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Guidelines

International Alliance of Urolithiasis Guideline on Shockwave Lithotripsy

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Abstract

Different international associations have proposed their own guidelines on urolithiasis. However, the focus is primarily on an overview of the principles of urolithiasis management rather than step-by-step technical details for the procedure. The International Alliance of Urolithiasis (IAU) is releasing a series of guidelines on the management of urolithiasis. The current guideline on shockwave lithotripsy (SWL) is the third in the IAU guidelines series and provides a clinical framework for urologists and technicians performing SWL. A total of 49 recommendations are summarized and graded, covering the following aspects: indications and contraindications; preoperative patient evaluation; preoperative medication; prestenting; intraoperative analgesia or anesthesia; intraoperative position; stone localization and monitoring; machine and energy settings; intraoperative lithotripsy strategies; auxiliary therapy following SWL; evaluation

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of stone clearance; complications; and quality of life. The recommendations, tips, and tricks regarding SWL procedures summarized here provide important and necessary guidance for urologists along with technicians performing SWL.

Patient summary: For kidney and urinary stones of less than 20 mm in size, shockwave lithotripsy (SWL) is an approach in which the stone is treated with shockwaves applied to the skin, without the need for surgery. Our recommendations on technical aspects of the procedure provide guidance for urologists and technicians performing SWL.

1. Introduction

Urolithiasis is one of the most frequently noted conditions in urology and recommendations regarding management are a valuable tool for clinicians. Different international associations including the American Urological Association, the European Association Urology, and the Chinese Urological Association have proposed their own guidelines on urolithiasis [1,2]. However, the focus is primarily on an overview of the principles of urolithiasis management. Step-by-step technical details for the procedure would be much more practical for urologists in guiding best clinical practice.

The International Alliance of Urolithiasis (IAU) has recently released a series of urolithiasis management guidelines, including guidelines on percutaneous nephrolithotomy (PCNL) and retrograde intrarenal surgery (RIRS) [3,4]. The present guideline on shockwave lithotripsy (SWL) is the third in the IAU series on urolithiasis management and includes preoperative evaluation, procedural tips and tricks, and follow-up strategies, with the goal of offering a clinical framework for surgeons and technicians performing SWL.

For the IAU guideline on SWL, all recommendations were collated, appraised, and summarized via a structured assessment of studies with a high level of evidence and published in English between January 1, 1984 and January 1, 2022. A comprehensive literature search covering all aspects of SWL was performed using the PubMed database. The search terms included "shock wave lithotripsy", "shockwave lithotripsy", "ESWL", and "SWL" (Fig. 1). We assigned a grade recommendation (GR) using a modified GRADE methodology [5], whereby the body of evidence is assigned a rating of A (high-quality evidence; high certainty), B (moderate-quality evidence; moderate certainty), or C (low-quality evidence; low certainty). A classification system modified from the Oxford Centre for Evidence-Based Medicine Levels of Evidence was used to grade the level of evidence (LE) according to the study nature and homogeneity [6]; level 1 is the highest level, and level 5 is the lowest.

2. Guideline

2.1. Indications and contraindications

2.1.1. Indications

- Renal or ureteral stones with a diameter up to 20 mm or stones in the lower calyx with a diameter up to 15 mm (LE: 1, GR: A).
- Renal stones or ureteral stones larger than 20 mm in cases for which endoscopic lithotripsy is not available or contraindicated. However, repeated SWL and a JJ stent may be required (LE: 2, GR: B).
- SWL is an effective and minimally invasive therapeutic option for vesical or urethral stones of less than 20 mm (LE: 2, GR: B).

Stone burden is always the risk factor compromising the stone-free rate (SFR) following SWL. The upper cutoff value for upper urinary tract stones is generally 20 mm, and is 15 mm for lower-pole stones [6,7]. Unfavorable anatomy characteristics of the lower calyx for SWL include a long infundibulum, a narrow infundibular neck, and an acute infundibulopelvic angle [8]. Homogeneous stones with high density (≥1000 Hounsfield units) are generally resistant to SWL [9,10]. The likelihood of stone disintegration in SWL is significantly reduced when the skin-to-stone distance is >100 mm [11].

SWL monotherapy is generally not recommended for stones larger than 20 mm [12]; however, SWL may be considered only if patients are keen to avoid invasive procedures and/or anesthesia and they are well informed and willing to undergo repeated SWL and stenting if needed. For stones larger than 20 mm, a higher SFR can be obtained with PCNL or RIRS, but at the expense of greater cost and potential higher complication rates [13].

SWL is an effective and minimally invasive therapeutic option for vesical or urethral stones of <20 mm in size [14]. It has also been shown that SWL is safe for stones in transplanted kidneys and ectopic kidneys, with an acceptable SFR [15]. Great care should be taken to control any risk factors to ensure that the kidney does not become obstructed after SWL.

2.1.2. Contraindications

- Pregnancy (LE: 4, GR: B).
- Untreated coagulation abnormalities (LE: 4, GR: B).
- Tumor, aneurysms, or other significant pathology in the shockwave path (LE: 4, GR: B).
- Uncontrolled urinary tract infection (UTI) (LE: 3, GR: B).
- Anatomic obstruction distal to the stone (LE: 4, GR: B).
- Untreated or severe hypertension (LE: 4, GR: B).

SWL in pregnancy is associated with low birth weight, placental displacement, miscarriage, and potential hazards of ionizing radiation, so it is contraindicated [16]. Untreated

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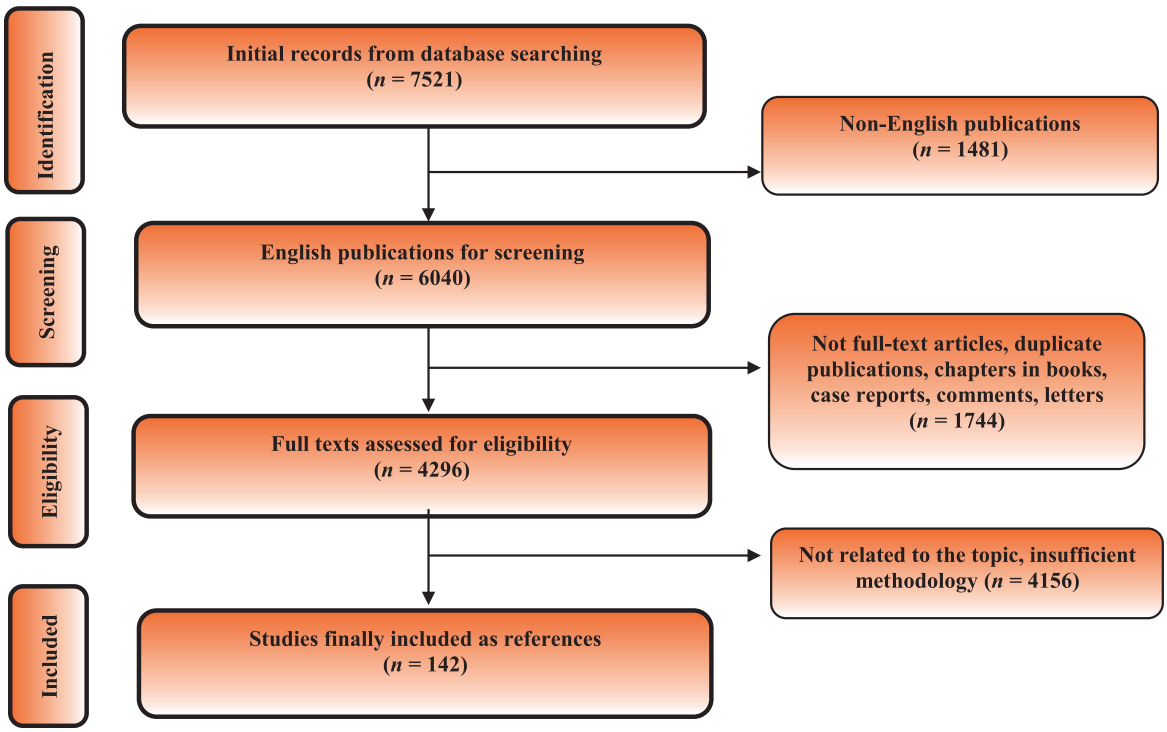

Fig. 1 – PRISMA diagram for screening of references for the guideline.

coagulation abnormalities dramatically increase the risk of perirenal and subcapsular hematomas, so patients taking medications have an absolute contraindication for SWL [17–19]. A urinalysis is mandatory before SWL in all cases. If bacteriuria and/or pyuria are present (particularly with a positive nitrite test), patients should be treated on the basis of a urine culture sensitivity test before SWL [20].

It has been reported that severe or untreated hypertension (diastolic blood pressure >90 mm Hg) increases the risk of perirenal hematoma formation following SWL [21,22]. The patient's blood pressure should be evaluated and controlled properly before and during the entire SWL procedure. Patients with a pacemaker can be treated with SWL provided that appropriate technical precautions are taken [23].

2.2. *Preoperative patient evaluation*

2.2.1. *Urinanalysis and a urine culture sensitivity test*

- Urinanalysis and a urine culture-sensitivity test are recommended before SWL (LE: 3, GR: B).

Urinary microscopy and a urine culture test if needed should be performed in all cases before any SWL procedure. The presence of bacteriuria on a preoperative urine examination represents a potential risk for postoperative complications, and any UTI before SWL should be adequately treated with appropriate antibiotics [24–26]. A urine dipstick test can be performed on the day of the SWL procedure for logistical purposes to rule out a potential UTI.

2.2.2. *Imaging before SWL*

- Noncontrast computed tomography (NCCT) is recommended before SWL (LE: 3, GR: B).

Kidney-ureter-bladder (KUB) X-ray and ultrasonography examinations are adequate to evaluate the stone burden and the presence and degree of hydronephrosis, and to distinguish radiolucent and radiopaque stones before SWL. They are also essential to outline the SWL indication and select the imaging modality for SWL.

NCCT imaging allows accurate determination of the stone burden, stone density, skin-to-stone distance, the presence and degree of urinary tract dilatation, and the morphologic status of the renal parenchyma [9,27,28]. In addition, contrast-enhanced CT can provide detailed information on stone location and renal collecting system anatomy, especially in complex cases such as calyceal diverticula and parenchymal calcification.

2.3. *Preoperative medications*

2.3.1. *Antibiotic prophylaxis and UTI treatment*

- Antibiotic prophylaxis is not necessary in patients with sterile urine (LE: 1, GR: A).
- In patients with a positive urine culture, antibiotics should be administered according to culture-antibiogram test findings (LE: 5, GR: A).

In patients with a positive urine culture and sensitivity pattern available before SWL, pretreatment with appropriate antibiotics should always be undertaken [7]. However, the optimum administration period for antibiotics has not been well investigated.

Antibiotic prophylaxis before SWL in cases with sterile urine may be unnecessary [29]. However, it is definitely necessary in patients with nephrostomy tubes. In patients with internal stents, antibiotics might occasionally but not always be necessary. Antibiotics should always be administered in cases with a higher risk of a bacterial burden, such as patients with an indwelling catheter or infected stones [30,31].

2.3.2. Antithrombotic therapy management

- Interruption of antithrombotic therapy, in consultation with the patient's primary care physician, is required to minimize the risk of perioperative bleeding and hematoma formation in patients undergoing SWL (LE: 4, GR: A).
- Temporary discontinuation or bridging of antithrombotic therapy should be discussed with the appropriate specialist (LE: 5, GR: A).

SWL is classified as a procedure with a high risk of bleeding [32]. Interruption of antithrombotic therapy is required to minimize bleeding complications, such as prolonged gross hematuria and perinephric hematoma [33,34]. However, the risks associated with cessation of antithrombotic treatment, including thromboembolism, must also be considered. This consideration mainly depends on the patient's clinical characteristics, primary disease, the duration of cessation, and the treatment received [35–38]. Temporary discontinuation or bridging of antithrombotic therapy should be discussed in detail with the specialist responsible for a rational approach.

In patients receiving anticoagulant therapy, withdrawal of oral anticoagulants is recommended; bridging is required only in patients with a high risk of thromboembolic events [35,36]. The timing of cessation for anticoagulant therapy is largely determined by the International Normalized Ratio values for vitamin K antagonists (warfarin, acenocoumarol) and by renal function for direct oral anticoagulants (dabigatran, rivaroxaban, apixaban, edoxaban), as listed in Table 1 [39–43]. Oral anticoagulant therapy may be restarted at 48–72 h after SWL [36].

In patients on antiplatelet therapy for primary prevention, aspirin should be withdrawn 7–10 d before SWL [32,35]. In patients with low thrombotic risk, antiplatelet therapy should be withdrawn before SWL (aspirin 7–10 d, ticagrelor 3–5 d, clopidogrel 5 d, and prasugrel 7 d) [35,44]. Lastly, in patients with moderate to high thrombotic risk, the SWL procedure should be postponed until the thrombotic risk is low [36]. Antiplatelet therapy may be restarted after 48–72 h [36].

Table 1 – Usual time for discontinuing anticoagulation before surgery [36]

Drug class	Parameter	Timing of anticoagulation interruption before surgery
Direct oral anticoagulants	**Renal function**	
Dabigatran	CrCl <50 ml/min	4 d
	CrCl 50–79 ml/min	3 d
	CrCl ≥80 ml/min	2 d
Rivaroxaban, apixaban, edoxaban	CrCl 15–30 ml/min	3 d
	CrCl ≥ 30 ml/min	2 d
Vitamin K antagonists	**International Normalized Ratio**	
Acenocoumarol	<2	2 d
	2–3	3 d
	>3	4 d
Warfarin	<2	4 d
	2–3	5 d
	>3	6 d

CrCl = creatinine clearance.

2.3.3. Perioperative hydration

- Diuretics along with hydration are recommended for SWL of renal stones (LE: 2, GR: B).

A diuretic (furosemide) administered before SWL and followed by continuous infusion of 0.9% normal saline during SWL can improve renal stone clearance [45]. A fluid film surrounding the stone facilitates better fragmentation of renal stones [45].

2.4. Prestenting

- Prestenting is not routinely recommended for patients undergoing SWL (LE: 1, GR: A).

Routine pre-stenting does not bring benefit of increased SFR nor decreased need for auxiliary treatment after SWL. In addition, more lower urinary tract symptoms (LUTS) are likely to be induced by prestenting [46–48]. However, evidence has shown that stenting reduces the risk of steinstrasse [49,50]. As the incidence of steinstrasse increases with the size of the stone, prestenting may be considered for stones with a diameter >20 mm or a stone surface area >200–300 mm^2 [7,49]. Prestenting is a reasonable precaution for frail patients to avoid the risk of acute ureteral obstruction, irrespective of the size of the stones [51].

2.5. Intraoperative analgesia and anesthesia

- Sufficient analgesia and pain relief during SWL treatment is mandatory (LE: 1, GR: A).
- Nonsteroidal anti-inflammatory drugs (NSAIDs), opioids, and simple analgesics all provide adequate or reasonable analgesia during SWL (LE: 2, GR: B).
- Electrocardiogram (ECG) recording and oxygen inhalation should be used during SW (LE: 5, GR: C).

Intravenous sedation is a suitable pain management protocol for most patients undergoing SWL treatment. General anesthesia is another safe option for SWL, and may result in a higher SFR as it allows better targeting, resulting in efficient fragmentation. General anesthesia is the strategy of choice for infants and young children or extremely anxious patients [52–55]. Local anesthesia in SWL provides comparable pain control to systemic analgesics and decreases the need for analgesic supplementation [56]. Pretreatment with an NSAID agent has proven to be effective in reducing the need for further administration of analgesic and sedative drugs [57]. Complementary therapy including audiovisual or music distraction seems to have acceptable advantages in terms of lowering analgesia requirements and patient anxiety during SWL. However, the quality of evidence is poor and the majority of the studies are single-arm case series only [58,59].

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ECG recording should be carried out during SWL to detect arrhythmia that may be caused by the electromagnetic field established during shockwave generation. Moreover, it might be wise to use oxygen inhalation to avoid low oxygen saturation that might occur with certain analgesics.

2.6. Patient position, stone localization, and monitoring

2.6.1. Patient position

- A stable supine position is preferred regardless of the stone location if an under-table and an over-table shock wave generator are available (LE: 3, GR: A).
- If an over-table shock wave generator is unavailable, the prone position is applied for distal ureteral stones and for stones inside the pelvis (LE: 1, GR: A).

Respiratory movement of the kidney and occasionally patient movement may cause stones to move out of the shockwave focus, resulting in lower disintegration rates, so a stable and comfortable patient position is essential for optimal stone fragmentation during SWL [51]. Neck rolls, knee rolls, wedges, and arm rests are accessories that can help to stabilize the patient's position. With a lithotripter offering both under-table and over-table positions, the patient can be treated in the supine position for all stone locations. Since the iliac crest blocks shockwaves, stones located in the ureter below L4 require a ventral or ventrolateral position of the shockwave head if the lithotriptor head is movable and can be located over the table. For lithotriptors with a shockwave head located under the table, patients have to be treated in the prone position. Abdominal compression belts may be used to reduce respiration-induced stone (kidney) movements and thus increase the efficacy of stone fragmentation [51]. A meta-analysis showed that SWL for distal ureteral stones, treatment in the supine position may be the preferred option as this approach can increase SFRs compared to the prone position [60,61]. However, it is always necessary to choose the patient position on an individual basis.

2.6.2. Stone localization and shockwave head positioning

- Either fluoroscopy or ultrasound is applied to monitor stone localization (LE: 2, GR: A).
- The shockwave head should be positioned according to the stone location and imaging modality (LE: 3, GR: A).
- Stone localization should be reconfirmed at regular intervals throughout the treatment (LE: 3, GR: A).

Although studies have showed that ultrasound is as effective as fluoroscopy in detection of urinary stones during SWL, ultrasound-guided SWL is considered to be more difficult [62,63]. Some new lithotripters with automated systems seem to have greater efficacy and decrease the learning curve [64]. The use of fluoroscopy is more common, but use of ultrasound can be advantageous for radiolucent stones and avoid unnecessary exposure to ionizing radiation. Ultrasound monitoring also allows real-time imaging during the whole procedure. However, the accuracy of ultrasound is lower in the case of mid-ureteral stones owing to the presence of bowel gas and the absence of anatomic landmarks. In the case of a nondilated collecting system or an indwelling ureteral stent, detection of mid-ureteral stones is particularly more difficult.

Positioning of the shockwave head will vary according to the imaging technique used and the stone location. An under-table generator is used to treat most upper urinary tract stones up to the fourth lumbar vertebra. An over-table head position might be superior/advantageous in the management of ureteric stones distal to the fourth lumbar vertebra in the supine position.

Since the targeted stones may move out of the shockwave focus on patient or stone movement, the shockwave focus (target) should be reconfirmed at regular intervals throughout the treatment. If there is an apparent patient movement, stone targeting must be rechecked immediately. Otherwise, the stone location should be periodically checked, for example, every 300–500 shocks or continuously when using ultrasound [65–67].

2.6.3. Radiation exposure management

- Fluoroscopy time, distance, mode setting, and shielding should be considered during treatment to reduce the patient's radiation exposure (LE: 3, GR: A).
- Precautions to reduce radiation exposure should be taken when using fluoroscopy (LE: 3, GR: A).

When using fluoroscopy, urologists should take all necessary precautions according to the as low as reasonably achievable (ALARA) principles to reduce exposure to ionizing radiation [68,69]. A lower exposure time directly limits the radiation dose, while a greater distance between the patient and the radiation source reduces exposure by the square of the distance [70,71]. Lead used to shield ionizing radiation is also an effective approach for reducing radiation exposure [72]. When working with ionizing radiation equipment, it is crucial to use shielding whenever possible. Other measures to reduce the radiation dose include intermittent fluoroscopy, use of collimators, decreasing the radiation field as soon as the stone has been identified, holding of the last image, avoiding image magnification, application of dose level settings, pulsed fluoroscopy, and a focus on training operators in awareness of ALARA [71,73,74]. Use of ultrasound can also avoid radiation exposure for patients and staff.

2.7. Machine and energy settings

- Adjust the shockwave parameters according to the characteristics of the individual case (LE: 3, GR: A).
- Start with low-energy shockwaves and use slow ramping up to the desired energy level (LE: 1, GR: A).
- A low shockwave frequency is recommended for less renal vascular and tissue injury and better stone fragmentation (LE: 1, GR: A).

The disintegration effect is cumulative and depends on the energy delivered. The number of shockwaves and the energy delivered with each single shockwave determine the total energy dose. Overtreatment must be avoided, since the risk of side effects is also directly related to the total energy dose. Most commonly 2000–4000 shockwaves are considered the upper limit. The total energy needed to disintegrate a stone largely depends on its size, location, hardness, and composition, as well as obesity and other risk factors. Very obese patients might require additional energy. In certain conditions, a lower number of shockwaves may be needed for treatment. This approach should be applied for cases with diabetes mellitus, age >65 yr, impaired renal function, or hydronephrosis, and in particular for pediatric patients [75–77]. Pretreatment application of low-energy shockwaves is recommended. Pretreatment with 100–500 low-energy shockwaves and a 3-min pause before the clinical dose of shockwaves causes a vasoconstrictive response in the treated kidney [78]. However, the mechanism underlying this protection when using SW voltage ramping is unknown [66,77,79].

The damage to renal tissue and resulting hematomas may be caused by cavitation effects, whereby the tensile stress of the shockwaves may create small vapor bubbles in the blood. Several studies have indicated that higher acoustic energy and higher pulse repetition frequencies result in stronger cavitation bubbles. A lower shockwave rate reduces cavitation effects and the subsequent risk of tissue damage. In high-frequency mode, these bubbles remain when the next shock is fired. The bubbles can absorb the energy and accumulate, resulting in a reduction in SWL efficacy. At a slower rate, the bubbles dissipate between shocks and allow more effective stone comminution [80–83].

2.8. Intraoperative lithotripsy strategies

- A bubble-free coupling area is highly important to achieve good and efficient energy transmission (LE: 2, GR: A).
- Bowel gas in the target trajectory should be avoided (LE: 5, GR: C).

Proper bubble-free coupling for shockwave transmission from the source to the patient is one of the most critical issues for successful SWL [84,85]. It was demonstrated that the stone fragmentation efficiency decreased by 20–40% when only 2% of the coupling area contained air bubbles [84]. Several air bubbles may inevitably be trapped in the interface between the water cushion and the patient's skin on initial coupling. These air bubbles can be easily removed by gently swiping the area between the patient and the inflated water cushion using a hand [65,86]. Hydrophilic gel can be applied for coupling. Devices the use video cameras have been developed to check if the transmission zone is free of air bubbles and that the coupling is optimal [7,87].

2.9. Ancillary therapy following SWL

2.9.1. Medical expulsive therapy

- Use of α-blockers (eg, tamsulosin) improves stone passage after SWL (LE: 1, GR: A).

Despite conflicting results, most randomized controlled trials and several meta-analyses confirm that α-blocker use after SWL for ureteral or renal stones improves stone passage. Use of α-blockers might also reduce the need for additional pain medication [88,89]. The type of α-blocker is not correlated with the expulsion rate.

2.9.2. Postural expulsive therapy

- Mechanical percussion and diuretic therapy can assist in the passage of stone fragments after SWL and improve the SFR (LE: 2, GR: B).

Meta-analysis results showed that mechanical percussion, forced diuresis, body inversion (PDI) and external physical vibration lithecbole (EPVL) are safe and effective methods that assist in clearance of stone fragments following SWL, especially for lower-pole stones [90,91].

2.9.3. Repeat SWL

- Repeat SWL is an alternative modality for upper urinary tract stones [92,93] (LE: 3, GR: B).
- The time interval between two SWL sessions for kidney stones should not be less than 1–2 wk. For ureteral stones, an interval of 1 d might be sufficient [94,95] (LE: 5, GR: B).

Repeated SWL is an alternative modality following failed SWL, even though the SFR of retreatment is compromising [96].

Renal contusion generally improves within at least 1–2 wk, so a time interval of at least 1–2 wk between two SWL sessions is required for renal stones [92]. There is no evidence that SWL for ureteral stones can lead to renal hematoma, because of the lack of involvement of the renal parenchyma in the target area [95,97]. For ureteral stones, an interval of 1 d between SWL treatments might be sufficient.

2.9.4. Ureteroscopy for persisting obstructing fragments

- Ureteroscopy can be considered a treatment option for persisting obstructing fragments after SWL (LE: 5, GR: B).

Multiple small fragments embedded in the ureteral mucosa are usually associated with subsequent development of a ureteral stricture. Fragments causing obstruction should be removed endoscopically. Ureteroscopy is a safe and effective procedure with a moderate success rate and a low rate of complications for persisting obstructing fragments after SWL [98–102].

2.10. Evaluation of stone clearance

- KUB X-ray and ultrasonography are adequate for evaluation of stone clearance after SWL, while low-dose CT provides the most accurate information on stone-free status (LE: 2, GR: A).
- The time point for evaluation of stone clearance should be 2–3 mo postoperatively (LE: 3, GR: A).

Clearance following SWL is defined in most studies as complete absence of fragments. KUB X-ray and ultrasonography are generally adequate for detection of radiopaque or

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radiolucent stones [103,104]; KUB X-ray combined with ultrasound is recommended in selected patients [105]. Ultrasonography does not expose patients to radiation, but provides limited accuracy for stone information. Low-dose CT provides the most accurate information on stone-free status [106]. The time point for evaluation should be 2–3 mo after SWL [107,108]. It is important, however, that the time for follow-up examination is decided by individual clinical circumstances.

2.11. Complications

The incidence of complications after SWL is determined by three main factors: the formation and passage of stone fragments; infection; and the impact on renal and nonrenal tissues [109]. It has been reported that the rate of complications after SWL is 18.4% for Clavien grade I–II and 2.5% for Clavien grade III–IV complications [110].

2.11.1. Hematoma

- Risk factors for hematoma formation following SWL include use of antiplatelet agents, uncontrolled hypertension, and diabetes [26,111] (LE: 4, GR: A).

It has been reported that the incidence of perirenal or intrarenal hematoma detected on ultrasound is between 0.1% and 0.6% [112]. The probability of hematoma increases with patient age.

Gastrointestinal tract injury may occur after SWL. Although the incidence is low, hematoma formation may occur in the colon, pancreas, liver, and spleen. This is related not only to the number and power of shockwaves but also to the patient's body position.

Most hematomas are clinically asymptomatic. Hematomas following SWL are usually managed conservatively and will be absorbed spontaneously. If hematoma formation results in an unstable clinical situation, intervention such as embolization or surgery may be warranted.

2.11.2. Bleeding

- Use of low-frequency shockwaves can reduce bleeding complication after SWL (LE: 2, GR: A).

Hematuria is a common finding following SWL: almost all patients will experience hematuria after SWL, but most occurrences are self-limiting. Tissue injury and subsequent bleeding increase with the shockwave frequency. Reducing the frequency of shockwave administration can not only reduce the occurrence of bleeding but also play a positive role in the fragmentation of stones [82]. The standard frequency recommended is approximately 80–90 waves/min. However, studies have found that a rate of 60 shockwaves/min performs better than 80 shockwaves/min in the treatment of distal ureteral stones, while reducing bleeding complications [113].

Subcutaneous hemorrhage was also a complication after SWL during the early stage of the approach. However, improvements in SWL technique mean that this complication rarely occurs now.

2.11.3. Fever

- A positive urine culture and urinary tract obstruction are associated with a higher risk of infection and fever after SWL (LE: 4, GR: A).

Fever is mainly caused by infection after or during SWL. SWL itself may lead to kidney injury and vascular injury, which in turn facilitate migration of urinary bacteria into the blood. This might result aggravated infection, fever, and septicemia. In addition, some stones contain bacteria that can be released into the urine and further absorbed by the body in cases of vascular injury. Some 1–4% of patients undergoing SWL experience steinstrasse formation, which may also cause ureteral obstruction with fever and secondary infection [114].

When preoperative urine cultures are positive or there is urinary tract obstruction, the risk of infection is greatly increased. However, routine administration of antibiotics is not necessary for patients when tests confirm that urine is sterile before SWL [31].

2.11.4. Pain

- NSAIDs and α-receptor antagonists in combination can relieve pain following SWL caused by the passage of small fragments (LE: 2, GR: A).
- PDI and EPVL might actively expel stone fragments and thus minimize post-SWL pain (LE: 2, GR: B).

Pain or renal colic following SWL is mainly a result of acute obstruction of the urinary tract caused by the passage of stone fragments [109,115] and occurs at an incidence of 2–5% [1]. Stone burden, ureteral patency, and the energy setting used are risk factors for post-SWL pain and renal colic [109].

NSAIDs are the first-line choice for relief of the pain of renal colic following SWL [116,117]. NSAID combination with α-receptor antagonists might be better in relieving pain, counteracting renal colic, and facilitating the passage of stone fragments [118,119]. An increase in fluid intake and moderate exercise are also required, and PDI and EPVL may result in active expulsion, thus minimizing post-SWL pain caused by the passage of stone fragments [90,120–122].

2.11.5. Steinstrasse formation

- Large stone burden is a risk factor for steinstrasse following SWL (LE: 1, GR: A).
- Internal stents are not required to prevent steinstrasse for stones of <20 mm in size (LE: 2, GR: A).
- Stent placement should be considered in patients with a stone >20 mm in an anatomically or functionally solitary kidney (LE: 2, GR: A).

Steinstrasse is noted in 5–10% of cases following SWL [123,124]. A larger stone burden is a risk factor for steinstrasse following SWL [125,126]. The risk of steinstrasse increases with the stone burden, whether or not an internal stent is present [50,127]. Pre-SWL stenting in patients with stones larger than 20 mm decreases the risk of steinstrasse,

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as well as the risk of acute clinical symptoms in cases of steinstrasse [49,128].

Conservative management is recommended for patients with steinstrasse. However, repeated SWL is required when passage of the fragments is delayed by more than 2 wk, if any obstruction is moderate, or if there are stone fragments larger than 5 mm [127]. In the case of confirmed deteriorating clinical symptom, obstruction, or infection, further ureteroscopy or percutaneous nephrostomy is required to relieve obstruction and for control of infection [127,129,130].

2.11.6. Long-term adverse effects

- There is little high-level evidence to support the hypothesis of long-term adverse effects following SWL (LE: 1, GR: A).

Even though several retrospective studies and case reports have revealed new onset of disease in patients after SWL [131–134], most of these papers were published a long time ago. Furthermore, later studies report contrary results, so there are controversies regarding the long-term adverse effects of SWL. Unfortunately, there is little high-level evidence to confirm the hypothesis of long-term adverse effects following SWL. Since stone disease is a chronic condition, it is difficult to separate adverse events from the patient's own natural history and to distinguish whether such events are a consequence of SWL. Indeed, with the advances in SWL machine technology and increased experience in SWL, potential long-term adverse effects, including hypertension, diabetes mellitus, chronic kidney disease, and decreases in fertility, are no longer suspected as being related to SWL [135].

2.12. Quality of life (QOL) following SWL

- Shorter treatment duration, less pain, and a desire to have stones removed noninvasively without general or regional anesthesia lead to the higher patient QOL following SWL (LE: 2, GR: A).

Although patients have lower scores for physical functioning and QOL after SWL [136], SWL remains the treatment with least impairment of QOL in comparison to ureteroscopy and PCNL [137]. Shorter treatment duration, less operative pain, and a desire to have stones removed noninvasively without general or regional anesthesia lead to higher patient QOL after SWL [138].

Patients with larger stones (>20 mm) tend to have impaired QOL as a result of higher retreatment rates, as well as renal colic during the passage of relatively large stone fragments [139]. However, residual fragments of $\leq$2 mm have nearly no impact on QOL [140].

Prestenting does not contribute to higher SFRs following SWL in patients with a moderate stone burden [47], but is associated with LUTS, haematuria, and UTIs [141], and can therefore reduce QOL.

3. Conclusions

SWL is a well-established procedure for stones of <20 mm in size. The recommendations, tips, and tricks regarding SWL summarized here should provide important guidance for urologists and technicians performing SWL.

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Study concept and design: Zeng, Sarica.
Acquisition of data: Zhong.
Analysis and interpretation of data: Zhong, Zeng.
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