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European Association of Urology

Review – Stone Disease

Optimizing Shock Wave Lithotripsy in the 21st Century

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Article info

Article history:
Accepted April 20, 2007
Published online ahead of print on May 2, 2007

Keywords:
Shock wave lithotripsy
Treatment outcome
Adverse effects
Instrumentation
Methods
Ureteric stones
Obesity

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Abstract

Objective: Shock wave lithotripsy (SWL) has radically changed treatment of stone disease and appears to be the first option for the majority of patients. This review of current literature focused on suggestions for optimising technique, patient selection, results, and lithotriptor comparison for SWL.

Methods: Literature search for SWL was performed for recently published papers in English language. Topics of interest were treatment protocols; patient evaluation; pre-SWL prediction of outcome; lithotriptor technology; efficacy; and methods to assess the effects, decrease complications, and compare lithotriptors. Earlier classic papers on SWL and guidelines for stone disease were also reviewed.

Results: Recent literature contained important recommendations about SWL concerning (1) methods to predict stone fragmentation; (2) identification of factors contributing to treatment failure for lower pole and ureteric calculi; (3) guidelines from urological associations; (4) manoeuvres and changes in SWL delivery (slower rate, twin-pulse technique) to increase efficacy and decrease complications; (5) clarification of the role of medical treatment (antibiotics, α-blockers); (6) role of SWL in calyceal stones, CIRF, and abnormal kidneys; (7) obesity and SWL; and (8) methods to evaluate and compare lithotriptors.

Conclusions: SWL delivered in an outpatient setting as an anaesthesia-free treatment is still considered the first option for the majority of stones with a minimal number of complications. Better understanding of the physics of shockwave delivery is required, together with treatment optimisation by limiting renal damage and better selection of patients because this approach will offer maximum benefit to patients and physicians, as well as more cost-effective treatment.

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0302-2838/$ – see back matter © 2007 European Association of Urology. Published by Elsevier B.V. All rights reserved. doi:10.1016/j.eururo.2007.04.066

1. Introduction

The use of shock waves has radically changed the treatment of urinary lithiasis. The stone-free rate (SFR) achieved in early series with the Dornier HM3 ranged from 72–90% [1–3]. Shock wave lithotripsy (SWL) became rapidly acknowledged as a first-line, effective, noninvasive method for the majority of stones, but eventually a series of limitations were revealed. Numerous efforts focused on improving the equipment and technique of SWL in newer-generation machines, but did not always lead to superior results. Essential modifications involved (1) new shock wave generator sources; (2) smaller focal zone to minimize pain and tissue trauma, and maintain efficacy, thus achieving treatment; (3) minimal analgesia required on outpatient basis; and (4) localisation of the stone by ultrasound (US) and/or X-ray. These changes led to treatment with fewer complications and expanding indications (ie, treatment of bigger stones, encrusted stents, etc). The current objective is treatment of stone disease with maximal clearance and minimal morbidity to the patient. This concept, together with progress in ureteroscopy and endourology, has made open surgery almost an anecdotal procedure.

However, significant issues still remain unanswered, and advances in SWL research have not always led to better treatment. Principles of shock wave delivery and their effect in renal tissue are becoming clearer, and significant modifications in technique and technology have been described. Newer-generation machines have never reproduced the results of the HM3. Today's lithotriptors are considered both user- and patient-friendly machines with advanced design and additional features, but the critical issues are still efficacy and safety. We attempt to summarise important proposals from the latest literature in various aspects of SWL.

2. Current diagnostic and therapeutic evaluation of SWL

With the progress made since its introduction, SWL has become the initial treatment for the majority of stone patients. However, "gray" areas still exist in the selection of patients, the technique, the evaluation of results, and so on, and will require clarification. Consequently, we have reexamined the basic philosophy and principles that accompany SWL. In this review our objective was to identify recent developments in SWL evaluation and clarify their effect in everyday practice. A Medline search was performed with a special interest in published papers on SWL in English language from 2000 on to identify the latest proposals for improvement of treatment and assessment of its effects. We also reviewed classic papers and reviews on the subject, dating back to the introduction of SWL, and the guidelines from European Urological Association and American Urological Association.

2.1. *Identification of the best patients/candidates for SWL*

The modern trend has led to active treatment of more stones in the urinary tract, thus their mean size is actually decreasing. Nevertheless, spontaneous stone passage can be expected for almost 80% of stones $\leq$4 mm in diameter. Conservative treatment is a reasonable option for a significant percentage of patients, like those with a 4- to 5-mm calculus and no symptoms or hydronephrosis [4]. A meta-analysis of 2074 patients found a spontaneous passage rate for stones $<$4 mm of 38% versus 1.2% for those $>$6 mm, with highest rate for distal stones (45%) as expected [5]. A variety of treatment options are available for the rest: SWL, ureteroscopy (URS, flexible or rigid), percutaneous nephrolithotomy (PNL), laparoscopy, and even open procedures. The issue is choosing the optimal therapy for an individual patient. Numerous factors that might affect the outcome should be considered: size, location, composition of the stone, anatomy of the urinary tract, surgeon expertise, equipment availability, patient preference, and duration of symptoms.

Modern imaging and statistical methods may provide assistance in selecting those suitable for shock wave treatment. Pretreatment imaging by noncontrast computed tomography (CT) might aid in identifying patients with stones amenable to SWL. Pareek et al [6] studied Hounsfield units (HU) measurement to determine the likelihood of stone fragmentation and found a significant inverse relationship between stone clearance and HU. Others have used X-ray coherent scatter analysis, HU density, shape of stones, and so on [7–9]. These results have to be replicated and verified, but this approach is a new path towards better prediction of SWL outcome. Examination of stone composition in recurrent stone formers can also help in that aspect, leading to alternative treatments for hard-to-break stones (wewellite, cystine, etc).

Other groups have developed statistical programs and artificial neural networks (ANNs) to predict, among others, (1) the incidence of certain genetic factors, (2) presence of upper tract calculi in recurrent stone formers, (3) spontaneous passage of distal stones, and (4) SWL outcome by predicting stone growth [10].

2.2. *Recognizing patients likely to fail SWL*

The identification of patients who will probably end up with residual fragment(s), and therefore possibly need other forms of treatment, is a challenge. In this context, much debate has been ventred around lower pole stones (LPS). A meta-analysis of 2927 patients with LPS showed a decreased SFR for SWL (52.9%) versus PNL (90%) [11]. In the Lower Pole Study Group, SWL and PNL were compared; 128 patients were randomised and the SFR difference was impressive: SWL 37%, PNL 95% [12]. The conclusion was that even stones of 11–20 mm are best treated by PNL, with no difference in complication rates or quality of life. Preminger [13] compared SWL, PNL, and flexible URS; the latter appeared as a reasonable alternative to the other two in low-volume disease and was used as primary treatment only for specific situations: obese patients, bleeding diathesis, failure of SWL, and patients with complicated renal anatomy. The ''lower Pole II'' study group compared SWL and URS for isolated stones $\leq$1 cm [14]; they did not reveal a statistically significant difference (maybe because of an underpowered study and early termination), implying that SWL should be offered first.

Factors that might explain low clearance for LPS include: lower pole dependency, infundibulopelvic angle (IPA) $<70^\circ$, infundibular width <5 mm, infundibular length >3 cm, lower infundibular length to diameter ratio >7, infundibular diameter <4 mm, and presence of a single minor calyx [15–17]. ANN analysis found the following variables to be associated: pathologic urinary transport, IPA, body mass index (BMI), and caliceal pelvic height, with a 15-fold relative weight over other inputs [18].

For ureteric stones, Delakas et al [19] identified presence of a stone in the distal ureter, size >10 mm, presence of ureteric obstruction, and a BMI > 30 as independent predictors of SWL failure. Gettman and Segura [20] favoured SWL as first-line therapy for proximal stones <1 cm in diameter, whereas for stones >1 cm they preferred URS or even PNL as alternatives to SWL, especially if an HM3 machine was not available. For distal stones they proposed URS as the initial or preferred treatment. Others still recommend SWL as the first-line treatment for all the ureteric, or only the distal stones [21,22].

2.3. *Methods to increase SWL efficacy*

Poor translation of clinical observation into improved efficacy for SWL is a result of incomplete understanding of shock wave physics, mechanism(s) of stone fragmentation, and results. Continuous efforts to improve efficacy have led to careful recommendations for renal and ureteric stones. The correct stone size and cut-off limits have to be identified. The American Ureteral Stones Guidelines Panel Summary Report [23] suggested (1) SWL as first-line treatment for proximal stones <10 mm; (2) SWL, URS, and PNL as options for proximal stones >10 mm; and (3) SWL and URS as options for distal stones.

In the European Guidelines on Urolithiasis [24], active treatment was suggested for all stones >6–7 mm. SWL *in situ* is considered the first option for treatment in the ureter (together with URS for the middle and distal part) except for uric acid stones, for which a stent and oral chemolysis are the preferred treatment. In the kidney, for stones up to 20 mm, SWL is the recommended treatment, with the addition of antibiotics for infectious stones. Only in uric acid stones is oral chemolysis preferred to SWL. For stones >20 mm, PNL is the first-line treatment. For staghorn stones (either partial or complete), the preferred treatment modality is again PNL and the role of SWL is secondary. Only in patients with small stones and a nondilated system should SWL monotherapy be considered a reasonable alternative. The combination of PNL and SWL appears to be superior to that of SWL and PNL.

Accurate pretreatment assessment of stone burden is therefore crucial for a good outcome. The classic method was by a plain KUB (kidneys, ureters, blader) film; however, the increase in the use of noncontrast CT as the initial imaging study for suspected renal colic has changed this practice, and either a combination of CT and KUB or CT alone (plus/minus reconstruction with coronal images) may be used [25].

A promising suggestion to improve SWL outcome is the use of certain manoeuvres to increase stone clearance, referred to as mechanical percussion, diuresis, and inversion therapy (PDI). Chiong et al [26] in a recent study of patients with LPS found a SFR of 62.5% for PDI and SWL, versus 35.4% for SWL alone. Still, the time consumed and the repeated visits make this procedure unattractive for wider use.

The observation that decreased frequency of shock wave delivery in animal and in vitro models led to increased per shock efficiency, which brought about changes in the mode and duration of a session. Vallencien et al [27] performed SWL in human stones in vitro in various shock wave frequencies and found that slower frequencies were better. Paterson et al [28] described superior results with 30 versus 120 shock waves per minute in fragmenting artificial stones. Similar results were reported in human patients with 60 versus 120 shock waves per minute in a prospective, randomized, double-blind study [29].

The twin-pulse technique is a different approach. Using two identical shock wave generators and reflectors in a 90° angle, Sheir et al [30] had the best results, rendering 50 patients stone-free in 1 mo. Zhou et al [31] used another modification of the standard lithotriptor (HM3, 20 kV) with an auxiliary shock produced by a piezoelectric annular array 500–600 ms afterwards (4 kV) to fragment phantom stones with an efficiency of 95.2%.

Other proposals include efforts for gating devices blocking shock waves that will miss the stone, administration of chemolytic medication pre-SWL (EDTA for calcium oxalate stones or tromethamine for uric acid stones), and even fasting the night before to increase urine specific gravity [32–35].

2.4. *Suggestions to decrease complication rates*

SWL is probably the least invasive, but not complication-free, procedure used to treat stone disease. There are well-known adverse effects, like those related to stone fragments (residual stone, steinstrasse, obstruction), infection (urinary tract infection [UTI], urosepsis, etc), and effects on tissue (renal hypertension, insufficiency, haematoma) and on fertility and pregnancy, especially for kidney stones, even though in a small proportion of patients [36]. These results have been associated with the total number, the energy level of the shock waves, and the total energy given. Research in lithotripsy shows that shock wave-induced trauma is primarily a vascular lesion, that injury is dose-dependent, and that haemorrhage can lead to a permanent loss of functional renal mass [37].

Recently, research has been directed towards assessing changes in the shock wave delivery rate on morbidity and efficacy of lithotripsy. Animal studies showed an increased per-shock efficiency of fragmentation by reducing shock wave rate [27]. Newer lithotriptors have reduced focal point size and increased aperture, leading to an increased peak point pressure, but these features have led to higher re-treatment rates. Cavitation and erosion are now considered the main determinants of successful disintegration. A higher delivery rate may interfere with subsequent shock waves, thus lowering the efficiency of treatment. Better results are achieved with lower rates of delivery, but the best rate remains to be identified [28,29,32,38].

This changed rate and method of shock wave delivery might also play a protective role by limiting parenchymal damage. Zhou et al [31] and Sheir et al [38] actually reported decreased renal damage by modifed SWL procedures: the first using two generators in an angle; the other using dose-escalation by three methods (gradually increasing output had better comminution efficiencies than decreasing or constant output) [31,38]. Sokolov et al [39] proposed using two confocal generators (dual pulses) and found better fragmentation than with single-pulse treatment. A different way to use two generators is by a carefully timed close interval to achieve improved stone comminution and reduced renal injury [40].

Medical treatment and its effect on complication rates is another area of enormous interest. Allopurinol has been found to decrease conjugated dienes produced during lithotripsy, possibly by acting as a free radical scavenger, thus reducing renal tissue damage [41]. The role of infectious complications following SWL has been a controversial subject with regards to the need for prophylactic antibiotics. Owing to the risk of bacteria entering the bloodstream and causing a variety of clinical problems, some have suggested prophylactic antibiotic use. Nevertheless, several studies have shown that the best policy is antibiotic administration in patients with (recurrent) UTIs, infection stones, positive urine cultures, and pre-SWL instrumentation [42].

2.5. *Optimizing treatment for ureteric stones*

Considerable progress has been achieved in the treatment of ureteric stones. No guidelines support the superiority of either SWL or URS over another because both have advantages and disadvantages [43]. SWL is less invasive but usually requires more time and possibly re-treatment for the patient to be stone-free, whereas URS usually clears the stone in a single session but requires anaesthesia, and patient satisfaction rate is reduced with ureteric stents [22,44].

The use of a ureteral stent and its effect in SWL have not yet been clarified in all circumstances. Most agree that there is probably poorer outcome in SFR following lithotripsy with a ureteric stent in place for small stones, but for stones over 2 cm there might be a benefit from reduced complications, improved localisation, and stone manipulation [45]. Additional problems caused from encrustation mostly affect forgotten stents and rarely one inserted pre-SWL. Recent papers are suggesting that treatment of patients with ureteric stones in a prone or rotated position achieved a better SFR, increased tolerance of shock waves, and required a lower mean number of sessions [46,47]. Another interesting proposal by Tombal et al [48] assessed the efficacy of emergency SWL within 6 h from the onset of renal colic and found that this practice increased SFR in 48 h by an average of 13%; results depended mainly on stone size and location.

Expulsive medical management of urolithiasis is a topic requiring further attention and research. A meta-analysis in *Lancet* of articles about α-blockers, calcium channel blockers, steroids, diazepam, and their combinations concluded that they can help passage of distal ureteric stones, possibly through ureter relaxation in the stone region and by increasing hydrostatic pressure proximally [49]. α-Blockers and calcium channel blockers resulted in a 65% greater likelihood of spontaneous stone passage than those in control groups, and reduced time to pass the stone, pain episodes, and analgesic requirements. Recent literature suggests that tamsulosin might increase clearance rates following SWL, but further studies are required [50,51].

2.6. Calyceal stones, renal abnormalities, and SWL

Before SWL, most asymptomatic small renal stones were left untreated. Following progress in lithotriptors, and use of laser energy and flexible ureteroscopes, many options have become available. There is a shift in SWL towards treating smaller calyceal calculi [6,52]. A recent review from the Medical Research Council by Keeley et al [4] regarding prophylactic SWL for small asymptomatic calyceal stones found no advantage over observation in terms of SFR, quality of life, renal function, or hospital admissions, with a mean follow-up of 2.2 yr. These data need validation by longer follow-up because prospective randomised controlled trials have outcomes up to 2 yr [53]. A significant percentage (almost one third) of patients with small asymptomatic renal stones eventually will develop symptoms, according to Glowacki et al [54], but their inclusion criteria cannot easily be matched to other patient cohorts.

The role of SWL in renal abnormalities is gradually being clarified. For stones in renal diverticula, it is generally agreed that stone clearance remains poor, and stone fragmentation is not always identified; an erect radiograph might reveal layering of fragments and avert further SWL sessions [55]. Most recent studies are focusing on other treatment options, and percutaneous management alone or in combined approaches for difficult cases can offer the best chances [56,57]. In other renal anomalies of number (duplex), shape (horseshoe, malrotated), and location (ectopic, crossed), problems are related to difficult localisation, incomplete clearance, and presence of pelviureteric junction obstruction. A recent review of SWL series in anatomically anomalous kidneys shows an SFR of 28–80% and that repeat sessions are needed for many patients [58]. It appears that the HM3 machine might be more efficacious than newer lithotriptors, and that stone size and localisation are the most influential factors for the result of SWL. The role of careful monitoring cannot be overestimated for these patients; PNL might be preferable for large stones.

2.7. Outcome of SWL: clinically insignificant residual fragment or stone-free?

In traditional open surgery, the postoperative presence of residual fragments was considered a failure, but with SWL stone clearance usually takes longer. With expanding indications, the presence of clinically insignificant residual fragments (CIRFs) has become more common. This term should only be used for asymptomatic, nonobstructive, noninfectious, residual fragments post-SWL up to 4 or 5 mm associated with sterile urine [59]. The most important factor is understanding the natural history of CIRF. Streem et al [60] reported that, in a follow-up of 23 mo, 16% of stones were smaller, 42% stable, and 18% increasing in size. Buchholz et al [61] found that, 2.5 yr posttreatment, almost 13% of fragments had not passed spontaneously. Osman et al [62] reported that, after 5 yr, 21.4% of these patients had stone recurrence and needed retreatment, so close follow-up and adequate metaphylaxis are required. Rassweiler et al [59] reviewed almost 14,000 patients for long-term results of SWL on renal stones: They argued that small asymptomatic calyceal stones can be treated by lithotripsy with a high SFR, and showed that CIRF after SWL has to be examined and distinguished separately. Passage of fragments may continue up to 2 yr post-SWL, and newer lithotriptors have increased CIRF rates. Over time though, the result was that 20% would have significant residual fragments, so the authors believe that, in asymptomatic patients, any endoscopic procedure is overtreatment.

2.8. Obesity and SWL

Obesity has become an epidemic, predisposing to a number of serious illnesses and also to stone disease [63]. For these patients many issues have to be dealt with for successful results. The first problem is diagnosis. Symptoms and physical examination are often not helpful. Imaging studies pose another challenge: Weight restrictions might preclude the use of a KUB film; a stone might be missed because of poor penetration. Ultrasound cannot always identify a stone, and CT might be unavailable in morbidly obese patients or those with respiratory problems. Reinforced tables may be required, but the distance between F1–F2 focal points can be insufficient. Tricks like abdominal straps to reduce the distance and high-power settings to treat a stone in the extended stone pathway have been used [64]. Sometimes, a stent can be inserted, with the stone being pushed back to the kidney (in a posterior calyx, if possible). The additional benefit for these patients is SWL under analgesia, thus avoiding problems related to anaesthesia when URS or PNL is required.

2.9. *Consensus on lithotriptor terminology*

SWL for stone disease in the urinary tract has been widely accepted all over the world. However, major differences in reporting results have made comparisons almost impossible. Furthermore, ambiguous definitions have a negative impact on its effectiveness. If meaningful comparisons between machines are to be made, presentation of stone characteristics (size, location, number, and type), treatment characteristics (number of treatments, energy, shock waves used), complications (pain, analgesia or anaesthesia, steinstrasse, auxiliary procedures, optimal time for screening for residual fragments), and outcome of treatment (on the total population or in those with adequate follow-up, by means of SFR or success rate, stratification for stone size and site, in what time post-SWL, reporting CIRF and by what definition, by which imaging study, reviewed by one or more specialists, etc) should be uniformly defined [65]. Standardising these criteria will offer researchers the ability to evaluate results from different machines and studies.

2.10. *Evaluation of different lithotriptors*

The ability to compare different machines will allow use of the best technology available for SWL. The optimum way involves prospective randomised studies in the same centre, comparing different lithotriptors with various shock wave generators and different generation machines. This approch cannot be achieved in practice because most centres do not have the space, money, or staff required for such a task.

Studies comparing lithotriptors are rather rare in the literature, and results are often contradictory. Sofras et al [66] compared the Dornier HM3 and the EDAP LT01 in 1000 patients by assessing SFR in 3 mo (87.5% vs. 90.4% and found no difference for renal stones up to 1 cm. Portis et al [67] performed a matched-pair analysis of 48 patients with solitary renal/ureteral calculi with two machines and concluded that the HM3 machine provided superior, but not statistically significant, clinical results to the LithoTron ($p = 0.08$). Graber et al [68] compared the HM3 and the Lithostar Plus in renal stones <1 cm and pelvic stones <2 cm: SFR in 3 mo was identical (89% vs. 87%), but the HM3 achieved stone disintegration with fewer shock waves, fewer complications, and lower re-treatment rate than the Lithostar Plus. Sheir et al [69] compared the Dornier FML 5000 and the Dornier Lithotriptor S; the SFR was better for the second ($p = 0.03$). The DoLi S achieved superior results in renal stones ($p < 0.05$) and stones <10 mm ($p = 0.03$), but not in ureteric calculi.

Others compared different generation machines. Cass et al [70] performed a comparative study of 13864 calculi between an unmodified Dornier HM3 (5698 patients) and Medstone STS (8166 patients). The SFR was 69.5% with the Dornier HM3 and 72.1% with the Medstone for single renal stones, and 81.5% versus 83.2% for single ureteral stones. Ng et al [71] compared the Piezolith 3000 to the previous Piezolith 2300 by matched-pair analysis in 25 pairs, without differences in outcome. A recent comparison between three lithotriptors showed that the Dornier MPL9000 had the best treatment outcomes in terms of SFR and re-treatment rate, compared with Piezolith 2300 and Dornier Compact Delta [72].

Most studies have inherent flaws (eg, different units, in different centres, with different staff and characteristics of patient groups) that make comparison almost impossible. The definition of successful outcome is frequently different (SFR or clinical success rate), and a KUB film might miss a fragment in up to 13% of patients [73]. A more objective way to assess machines was suggested: The effectiveness quotient (EQ), introduced by Clayman et al [74], seemed a logical step forward. The formula incorporated the SFR in 3 mo and also the percentage of other procedures required, like URS or re-treatment by SWL:

$$\text{Effectiveness Quotient} = 100\%\ \text{Stone Free}/100\%\ \text{Stone Free} + \%\ \text{Re-treatment} + \%\ \text{Auxiliary Procedures}(\%)$$

The EQ was a way to compare performance of lithotriptors. However, a number of issues concerning the EQ still puzzle researchers that use it. The formula requires only the SFR, without consideration of the fragmentation of stones and the presence of residual stones or CIRF, even though in these patients frequently no further treatment is required. Another problem lies in applying the same degree of importance in the percentage of auxiliary procedures and re-treatment rates to that which applied 15 yr ago. These modalities no longer generate the same risk, complications, or even results today.

To further add to the confusion, presentation of results sometimes makes calculation difficult; in others data are not present in a way to permit meta-analysis. The lack of exact definition of an auxiliary procedure, even though it should be straightforward, may lead to completely different results, and the same applies to the re-treatment rate, which gives a totally different result when the number of patients or the total number of treatments or re-treatments is reported. Thus, the EQ may no longer be as relevant a measure of outcome as when it was first introduced.

3. Conclusions

SWL has revolutionized the treatment of stone disease. It remains the first option for most renal and ureteric stones. It is associated with a low complication rate. However, better understanding of the physics of shock wave delivery is required, together with treatment optimisation, which limits renal damage and offers better selection of patients. The improved outcome of SWL will offer the maximum benefit to patients and physicians, as well as provide better value for money for health care providers.

Conflicts of interest

The authors have nothing to disclose.

Acknowledgements

To Greek State Scholarships Foundation (IKY).

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Editorial Comment on: Optimizing Shock Wave Lithotripsy in the 21st Century

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Shock wave lithotripsy (SWL) dramatically changed the therapeutic approach for lithiasis during a very short period of time. After the first decade, SWL was accepted worldwide as first-line therapy in most cases of urinary lithiasis. An important characteristic of the second- and third-generation lithotriptors is represented by their improved tolerability, thus allowing this procedure to be performed on an outpatient basis without anesthesia or under neuroleptic analgesia. Despite this improvement, the overall efficacy of these lithotriptors remains low by comparison to that of Dornier HM 3.

In recent years, due to advances in flexible ureteroscopy and improvement of intracorporeal lithotriptors, a larger number of retrograde endoscopic procedures have been performed, with better stone-free rates, fewer complications, and, in a significantly increasing proportion, under local anesthesia. These changes raised controversies whether intracorporeal or extracorporeal lithotripsy may represent the first-choice therapy for urolithiasis with certain locations.

According to the European Association of Urology (EAU) guidelines on urolithiasis, SWL and retrograde ureteroscopy have similar value for calculi located in the mid or distal ureter [1].

Regarding the proximal ureter, SWL still represents the first-line therapy, although the efficacy of the flexible retrograde approach has been improved, with a stone-free rate superior to that of semirigid ureteroscopy and reduced aggression of tissues. Various studies, evaluating combined semirigid and flexible ureteroscopy for ureteral lithiasis, report overall, proximal, and distal ureteral stone-free rates of 91.7%, 87.3%, and 94.2%, respectively [2].

For pyelocaliceal lithiasis, various therapeutic alternatives currently exist. The most appropriate approach must be decided individually according to various parameters such as size, location, and chemical composition of the calculi, associated pathology, technical capabilities, and the patient's choice.

In their review, Argyropoulos and Tolley consider a debatable issue regarding the appropriate treatment choice for lower pole stones [3]. Various formulas were designed to predict stone clearence in SWL-treated lower pole calculi [4]. Nevertheless, the influence of lower calyx anatomy over the procedure's success rate is significantly higher for SWL compared to the flexible retrograde approach, especially using the new generation of flexible ureteroscopes, with dual or exagerated active deflection [5–7].

Due to technological progress, indications for either intracorporeal or extracorporeal lithotripsy will probably continue to change during the next decade.

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DOI: 10.1016/j.eururo.2007.04.067

DOI of original article: 10.1016/j.eururo.2007.04.066

Editorial Comment on: Optimizing Shock Wave Lithotripsy in the 21st Century

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As mentioned in the paper of Argyropoulos and Tolley [1], extracorporeal shock wave lithotripsy (ESWL) revolutionized stone treatment in the 1980s. Soon after its introduction the main indications of ESWL were defined and >90% of stones were treated with this technique. Further developments such as ESWL in a dry surrounding, without anesthesia but in sedoanalgesia and as an outpatient procedure were demanded. With the use of the second-generation lithotriptors quality of stone disintegration unexpectedly fell, but the above-mentioned goals were fulfilled, consoling urologists for the loss of disintegration efficacy. What else should they do? Most of the institutions had replaced the lithotripter HM3 by a second-generation lithotriptor and nobody had the courage to retreat it.

However, the key to success in ESWL is effective stone disintegration. Retreatment rate, complications, and total costs including loss of working hours depend on this. Incomprehensibly, we accepted this step backward for the second-generation lithotriptors. To date we have made no relevant progress in efficacy of disintegration except knowledge of the positive influence of lower shock wave frequency.

Investigation of other matters such as better preoperative stone location and density (computed tomography scan), patient selection, management of complications, the use of stents, and ureter relaxing medication have led to improved effectiveness of ESWL. But why more than 20 yr after introduction of ESWL have we still not yet been able to recover the stone disintegration efficacy of the HM3? Endourologic instruments were improved quickly and endoscopy is now displacing good indications for the less invasive ESWL because the new generation of lithotriptors is less effective. Guidelines to treat stones are constantly expanded in favor of endoscopy.

How can we improve disintegration potential? The main reason for losing disintegration quality seems to lie in the shock wave energy transfer through the human body to the stone. The connection between the patient and the shock wave source, geometry of the focal zone, and cavitation effects at the stone seem to be the main issues of research.

We should improve disintegration efficacy quickly before the ''sexy'' and popular endoscopy has totally replaced the less invasive and excellent, but ''boring,'' tool of ESWL.

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DOI: 10.1016/j.eururo.2007.04.068

DOI of original article: 10.1016/j.eururo.2007.04.066