

ESWL: Technical Background

Shock Waves

The Dornier extracorporeal shock wave lithotripter relies on the fundamental properties of shock waves to function. Shock waves are characteristic of explosions and of supersonic flow of air over a body, such as a jet. In ESWL, the source of the explosion is an electrode which produces a spark. The mini-explosion produces an instant rise in temperature and pressure in the fluid immediately around the source of the spark, causing the fluid to expand at supersonic speed. A blast wave forms from this point, carrying the excess energy from the point of the explosion to distant parts of the fluid (154).

Unlike sound waves, such as ultrasound waves, shock waves are not sinusoidal periodic oscillations. Instead, a graph of pressure vs. time shows a shock wave as a single distinct peak that gradually decays. This wave loses its energy less quickly if it travels through an uninterrupted medium than an interrupted one. Thus, the Dornier lithotripter employs a water bath, so that the wave travels directly from the water to the soft tissues of the body, which have similar acoustic properties. Developers of other lithotripters, such as the Medstone lithotripter, are experimenting with a fluid-filled belt rather than an open bath.

To focus the wave on the stone, the lithotripter uses a semi-ellipsoidal reflector around the tip of the electrode. The spark is generated at the focal point (f1) of the reflector. The shock wave produced spreads in a circular form, like a pebble dropped in a pond, until it reaches the ellipsoidal wall. Each point of the ellipsoidal wall becomes a generating point for a new circular wave. These wave fronts move outward again until they convene simultaneously at the second focal point (f2). The stone is positioned at this second focal point, the point of greatest force (22).

At the interface of the tissue and the stone, there is a large difference in acoustic impedance. A large pressure zone is created as the shock wave passes from the tissue to the stone, and in this zone, the pressure exceeds the strength of the stone material and causes it to fragment and break. With the application of repeated shock waves, the stone can be broken into small fragments of less than 2 mm that can pass through the urinary tract with the urine (187).

To ensure maximum efficiency for transmission of the shock wave, the water in the water bath must be treated. The Dornier lithotripter includes a water treatment system that softens, degasses, and regulates the temperature of the water as it is exchanged between

the treatment of each patient. The water softening system removes soluble impurities from the water, which purifies the water and adjusts its electrical conductivity. The water degassing unit removed dissolved gas and bubbles in the water to ensure efficient wave transmission. The water temperature is kept near body temperature for the comfort and safety of the patient (187).

The Shock Wave Generating System

The shock wave in the Dornier lithotripter is generated by a spark from an underwater electrode. The electrode has a positive and a negative point, is connected to a high-voltage generator, and is located at the first focus of the brass semi-ellipsoid shell. When the electrode is charged by the generator, it produces a brief (1 microsecond) spark caused by the electrical current across the electrode. The generator can be adjusted to produce power ranging from 18,000 to **24,000** volts (137). Thus, the strength of the treatment can be varied in two ways: by the number of shocks given (as few as 500 to as many as 2,500 or more), and the force of the shocks, which varies by the voltage.

The generator is coupled to an electrocardiogram, which synchronizes the shock wave with the patient's heart beat. The voltage generator can only be activated when the heart is contracting and is refractory to external stimuli (the time after the QRS peak in the electrocardiogram recording) (187).

An electrode is not the only possible method of producing an extracorporeal shock wave. A laser is another potential form of energy that can produce the mini-explosion that, in turn, produces the shock wave. At least one American firm, International Biomedics, is developing a laser-driven lithotripter (172). Its potential benefits include a cheaper source of energy; the present electrodes used in the Dornier lithotripter cost \$180 or more apiece, and a single treatment may use two or three electrodes.

The Stone Location System

The Dornier lithotripter uses fluoroscopic (X-ray) imaging to locate the stone. Since the second focus of the ellipsoid, where the shock waves converge, is only a 1.5 cm² area, efficient destruction demands that the stone be pinpointed accurately. The Dornier device includes two independent X-ray systems positioned so that their beams cross. The patient is adjusted, using a mechanical positioning system, until the stone to be

fragmented lies at the point of this intersection. At any time during the procedure, the lithotripsy operator can activate the X-ray scanning system briefly and get an updated picture of the stone (22). If the stone has moved in the course of the treatment, as it frequently does, the patient can be immediately adjusted so that the stone again lies at the intersecting point, and treatment can continue.

During the development of the device, Dornier experimented with ultrasound imaging to locate the stone. A major advantage of ultrasound is its safety relative to fluoroscope, since it does not produce ionizing radiation. However, Dornier was unable to develop a system that could image the stone adequately for precise location purposes (22). Dornier itself is still investigating the potential of ultrasound imaging (126), and at least two other ESWL developers (Northgate and EDAP) are also experimenting with ultrasound (153).

Patient Preparation

Many of the patient preparations associated with surgery are not necessary for ESWL. Patients may be given a laxative before treatment to eliminate any intestinal gas, which can interfere with the location of the stone during the procedure (24). Anesthesia is nec-

essary, although either regional or general anesthesia can usually be used; preferences vary by center. In the first six U.S. hospitals with ESWL, as of May 1985, approximately 47.5 percent of patients had undergone regional (spinal or epidural) anesthesia, and the remaining 52.5 percent had undergone general anesthesia (11). Preferences among centers varied considerably, however; use ranged from only 10 percent general anesthesia at Charlottesville to 100 percent general anesthesia at Gainesville (11). The option of using regional rather than general anesthesia is one of the factors that increases the safety of ESWL relative to open surgery for certain patients.

Some patients, such as those with staghorn or ureteral stones, require adjunct procedures before or after ESWL. Ureteral stones, for example, can be manipulated up into the pelvis of the kidney before ESWL treatment, where there is more space for the stone to break up (105). In these patients, catheterization before ESWL treatment is often performed in an attempt to move the stone into the kidney. Patients with infected stones also require some additional pretreatment preparation, such as the administration of antibiotics 1 or 2 days before treatment (24). Finally, patients with stones of insufficient contrast density to be visualized adequately on X-rays may require the injection of a contrast medium before the procedure (24).