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Supine versus Prone Position during Extracorporeal Shockwave Lithotripsy for Treating Distal Ureteral Calculi: A Systematic Review and Meta-Analysis

Key Words

Extracorporeal shockwave lithotripsy · Shockwave lithotripsy · Prone · Supine · Urolithiasis

Abstract

Purpose: We aimed at evaluating the efficacy of extracorporeal shockwave lithotripsy (SWL) for treating distal ureteral calculi performed in supine vs. prone position. **Materials and Methods:** Eligible studies were identified by 2 reviewers using PubMed, Embase, and Web of Science databases. Outcomes included stone-free rate after the first and the final SWL session, the mean number of shocks per SWL session, the mean percentage of power used in the first SWL session, and the mean number of SWL sessions per patient. **Results:** Pooled data among the 647 included patients showed that supine SWL was associated with a significantly higher stone-free rate than prone SWL. This difference was consistent for both the first SWL session (OR 4.17; 95% CI 2.53–6.87; $p < 0.00001$) and the final session (OR 3.02; 95% CI 1.96–4.67; $p < 0.00001$). No differences in the mean number of shocks per SWL session, the mean percentage of power used in the first SWL session, and the mean number of SWL sessions per patient were observed between the positions. SWL complications were infrequent and the incidence was insufficient for further analysis. **Conclusion:** SWL is safe and effective for the management of distal ureteral calculi, and supine SWL is more effective than prone SWL for achieving a stone-free status.

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Introduction

Since its initial application in the early 1980s, extracorporeal shockwave lithotripsy (SWL) has revolutionized the management of urinary stones, and rapidly expanded from fragmentation of stones in the kidney to those in the mid and distal ureter [1]. The European Association of Urology and the American Urology Association guidelines stated that both SWL and ureteroscopy were acceptable primary approaches for management of distal ureteral calculi [2]. Because SWL has the advantages of being minimally invasive, lacks severe undesirable side effects, and does not require the use of general anesthesia, it has gained widespread acceptance and use for treating distal ureteral stones in certain areas [3].

However, how a patient's position should be during SWL for distal ureteral calculi is still a matter of controversy. Traditionally, most clinicians preferred prone SWL because shockwaves can be blocked by the bony pelvis when the patient is in a supine position, which reduces SWL efficacy [4]. However, with constant advances in technology and increased experience, more urologists believed that the supine position was more cost effective and they claimed that shockwaves could traverse from gaps of the bony pelvis to reach stones lying in the distal ureter [4]. It has also been suggested that the prone position had

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a higher risk of causing intestinal perforation and other complications [5, 6].

Current treatment guidelines do not provide sufficient information regarding the patient's position during SWL. Hence, the aim of this study was to assess the efficacy of SWL for treating distal ureteral calculi performed in the supine vs. prone position through a comprehensive review and meta-analysis of previous comparative studies.

Materials and Methods

Literature Research

All studies published in English between 1980 and 2015 were searched in the PubMed, Embase, and Web of Science databases. The following search strategy was used to identify relevant reports: extracorporeal shock wave lithotripsy or extracorporeal shock-wave lithotripsy or SWL or ESWL and prone or supine or transgluteal. References within the identified articles were also researched. All computer searches were supplemented with manual searches. When multiple reports described the same study population, either the most formal or the most recent report was used.

Inclusion and Exclusion Criteria

All available randomized controlled trials (RCTs), case-control studies (CCSs), and cohort studies that compared the efficiency of supine (or transgluteal) SWL with prone SWL for treating distal ureteral calculi were included. However, patients with multiple stones, pretreatment procedures such as percutaneous nephrolithotripsy, pyelolithotomy, double-J stent, a percutaneous nephrostomy tube, or patients who received adjuvant medical treatment were excluded. Finally, reports that were not extractable or whose data were not available were not included in the analysis.

Data Extraction

Two authors (T.L. and L.G.) extracted data independently using a pre-designed data extraction form. After extraction, the 2 authors met to combine their findings, and any discrepancies in the extracted data were resolved through discussion. If an agreement could not be reached, the issue was resolved through consultation with an independent third author (Q.W.).

Outcomes of Interest

The primary outcomes investigated were patient stone-free rate after the first and the final SWL treatment session, followed by the mean number of shocks per SWL session, the mean percentage of power used in the first SWL session, and the mean number of SWL sessions per patient. Stone-free status was defined as having either no or only clinically insignificant residual stone fragments (<3 mm), evaluated by kidney-ureter-bladder radiography or ultrasonography performed at the third month or longer after the last SWL session.

Quality Assessment

Two authors assessed each study according to the Centre for Evidence-Based Medicine in Oxford and modified the Newcastle-Ottawa Quality Assessment Scale 7 for controlled trials. In the modified Newcastle-Ottawa scale, a score of 1–9 stars was allocated to all controlled studies.

Data Analysis

The meta-analysis was performed using the random-effects method for studies with significant heterogeneity and fixed-effects method for those without significant heterogeneity using Review Manager 5.2 (Cochrane Collaboration, Oxford, UK). Statistical heterogeneity among trials was evaluated using I^2 and χ^2 tests, with significance set at $p < 0.05$. I^2 values of 25, 50 and 75% corresponded to low, medium, and high levels of heterogeneity, respectively. The weighted mean difference (WMD) and OR were used to describe results for continuous and dichotomous variables, respectively. All results were reported with 95% CI.

Articles published within the last 5 years were retained for sensitivity analysis to explore the influence of progression on SWL.

Results

Description of Studies

Two hundred and two studies were identified from the electronic and manual database searches. After assessment, 4 trials, 1 RCT [7] and 3 CCSs [6, 8, 9] were selected for further analysis (fig. 1).

The 4 trials reported data on 647 patients: 328 and 319 patients received SWL in the supine position and prone position, respectively. The study characteristics and methodological quality assessment of these 4 trials are summarized on table 1. The baseline information was comparable between patients in the supine and prone groups. Some continuous data reported by Istanbuluoglu et al. [9] were presented as medians and ranges; the formulas described by Hozo et al. [10] were used to calculate means and SD.

Stone-Free Rate after the First SWL Session

Three studies including 305 patients reported success rates for SWL in the supine and prone positions after the first SWL session. Heterogeneity in pooled analysis was not significant ($p = 0.77$; $I^2 = 0\%$). Based on a meta-analysis of data from these 3 trials, the stone-free rate in the supine group (77.2%) was significantly higher than that in the prone group (44.8%; OR 4.17; 95% CI 2.53–6.87; $p < 0.00001$; fig. 2). After excluding the trial by Guntekin et al. [6], a sensitivity analysis demonstrated statistical significance between supine and prone positions (OR 4.49; 95% CI 2.45–8.24; $p < 0.00001$). This finding indicated that the meta-analysis was not influenced by progression on SWL.

Stone-Free Rate after the Final SWL Session

All the 4 studies including 647 patients reported a stone-free rate for SWL in the supine or prone position after the final SWL session. Heterogeneity between studies was insignificant in the pooled analysis ($p = 0.19$; $I^2 = 36\%$). The

Fig. 1. Flow diagram of meta-analysis.

Table 1. Study characteristics

Study, year	Design	No. of patients		Age, years		Stone size		Level of evidence	Newcastle-Ottawa scale	Anesthesia
		supine	prone	supine	prone	supine	prone			
Guntekin 1994 [6]	CCS	59	38	48	48	9.1±3.4 mm	9.2±3.1 mm	3c	★★★★	Analgesics and sedation if necessary
Istanbulluoglu 2011 [9]	CCS	148	194	50.16 (10–84)	41.12 (2–81)	61.32 (16–204) mm ²	59.04 (10–238) mm ²	3b	★★★★★	Sedoanalgesia
Phipps 2013 [8]	CCS	72	38	51.3±1.8	48.3±2.2	7.6±0.3 mm	7.9±0.4 mm	3b	★★★★★	NM
Kamel 2015 [7]	RCT	49	49	44.3±4.3	47.6±3.5	8.6±0.5 mm	8.4±0.65 mm	2b	★★★★★★	Sedoanalgesia
				WMD 2.06 95% CI –3.08 to 7.19 p = 0.43	WMD* –0.06 95% CI –0.50 to 0.38 p = 0.78					

NM = Not mentioned. * Trial of Istanbulluoglu was excluded from the meta-analysis for stone size.

meta-analysis of pooled data demonstrated a significantly higher stone-free rate after the final session for SWL in the supine position (89.6%) than in the prone position (72.7%; OR 3.02; 95% CI 1.96–4.67; $p < 0.00001$; fig. 3). A sensitivity analysis also found a significant difference in the stone-free rate after the final SWL session between the supine and prone positions (OR 3.06; 95% CI 1.95–4.79; $p < 0.00001$).

Mean Number of Shocks per SWL Session

All trials including 647 patients reported the mean number of shocks per SWL session in both positions. However, data heterogeneity was observed in the pooled

analysis ($p < 0.00001$; $I^2 = 96\%$). The meta-analysis did not show a significant difference (WMD 119.60; 95% CI –200.38 to 439.59; $p = 0.46$; fig. 4). Similarly, no significant difference was observed in the sensitivity analysis (WMD 320.02; 95% CI –14.93 to 654.97; $p = 0.06$).

Mean Percentage of Power Used in the First SWL Session

Two of the 4 trials with 208 patients revealed the mean percentage of power used in the first SWL session in the supine vs. prone position. Heterogeneity was observed in pooled analysis ($p = 0.0007$; $I^2 = 91\%$) and there was no

Fig. 2. Stone-free rate after the first SWL session (**a**) and sensitivity analysis for stone-free rate after the first SWL session (**b**).

Fig. 3. Stone-free rate after the final SWL session (**a**) and sensitivity analysis for stone-free rate after the final SWL session (**b**).

Fig. 4. Mean number of shocks per SWL session (**a**) and sensitivity analysis for mean number of shocks per SWL session (**b**).

statistically significant difference in the mean percentage of power used in the first SWL session between the 2 positions (WMD -1.85; 95% CI -4.20 to 0.50; $p = 0.12$).

Mean Number of SWL Sessions per Patient

Two studies [7, 8] restricted the maximum number of SWL sessions to 2, whereas a third study [9] had a maximum of 4 sessions; however, this was not mentioned by Guntekin et al. [6]. Thus, pooled data by Istanbulluoglu et al. [9] and Guntekin et al. [6], where the mean number of SWL sessions per patient was reported, were evaluated. Heterogeneity was observed ($p = 0.05$; $I^2 = 74\%$) and no significant difference was revealed (WMD -0.21; 95% CI -0.67 to 0.24; $p = 0.36$).

Treatment Complications

Among the 4 trials analyzed, Guntekin et al. [6] have reported that most patients experienced transient hematuria and small erythematous areas on the skin, while 6 patients developed colic, and 3 patients developed a fever secondary to urinary infection. Istanbulluoglu et al. [9] have reported various degrees of petechiae and early hematuria in almost all cases. However, no complications were reported by Phipps et al. [8] and Kamel et al. [7]. With these limitations, the reported data were not suitable for meta-analysis. Meanwhile, no major or severe complications were encountered in any of these trials.

Discussion

The basic mechanism of SWL is the production of an acoustic wave that can be focused at a specific location for stone fragmentation [11]. However, blockage of shockwaves by the bony pelvis during SWL in the supine position would reduce the efficacy of SWL [4], which has traditionally restricted the use of SWL for treating distal ureteral calculi. In 1998, Jenkins et al. [5] proposed using SWL in a prone position to fragment distal ureteral calculi, following which numerous other studies have established the safety and efficacy of this procedure.

However, there are drawbacks in performing SWL in the prone position, including patient discomfort on inspiration and expiration, increased intra-abdominal pressure, and decreased lung capacity [4, 12]. With advances in technology and increase in confidence and experience, more urologists regard SWL in a supine position to be more cost effective. They have claimed that the SWL shockwaves can traverse gaps in the bony pelvis, such as the sciaticum majus foramen and sciaticum minus foramen, to reach and fragment stones blocking the distal ureter [4].

However, this controversy has not been resolved, which prompted us to evaluate current evidence and draw a conclusion on this issue. In our study, pooled data on stone-free rates after the first and the final SWL ses-

sions showed that SWL in the supine position can be more effective compared with SWL in the prone position. Considering the ongoing progress in SWL technology, only articles published in the last 5 years were used for sensitivity analyses, which yielded parallel results. However, the pooled result may be easily understood. In the supine position, the lithotripter treatment head is in contact with the patient's posterior abdomen and shockwaves entering the body traverse homogenous muscle tissues, reaching the stone with attenuation of only 20% of its power [13]; however, in the prone position, shockwaves entering the body would be significantly decreased because they traverse the air-filled bowel. This decrease would undoubtedly reduce the shockwave efficacy in stone fragmentation [13].

Besides, Becht et al. [14] have achieved a 95% stone-free rate for patients with distal ureteral stones using SWL with the patient in a supine position and the pelvis nearly in the horizontal position. This position allowed X-rays and shockwaves to enter through the foramen obturatum or the greater sciatic notch. Other authors reported success rates of 94 and 89% using SWL with patients in a sitting position [4] and 'straddle' (horse-riding) position [15], respectively. All of these modified positions ensure that the shockwaves traverse more homogeneous muscle tissue and reach the stone without significant attenuation [16], which greatly improves SWL efficacy.

Moreover, the skin-to-stone distance is often significantly greater in the prone position; consequently, there is greater attenuation of shockwave power and decreased fragmentation efficacy [8].

On the basis of acoustic wave delivery characteristics, Zomorodi et al. [16] have reported that the number of shocks per SWL treatment session, number of SWL sessions per patient, and the shock voltage per session were all significantly lower in supine position. Nevertheless, Phipps et al. [8] have stated that the supine position could be better tolerated by patients during SWL. However, in our study we found no significant differences between the supine and the prone position in the mean number of shocks per SWL session, the mean percentage of power used in the first SWL session, or the mean number of SWL sessions per patient. Collectively, these results do not decrease the validity of our conclusion, because the greater skin-to-stone distance and increased shockwave attenuation in the prone position would decrease fragmentation efficacy even using the same shockwave generated by the same lithotripter.

Another natural parameter that needs to be assessed with regard to SWL is the one related to complications in

procedure. The American Urology Association and European Association of Urology guideline panels believed that the complication rates were low and that the most relevant complications were sepsis, steinstrasse, ureteral injury and stricture, and urinary tract infection [2]. The SWL-associated complication rate has been reported to range between 0 and 6% [17]. However, although Phipps et al. [8] and Kamel et al. [7] did not mention any procedure-associated complications, Guntekin et al. [6] and Istanbuloglu et al. [9] have reported transient hematuria, small erythematous areas, or varying degrees of petechiae in most patients. The difference may be explained by the fact that hematuria and cutaneous petechiae at the shockwave entry site would spontaneously resolve within 24–48 h after the SWL session [18]. While many recent publications do not mention their occurrence, they did not regard petechiae or hematuria as complications [18]. Besides, potential infection problems could be avoided by preoperatively identifying patients with such a risk and administering appropriate antibiotic treatment [17]. Obstructing fragments can usually be successfully treated with repeated SWL sessions and, if necessary, stent insertion [17]. Furthermore, Maker et al. [13] has stated that, despite the rarity of intestinal perforation, it occurs at a higher frequency during SWL in the prone position, which was not presented in our study. In brief, the frequency of complications following SWL for ureteral stones is low.

In addition, ureteroscopy has been safer and more efficacious than other methods since the introduction of smaller flexible and semi-rigid ureteroscopes. Thus, ureteroscopy lithotripsy is another alternative efficient and important choice for the management of ureteral stones for those unwilling or unsuitable to receive SWL treatment. In the meantime, laser lithotripsy should be preferred, because it allows a higher stone-free rate when compared to pneumatic lithotripsy [19].

From the summarized results, significant heterogeneity was identified and the following factors may have contributed to this. First and foremost, the size, composition and location of the ureteral calculi are different, making patient matching challenging. Second, the dietary and exercise habit or the ureteral tube diameter varied; all these affect the baseline and comparability. Third, the basic mechanism of SWL is to manually focus an acoustic wave at the stone, so that the results could be easily influenced by surgeons' experience and degree of trainee.

Finally, our study has several limitations that must be considered. First, only one RCT and 3 CCSs were included in the pooled analysis, which had a large impact on our

conclusions. Second, there are inevitable differences in the judgment and standards of the authors of these studies, which were conducted in different districts and at different institutions. All of these factors influenced the quality of both the original and pooled results and the conclusions drawn from these analyses.

Conclusion

The results of this systematic review and meta-analysis suggested that SWL in the supine position has a higher stone-free rate than SWL in the prone position for treating distal ureteral calculi. Both positions were equivalent with regard to the mean number of shocks per SWL session, the mean percentage of power used in the first SWL session, and the mean number of SWL sessions per patient. SWL complications were rare. In conclusion, SWL

for distal ureteral calculi is a safe procedure and it is more effective in the supine position than in the prone position. However, the safety and efficacy of the supine position would be better established with further large multicenter prospective RCTs.

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Disclosure Statement

No competing financial interests exist.

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