COMPARISON OF EFFICACY BETWEEN LASER AND PNEUMATIC LITHOTRIPSY FOR URETERAL STONE MANAGEMENT: A SYSTEMATIC REVIEW AND META-ANALYSIS

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ABSTRACT

Objective: This study aimed to evaluate the efficacy of ureteroscopy lithotripsy (URS) using laser lithotripsy compared to pneumatic lithotripsy for ureteral stone management. Material & Methods: A systematic search was conducted in PubMed and ScienceDirect. The search and screening process in this study followed the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guideline to include relevant RCTs. The included studies were assessed for their risks of bias using the Cochrane risk of bias tool 2 (RoB 2). The comparison of outcomes, which includes stone-free rate, DJ-Stent use, and mean fragmentation time between laser and pneumatic lithotripsy was analyzed using Review Manager 5.4. Results: A total of 11 RCTs evaluating a total of 235 patients with ureteral stone were analyzed in this review. Compared to pneumatic lithotripsy, laser lithotripsy has a significantly higher stone-free rate (OR 2.39, 95% CI 1.78-3.21, p < 0.001), longer mean fragmentation time (MD 4.11, 95% CI 3.17-5.04, p < 0.001), and lower DJ stent use rate (OR 0.53, 95% CI 0.36-0.76) based on the forest plot analysis. Conclusion: Patients undergoing laser lithotripsy have a higher stone-free rate, a lower DJ stent use rate, and albeit a longer mean fragmentation time compared to pneumatic lithotripsy.

Keywords: Ureteroscopy lithotripsy, laser lithotripsy, pneumatic lithotripsy.

INTRODUCTION

Urolithiasis is one of the most common causes of morbidity in the field of urology. Ureter is the most common urinary organ affected by the formation of stone (76.4%) followed by the kidney (15.8%). Ureterolithiasis occurred in a variety of age groups. Among adults, anatomical abnormalities, and other external factors are believed to have a major role in the formation of ureterolithiasis. The prevalence of ureterolithiasis varies among age, sex, and race. Men are more prone to urolithiasis compared to women with a prevalence ratio of 2:1.
Most patients came with complaints of colicky flank pain felt spreading to the scrotal area. The management of patients with ureterolithiasis varies from oral pharmacotherapy to surgical interventions. Approximately 75 to 90% of ureteral stones can be expelled spontaneously. This phenomenon relies on the diameter of the stone. Education regarding lifestyle changes to patients with stones less than 4 mm in diameter and without complications, such as fever, hydronephrosis, and unbearable pain may help the spontaneous process of expulsion. In cases where the size of the stone is more than 5 mm, medical expulsion therapy (MET) may help spontaneous expulsion in 40% of cases.

The active act of stone removal is one of the possible alternatives that need to be performed if there is a complication or failure of therapy using METs. There are several modalities of operative treatment, such as open surgery, extracorporeal shock wave lithotripsy (ESWL), laparoscopic ureterolithotomy, and ureteroscopy (URS). Currently, minimally invasive surgeries like URS or laparoscopy are commonly used. The reason between URS or laparoscopic use is the few amounts of complications that may arise compared to the open alternative. The trend of operative interventions for stone management is increasing as there are consequences for conservative management failure, including potential persistent pain during the therapy. The main risk for intervention is the potential risks from anesthesia, upper urinary tract infection, and ureteral injury, which could be reduced by state of the art techniques with certain triptors.

There are several alternatives of energy that can be used to fragment ureteral stones, such as ultrasonic wave, electrohydraulic, pneumatic, and laser. However, pneumatic lithotriptor is the most commonly used compared to other alternatives due to its efficacy for many types of stones. The current improvement of technology generates new alternatives like laser. Laser has several modes to fragment stones. Laser Ho YAG is reported to have good outcomes. The use of Laser is recently reported to have several advantages compared to pneumatic lithotriptors. However, there are also other publications that highlighted the efficacy of pneumatic lithotriptors over other alternatives including laser.

**OBJECTIVE**

This study aimed to evaluate the efficacy of ureteroscopy lithotripsy (URS) using laser lithotripsy compared to pneumatic lithotripsy for ureteral stone management.

**MATERIAL & METHODS**

We performed a systematic search in the PUBMED and Science Direct databases. The search and screening process was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The main keywords used during the search were lithotriptor, laser, and pneumatic. The measured dependent variables were: stone-free rate, mean fragmentation time, and the use of DJ stent after every procedure.

This meta-analysis included only randomized controlled trial design studies which compare laser to pneumatic lithotripsy. Case-control, cross-sectional, cohort, and non-randomized controlled trials were excluded. The inclusion and exclusion criteria are presented in table 1.

Data were independently extracted from each study applying a standardized form by all reviewers and the disparity of the reviewers was solved by discussion. If the reviewers could not reach a consensus, another author was consulted to resolve the dispute and a final decision was made by the majority of votes.

The risk of bias of the studies was performed to determine the quality of each included study. The

**Table 1. Inclusion and exclusion criteria of the research.**

<table>
<thead>
<tr>
<th>Inclusion</th>
<th>Exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Randomized controlled trials (RCTs)</td>
<td>Research in the form of abstract only</td>
</tr>
<tr>
<td>Studies comparing pneumatic and laser lithotripsy for ureteral stone management</td>
<td>Studies evaluating patients with kidney stone undergoing a laser and pneumatic lithotripsy combination</td>
</tr>
<tr>
<td>Studies with 2 arms or more</td>
<td>Studies evaluating pediatric patients</td>
</tr>
<tr>
<td>Patients undergoing URS</td>
<td></td>
</tr>
</tbody>
</table>

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studies were evaluated using the Cochrane risk of bias tools (RoB) for randomized trial, which assessed several parameters: selection bias, performance bias, detection bias, reporting bias, and incomplete outcomes. This review did not use other tools as the included studies were all RCTs.

Every included article was presented in the baseline characteristics table. The studies’ authors, year, sample size in each arm, age, design, stone size in centimeters (cm), stone-free rate, DJ stent use rate, and mean fragmentation time (MFT) are reported for each study. The samples were divided into the laser lithotripsy (LL) and pneumatic lithotripsy (PL) groups.

The visualization of each study result was presented in forest plot. Continuous data were presented as mean and standard deviation, in which the difference was compared between each study. Dichotomous data from the proportion and sample size were analyzed as odds ratio. The analysis was performed using Review Manager 5.4.

RESULTS

A total of 11 studies were included in this meta-analysis. The data from each study was analyzed and presented in the forest plot. Heterogenous research data was analyzed using a random-effects model, whereas homogenous data was analyzed using a fixed-effects model. The flow of this research is briefly described in the prism flowchart in figure 1.

Every included study was analyzed both qualitatively and quantitatively as well as presented as a tabulation in Table 2. There are 2033 patients from 11 studies with an average age of 41.6 ± 3.8 years old.

Figure 1. PRISMA diagram describing the systematic search and screening process.
The 2035 samples in this study were divided into the laser lithotripsy group consisting of 1021 samples and pneumatic lithotripsy consisting of 1014 samples. From the overall meta-analysis, the data is quite homogeneous based on the results from $I^2$, so the analysis uses a fixed effect model. The components assessed in this meta-analysis were SFR, DJ stent usage rates, and MFT.

Table 2. Studies’ Baseline Characteristics.

<table>
<thead>
<tr>
<th>No</th>
<th>Author</th>
<th>Year</th>
<th>Intervention</th>
<th>Samples</th>
<th>Age (years)</th>
<th>Stone size (mm)</th>
<th>Follow-Up (months)</th>
<th>Early SFR (n)</th>
<th>Stone Migration (%)</th>
<th>Stent (n)</th>
<th>MFT (minutes ± SD)</th>
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<td>2013</td>
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<td>56</td>
<td>35.9</td>
<td>11.7</td>
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<td>56</td>
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<td>-</td>
<td>13.7 ± 12.6</td>
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<tr>
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<td></td>
<td>36.4</td>
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<td>46</td>
<td>-</td>
<td>-</td>
<td>7.9 ± 4.2</td>
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<td>2</td>
<td>Binbay</td>
<td>2011</td>
<td>Laser</td>
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<td>40.2</td>
<td>11</td>
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<td>39</td>
<td>2.5</td>
<td>3</td>
<td>10 ± 40</td>
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<td>40</td>
<td>39.6</td>
<td>11.8</td>
<td>15.3</td>
<td>32</td>
<td>10</td>
<td>40</td>
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<td>44</td>
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<td>9.4</td>
<td>79</td>
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<td>44</td>
<td>1.17</td>
<td>11.52</td>
<td>112</td>
<td>18.5</td>
<td>25</td>
<td>12.24 ± 3.95</td>
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<td>Cimino</td>
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<td>Laser</td>
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<td>48</td>
<td>11</td>
<td>-</td>
<td>-</td>
<td>1.66</td>
<td>-</td>
<td>-</td>
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<tr>
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<td></td>
<td></td>
<td>Pneumatic</td>
<td>57</td>
<td>51</td>
<td>10.2</td>
<td>-</td>
<td>-</td>
<td>10.53</td>
<td>-</td>
<td>-</td>
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<td>5</td>
<td>Garg</td>
<td>2009</td>
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<td>34</td>
<td>44</td>
<td>11.1</td>
<td>11.35</td>
<td>33</td>
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<td></td>
<td></td>
<td>Pneumatic</td>
<td>25</td>
<td>43</td>
<td>11.1</td>
<td>7.92</td>
<td>21</td>
<td>16</td>
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<tr>
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<td>43.9</td>
<td>12.8</td>
<td>-</td>
<td>32</td>
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<td>5</td>
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<td>46.1</td>
<td>1.31</td>
<td>-</td>
<td>32</td>
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<td>12</td>
<td>53.5 ± 29.2</td>
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<td>7</td>
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<td>Laser</td>
<td>493</td>
<td>40.3</td>
<td>8.5</td>
<td>12</td>
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<td></td>
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<td>8.8</td>
<td>12</td>
<td>395</td>
<td>4.30</td>
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<td>8</td>
<td>Maghsoudi</td>
<td>2008</td>
<td>Laser</td>
<td>39</td>
<td>42.5</td>
<td>12.07</td>
<td>-</td>
<td>-</td>
<td>2.40</td>
<td>-</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Pneumatic</td>
<td>40</td>
<td>38.5</td>
<td>10.2</td>
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<td>7.30</td>
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<tr>
<td></td>
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<td>37.6</td>
<td>10.17</td>
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<td>16</td>
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<td>7.86 ± 3.25</td>
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<td>Rabani</td>
<td>2019</td>
<td>Laser</td>
<td>58</td>
<td>41.7</td>
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<td>-</td>
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<td>8.55</td>
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<tr>
<td></td>
<td></td>
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<td>Pneumatic</td>
<td>59</td>
<td>41.1</td>
<td>9.77</td>
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<td>8.55</td>
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<td>11</td>
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<td>2020</td>
<td>Laser</td>
<td>48</td>
<td>36.72</td>
<td>113.6</td>
<td>3</td>
<td>47</td>
<td>4.20</td>
<td>40</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Pneumatic</td>
<td>53</td>
<td>41.54</td>
<td>13.22</td>
<td>3</td>
<td>51</td>
<td>3.70</td>
<td>40</td>
<td>-</td>
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</table>

There are 8 studies evaluating the SFR results of the groups. Pooled analysis showed that the studies were homogeneous ($I^2 = 34\%, p = 0.16$). Analysis was therefore performed using the fixed-effects model. LL group had a higher SFR compared to the PL group (OR: 2.39 95% CI 1.78-2.31, $p<0.001$) as shown in figure 2.

Figure 2. The SFR results analysis presented in the forest plot indicating a favorable tendency towards the LL group.
There are 6 studies evaluating DJ-stent use after both procedures. The pooled analysis results showed homogeneity ($I^2 = 0\%$, $p = 0.52$). As the samples were homogeneous, a fixed-effects model was used. The forest plot analysis in figure 3 showed a significantly higher DJ Stent use among the PL group compared to the LL group (OR 0.53, 95% CI 0.36-0.71, $p = 0.0007$).

There are 5 studies evaluating stone fragmentation time results between the groups. Pooled analysis results showed a low level of heterogeneity ($I^2 = 37\%$, $p = 0.17$), leading to fixed-effects model analysis. The MFT of the PL group was significantly 4.11 minutes lower compared to the LL group (MD 4.11, 95% CI 3.17-5.04, $p = 0.0007$) as shown in figure 4.

DISCUSSION

Ureteral colic is a common complaint among patients found daily in the practice of general practitioners. The pathogenesis of this condition is due to an obstruction of urinary flow leading to urinary tract distention. The increase of pressure of the urinary tract will cause a release of inflammatory mediators perceived as a painful sensation by the body. There are several causes of ureteral obstruction, including ureteral stone, blood clot, tumor, and trauma. Ureteral stone is the most common etiology for ureteral obstruction. Stones with more than 5 mm in size are usually treated with medical expulsive therapy (MET), such as alpha-blockers, calcium channel inhibitors, or PDE5 inhibitors to reduce colicky pain episodes as well as increasing the chance for spontaneous expulsion. Failure of METs is usually followed by surgical interventions. One of the most common surgical procedures is Ureterorenoscopy (URS). Innovations in URS have led to better optical use and the utilization of new energies to increase efficacy in ureteral stone management.

Among all energy alternatives in URS, pneumatic and laser energies are the most commonly used. Currently, the efficacy between laser and pneumatic lithotripsy is still being debated. Laser is considered better in terms of fragmentation time and flexibility, however, pneumatic is considered better in terms of cost and application. Previous meta-analysis attempted to compare laser and pneumatic URS, however, the review had not analyzed the
parameters of MFT and DJ stent use rate in great detail. Moreover, there were three published RCTs after the publication of said review comparing the efficacy and safety between the two methods.

One of the variables for efficacy is SFR, which was explained in 8 studies: Bagbanci et al, Binbay et al., Garg et al., Kassem et al., Li et al., Nour et al., Rabani et al., and Razaghi et al. The meta-analysis in this study showed a higher SFR among the LL group, except the result by Kassem et al. The difference shown in the study by Kassem et al is possibly due to the relatively small sample size in the two arms of the study. The pooled analysis showed a 2.39 fold increase of SFR of the LL group compared to the PL group.

There is a difference in mechanism between the pneumatic and laser groups affecting the efficacy of both modalities to reach stone fragmentation. Pneumatic lithotripsy works by generating mechanical energy similar to how a hammer breaks a stone by transmitting an air projectile with a frequency up to 12 times per minute. Stone fragmentation occurs due to the transmission of repeated kinetic energy towards the stone. The main problem that may occur due to pneumatic lithotripsy is retrograde expulsion of the stone. Laser lithotripsy (Holmium: YAG) uses photothermal energy as a source for stone fragmentation. The released energy would lead to gradual stone fragmentation.

This review also discussed the rate of DJ stent use among the two groups. There are 6 studies evaluating DJ stent use, Bagbanci et al., Binbay et al., Garg et al., Kassem et al., Li et al., and Nour et al. Quantitative analysis showed that the patients in the PL group underwent DJ stent placement more frequently compared to the LL group. There is a variety of indications for DJ stent use after URS, several of which are to reduce the possibility of post-procedural obstruction and pain. The majority of DJ stent use is to reduce obstruction due to residual stones. This study showed that the LL group has a higher SFR which may be related to lower DJ stent use rate. Laser is known to be able to fragment stone into smaller pieces compared to the pneumatic alternative. Smaller fragments have a higher probability of spontaneous expulsion compared to larger ones. Most URS use semi-rigid scopes which could lead to larger fragments that are more difficult to be extracted. The use of ballistic energy lead to a possibility of retropulsion during the procedure. These factors lead to a higher DJ stent use rate among the PL group compared to the LL group.

One of the important outcomes for efficacy is MFT. There are 5 included studies evaluating MFT as an outcome: Bagbanci et al., Garg et al., Kassem et al., Manohar et al., dan Razaghi et al. The analysis of the studies showed that, on average, LL is 4.11 minutes slower compared to PL. The MFT results in this review implied that PL is more effective compared to LL in terms of procedure duration. The direct mechanism of PL to fragment stone plays a huge role in effectiveness in duration compared to LL. This finding is different compared to the previous meta-analysis which showed a longer operating time in the PL group compared to the LL group. The difference in results is due to the difference in duration parameters evaluated. This review evaluated the duration of MFT without taking into account other factors that may affect the operating time during the entire procedure. Other additional factors may increase the overall time of the PL procedure.

CONCLUSION

Patients undergoing URS with LL have a higher SFR and lower DJ stent use rate compared to the PL group, however, LL requires more time to fragment stones compared to PL. Further studies should focus on the comparison between the procedures with the same amount of energy used, using a larger sample size to evaluate potential adverse events during and after both procedures.

REFERENCES