Predictors of successful emergency shock wave lithotripsy for acute renal colic

Adel Kurkar1 · Ahmad A. Elderwy1 · Mahmoud M. Osman1 · Islam F. Abdelkawi1 · Mahmoud M. Shalaby1 · Mohamed F. Abdelhafez1

Received: 1 April 2022 / Accepted: 9 May 2022 / Published online: 3 June 2022 © The Author(s) 2022

Abstract
The role of emergency shockwave lithotripsy (SWL) in persistent pain control in patients with ureteral stones is not well established. The aim of this study is to evaluate efficacy as well as the predicting variables for successful early SWL patients with symptomatic ureteral stones. Eighty-six patients with a persistent renal colic secondary to single ureteral stone (6–12 mm) were prospectively enrolled in this study. SWL was performed within 24 h of the onset of flank pain. Pain control and stone-free rate after emergency SWL session were 58.1% and 44.2%, respectively. Seven patients required post-SWL ureteroscopy and ureteral stent placement for uncontrolled pain. The overall 3-month stone-free rate after SWL monotherapy was 83.7%. On multivariate analysis, predictors for pain relief after emergency SWL were lower Hounsfield (HU) stone density, mild hydronephrosis (HN) at presentation and presentation during the first colic episode. Lower HU stone density was the single predictor of successful stone clearance after single emergency SWL session on multivariate analysis. In conclusion, early SWL is feasible and effective in management of ureteral stones presented by renal colic with low HU.

Keywords Emergency shockwave lithotripsy · Renal colic · Ureteral stone

Introduction
The prevalence of nephrolithiasis is reported to be 13% [1]. In addition, there is also a noticeable increase in the number of patients who receive an active treatment for upper urinary tract calculi (UUTC). Park et al., (2016) reported an increase of different modalities of intervention including SWL, ureteroscopy (URS) and percutaneous nephrolithotomy (PNL) by 102, 110, and 180%, respectively, over the last 10 years [2]. Although many factors are expected to influence the treatment decision for patients with UUTC, pain relief remains the first concern in an acute episode [3]. Non-steroidal anti-inflammatory drugs (NSAID) are the first-line drugs with a better efficacy in pain control compared to opioids only or combined opioids and antispasmodics [4]. Pethidine in particular should be avoided because of the higher rate of vomiting and need for further analgesia [5].

Traditionally, after control of pain, the definitive treatment of stones was delayed with options including medical expulsive therapy (MET), SWL, and ureteroscopy [6]. Recently, the utilization of both SWL and URS as emergency procedures with the aim to decrease the time of stone-related symptoms, morbidity, and possible complications was found to be safe and effective [7].

In this study, we evaluate the efficacy as well as the predicting factors for successful emergency SWL in patients with persistent flank pain despite of receiving medical treatment.

Patients and methods
After the approval of our institutional ethical review board, we conducted a prospective study including adults presented to emergency department of our hospital between July 2008 and June 2011 for acute renal colic. Persistent flank pain was defined as uncontrolled pain after receiving 2 doses of 30 mg of intravenous Ketorolac within 6 h. Inclusion criteria were patients who are 18 year old or older with persistent
flank pain secondary to medium sized single ureteral stone (6–12 mm).

We excluded from this study patients with history of surgical intervention, patients with evidence of urinary tract infection and or renal failure, patients with stone size > 12 mm or less than 6 mm, marked hydronephrosis or peri-renal urinoma, patients with ureteral stricture and patients with solitary kidney or bilateral hydronephrosis.

Sample size calculation was carried out using Epi-info™, version 3.3 (CDC, 2005). A calculated sample of 73 or more was needed, with a \( p \) value < 0.05 and 95% power.

A total of 163 patients were assessed for eligibility. Monitoring of vital signs, plain X-ray of the urinary tract (KUB), abdominal ultrasound, non-contrast computed tomography (NCCT) of the abdomen and pelvis, urinalysis, complete blood count, and coagulation profile were done for all patients.

Characterization of the stone was based on the KUB and NCCT imaging and included stone size (largest longitudinal and transversal diameter measured by CT), stone location (lumbar, iliac or pelvic), stone outline (smooth or irregular), and stone density measured by Hounsfield units (HU). Radiography with KUB was performed in all patients to assess whether the stone was radio-opaque or not. The presence of hydronephrosis was defined by ultrasound and patients were divided into 3 groups according to the degree of HN. Mild HN if the renal pelvis only was dilated, moderate HN if the renal pelvis and some calices were dilated, and severe HN if had severe uniform dilatation of the renal pelvis and calices with cortical thinning.

Based on our inclusion and exclusion criteria, 86 patients (52 men, 34 women) were included in the study and a written consent was signed. They underwent emergency extracorporeal shock wave lithotripsy (SWL) as soon as possible (within 24 h of the onset of colicky pain) using a Dornier Lithotripter S with dual ultrasound/fluoroscopic monitoring. All patients received intravenous perfusion of 500 ml saline, 1 gm of IV first-generation cephalosporin and 30 mg ketorolac IV 20 min before the session. No anesthesia was used, but 0.1 mg/kg diluted IV morphine was given during the session.

Lumbar ureteral stones were fragmented with the patient in the supine position, iliac and pelvic stones in prone position. SWL protocol with a total count of 4000 SW/session at power of 16–20 kV and frequency of 60–70/min was utilized.

The primary end point after the emergency SWL was pain relief (VPAS \( \leq 3 \)) after the SWL session and the secondary end point was stone clearance which was checked with ultrasound and KUB at the end of session or CT KUB if needed, as well as 3 weeks later.

Statistical analysis was performed using inter-cooled STATA®, (version 9.2). A univariate analysis was done to compare the two treatment groups. Analysis included the Chi-square test or Fisher’s exact test for comparison of the categorical data, and the Mann–Whitney \( U \) test compared the non-categorical data. A multiple regression model was used for factors maintaining a statistically significant impact on the time to stone clearance, indicating that they act independently.

**Result**

Eighty-six patients were enrolled; the basic characteristics of patients at presentation are summarized in Table 1.

Pain relief (VPAS \( \leq 3 \)) and stone-free rate after emergency SWL session were 58.1% and 44.2%, respectively. Refractory pain (VPAS \( \geq 7 \)) occurred in 11 patients (12.7%); of them 7 required urgent ureteroscopy. The remaining 25 patients (29%) reported a controlled (tolerable) pain with VPAS (4–6) and of them 24 required a second SWL session (Fig. 1).

The overall 3-month stone-free rate after SWL monotherapy (up to 3 sessions) was 83.7%. Ureteroscopy was used in (7, 4, and 3) patients after first, second and third SWL sessions, respectively, i.e., a total of 14 patients (16.2%).

On multivariate analysis, predictors for pain relief after emergency SWL were lower HU stone density (OR 0.992, 95% CI 0.985–0.998, \( p = 0.016 \)), mild HN at presentation (OR 9.904, 95% CI 1.058–92.689, \( p = 0.044 \)) and presentation during the first colic episode (OR 5.345, 95% CI 1.036–27.573, \( p = 0.045 \)).

Those with relieved renal pain after early SWL had median HU stone density of 650 compared to 990 for those

| Characteristics                             | N (%)          |
|---------------------------------------------|----------------|
| Age (mean ± SD)                             | 39.9 ± 14.1    |
| Sex (M:F)                                   | (17:19)        |
| Stone diameter mm (mean ± SD)               | 8.8 ± 1.3      |
| Stone outline smooth: irregular             | 38:48          |
| HFU (mean ± SD)                             | 842.7 ± 1232.1 |
| BMI (mean ± SD)                             | 23.9 ± 2.7     |
| Pain relief                                 | 50 (58%)       |
| Single session success                      | 38 (44.2%)     |
| Presence of hydronephrosis                  | 55 (63.9%)     |
| Laterality (L:R)                            | 39:47          |
| Stone location                              |                |
| Upper                                       | 46             |
| Middle                                      | 12             |
| Lower                                       | 28             |

*HFU (Hounsfield unit), BMI (Body mass index)*
with persistent renal pain ($p < 0.001$) (Table 2). Lower HU stone density was also the single predictor of successful stone clearance after single emergency SWL session on multivariate analysis (OR 0.978, 95% CI 0.963–0.993, $p = 0.004$) (Table 3).

**Discussion**

Despite of the well-established role of SWL as a minimally invasive tool for the management of ureteral stones, there has been no consensus about its role in the emergency setting especially in those with refractory renal colic. Nowadays with the revolutionary improvements of SWL machines and their readily availability such a role has to be legitimately established [8].

Many factors affect the choice of the modality of ureteral stone treatment. For ureteral stones > 6 mm, both URS and SWL have higher stone-free rate compared to medical expulsive therapy. Both modalities will render the patient more rapidly stone free without the prolonged use of multiple medications and minimize trips to the emergency department for pain control [9].

---

**Table 2** Predictors for pain relief after emergency SWL (multivariate analysis)

| Variable                  | Pain relief after emergency SWL |
|---------------------------|---------------------------------|
|                           | OR (95% CI)                     |
| Age                       | 1.00 (0.94–1.06)                | 0.913 |
| Male                      | 4.05 (0.67–24.47)               | 0.128 |
| BMI                       | 0.80 (0.50–1.27)                | 0.339 |
| Presentation during the first colic episode | 5.35 (1.04–27.57) | 0.045* |
| Stone at lumbar ureter    | 0.90 (0.18–4.41)                | 0.899 |
| Stone length              | 0.34 (0.06–1.79)                | 0.075 |
| Stone width               | 1.30 (0.30–5.60)                | 0.160 |
| Irregular stone outline   | 2.20 (0.44–10.96)               | 0.641 |
| HU stone density          | 0.992 (0.985–0.998)             | 0.016* |
| Mild HN at presentation   | 9.90 (1.06–92.69)               | 0.044* |

*p < 0.05

**Table 3** Predictors for stone clearance after emergency SWL (multivariate analysis)

| Variable                  | Stone clearance after emergency SWL |
|---------------------------|-----------------------------------|
|                           | OR (95% CI)                      |
| Age                       | 0.99 (0.90–1.09)                | 0.822 |
| Male                      | 1.20 (0.07–20.28)               | 0.901 |
| BMI                       | 1.02 (0.52–1.98)                | 0.961 |
| Presentation during the first colic episode | 1.77 (0.18–17.05) | 0.623 |
| Stone at lumbar ureter    | 0.89 (0.07–10.92)               | 0.927 |
| Stone length              | 0.80 (0.26–2.44)                | 0.690 |
| Stone width               | 1.03 (0.08–12.73)               | 0.983 |
| Irregular stone outline   | 0.49 (0.03–7.59)                | 0.610 |
| HU stone density          | 0.98 (0.96–0.99)                | 0.004* |
| Mild HN at presentation   | 1.98 (0.13–29.72)               | 0.622 |
The balance between SWL and URS is not that simple. With an overall stone-free rate of 90%, URS may exemplify an over treatment considering that the patient will undergo a surgical procedure under anesthesia with the possible complications of both [5]. Since its first introduction [10], it has been previously shown that immediate SWL is a safe procedure and have good outcomes in the first 24 h, moreover they reduce the requirement of auxiliary procedures and the need of hospitalization [11–13].

In this study, emergency SWL was effective in pain control in 58.1% of patients. The predictor for success pain control was low HU stone density. In addition, 44.2% of patients were stone free after emergency SWL session. Predictors for stone clearance were lower HU stone density, mild HN at presentation and presentation during the first colic episode.

Panah A et al., found that stone size and Hounsfield units are important factors that affect the success of the emergency SWL, this was in agreement with our study which found that Lower HU stone density was also the single predictor of successful stone clearance after single emergency SWL session on multivariate analysis [14].

Cornelius et al. showed different results when they compared success rate of early SWL versus delayed SWL and found that BMI > 30 is the predictor of stone-free rate on multivariate analysis [15]. While Ghaliani et al. concluded that stone size may be the main predictive factor for successful emergency SWL [16]. In fact, we did not find that age, sex, BMI, stone length, stone location, stone outline or hydronephrosis affect stone clearance in our study.

To the best of our knowledge, this study is the first one to investigate the predictors of successful SWL and pain relief during the acute attack of renal colic. We found that lower HU stone density, mild HN at presentation and presentation during the first colic episode are predictors for pain relief.

Conclusion

Emergency SWL is an effective modality combining both pain relief and the definitive treatment of ureteral stones. Our analysis indicate that patients who present during the first colic episode with mild backpressure changes and have low HU stone density are the most likely to benefit from this approach.

Author contributions AK: conceptualization, methodology, software, data curation, investigation, formal analysis, writing original draft, visualization and supervision. AAE: methodology, investigation, software, writing, reviewing, editing and visualization. MMO: investigation and visualization. IFA: methodology, investigation, writing original draft and visualization. MFA: Software, data curation, investigation, formal analysis, writing original draft and visualization.

Funding Open access funding provided by The Science, Technology & Innovation Funding Authority (STDF) in cooperation with The Egyptian Knowledge Bank (EKB). This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Availability of data and materials All related data and materials are available from the corresponding author upon request.

Declarations

Conflict of interest The authors declare no competing interest.

Ethical approval This study was approved by the ethical committee of Assiut University, Egypt and was performed in agreement with the guidelines of the declaration of Helsinki.

Consent to participate A written informed consent was obtained from all the participants.

Consent to publish Participants have consented to the submission of the data.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

1. Sorokin I, Mamoulakis C, Miyazawa K, Rodgers A, Talati J et al (2017) Epidemiology of stone disease across the world. World J Urol 35(9):1301–1320. https://doi.org/10.1007/s00345-017-2008-6
2. Park J, Suh B, Lee MS, Woo SH, Shin DW (2016) National practice pattern and time trends in treatment of upper urinary tract calculi in Korea: a nationwide population-based study. J Korean Med Sci 31(12):1989–1995. https://doi.org/10.3346/jkms.2016.31.12.1989
3. Engeler DS, Schmid S, Schmid HP (2008) The ideal analgesic treatment for acute renal colic–theory and practice. Scand J Urol Nephrol 42(2):137–142. https://doi.org/10.1080/00345017.2008.1673716
4. Afshar K, Jafari S, Marks AJ, Eftekhari A, MacNeilay AE (2015) Nonsteroidal anti-inflammatory drugs (NSAIDs) and nonopioids for acute renal colic. Cochrane Database Syst Rev (6):CD006027. https://doi.org/10.1002/14651858.CD006027.pub2
5. Turk C, Petrik A, Sarica K, Seitz C, Skolarikos A et al (2016) EAU guidelines on diagnosis and conservative management of urolithiasis. Eur Urol 69(3):468–474. https://doi.org/10.1016/j.eururo.2015.07.040

 Springer
6. Turk C, Petrik A, Sarica K, Seitz C, Skolarikos A et al (2016) EAU guidelines on interventional treatment for urolithiasis. Eur Urol 69(3):475–482. https://doi.org/10.1016/j.eururo.2015.07.041

7. Arcainiolo D, De Sio M, Rassweiler J, Nicholas J, Lima E et al (2017) Emergent versus delayed lithotripsy for obstructing ureteral stones: a cumulative analysis of comparative studies. Urolithiasis 45(6):563–572. https://doi.org/10.1007/s00240-017-0960-7

8. Drake T, Grivas N, Dabestani S, Knoll T, Lam T et al (2017) What are the benefits and harms of ureteroscopy compared with shock-wave lithotripsy in the treatment of upper ureteral stones? A Systematic Review. Eur Urol 72(5):772–786. https://doi.org/10.1016/j.eururo.2017.04.016

9. Cui X, Ji F, Yan H, Ou TW, Jia CS et al (2015) Comparison between extracorporeal shock wave lithotripsy and ureteroscopic lithotripsy for treating large proximal ureteral stones: a meta-analysis. Urology 85(4):748–756. https://doi.org/10.1016/j.urology.2014.11.041

10. Tombal B, Mawlawi H, Feyaerts A, Wese FX, Opsomer R et al (2005) Prospective randomized evaluation of emergency extracorporeal shock wave lithotripsy (ESWL) on the short-time outcome of symptomatic ureteral stones. Eur Urol 47(6):855–859. https://doi.org/10.1016/j.eururo.2005.03.006

11. Bucci S, Umari P, Rizzo M, Pavan N, Liguori G et al (2018) Emergency extracorporeal shockwave lithotripsy as opposed to delayed shockwave lithotripsy for the treatment of acute renal colic due to obstructive ureteral stone: a prospective randomized trial. Minerva Urol Nefrol 70(5):526–533. https://doi.org/10.23736/S0393-2249.18.03084-9

12. Kumar A, Mohanty NK, Jain M, Prakash S, Arora RP (2010) A prospective randomized comparison between early (<48 hours of onset of colicky pain) versus delayed shockwave lithotripsy for symptomatic upper ureteral calculi: a single center experience. J Endourol 24(12):2059–2066. https://doi.org/10.1089/end.2010.0066

13. Liu CS, Zhang P, Shao ZQ, Zheng SB (2010) Extracorporeal shockwave lithotripsy in treatment of bilateral ureteral calculi with renal colic during emergency. J Southern Med University 30(1):189–190

14. Panah A, Patel S, Bourdoumis A, Kachrilas S, Buchholz N et al (2013) Factors predicting success of emergency extracorporeal shockwave lithotripsy (eESWL) in ureteric calculi—a single centre experience from the United Kingdom (UK). Urolithiasis 41(5):437–441. https://doi.org/10.1007/s00240-013-0580-9

15. Cornelius J, Zumbuhl D, Afferi L, Mordasini L, Di Bona C et al (2021) Immediate shockwave lithotripsy vs delayed shockwave lithotripsy after urgent ureteral stenting in patients with ureteral or pyeloureteral urolithiasis: a matched-pair analysis. J Endourol 35(5):721–727. https://doi.org/10.1089/end.2020.0384

16. Ghalayini IF, Al-Ghazo MA, Khader YS (2008) Evaluation of emergency extracorporeal shock wave lithotripsy for obstructing ureteral stones. Int Braz J Urol 34(4):433–440. https://doi.org/10.1590/s1677-55382008000400005

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.