, which greatly limits its stone fragmentation efficacy, especially for large stones. Recently, Sun et al reported using 70-W high-power Ho:YAG laser PCNL with percutaneous tracts of 26 Fr that greatly increased the speed of lithotripsy. Gu et al also demonstrated that 45-W (3.0 J × 15 Hz) Ho:YAG laser PCNL in combination with the EMS (Electro Medical Systems) pneumatic and ultrasound lithotripsy system is an effective treatment for complicated renal calculi.
We hypothesized that the application of multitract MPCNL with high-power Ho:YAG laser lithotripsy would decrease the complications and operating time in treating large staghorn renal calculi. In our present study, we therefore performed a modified MPCNL technique with a specially designed 8.5/11.5 nephroscope via the 18-Fr to 20-Fr tracts, using either a 70-W high-power Ho:YAG laser or a 30-W low-power Ho:YAG, and compared the results between the 2 groups. To our knowledge, this is the first report concerning a combination of multitract MPCNL and high-power Ho:YAG laser lithotripsy for the treatment of staghorn calculi.

MATERIAL AND METHODS

Patients

From January 2008 to September 2010, 273 consecutive patients with large staghorn kidney stones (diameter ≥4 cm, based on kidney-ureter-bladder [KUB] films) in our hospital, irrespective of the number of stones and amount of hydronephrosis, were randomly enrolled to undertake multitract MPCNLs with a pulsed Ho:YAG laser (VersaPulse 100 Power-Suite, Coherent Medical Group, Santa Clara, CA). Exclusion criteria were general contraindications of surgery, uncorrectable coagulation disorders, pyonephrosis, upper tract urinary infection without effective antibiotic control, and previous renal surgery for stones. To evaluate the effect of power on the outcomes, patients were randomized to either the low-power group (30 W, 2.0 J/pulse and 15 pulse/s) or the high-power group (70 W, 3.5 J/pulse and 20 pulse/s), using the block randomization technique. This was a nonblinded study and the study protocol was approved by the institutional ethics committee. Informed consent for the whole study protocol, including randomization, procedure, and examinations was obtained from all patients before considering them for this study. Serum hemoglobin and creatinine levels were determined preoperatively. For research, preoperative split renal function was assessed using 99mTc-DTPA (diethylenetriaminepentaacetic acid) radioisotope renography to determine the glomerular filtration rate (GFR) of both kidneys.

Surgical Procedure

The same medical team performed all of the whole operations. Patients were placed in the supine lithotomy position. Under continuous epidural anesthesia, a 5-Fr ureteral catheter was placed indwelling with cystoscopic guidance up to the renal pelvis, to create an artificial hydronephrotic kidney by retrograde infusion of saline to facilitate renal puncture and prevent downward movement of the stone during manipulation. The patient was then changed to a prone position. Percutaneous access was created with the puncture under ultrasonic guidance, followed by track dilation to allow for insertion of an 18-20-Fr working sheath with a fascia dilator. Lithotripsy was performed using an 8.5/11.5-Fr modified nephroscope (Lixun nephroscope, Richard Wolf, Knittlingen, Germany) with either a 30-W or a 70-W Ho:YAG laser with a 1000-μm optical fiber. Small fragments and stone debris were flushed out by a forceful pulse flow produced by an endoscopic perfusion pump (Huaman Ligong University Medical Corporation, Guangzhou, China).

In general, the initial puncture was made in the middle pole posterior calyx to provide access to most of the renal collecting system and for the removal of most of a staghorn stone. Then, 2 or more tracts (18-20 Fr) were created according to the sites of residual stones. After stone extraction, a 5-F double-J catheter was inserted in an antegrade fashion and 18-F nephrostomy tubes were placed in all percutaneous tracts at the end of the procedure (Fig. 1).

Perioperative Assessment and Follow-Up

Serum hemoglobin and creatinine levels were determined on the first postoperative day. Postoperative stone clearance was documented on X-ray KUB. Stone-free status was defined as complete absence of stones or residual fragments <4 mm. The nephrostomy tubes were removed 4-6 days after the operation, whereas the double-J catheter was removed 4 weeks postoperatively. All patients were followed up for at least 6 months, with intravenous pyelography, radioisotope renography, and serum creatinine estimation performed again at 6 months postoperatively.

Statistical Analysis

Operation time was the primary endpoint. Secondary outcomes were drop in hemoglobin, blood transfusion requirement, and improvement of GFR of the operated renal. The Statistical Package for the Social Science software was used for data processing (SPSS, Inc., Chicago, IL). Continuous data were compared with the Student’s t-test or the paired t-test as appropriate. Proportions were compared with chi-square test or Fisher’s exact probability test. Statistical significance was defined as P < .05 for a 2-tailed test.

RESULTS

Two-hundred ninety-one renal units in 273 patients were successfully treated with single-session PCNLs. The average patient age was 49.2 years (range 22-73). The stone size was defined as the maximal diameter measured on the preoperative X-ray film, and the average stone size was 5.54 ± 0.7 cm. The 2 groups had comparable demographic data and baseline characteristics (Table 1).

Of the 291 treated renal units, 762 tracts were established and the number of tracts required per renal unit was 2.4. In the low-power group, the mean number of tracts required per renal unit was 2.73 ± 0.6 (2 tracts in 52 kidneys [36.1%], 3 tracts in 80 kidneys [55.6%], and 4 tracts in 12 kidneys [8.3%], respectively). In the high-power group, the mean number of tracts was 2.66 + 0.6 (2 tracts in 60 kidneys [40.8%], 3 tracts in 78 kidneys [53.1%], and 4 tracts in 9 kidneys [6.1%], respectively). The operation time was measured from the establishment of percutaneous access to the end of stone fragmentation. Compared with the low-power group, the high-power group had a 19% decrease in the operation time (P < .01, Table 2).

No intraoperative pelvic perforation was observed in both groups. No significant difference in mean blood loss was observed between the 2 groups. Four patients in the low-power group and 6 in the high-power group received blood transfusions because their hemoglobin dropped below 80 g/L. No patient required angiographic intervention or open surgery for severe bleeding. One patient in
the low-power group had pleural effusion after a supra-
costal puncture and required a chest tube, which was
removed 2 days later. Fourteen patients had a postoper-
ative fever of 38.5°C or greater (axillary temperature),
and all were resolved after antibiotic treatment. No pa-
tients experienced postoperative septic shock. The total
stone-free rate was 83.2%. Of the 49 renal units with
residual stone/fragments, 19 received extracorporeal shock-
wave lithotripsy, 12 undertook a second-look PCNL, and
18 had no further treatment except regular follow-up.
Radioisotope renography of the operated renal unit at
6 months postoperatively showed significant improve-
ment in renal function in both groups (39.94 ± 6.1 vs
31.3 ± 8.8 and 40.53 ± 6.0 vs 32.38 ± 8.7, respectively,
both P <.01). No significant difference was noted in the
postoperative improvement of GFR of the operated renal
kidney and the postoperative decline of serum creatinine
between the 2 groups (Table 2).

COMMENT
The treatment of large, complete staghorn calculi usually
requires a sandwich combination of PCNL and shock-
wave lithotripsy or sometimes open surgery. Complete
removal of the stone is an important goal to prevent
further stone growth and any associated infection, and to
preserve renal function. The goal to a complete re-
moval of the renal staghorn calculi has encouraged mul-

---

Figure 1. (A) Intraoperative surface view of a patient undergoing MPCNL using 2 tracts. The arrow shows water irrigation
flowing out from the other tract during the operation, which not only reduces renal pelvic pressure but also facilitates the
elimination of stone fragments. (B) Postoperative surface view of a patient undergoing MPCNL using 3 tracts. Preoperative
(C) and postoperative (D) KUB films of the same patient with left renal calculi treated with MPCNL using 3 tracts.
multiple tracts carried out in a single session of PCNL.\textsuperscript{1,2} Despite the fact that standard PCNL is a well-recognized, safe, and minimally invasive management option for upper urinary tract calculi, it can still be associated with significant morbidity, such as bleeding, sepsis, and injury to adjoined viscera.\textsuperscript{13} In our present study, we performed a modified multitract MPCNL and the results showed that the stone-free rates in both groups were comparable with procedures using multitract standard PCNL, whereas the blood transfusion requirement was less than that reported by Aron et al.\textsuperscript{11}

The disadvantage of our multitract MPCNL instead of PCNL is that the operation time may be increased by the limited percutaneous working sheath. To increase the efficacy of lithotripsy, we used a 70-W high-power Ho:YAG laser. In previous studies, Ho:YAG laser lithotripsy was mainly reported for retrograde ureteroscopic treatment for distal, mid, and upper ureteral stones and small renal stones,\textsuperscript{14} with a low power setting of 10-20 W,\textsuperscript{15,16} which resulted in a slow fragmentation speed. Although a higher power setting may yield faster lithotripsy, it is accompanied by a potential increased risk of urothelial wall damage, so that many surgeons hesitate to perform high-power Ho:YAG laser lithotripsy. Up to now, there are only a few reports concerning the use of a Ho:YAG laser for PCNL to treat large renal calculi.\textsuperscript{9,10} In the present study, by comparing with the energy output set at 2.0 J/H\textsuperscript{11003} 15 Hz, we demonstrated that MPCNL with a high-power Ho:YAG of 70 W (3.5 J \times 20 Hz) could produce better lithotripsy efficacy without increasing intraoperative complications or delaying postoperative renal function recovery.

The pulse energy output of the Ho:YAG laser correlates with the lithotripsy efficiency, which means that higher-power and higher-frequency setting leads to faster fragmentation and shorter operation time.\textsuperscript{17} This is further supported by our study. Different from the 10-30 W Ho:YAG laser working in a fragmentation fashion of “pulverizing and drilling” the stone, the high-power Ho:YAG laser works by “vaporizing and bursting” the stone. We found that at the beginning of stone fragmentation, once the laser fiber touched a stone with 70-W energy outputs, stone dusts were produced immediately at the contact surface. The stone quickly decreased in size and then burst into small fragments, which can be easily passed through the 20-Fr dilator sheath by water irrigation. In this way, even large renal stones can be fragmented in a significantly shorter time (see the video).

To prevent the potential risk of urothelial wall damage caused by inadvertent contact with the urothelium, Jou et al\textsuperscript{15} used a specially designed laser fiber guider to hold the laser fiber steady, and Sun et al\textsuperscript{9} used a 1000-\mu m laser fiber to decrease the influence by water irrigation during lithotripsy. In the present study, we used a 1000-\mu m end-firing laser fiber together with an 8.5/11.5-Fr modified nephroscope. Because the 1000-\mu m laser fiber had a slighter thrill and was less influenced by water irrigation in the smaller-bore working channel of the modified

### Table 1. Demographic data and baseline characteristics of the 2 groups

<table>
<thead>
<tr>
<th></th>
<th>Low-power Group</th>
<th>High-power Group</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients/operated renal units</td>
<td>136/144</td>
<td>137/147</td>
<td>—</td>
</tr>
<tr>
<td>Male/female (n)</td>
<td>79/57</td>
<td>86/51</td>
<td>—</td>
</tr>
<tr>
<td>Mean age (y)</td>
<td>49.9 ± 11.3 (26-70)</td>
<td>48.4 ± 10.2 (22-73)</td>
<td>.274</td>
</tr>
<tr>
<td>Mean stone size (cm)</td>
<td>5.51 ± 0.7</td>
<td>5.63 ± 0.6</td>
<td>.181</td>
</tr>
<tr>
<td>Serum hemoglobin (g/L)</td>
<td>128.65 ± 13.8</td>
<td>128.75 ± 18.5</td>
<td>.958</td>
</tr>
<tr>
<td>Serum creatinine (\mumol/L)</td>
<td>94.02 ± 25.4</td>
<td>93.78 ± 22.1</td>
<td>.933</td>
</tr>
<tr>
<td>GFR of the kidney to be operated (mL/min)</td>
<td>31.37 ± 8.8</td>
<td>32.381 ± 8.7</td>
<td>.325</td>
</tr>
</tbody>
</table>

### Table 2. Comparison of intraoperative data and postoperative outcome of the 2 groups

<table>
<thead>
<tr>
<th></th>
<th>Low-power Group</th>
<th>High-power Group</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation time (min)</td>
<td>129.20 ± 17.2</td>
<td>105.18 ± 14.2</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Drop in hemoglobin (g/L)</td>
<td>10.34 ± 3.5</td>
<td>10.78 ± 3.6</td>
<td>.301</td>
</tr>
<tr>
<td>Blood transfusion requirement (n)</td>
<td>4</td>
<td>6</td>
<td>.749</td>
</tr>
<tr>
<td>Improvement of GFR at 6 mo postoperatively (mL/min)</td>
<td>8.58 ± 4.7</td>
<td>8.15 ± 5.1</td>
<td>.456</td>
</tr>
<tr>
<td>Tracts required per operated renal unit (n)</td>
<td>2.73 ± 0.6 (2-4)</td>
<td>2.66 ± 0.6 (2-4)</td>
<td>.333</td>
</tr>
<tr>
<td>Pelvic perforation (n)</td>
<td>0</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Pleural effusion (n)</td>
<td>1</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Postoperative fever (n)</td>
<td>9</td>
<td>8</td>
<td>.778</td>
</tr>
<tr>
<td>Postoperative septic shock (n)</td>
<td>0</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Postoperative hospital stay (days)</td>
<td>6.18 ± 1.9</td>
<td>6.64 ± 2.6</td>
<td>.072</td>
</tr>
<tr>
<td>Stone-free rate (%)</td>
<td>84.7 (122/144)</td>
<td>81.6 (120/147)</td>
<td>.481</td>
</tr>
</tbody>
</table>
nephroscope, we could obtain a clear operation field and precisely control the fiber tip movement during lithotripsy. Our experience showed that, for skilled surgeons, the 1000-μm laser fiber tip could be kept right on the target steadily. In addition, fragmenting the stone under direct vision is helpful to avoid inadvertent injury to the urothelium. Our data suggested that the 70-W high-power Ho:YAG laser MPCNL, when carefully operated, is safe in terms of perioperative bleeding and renal function.

With a purpose to overcome the disadvantage of long operating time of MPCNL, in addition to high power Ho:YAG, we also used an “endoscopic perfusion pump,” which provides a forceful pulse flow of irrigation to flush out the stone fragments. The pump can generate a pressure up to 300 mm Hg in about 3 seconds before it stops working for 2 seconds. Rapid removal of the endoscope out of the sheath synchronized with the low-flow irrigation period would create a relative vacuum within the sheath and, together with the recoil of the system from the transient high pressure from the irrigation, would flush the stone fragment out18 (see the video).

There were concerns about whether this pressurized irrigation would create a dangerously high intrapelvic pressure and cause postoperative fever. The effect of high-pressure perfusion on renal pelvic pressure in MPCNL, however, has been proven to be safe in previous studies.19,20 Furthermore, in multitract MPCNL, water irrigation may flow out from the other tract during the operation, which reduces renal pelvic pressure. Moreover, small stone fragments can be flushed out from 1 tract when the pulse flow comes from the other tract (Fig. 1A). Hence, the operative time is reduced and the stone clearance rate is improved.4 In our study, the rate of postoperative fever was compared favorably with those reported in the literature.9,11

CONCLUSIONS
A combination of multitract MPCNL and high-power Ho:YAG laser lithotripsy can greatly decrease the operative time without increasing the intraoperative complications or delaying postoperative renal function recovery when compared with low-power Ho:YAG laser lithotripsy.

References