Extracorporeal Lithotripsy

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KEYWORDS

• External lithotripsy • Sialendoscopy • Sialolithiasis • Salivary glands • Minimally invasive surgery

KEY POINTS

- Extracorporeal shock wave lithotripsy (ESWL) breaks calculi into fragments due to generated shock wave impulses.
- ESWL has a low rate of success rate for eliminating stones.
- Whatever ESWL device you choose, piezoelectric, electromagnetic, electrohydraulic, the results will be approximately the same.
- Low-energy shock waves disconnect the stone from the surrounding tissue, allowing saliva leakage around the stone and possible revascularization of the affected gland.
- Large focal zone of the of the low-energy lithotripter enables the use of this type of generator without ultrasound direction.

Introduction: nature of the problem

Formation of stones, or calculi, can occur in various organs of the body. Two treatment approaches are possible: either to remove the stone in one piece or to crush it and remove the fragments. The term lithotripsy is applied to the second approach.

Extracorporeal shock wave lithotripsy (ESWL) breaks calculi into fragments due to generated shock wave impulses. Shock waves may be produced extracorporeally by piezoelectric, electrohydraulic, and electromagnetic techniques, or intracorporeally by using electrohydraulic, pneumatic, or laser sources during interventional sialendoscopy (Box 1). Before ESWL was implemented for sialolithiasis cases, it was successfully tested as a treatment modality for the urinary stones, renal stones, and gall bladder stones in the 1970s. Therefore, it was already proven that the method is safe and effective. The first report on the use of shock waves to fragment sialoliths was published in 1986 by Y. Marmary, and was quickly followed by reports of H. Iro, Katz, H.P. Cook, and other investigators.

However, some improvements and modifications were needed to apply the method to the salivary glands. First, the lithotripsy devices used in urology appeared to be too large for the maxillo-facial area. Second, the lithotripters of the 1980s and 1990s had very broad focus of shock waves distribution that could cause damage to dentition up to removal of dental fillings and periosteal irritation. These problems were solved in the 2000s.

The current article is dedicated to the extracorporeal lithotripsy. However, although the described sialolithotripsy itself is extracorporeal, it requires intracorporeal assistance of endoscopy that brings the whole method into the area of minimally invasive surgery.

Surgical technique

The tool #1: extracorporeal shock wave lithotripters

There are up to 60 various lithotripters currently available in the market (Box 2). All of them allow contact-free fragmentation of calculi, but not all of them are suitable for sialolithotripsy. ESWL lithotripters deliver significant amounts of electric energy, previously stored in a *capacitor bank*, in very short periods of time. Shock waves themselves are high-energy waves, consisting of a single high-pressure peak with a steep onset and a gradual decline into a pressure trough.

There were several published studies dedicated to the in-depth comparison of these 3 types of lithotripters. They demonstrated that all of them are almost similarly effective. All devices are equally safe and produce no macroscopically or microscopically detectable tissue changes.

Specific modifications for the salivary gland calculi were developed mainly in the 1990s and the 2000s by several manufacturers (Medispec Ltd., Yehud, Israel; Storz Medical AG, Tägerwilen, Switzerland; Sialo Technology, Ashkelon, Israel). Of them, Minilith SL1 (Storz Medical) and Sialowave (Medispec) are most widely used (Figs. 1A, 2 and 3). The shock wave unit of Sialowave consists of a reflector and a dry natural rubber membrane, called contact membrane, filled with water, an underwater electrode, and a high-voltage power supply. The energy of the shock wave can be adjusted between 10 and 24 Kv. The shock wave applicator itself is a disposable part and needs to be replaced after 50,000 shocks (pulses).

Salivary calculi, which develop from crystals that separate from saliva and build up on the inner surfaces of the salivary

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Box 1. Classification of lithotripsy

Extracorporeal lithotripsy
- Piezoelectric
- Electrohydraulic
- Electromagnetic

Intracorporeal lithotripsy
- Electrohydraulic
- Pneumatic
- Laser assisted

Low-energy extracorporeal lithotripsy

Outdated terminology
- Electronic lithotripsy
- Ultrasonic lithotripsy

ducts, are composite materials having weak spots and flaws, and are generally composed of crystals joined together by organic components of saliva. These organic deposits are weak. Compression and tension of the stone result in loss of cohesiveness, due to growth of microscopic flaws. Stones with a heterogeneous and laminated structure are more fragile than homogeneous calculi. Shock waves fragment stones by means of cavitation, squeezing, spallation, superfocusing, and stone fatigue. The shock waves produced by electrohydraulic lithotripters pass through water-filled cushion to the sialolith, producing stress and cavitation that fragment the calculus. The soft tissue and the saliva around the stone do not interfere with the passage of the shock waves and the wave is propagated through the stone, subjecting it to stress. The energy from the sialolith-saliva contact forms expansion waves, inducing cavitation bubbles. When the bubbles collapse, a jet of saliva is projected through the bubbles to the surface of the stone. This action is usually enough to fragment the stone.

A miniature ESWL lithotripter (Fig. 1B, C) was developed in 2007 (Sialotechnology, Ashkelon, Israel) to assist in sialolithiasis management. It has a miniature generator and applicator, focal point depth of 15 × 15 × 25 mm, large focus zone at 50% of 35 mm, and a penetration depth of 120 mm. The size of the generator is 52 cm height and 42 cm length (20 kg weight), and the working head is reduced to fit the dimensions of the head and neck region. The usual technique delivers 1000 to 1500 shock waves per session. The miniature lithotripter can use an ultrasonic aiming system, or can be directed to the stone using endoscopic identification with the transillumination effect and also clinical directions. Ninety-three percent of the patients were symptom-free following the first treatment. Reduction of the energy (0.09 mJ/mm^2) in this type of lithotripter allow the use of low-energy shock waves and to change the modality of treatment to disconnection instead of fragmentation. Due to the authors' experience with ESWL, we saw that salivary stones do not react like urinary stones and are resistant to external shock waves; this is the reason we directed our target to disconnect and not to fragment the sialolith.

Box 2. General technicalities in brief

Electromagnetic lithotripters are electrode-free and have a high-voltage generator with an electromagnetic source. Each shock is generated by allowing a high-current pulse to flow through an electromagnetic coil, resulting in an electromagnetic force at the output.

Piezoelectric lithotripters use electromechanical interaction between the mechanical and the electrical state in crystalline materials. To generate a directed wave, many piezoelectric crystals are arranged on a spherical cap and excited synchronously. This focuses the energy in the shock wave resulting in pressure amplitudes of up to 100 MPa in a precisely limited space.

Electrohydraulic lithotripters induce shock waves by electrical breakdown (15—30 kV) of water between 2 electrodes located at the focus closest to a para ellipsoidal reflector. Electric energy is stored in a capacitor bank by a power supply. The electrodes are connected to the capacitor terminals and submerged under water. The bank is charged and triggered to discharge across the underwater spark gap by means of a secondary spark gap.

The tool #2: sialoendoscope

Sialoendoscopes are produced by various manufacturers (PolyDiagnost GmbH, Hallbergmoos, Germany; Karl Storz, Berlin, Germany) and are divided into diagnostic and therapeutic devices. The diagnostic endoscopes usually have the exterior diameter of 0.65 to 0.9 mm and are suitable for observation and irrigation. Semirigid optic specifications vary from 3000 to 30,000 pixels.

A telescopic system with at least 6000 pixels of illumination fibers and focal length of 2 to 15 mm and 70° field of view is adequate. The best results can be obtained with the 10,000 pixel optic with 120° field of view. The micro-endoscopes can change the view field from 0° to 70° and further to 120°. The diameter of the telescope is usually 0.5 or 0.9 mm. The endoscopes can be either designed with the fixed exterior diameter or have disposable sleeves of various diameters. For example, the Polydygnost Modular salivascope (PolyDiagnost GmbH) has a reusable handle and 4 sets of disposable sleeves: 1.1 mm, 1.3 mm, 1.6 mm, and 2.0 mm in diameter.

Therapeutic endoscopes start from 1.1 mm in diameter. The modular handle has 3 channels for the telescope, irrigation, and a special channel for surgical instruments. The armamentarium for the up-to-date endoscopes includes micro baskets of 0.4 to 0.6 mm with 3, 4, or 6 wires suitable for a stone extraction, miniforceps with double-action jaws for disintegrated calculi of calculi fragments, flexible minibiopsy forceps, and high-pressure balloons for dilatation. The forceps are autoclavable, and the stone extractors are disposable.

Extracorporeal shock wave lithotripsy: techniques

Traditional ESWL technique
The Nahlieli low-energy shock waves technique

Preoperative planning

Patient history and clinical examination are performed in-depth. The important clinical factor is the bimanual examination to assess the mobility and the possibility to feel the deepest of the stone proportional to the mylohyoid muscle