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REVIEW

Extracorporeal shock wave lithotripsy: What is new? ☆

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ESWL;
Technique;
Optimisation

ABBREVIATIONS

PCNL, percutaneous nephrolithotomy;
EAU, European Association of Urology;
US, ultrasonography

Abstract ***Objectives:*** Thirty years after its introduction, extracorporeal shockwave lithotripsy (ESWL) is still first-line treatment for more than half of all urinary tract stones, but machines and treatment strategies have significantly developed over time. In this review, we summarise the latest knowledge about the clinically important aspects of ESWL.

Methods: We searched PubMed to identify relevant reports and the latest European Association of Urology guidelines, and standard urological textbooks were consulted.

Results: New technical developments include: Twin-head and tandem-pulse shock-wave generators; wide-focus, low-pressure systems; optimised coupling; and automated location and acoustic tracking systems. Indications have been refined, making possible the identification of patients in whom ESWL treatment is likely to fail. By lowering the shock-wave rate, improving coupling, applying abdominal compression, power 'ramping' and postoperative medical expulsion therapy, treatment protocols have been optimised.

Conclusions: Promising new technical developments are under development, with the potential to increase the stone-free rate after ESWL. For optimal results, the refined indications need to be respected and optimised treatment protocols should be applied.

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Introduction and historical background

The first lithotripter for the treatment of human kidney stones, the HM1 (Human Model 1, Dornier, Germany; now Dornier MedTech America, Inc., Kennesaw, GA, USA), was introduced in 1980 by Chaussy et al. [1]. This is a classical example of a 'spin-off' from a military development, as in this case observations from the Dornier Star Fighter programme were translated into the development of this innovative medical device [2].

The first serial lithotripter, the Dornier HM3, became so successful that ESWL quickly replaced open stone surgery and became the first-line option for most stones in the upper urinary tract [3], and until the present, despite all the advances in percutaneous nephrolithotomy (PCNL) and transurethral stone treatment (ureteroscopy) [4], still more than half of all stones worldwide are treated using ESWL [5].

The current third- and fourth-generation machines are versatile, user-friendly and safe. Usually in a day-case setting, procedures are conducted under analgesia or sedo-analgesia [6].

One drawback remains: Despite all technical advances, the stone-free rates of the reference machine, the Dornier HM3, have never been reached again [7].

Evidence acquisition

With no specific system, we searched the Medline (PubMed) database using the following keywords; 'shock wave lithotripsy', 'SWL', 'ESWL', 'lithotripter' and 'lithotripsy'. Only recent papers in English were included. In addition, the latest European Association of Urology (EAU) guidelines were consulted; expert opinions of experienced stone surgeons and ESWL technicians were incorporated.

Evidence synthesis

Physics of stone fragmentation

Various mechanisms responsible for stone disintegration have been described. The original concept of tear and shear forces leading to stone fragmentation [1] was later completed by the description of cavitation [8], spallation [9] and quasi-static [10] as well as dynamic squeezing [11].

The underlying concept is that repetitive stress finally leads to stone fragmentation. For the development of new lithotripters it would obviously be advantageous to know which individual variable calculated from the shock-wave model, e.g. acoustic energy, energy flux density and effective energy, can reliably predict stone disintegration or tissue damage, but despite all efforts this is not yet possible [12].

Lithotripter technique; change of focus

Unchanged in the latest generation of machines in comparison to the HM3, four components remain essential and thus can be found in all modern machines, regardless of the manufacturer. These are the shock-wave generator, a mechanism to focus the shock waves onto a target, a system for stone location, and a coupling medium [13].

For the shock-wave source there are several promising concepts under development and currently under evaluation. The Direx Duet (Direx Corp., Natick, MA, USA) is a dual-head lithotripter where two shock-wave heads are installed at 72° and deliver shock waves which meet at one focal point [14]. Firing is either synchronous, with both heads firing simultaneously, or asynchronous, where the firing alternates between the shock-wave sources. However, the latest publications on this technique are experimental *in vitro* studies and this device it is not in widespread clinical use.

Another system of delivering two shock waves is the tandem-pulse shock-wave generator, where a second shock wave is emitted along the same acoustic axis in rapid succession, to drive the forceful collapse of bubbles against the stone [15]. However, these machines have as yet shown no significant advantage in terms of the stone-free rate.

Classically, shock waves are generated electrohydraulically, electromagnetically or piezoelectrically. Recently, with the Sonolith® i-sys (EDAP TMS, Vaulx-en-Velin, France) an electroconductive system has been used, for which promising results are reported [16]. In this generator the spark electrodes are surrounded by a highly conductive solution, resulting in a shock wave generated at the same geometric point and at the same intensity from shot to shot, reducing the potentially efficacy-reducing 'jitter' effect known from conventional electrohydraulic shock-wave sources [12].

To date, the consensus is that focal width is critical in stone fragmentation [12]. Whilst the original Dornier HM3 had an intermediate-sized focus of $\approx$12 mm in diameter, and at $\approx$40 MPa a moderate peak pressure, later-generation machines tended to have smaller focal zones with higher peak pressures. Their wider area of shock-wave entry over the skin made treatment less painful but also less effective, as the small focus made it difficult to target the stone and changed the mechanism of energy delivery on the target. Recently, wide-focus, low-pressure lithotripters have become commercially available (XiXin Medical Instruments Co. Ltd., Suzhou, China). With a focal zone of 18 mm and a low acoustic peak pressure of $<$20 MPa they show very encouraging results in terms of stone fragmentation, patient comfort and side-effects [17]. The first *in vivo* series of 297 patients had a stone-free rate of 86% at mean number of 1532 shock waves per session. However, drawbacks of this re-