Extracorporeal Shock Wave Lithotripsy

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Introduction

The introduction of extracorporeal shock wave lithotripsy (ESWL) in the early 1980s revolutionised the treatment of urolithiasis and provided an apparently near-ideal minimally invasive procedure. Shock waves that are generated by a source external to the patient propagate through the body before being focused on a kidney stone. These waves cause stone fragmentation directly by producing mechanical stress or indirectly by collapsing of cavitation bubbles formed by the negative pressure in their trail. The initial result of ESWL was promising, with a greater than 90% success rate achieved.1 Although the subsequent development of ESWL has been less satisfactory, it remains the most commonly performed procedure to treat stone disease.

History

Shock waves are high-energy pressure amplitudes generated in fluid media, such as air or water, by an abrupt release of energy within a small space. The waves propagate according to physical laws of acoustics, and are transmitted through the media with low attenuation. The interest in shock waves started from a military programme. In the 1950s, Dornier, a German aerospace firm, took note of the different degrees of injuries sustained by crewmembers inside a tank turret after the tank was hit by a shell. This phenomenon was attributed to the relationship of each crewmember’s position as it related to the entry point and distribution of shock waves throughout the tank turret. An unusual pattern of metal fatigue in aircraft was also observed and was thought to be caused by the previously unrecognised effects of shock waves. It was postulated that shock waves produced by supersonic aircraft were being focused inadvertently by the contours of one part of the plane’s fuselage onto another part of the plane, which resulted in the acceleration of metal fatigue. To explore these propositions, Dornier established a programme to develop a system for the production of reproducible focused shock waves. In subsequent investigations, an engineer noted the effect on biological tissue (pain as from an electrical shock) when in contact with the shock wave set up. This phenomenon led to further investigation of the effect on biological structures. Thereafter, the idea of using focused shock waves to fragment human kidney stones arose, and a grant from the German government was obtained. In the early 1970s, an experimental programme was set up in Munich, led by Chaussy and colleagues. After 10 years of continuous efforts in in vitro and animal research, the first human trial of shock wave therapy on a renal stone was performed in February 1980.1 The success of this human trial opened up a new chapter in minimally invasive surgery for urolithiasis.

Basic Principle of ESWL

Every lithotripter contains three essential components - the generator and focusing system, the coupling system and the imaging system. The generator is the heart of a lithotripter: it is the source of shock waves. There are several commonly used mechanisms for shock wave generation, including electrohydraulic, electromagnetic and piezoelectric mechanisms. In order to focus the shock wave into a small target zone for more effective stone fragmentation, a focusing mechanism is needed. Depending on the type and configuration of shock wave generators, there are several focusing systems - ellipsoid reflecting surface for electrohydraulic generator, converging acoustic lens for planar electromagnetic generator etc. Finally, the imaging system, either fluoroscopy or ultrasound, will help to locate the target stone and position it into the focal zone of the generator.

Current Applications of ESWL in the Management of Urolithiasis

Theoretically, all stones can be treated by ESWL. However, due to better understanding of the limitations of ESWL and the improved outcomes of competing endourological procedures, ESWL is best applied in certain selected situations. The ideal situation will be a stone of size less than 2cm presenting in a normal urinary tract.

Absolute contraindications for ESWL include uncontrolled urosepsis, uncontrolled hypertension, distal obstruction for stone passage and pregnancy. There are also some situations, either related to the stone or to the patient, that are relatively not suitable for ESWL. Stone burden greater than 2 cm size will have higher retreatment rate and auxiliary procedure rate. It may also result in the steinstrasse (stone street) due to the production of large amount of small fragments causing ureteric obstruction. (Figure 1) Cystine stone is well known for its resistance for ESWL, and therefore, it is not advisable to offer ESWL to someone with known cystinuria.2

Patient’s factors that are relatively less favourable for
ESWL include obesity and abnormal renal anatomy. Due to the limitation of the geometric configuration of machine generator and focusing system, it may be sometimes difficult, if not impossible, to put the stone into the focal zone of the generator. Congenital urinary tract conditions, including horseshoe kidney, ureteropelvic junction obstruction, calyceal diverticulum etc, may affect the drainage of the urinary tract and result in suboptimal outcome. Unfavourable lower caliceal anatomy, such as a narrow or long infundibulum, or an acute infundibulo pelvic angle, may lead to poor clearance of stone fragments and therefore alternative treatments may be preferred. Also there are evidences suggesting that elderly patients may have poorer treatment result and also have higher complication rate.

Although ESWL is well known for its minimally invasiveness, there are still some associated complications. One of the major complications is vascular injury resulting in haematoma formation. Although the incidence of clinically significant haematoma was reported to be less than 1%, up to 20-25% of patients would have some degree of haematoma as detected by imaging after ESWL. In a porcine model, Willis et al had demonstrated by starting treatment at a lower energy level for at least 100 shocks, the size of vascular lesion would be significantly decreased. The protective effect of this prophylactic shock is probably related to the shock wave-induced vasoconstriction that could limit the development of haematoma. Therefore, it is recommended to start the first 100 shocks at about half of the maximal energy level for patients with renal stones.

The target stone will then be located by either fluoroscopy or ultrasound, and then positioned into the focal zone of the machine. Nowadays, most of the machines are using water cushion (“Dry head”) for transmission of shock waves into the patient’s body (coupling). Studies have shown that adequate application of gel between the cushion and body and avoid the trapping of air bubbles in between will improve the efficacy of shock wave transmission.

Ways to Improve Treatment Outcomes

Perioperative Management of ESWL and Ways to Improve Treatment Outcomes

After deciding to treat a patient with ESWL, urine culture should be done to rule out active infection. If the patient is on aspirin, other anti-platelet or anticoagulants, they should be stopped prior to the procedure to prevent bleeding complications. For aspirin, it should be stopped for at least 5 days.

The patient should avoid a full meal before ESWL. A single dose of antibiotic prophylaxis may be given to decrease the chance of infection. In the original HM3 lithotriptor, general anaesthesia was almost always necessary for pain control during ESWL. Nowadays, with the newer generations of lithotripters, most of the patients can be treated under simple analgesia and sedation. This makes the procedure more convenient and comfortable. However, in a retrospective review of the treatment outcome of patients having renal or proximal ureteric stones, patients who received general anaesthesia (87%) had a significant better stone-free rate at three-month than those received intravenous sedation alone (55%). (p< 0.001). In fact, treatment outcome could also be improved by giving more analgesia during treatment, in additional to a single dose of analgesic premedication. The reason for this difference in treatment outcome is probably related to the pain induced patient movement. Therefore, more liberal use of analgesia will help to improve the treatment result.

Vital signs, including blood pressure, pulse, oxygen saturation, should be monitored during the procedure. High blood pressure may increase the risk of haematoma formation. Therefore if the blood pressure cannot be controlled by adequate analgesics or simple antihypertensive, treatment should be stopped. Usually the stone will be treated till the recommended energy amount or till the stone is not visible by imaging. After the completion of treatment, usually the patient will be monitored serially to assess the fragmentation result and also the stone fragment clearance. Traditionally, we monitor the passage of stone fragments after ESWL and see whether any further treatment is needed for our patients. Studies suggested that the use of alpha-adrenergic blocker might help to speed up stone passage, minimise analgesic demand and also decrease incidence of steinstrasse. Therefore, a short course of alpha-adrenergic blocker can be prescribed as an adjunct treatment after ESWL.
Complications of ESWL

Immediate complications include stone fragment related complications such as ureteric colic and steinstrasse. Other complications include haematuria, haematoma formation and adjacent organ injury. There are still some controversy about the long-term complications of ESWL, including increased incidence of new onset hypertension in the elderly and new onset diabetes. Further prospective studies may be needed to assess the long-term sequel of ESWL.

Other Applications for ESWL

In addition to being one of the first-line treatments for urolithiasis for the past two decades, shock waves have been used in other branches of medicine. Other stones that can be fragmented by shock waves include bile duct stones and pancreatic and salivary gland stones. Shock wave therapy for gallstones is not needed to assess the long-term sequel of ESWL.

Shock waves are also used for treatment of other urological conditions, including Peyronie’s disease and chronic pelvic pain syndrome. Lastly, shock wave therapy is frequently employed by orthopaedic surgeons in the management of conditions such as tendinosis calcarea, epicondylitis humeri radialis, plantar fasciitis, delayed bone healing, and nonunion of long bones.

References