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Which localization method is optimal in ESWL: fluoroscopy or ultrasonography?

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Abstract

Background Urinary stone disease is a common urological disorder, particularly among middle-aged individuals. Extracorporeal Shock Wave Lithotripsy (ESWL) is often the first-line treatment for kidney and ureteral stones. Traditionally, fluoroscopy is used for stone targeting in ESWL, but it exposes patients and clinicians to radiation and cannot visualize non-opaque stones. Ultrasonographic targeting eliminates these issues. This study compares the advantages and disadvantages of fluoroscopy and ultrasound-targeted ESWL.

Methods At Düzce University Hospital, 100 patients with radio-opaque stones indicated for ESWL between February 2023 and February 2024 were divided into two groups. Group A underwent ESWL with fluoroscopic targeting, while Group B used ultrasonographic targeting. Patient demographics, stone size (measured by CT), and stone locations were recorded. The number of shocks per session, energy intensity (kV), and fluoroscopy time were noted for Group A. One week after each ESWL session, patients were evaluated by ultrasound or direct radiography. Success was defined as being stone-free or having ≤ 4 mm asymptomatic residual stones after up to four sessions. Failure was defined as no results after two sessions or the need for additional treatment.

Results The procedure success rate was 66% for men and 78% for women, with no statistically significant gender difference ($p > 0.05$). Stone locations were similar in both groups. Success rates were 66% in Group A and 74% in Group B, with no significant difference ($p > 0.05$). Successful procedures were associated with an average patient weight of 76.6 kg, stone size of 8.9 mm, and total energy of 12.2 kV, with significant differences compared to unsuccessful procedures ($p < 0.04$, $p < 0.04$, $p < 0.001$, respectively). No significant differences were found between Group A and Group B in terms of age, height, BMI, stone density (HU), and number of sessions ($p > 0.05$).

Conclusion Ultrasonography is as effective as fluoroscopy for imaging and focusing during ESWL treatment. It enhances the success of ESWL for non-opaque stones and reduces radiation exposure disadvantages.

Keywords Fluoroscopy, ESWL, Ultrasonography, Kidney stones, Localization method

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Introduction

Urinary stone disease is one of the most common urological conditions, particularly among middle-aged individuals. Due to the high recurrence rate, it causes significant morbidity and loss of productivity [1]. Studies indicate that 8.9% of men and 3.2% of women will develop stone disease at some point in their lives [2]. The treatment of stone disease ranges from non-invasive methods to surgical procedures. However, Extracorporeal Shock Wave Lithotripsy (ESWL) is the first-line treatment for kidney and ureteral stones in appropriate cases [3]. Due to its ease of application, low complication rates, and long history of use, ESWL is an alternative to surgical treatments [4]. It does not require surgical preparation and is easy to apply as it usually does not need anesthesia, except in pediatric patients and some exceptional cases. Therefore, especially as recommended by guidelines, it is suggested as the first choice for treating kidney and ureteral stones smaller than 20 mm [1].

The success of ESWL depends on various criteria such as the stone's location, size, density (HU), and the patient's body mass index. There are no serious contraindications for ESWL except for pregnancy, coagulopathy, and active urinary system infection [1]. One of the most critical criteria for successful application is the precise identification of the stone's location [5]. Therefore, good imaging of the stone during the procedure is one of the most important factors affecting treatment success. As experience increases, treatment success also improves similarly. Currently, fluoroscopy is most commonly used to determine the stone location during ESWL application. However, fluoroscopic focusing has significant disadvantages and application difficulties, such as radiation exposure for both the patient and the practitioner, inability to focus on non-opaque stones, and difficulty in focusing on distal-middle ureteral stones due to bone structures. Therefore, ultrasound-guided focusing has recently emerged as an alternative to fluoroscopy. The advantages of ultrasound include the absence of radiation exposure, making it safe for pediatric patients, easy visualization of non-opaque stones, and the ability to monitor stone fragmentation during the procedure. However, disadvantages include longer focusing times compared to fluoroscopy and the requirement for more experience. These advantages highlight the necessity of using ultrasound-guided stone focusing in ESWL. This study aims to compare the success of ESWL with ultrasonic and fluoroscopic stone focusing and to identify their respective advantages.

Material and method

A total of 100 patients with radio-opaque stones who were indicated for ESWL according to the European Urology 2023 guidelines were included in the study,

conducted at Düzce University Hospital between February 2021 and February 2024. Patients were randomized according to the order of presentation to the clinic, and the patients learned which method would be used for ESWL on the same day. All patients signed an informed consent form. Fluoroscopic and ultrasonographic focused ESWL treatment was performed by a single urologist with urinary ultrasound and ESWL experience and a single technician with ESWL experience. Patients whose stones could not be seen on direct urinary system radiographs and ultrasonography, patients with congenital kidney and ureter anomalies, and patients with positive urine culture were excluded from the study. The patients were divided into two groups: Fluoroscopy (A) and Ultrasonography (B). ESWL was applied to Group A patients with fluoroscopic guidance and to Group B patients with ultrasonographic guidance. Before treatment, the stone size was measured by a radiologist using the maximum stone diameter on computed tomography. The gender, age, height, weight, BMI of all patients were recorded before the procedure. All patients were screened for additional diseases. The anatomical locations of the stones were defined as upper, middle, and lower pole, and renal pelvis for kidney stones; and proximal, middle, and distal ureter for ureteral stones. The density (HU) of the stones of the 100 patients who completed the study was recorded in Hounsfield units (HU) before ESWL. Analgesia was provided on an outpatient basis using 20 mg tenoxicam. All patients underwent ESWL using the Spark® EM Model Extracorporeal Electromagnetic Shock Wave Lithotripsy Device (Fig. 1). Ultrasonographic focusing was provided using the GE Logiq S8 Ultrasound System for simultaneous lithotripsy observation. The ESWL protocol was standardized by positioning the stone during the expiratory phase. Lithotripsy was started at the lowest energy level while patients were in the supine position. The maximum energy was increased up to 15 kV. If the patient could not tolerate the discomfort caused by the shock wave, the energy level was reduced by one level before being increased again. In Group A, intermittent fluoroscopy was used. The focusing was adjusted at the beginning of the ESWL session and after every 300 shocks or when the patients moved. If stone fragmentation was visually observed, the energy level was not increased in this group. For the Ultrasonography group, focusing was adjusted at the beginning of the ESWL session and was based on real-time monitoring of stone localization. Ultrasonographic focusing was performed by the experienced physician in collaboration with the ESWL operator. After each session, the number of shocks, energy used (kV), and fluoroscopy time were noted. One week after each ESWL session, follow-up imaging was examined by a single experienced urologist using ultrasound or direct radiography. The procedure



Fig. 1 Spark EM model extracorporeal shock wave lithotripsy device

was considered successful if stone-free status or the presence of ≤ 4 mm asymptomatic residual stones was achieved after a maximum of four ESWL sessions. The procedure was deemed unsuccessful if no results were obtained after two ESWL sessions or if additional treatment was needed. For patients in the fluoroscopy group, cumulative radiation exposure was not measured considering pre-procedure imaging. This situation constitutes a limitation of the study.

Statistical analysis

Statistical analysis of categorical variables compared the distributions between groups (Ultrasonographic focusing versus Fluoroscopy, successful and unsuccessful procedures). All continuous variables followed a normal distribution. Statistical analysis was performed using the parametric independent groups t-test. The Mann-Whitney U test was used to compare groups that did not follow a normal distribution. For these variables, the median (range) was presented. A p-value of <0.05 was

considered statistically significant. Statistical analyses were conducted using IBM SPSS Statistics version 27.0 (Chicago, IL, USA). Sample size estimation was based on our retrospective data.

Results

A total of 100 patients were included in the study. ESWL with fluoroscopic focusing (Group A) was applied to 50 patients, and ESWL with ultrasonographic focusing (Group B) was applied to the other 50 patients. The procedure was performed by the same physician in both groups, with an additional physician experienced in ultrasound assisting in the ultrasonographic focusing.

When comparing the two groups, no statistically significant differences were found in age, height, weight, BMI, stone size, stone density (HU), number of sessions, or energy used ($p > 0.05$) (Table 1). The successful procedure rate was 66% in Group A and 74% in Group B, but this difference was not statistically significant ($p > 0.05$). The average fluoroscopy time in Group A was measured

Table 1 Demographic and stone characteristics of the patients [mean $\pm$ SD (range) or %]

	Group A(n = 50)	Group B(n = 50)
AGE (years)	47,8 $\pm$ 12,6	45,7 $\pm$ 14,4
Gender		
Male	34(%68)	30(%60)
Female	16(%32)	20(%40)
Height (cm)	166,9 $\pm$ 8,1	166,4 $\pm$ 9
Weight (kg)	78,5 $\pm$ 10,2	77 $\pm$ 10
BMI	28 $\pm$ 6,5	28,2 $\pm$ 0,7
Stone Size (nm)	8,78 $\pm$ 2,6	9,9 $\pm$ 4,1
Stone Density (HU)	787,6 $\pm$ 156,1	803,1 $\pm$ 204,8
Number of Sessions	2 $\pm$ 0,8	2,06 $\pm$ 0,8
Fluoroscopy Time (sn)	159,3 $\pm$ 76,9	-
Successful Procedure (%)	33(%66)	37(%74)
Energy Used (kV)	12,1 $\pm$ 0,7	12 $\pm$ 0,8

Table 2 Anatomical localization of stones

	Group A(n = 50)	Group B(n = 50)
Upper Pole of Kidney	3(%6)	2(%4)
Mid Pole of Kidney	12(%24)	14(%28)
Lower Pole of Kidney	8(%16)	5(%10)
Renal pelvis	15(%30)	12(%24)
Proximal Ureter	2(%4)	6(%12)
Mid Ureter	8(%16)	8(%16)
Distal Ureter	2(%4)	3(%6)
Stone side		
Right	25(%50)	21(%42)
Left	25(%50)	29(%58)

Table 3 Factors affecting ESWL outcome

	Procedure outcomes		
	Successful	Unsuccessful	p
Age (years)	44,6	51,6	0,1
Height (cm)	166,4	167,2	0,6
Weight (kg)	76,6	80,6	0,04
BMI	27,9	28,8	0,4
Stone Size (mm)	8,9	10,4	0,04
Stone Density (HU)	787,8	813	0,5
Number of Sessions	2,1	1,9	0,2
Energy Used (kV)	12,2	11,6	0,001

Graph: Relationship Between ESWL Outcome and Gender

as 159.3 $\pm$ 76.9 s, while the ultrasonography time was not recorded in Group B. Imaging revealed that 30% of the stones detected in Group A were in the renal pelvis, and 28% of the stones in Group B were in the mid-zone of the kidney. The least frequently detected stones were located in the distal ureter in Group A (6%) and in the upper pole of the kidney in Group B (4%). The location of stones on the right or left side was similar in both groups (Table 2).

All patients included in the study were grouped and compared as successful and unsuccessful procedures. The successful procedure rate was 66% for men and 78% for women, but there was no statistically significant

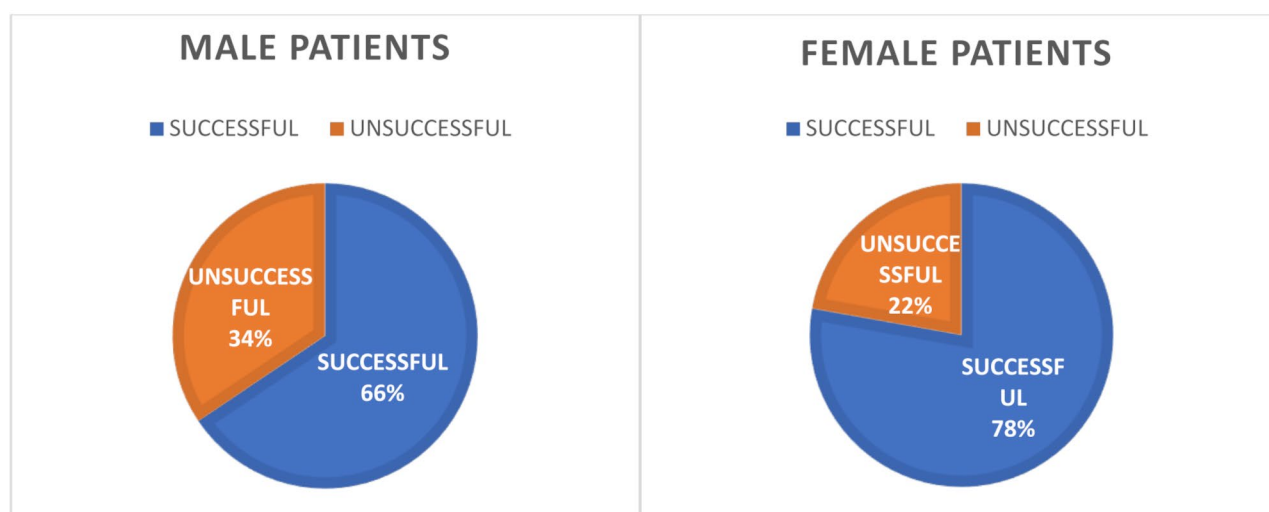
difference between genders regarding successful procedures ($p > 0.05$). In the group where ESWL was successful, the average body weight of the patients was 76.6 kg, the average stone size was 8.9 mm, and the average total energy used was 12.2 kV. Compared to unsuccessful procedures, these criteria showed significant differences ($p < 0.04$, $p < 0.04$, $p < 0.001$, respectively). No significant difference was found between successful and unsuccessful procedures in terms of age, height, BMI, stone density (HU), and number of sessions ($p > 0.05$). All parameters are summarized in Table 3.

Discussion

ESWL is a minimally invasive treatment for urolithiasis that offers ease of application due to not requiring hospitalization and causing minimal loss of work productivity. Traditionally, fluoroscopy is still frequently used for stone localization in ESWL treatments, which have a success rate of 80–90% [6]. Fluoroscopy is a familiar imaging method for urologists in urological interventions. However, like any method, it has disadvantages such as radiation exposure and the inability to localize radiolucent stones.

With technological advancements, ultrasonographic techniques have emerged as an alternative to fluoroscopy. Today, ultrasonography is a strong alternative in almost every field where fluoroscopy is used in surgical procedures. In ESWL treatment, this imaging method shows promise for stone localization. The most significant advantage of ultrasonographic focusing is that it eliminates radiation exposure for both the patient and the clinician and provides real-time imaging. Because real-time imaging allows continuous monitoring of stone localization throughout the procedure, the focus of shock waves on the stone can be maintained under constant control. In our study, although no significant difference was found between the two groups, the higher success rate with ultrasonographic focusing can be attributed to this advantage. This not only improves treatment success but also protects both the patient and the clinician from radiation exposure by avoiding the use of fluoroscopy.

Some studies have found that patients with a BMI > 25 are exposed to more radiation during ESWL [7]. In our study, the average fluoroscopy time was determined to be 159.3 s. While this duration may not create a significant radiation burden compared to other interventional procedures in urology clinics, it should be noted that patients often undergo computed tomography examinations before the procedure. Considering that multiple sessions may be applied to the same patient, the cumulative effect of radiation should be taken into account. This effect is not limited to the patient but also applies to the clinician exposed to radiation. Although the ultrasonographic focusing time was not separately evaluated in our



Graph: Relationship between ESWL outcome and gender

study, the requirement for additional skills in using ultrasonography stands out as a significant disadvantage.

Real-time imaging during lithotripsy is another important advantage of ultrasonography-focused ESWL. In our study, when the success criteria for stone localization were considered, neither fluoroscopy nor ultrasonography showed superiority over the other.

The average weight of patients with successful procedures was 76.6 kg, while the average weight of patients with unsuccessful procedures was 80.6 kg, and a statistically significant difference was found ($p < 0.04$). Based on these statistical data, it can be said that an increase in body mass index reduces the success rate of stone fragmentation. Similar findings supporting this are present in the literature [8].

The average stone size in successful procedures was 8.9 mm, while it was 10.4 mm in unsuccessful procedures, and this difference was found to be significant ($p < 0.04$). Thus, as expected, an increase in stone size reduces the success of the treatment. The literature indicates that an increase in stone size below 2 cm is known to reduce the success of ESWL [9].

It can be said that the energy intensity used in ESWL is also important for its success. The average energy used in successful procedures was 12.6 kV, while it was 11.6 kV in unsuccessful procedures ($p < 0.001$). This can be interpreted as the likelihood of stone fragmentation increasing as the energy intensity is increased.

When all patients were examined, the success rate of the procedure was 78% for women and 66% for men; however, the difference was not significant ($p > 0.05$). Similar to studies in the literature, our study found no effect of gender on the success of ESWL in stone fragmentation [10].

Studies have shown that an increase in stone density (HU) negatively affects the success of ESWL [11]. However, in our study, age, height, and stone density (HU) affected success rates according to our data. Although repeated sessions are recommended for ureteral stones, one of the significant findings of our study is that increasing the number of sessions does not contribute to the treatment. Therefore, it is clear that increasing the number of sessions in patients who do not benefit from the application is not advantageous [12].

Conclusion

This study showed that there is no superiority between ultrasound and fluoroscopic focusing in ESWL treatment in terms of treatment success. Ultrasonography can be considered a strong alternative to fluoroscopy, with advantages such as reducing radiation exposure, providing real-time imaging during stone fragmentation, and allowing visualization of non-opaque stones. Although ultrasonographic focusing appears disadvantageous due to requiring more expertise compared to fluoroscopic imaging, the combination of both methods with advancing technology could lead to more effective treatment in ESWL while also reducing radiation exposure. In conclusion, ultrasonography remains an indispensable imaging method in urology clinics. Using it alongside the standard protocol in ESWL increases effectiveness and serves as a strong imaging method in cases where fluoroscopy is inadequate.

Abbreviations

BMI	Body mass index
ESWL	Extracorporeal Shock Wave Lithotripsy
HU	Hounsfield units
kV	Kilovolt

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12894-025-01716-8>.

Supplementary Material 1

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Author contributions

Concept: D.B., Y.Ş., Design: D.B., A.T.T., Y.Ş., A.Y., Data Collection or Processing: D.B., N.E., Analysis or Interpretation: D.B., M.A.Ö., E.B., Literature Search: D.B., Y.Ş., A.Y., A.Y.B., Writing: D.B., N.E., Y.Ş.

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Data availability

The data file has been uploaded in the supplementary material section.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Clinical Research Ethics Committee of Düzce University (decision number 2020/128 dated 05.10.2020) and permission was obtained. Patients' written consent was obtained prior to the study and the procedures were in accordance with those outlined by the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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