

## Comparison of ultrasonography and fluoroscopy as guides for extracorporeal shock wave lithotripsy in nephrolithiasis patients: a systematic review

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### ABSTRACT

**BACKGROUND** Extracorporeal shock wave lithotripsy (ESWL) is one of the first-line treatment options for patients with renal stones <2 cm. The large variability in ESWL results may be due to the stone visualization methods using ultrasonography (USG), fluoroscopy, or a combination of both. This study aimed to review the efficacy and safety of the stone visualization method on the stone-free rate (SFR) and postprocedural complications in nephrolithiasis patients.

**METHODS** We conducted a systematic review of USG and fluoroscopy on ESWL until July 2022, based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. We assessed and collected summaries of the screened papers. The main outcomes assessed were the SFR of renal stones and postprocedural complications between imaging modalities.

**RESULTS** A total of 7 studies were assessed, including 6 comparative assessments of USG versus fluoroscopy and 1 comparative assessment of USG and fluoroscopy versus fluoroscopy only. Although all studies showed that USG had a higher SFR than fluoroscopy, only 1 study showed a significant difference ( $p = 0.008$ ). Additionally, superior results were obtained using a combination of USG and fluoroscopy compared with fluoroscopy only. Most studies agreed that USG was not inferior in post-ESWL complication results.

**CONCLUSIONS** Overall, the use of USG is comparable to fluoroscopy because it does not provide a significant difference in the SFR and complications. In most cases, USG is preferred because of the absence of radiation. The combination of fluoroscopy and USG also provides more promising results than a single modality.

**KEYWORDS** complications, ESWL, fluoroscopy, nephrolithiasis, treatment outcome, ultrasonography

Nephrolithiasis cases are increasing across the world. It affects one out of every 11 people in the United States. Changes in lifestyle patterns and technological advances greatly influence the increase in this incidence.<sup>1</sup> Extracorporeal shock wave lithotripsy (ESWL) is one of the treatment options for nephrolithiasis. The European Association of Urology currently recommends ESWL as the first-line treatment for patients with upper pole kidney stone size <2 cm and second-line treatment for lower pole

kidney stones >1 cm, with consideration of predictive factors. ESWL is usually preferred because it is a non-invasive procedure with a low complication rate, only requires light anesthesia, and is more widely accepted by patients.<sup>2,3</sup>

The stone-free rate (SFR) of ESWL to treat renal stones ranges from 47 to 92%. Many predictive factors cause a large variability in SFR and influence the outcome, including stone size, location and composition, skin-to-stone distance, renal anatomy,

patient positioning, and lithotripter power and frequency.<sup>4</sup> On the other hand, postprocedural complications vary in number and can occur in various forms, ranging from mild symptoms such as fever and mild bleeding to severe symptoms that require additional treatment. These complications can be influenced by the operator's technique in performing the therapy, which indirectly requires proper imaging guidance to obtain optimal results.<sup>5,6</sup>

ESWL is assisted by imaging devices to visualize the location of the stone where the shock wave should be targeted. Precise and real-time information about the stone's location is essential to maximize the waves' accuracy. Ultrasonography (USG) and fluoroscopy are used to locate the stones. Fluoroscopy has been widely used since the introduction of ESWL to treat nephrolithiasis in the 1980s and is available on all lithotripter devices. However, only radiopaque stones can be detected by fluoroscopy. Meanwhile, USG, which is available in modern lithotripters, can also detect radiolucent stones. USG usage also reduces the patient's exposure to ionizing radiation, which is beneficial in most cases.<sup>3,7-9</sup> Along with the times, technological developments have also started to combine both modalities in the same machine, which may help the operators perform better treatments than a single modality.<sup>4</sup> The existing studies have begun to compare modalities for ESWL therapy. However, no guidelines have specifically mentioned which modality is superior and better to use. We conducted this study to understand which modalities have better efficacy and fewer complications in our patients. Therefore, this study aimed to systematically review the efficacy and safety of USG compared with fluoroscopy or a combination of both during ESWL in nephrolithiasis patients.

## METHODS

### Search strategy

We conducted a systematic literature search on Cochrane Library, Google Scholar, USC Library, PubMed, Europe PMC, and several publisher databases from Sage Journal and Biomed Central for relevant literature until July 2022. The keywords and medical subject headings (MeSH) used were ("USG" or "Ultrasound" or "Ultrasonography" [MeSH Term]), ("fluoroscopy" [MesH Term]) and ("ESWL" or "Extracorporeal Shock Wave Lithotripsy" or

"Lithotripsy" [MeSH Term]). MeSH terms were used whenever possible and as all terms or fields when they were not. This systematic review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.<sup>10</sup> Due to the limited number of studies that compared USG and fluoroscopy data on ESWL, this study included both child and adult populations.

### Study selection and eligibility criteria

The articles included in this study were: (i) randomized clinical trials (RCTs), cohort, case-control, dissertation, and cross-sectional studies comparing the effects of imaging modalities (USG and fluoroscopy) during ESWL or studies comparing combined fluoroscopy and USG with either USG or fluoroscopy modalities; (ii) the study population included nephrolithiasis patients with stone size <2 cm; (iii) articles and studies that provided sufficient data regarding the outcomes (SFR with or without post-ESWL complications); (iv) there was no restriction regarding the country, patient's age, race, or sex.

The exclusion criteria were as follows: (i) case reports or case series studies; (ii) studies of nonhuman subjects; (iii) articles that were not available in full-text format or contained missing data (after the author attempted to contact them *via* e-mail); and (iv) articles that were not available in English.

### Data extraction and quality assessment

The collected articles were imported to the reference management tool using EndNote (version 20.4.1, Clarivate™, USA), and duplicate papers were removed. Subsequently, the abstracts and titles of the articles were screened based on the eligibility criteria. Screened papers were assessed thoroughly based on basic information about the study and then extracted into a spreadsheet, which included the name of the study, study design, sample size, imaging modalities used in the study, study location and period, baseline demographics, SFR, and clinical characteristics of the study participants.

We assessed the articles using Cochrane's preference tool, Cochrane's risk-of-bias tools for RCT (RoB 2) for clinical trial studies, and the risk of bias in non-randomized studies - of interventions (ROBINS-I) for observational studies. The results were categorized as "low risk," "high risk," or "uncertain" by all of the reviewers.<sup>11</sup>

## RESULTS

### The characteristics and quality of the studies

Of the 961 articles obtained from the search, seven reports met the inclusion criteria and were used in this systematic review (Figure 1). The years of the studies included varied from 2010 to 2021, consisting of five retrospective cohort studies, one prospective cohort study, and one dissertation with a prospective method. The populations assessed were adults (five studies) and children (two studies). The inclusion criteria for each study differed. Some studies carried out the assessment directly after undergoing ESWL once, whereas other studies assessed after several ESWL procedures. A summary of the characteristics of the studies is presented in Table 1.

Six studies performed a comparative assessment of USG versus fluoroscopy as a guide for ESWL on urolithiasis. Meanwhile, one study performed a comparison of combined USG and fluoroscopy compared with fluoroscopy alone. The stone locations were varied in each study. All studies included stones in the kidney.<sup>12</sup> Only subjects with a mean stone

size of <20 mm were included in all studies. The characteristics of the stone type were not mentioned in most studies, except Goren et al<sup>3</sup> who studied children with cystine stones and Arunagiri<sup>13</sup> who examined the type of stone at the end of the ESWL procedure (but not all of the patient's stones can be retrieved). Stone density was also only mentioned in a few patients (some were only examined in several patients). The stone characteristics in each study are presented in Table 1.

Among the six reports that performed comparisons of USG and fluoroscopy, only Goren et al<sup>3</sup> showed a significant difference between USG and fluoroscopy outcomes ( $p = 0.008$ ), with the remaining studies providing insignificant results. However, all studies provided similarities in the percentage of SFR, in which USG tended to be better or similar to fluoroscopy results. Additionally, most studies concluded that USG was recommended over fluoroscopy to avoid radiation exposure in patients. Chang et al<sup>4</sup> in 2020 concluded that combined USG and fluoroscopy had significantly superior results than fluoroscopy alone (Table 1).

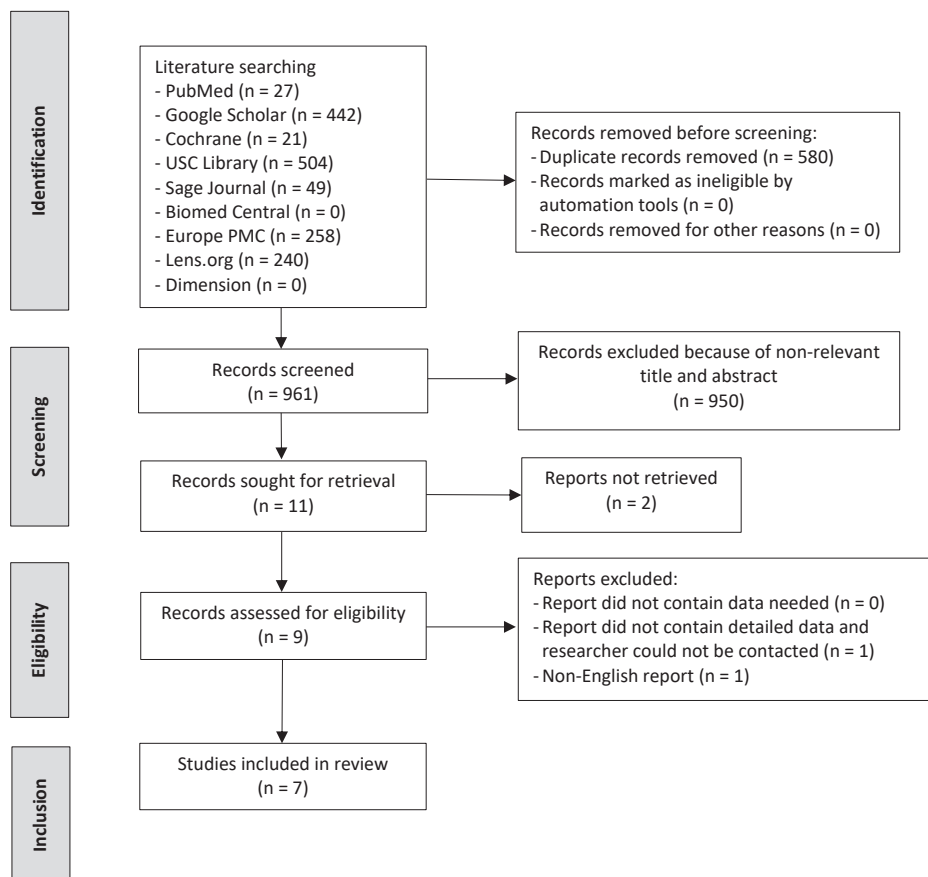


Figure 1. PRISMA flow diagram of study selection. PRISMA=Preferred Reporting Items for Systematic Reviews and Meta-Analyses

**Table 1.** Characteristic of each study

Author	Stone visualization method	Study type	Cases, N	Inclusion criteria	Treatment criteria	Stone size, mean (mm)	CT density (mean)	Location (USG/ fluoroscopy)	ESWL criteria	Initial SFR, n (%)	Auxiliary treatment, n (%)	Final SFR, n (%)	SFR*, p	Complications
Smith, <sup>14</sup> 2016	USG	Retrospective cohort	48	All patients with radiopaque calculi and underwent X-ray kidney, ureter, and bladder before treatment and at follow-up	SFR: no visible fragments ≤2 mm using X-ray or USG at 4 weeks Unsuccessful treatment: any patients requiring further treatment (SWL or endoscopic treatment) or significant residual fragments >2 mm	8.5	NA	NA	NA	29 (60)	-	-	0.18	n = 4 - ureteric stenting (n = 2) (CD grade III) - conservative management (n = 2) (CD grade II)
										21 (45)	-	-		n = 8 - ureteric stenting (n = 3) (CD grade III) - conservative management (n = 5) (CD grade II)
Van Besien, <sup>7</sup> 2017	USG  Fluoroscopy	Prospective cohort	57	Patients with radiopaque and upper urinary tract stone	Positive outcome: SFR status or asymptomatic residual fragments of 4 mm or less after a maximum of 4 SWL sessions Negative outcome: absence of any results after 2 SWL sessions or the need for supplementary therapy (URS, PNL, ureteric stent, or ESWL on an ureteric stone)	9	665 (n = 31)	Upper pole: 18/8 Mid pole: 12/19 Lower pole: 22/22 Renal pelvis: 5/8	Energy level: started at the lowest level, and raised one level after 60-120-180-360 and 600 shocks, with a maximum total shock wave energy of 62 Joule Procedure done in supine position with a frequency of 1 Hz	6	9	45 (79%) - stone-free, n = 30 - asymptomatic residual, n = 15	0.06	NA
										6	9	40 (70%) - stone-free, n = 24 - asymptomatic residual, n = 16		

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Table 1. (continued)

Author	Stone visualization method	Study type	Cases, N	Inclusion criteria	Treatment criteria	Stone size, mean (mm)	CT density (mean)	Location (USG/fluoroscopy)	ESWL criteria	Initial SFR, n (%)	Auxiliary treatment, n (%)	Final SFR, n (%)	SFR*, p	Complications
Ozkaya, <sup>8</sup> 2019	USG	Retrospective cohort	233 (male: 139, female: 94)	NA	SFR: absence of fragments or presence of insignificant stones <4 mm after the sessions Failure: inability to obtain fragmented stones after 3 sessions of ESWL	8.9 (3.66)	NA	Upper pole: 45/54 Lower pole: 40/30	Mean of shock waves: 60–80 beats/min, with total average beat of 2,530.5 Shock waves energy: 14–20 kV (gradually increased) with a total mean energy of 18 kV	-	-	215 (92.3%)	0.474	2 (0.4%)
Motolová, <sup>12</sup> 2021	Fluoroscopy	Retrospective cohort	262 (male: 154, female: 108)	Adult population, ESWL as primary intervention for nephrolithiasis, proximal, or prevesical ureterolithiasis 6–13 mm in size	SFR: patient without any residual stones or the absence of fragments ≥2 mm (max 3–4 sessions)	8.73 (3.98)	1,022.9	Mid pole: 148/178	Renal pelvis: 19/19 Proximal ureter: 15/20 Distal Ureter: 11/10	-	-	108 (90%)	1.000	1 (0.2%)

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Table 1. (continued)

Author	Stone visualization method	Study type	Cases, N	Inclusion criteria	Treatment criteria	Stone size, mean (mm)	CT density (mean)	Location (USG/fluoroscopy)	ESWL criteria	Initial SFR, n (%)	Auxiliary treatment, n (%)	Final SFR, n (%)	SFR*, p	Complications
Goren, <sup>3</sup> 2017	USG	Retrospective cohort	31 kidneys	Pediatric patients with first time kidney stone treated with ESWL, had complete follow-up data and analysis, and had confirmed cystine stone	SFR: absence of any fragments, within 3 months after the last SWL CIRFs: residual fragments ≤3 mm Failure: any sized fragments persisting 3 months after the last SWL session	16 (2.91)	NA	Upper pole: 6/4 Mid pole: 6/8 Lower pole: 10/3 Renal pelvis: 9/5	Shock waves: 60 beats/min Lowest shock waves energy: 9.5 kV (increased gradually to the maximum level in the first 1,000 shocks)	25 (80.6)	4 (12.9)	29 (93.5%)	<b>0.008</b>	n = 10 (32.3%) - Fever (n = 1), seinstrasse (n = 4) (CD grade I) - UTI (n = 1) (CD grade II) - Djs insertion (n = 3), URS for seinstrasse (n = 1) (CD grade IIIB) n = 14 (70%) - Fever (n = 1), seinstrasse (n = 3) (CD grade I) - UTI (n = 2) (CD grade II) - Djs insertion (n = 3), SWL (n = 2), URS for seinstrasse (n = 1) (CD grade IIIB)
	Fluoroscopy								Procedure done in supine position with general anesthesia or sedoanalgesia	4 (20)	6 (30)	12 (60%)		

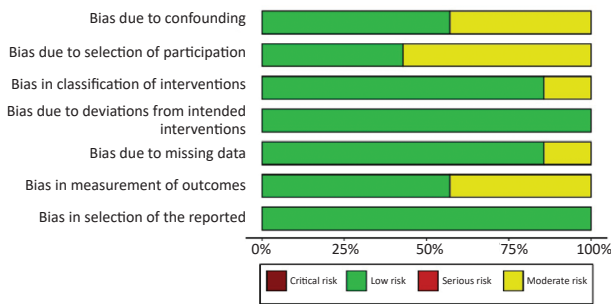
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Table 1. (continued)

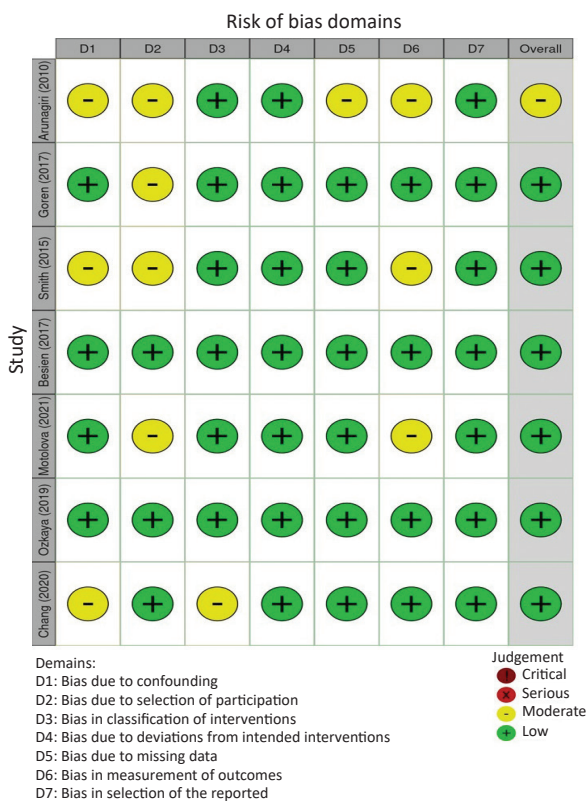
Author	Stone visualization method	Study type	Cases, N	Inclusion criteria	Treatment criteria	Stone size, mean (mm)	CT density (mean)	Location (USG/ fluoroscopy)	ESWL criteria	Initial SFR, n (%)	Auxiliary treatment, n (%)	Final SFR, n (%)	SFR*, p	Complications
Arunagiri, <sup>13</sup> 2010	USG	Dissertation-prospective	50 (male: 26, female: 24)	Renal stone 0.5–2 cm diameter in upper, middle calyx, or pelvis and ≤1 cm in lower calyx. No previous same treatment	SFR: residual calculi by X-ray, USG KUB, and CT KUB <5 mm had clinically insignificant	12.24	726 (161.886)	Upper pole: 8/2 Mid pole: 7/3 Lower pole: 12/8	Number of shock waves: 500–2,500 Shock frequency: 60/min	35 (70)	-	-	0.814	LUTS, n = 50 (50%) Hematuria, n = 10 (10%) Stent migration, n = 2 (2%) Steinstrasse, n = 2 (2%)
				All stones were located in a satisfactory functioning non-obstructed renal unit	residual fragment Failure: residual fragments >5 mm	14.04	727.20 (115.935)	Renal pelvis: 23/37	Procedure done in sitting position	32 (64)	-	-	-	-
Chang, <sup>4</sup> 2020	USG and fluoroscopy	Retrospective cohort	209 (male: 130, female: 79)	Patients with radio-opaque kidney stones, with stone size between 0.5–2.0 cm	SFR: absence of residual stones in the follow-up imaging Non-stone free: any residual fragments on KUB Re-treatment needed for further surgical intervention (repeat SWL, URSL, RIRS, or PNL) for symptomatic patients or patients with residual stone fragments >0.5 cm.	1.03 (0.37)	NA	NA	Number of shock waves: 60 shocks/min for both lithotripters with maximum per session of 3,000 Energy level: 14–19 KV	91 (43.5)	31 (14.8)	-	<0.001	4 (1.9%)
				Patients with stone fragments >0.5 cm	(repeat SWL, URSL, RIRS, or PNL) for symptomatic patients or patients with residual stone fragments >0.5 cm.	0.87 (0.33)	NA	Procedure done in a supine position without a restraint belt	61 (28.2)	77 (35.6)	-	-	-	-

CD=Clavien-Dindo; CIRFs=clinically insignificant residual fragments; CT=computed tomography; DJ=double J (stent); ESWL=extracorporeal shock wave lithotripsy; KUB=kidney ureter bladder; LUTS=lower urinary tract symptoms; NA=not available; PNL=percutaneous lithotripsy; RIRS=retrograde intrarenal surgery; SFR=stone-free rate; SWL=shock wave lithotripsy; URS=ureterorenoscopy; URSL=rigid ureteroscopic lithotripsy; USG=ultrasonography; UTI=urinary tract infection  
\*p<0.05 was considered statistically significant

Most studies have assessed the complication rate of each procedure. Some assessments were carried out using the Clavien-Dindo scale, and some only mentioned symptoms that occurred post-ESWL. The results presented here were quite diverse. Smith et al<sup>14</sup> and Ozkaya<sup>8</sup> noted that the complications arising from the two procedures were not significantly different. Goren et al<sup>3</sup> tended to show more complications from ESWL with fluoroscopic guidance. Meanwhile, Chang et al<sup>4</sup> stated that the combined use of USG and fluoroscopy resulted in a lower complication rate compared with fluoroscopy alone.



**Figure 2.** Risk of bias in non-randomized studies - of interventions (ROBINS-I) (summary plot)



**Figure 3.** Risk of bias in non-randomized studies - of interventions (ROBINS-I) (traffic plot)

**Risk of bias**

Risk of bias assessment was performed using the ROBINS-I scale. No fatal or severe bias was found in the seven studies assessed. An overview of the risk of bias is presented in Figures 2 and 3.

**DISCUSSION**

This systematic review examined the comparison of USG versus fluoroscopy as a guide for ESWL in patients with urolithiasis. From the six studies that compared USG with fluoroscopy, five studies found no significant difference in SFR results, although USG tended to have better results than fluoroscopy.<sup>3,7,8,12-14</sup> Despite the consistent results, each study had a different definition of SFR. However, USG provides comparable results with fluoroscopy. In this review, we classified the SFR results from one ESWL therapy as the initial SFR and the SFR results from repeated ESWL actions as the final SFR. Even with this classification, the definition of the final SFR was still different in several studies, such as Van Besien et al<sup>7</sup> and Goren et al<sup>3</sup> who defined SFR as a stone-free state after a maximum of four ESWL sessions, while Ozkaya<sup>8</sup> defined SFR only after three sessions of ESWL. The differences in the definitions of SFR in each study also led to differences in the concept of auxiliary therapy. Some studies defined repeated ESWL as adjunctive therapy; a few defined adjunctive therapy as other procedures (such as ureterorenoscopy, percutaneous lithotripsy, and stent placement); while others defined repeated ESWL as part of primary therapy until monthly follow-up targets were achieved.

In general, several factors can affect the final SFR outcome of ESWL (regardless of the difference in the guidance used), including size, location, stone composition, body habitus, and performance of ESWL.<sup>2</sup> In a previous study, Shehata et al<sup>15</sup> analyzed the use of USG-guided ESWL for nephrolithiasis in 50 children and found that fragmentation occurred in 47 (94%) cases, with stone-free status in 26 (52%), significant remaining stones in 21 (42%), and failure in 3 (6%) after three ESWL sessions. The success rate was significantly influenced by the size and number of stones but was not significantly affected by stone density.<sup>15</sup> In contrast, Grabsky et al<sup>16</sup> conducted a study in 124 children and found that SFR from a single ESWL session was achieved in 117 (88%) cases, with the final SFR from three ESWL sessions achieved in 122 (91.7%).



Based on the univariate analysis, they concluded that younger age, sedation type, and the presence of radiolucent stones were factors that significantly influenced ESWL results. In multivariate analysis, however, the presence of radiolucent stones was the only significant influencing factor.<sup>16</sup> Nevertheless, neither study could explain whether there was a direct relationship between the use of USG and the success rate of the SFR of ESWL.

In this review, the SFR results also tended to be influenced by many factors, which could confound the results. The first factor was the difference in SFR definition and assessment methods. Second, there were differences in the application limits for the use of ESWL, such as the maximum number of shock waves (some provided a limit of up to 3,000 and some less than 2,000 shock waves), the lowest energy limit when starting the therapy, and differences in machine specifications. Third, the sample population in each study was different, such as the condition of the included and excluded patients and comorbidities, including obesity. Fourth, there were differences in stone composition, such as stone density (ranged between 600–1,000 Hounsfield units [HU], except for four studies that did not include stone density data) and stone type (mentioned in two studies).<sup>3,7,8,12–14</sup>

Chang et al<sup>4</sup> found that using USG combined with fluoroscopy resulted in a much better SFR, with lower rates of re-treatment and complications. However, it should be noted that several factors have not been assessed in this study, such as stone composition, computed tomography (CT) values, and skin-to-stone distance, which may affect the final result.<sup>4</sup> Abid et al<sup>17</sup> also conducted a study comparing the addition of USG to fluoroscopy with fluoroscopy alone to assess the reduction in the duration of fluoroscopy on ESWL. From a comparison of 40 total samples of adults with kidney stones, adding USG to fluoroscopy could significantly reduce the fluoroscopic time ( $p < 0.0001$ ), indirectly reducing the amount of radiation exposure in the patient.<sup>17</sup> Unfortunately, studies that discussed the comparison between combined USG and fluoroscopy compared with USG only or fluoroscopy only have not been widely carried out, so no definite conclusion can be drawn. In the future, it is hoped that more studies will be conducted for comparison.

From the perspective of complications, there were no reports of complications directly related to the use of USG or fluoroscopy modalities or a tendency for

certain complications and symptoms found specifically with any of the modalities. A complication assessment was performed to assess the effectiveness of these modalities in reducing the number of complications that occurred after ESWL (especially to reduce the need for additional therapy). As a result, some studies reported similar complication rates on both USG and fluoroscopy (slight difference in percentage but with lower numbers on USG), while other studies reported significantly higher complications on fluoroscopy than on USG. The difference in these results can also be influenced by various factors, such as machines, operators, and the patients.

Smith et al<sup>14</sup> and Ozkaya<sup>8</sup> reported similar results between USG and fluoroscopy but did not assess the stone composition and HU levels, which could lead to bias between groups where complications and treatment failure are more likely to occur in harder stones. In addition, Ozkaya<sup>8</sup> also performed sedoanalgesia and double-J (DJ) stent placement in patients with hydronephrosis and stones >15 mm in size, which might reduce the incidence of complications. However, some studies stated that the DJ stent did not reduce the rate of post-ESWL complications.<sup>18,19</sup> Meanwhile, Goren et al<sup>3</sup> reported more significant complications on fluoroscopy, possibly due to specific samples aimed at cystine stones, a limited number of samples, and the fact that they did not place DJ stent prior to ESWL.<sup>3</sup> The comparisons obtained from all studies were still quite influenced by confounding factors, so the results were also inaccurate. General, post-ESWL complications with the help of USG give good results and are not inferior to fluoroscopy.

In general, using USG compared with fluoroscopy does not result in significant differences in SFR results. However, the absence of radiation exposure makes USG superior to fluoroscopy in the majority of cases, especially considering that ESWL may require repeat as well as follow-up with X-rays or CT scans that provide additional radiation exposure. However, it does not eliminate the existing potential of both USG and fluoroscopy owing to its advantages. Thus, they can be used according to the patient's condition.

The limitation of this study lied mainly in the high heterogeneity of each study (methodological and research samples), which can lead to bias. In addition, the lack of complete data in each study resulted in limited and inconclusive results. The sample size from each study also tended to be small and less

representative. Further research that can minimize the existing heterogeneity is needed for more definitive conclusions. Additionally, studies comparing the function of ESWL with fluoroscopy on ureteral stones are required.

In conclusion, the use of USG is comparable to fluoroscopy on SFR and nephrolithiasis complications. Although some studies mentioned slightly better results from USG guidance, USG is preferred due to the absence of radiation risk. However, each modality has its advantages and disadvantages. The combination of fluoroscopy and USG also provides promising results and is superior to the sole use of a single modality. Regardless, additional studies are needed for future comparisons.

#### Conflict of Interest

The authors affirm no conflict of interest in this study.

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