

Chapter 2

Brief Historical Background

It would be virtually impossible to come up with just one inventor of the first clinical application of shock waves: extracorporeal shock wave lithotripsy (SWL). As with many other technological developments, contributions came from brilliant scientists who happened to be working on the right topic at the precise moment. Regardless of conceiving ideas of a possible medical application of shock waves, it must be considered that going from laboratory experiments to a clinical prototype required a lot of self-confidence, an efficient coordination between physicists, engineers, and medical doctors, as well as a huge investment. Without a doubt, SWL revolutionized urology, and will get a place in the history of medicine as one of the most outstanding technological developments.

After demonstrating the feasibility of comminuting urinary calculi through shock waves without surgery, the next obvious step was to explore their use for treating calculi in other parts of the body. By trying to increase the efficiency of the equipment and reducing damage to affected tissues, many other applications, never thought of before appeared. Several research groups focused on the interaction between shock waves and living tissue, and started publishing results of multidisciplinary studies. In many countries, the use of shock waves to treat orthopedic-related ailments soon outscored the number of patients treated with SWL. Nowadays, biomedical applications of shock waves include such a large variety that it would be a huge project to thoroughly describe the historical development of each of them.

This chapter is a summary of the amazing development of SWL, as well as of the rising of some other clinical applications. For further information, the reader may consult the texts cited at the end of this book (Brendel 1986; Chaussy and Fuchs 1987; Jocham 1987; Lingeman et al. 1989, 2003; Delius and Brendel 1990; Haupt 1997; Lingeman 1997; Loske and Prieto 1999; Thiel 2001; Forssmann 2006; Chaussy et al. 2007; Loske 2007; Wess 2009; Dreisilker 2010b; Mittermayr et al. 2012).

The interaction of shock waves with living tissue became a topic of interest during the Second World War. Severe damage to lung tissue suffered by castaways swimming in the water when anti-submarine warfare weapons were detonated far

away was frequent (Krause 1997). Research mainly focused on how to protect the human body from shock waves and not on their beneficial uses. Interestingly, the concept of using shock waves to disintegrate calculi inside the human body is old. In the 1950s, Yutkin developed a device called *URAT-I* to comminute bladder stones using shock waves produced by electric discharges between two electrodes located at the tip of an endoscope (Loske and Prieto 1999; Wess 2009). The idea to noninvasively destroy calculi using pressure waves generated outside of the body is also old. It was conceived long before SWL was a reality. Initial trials to disintegrate concretions by means of ultrasound were performed during the 1940s. Lampert and colleagues (1950) successfully fragmented gallstones after 5–60 s exposure to continuous wave ultrasound. Similar experiments were reported by Berlinicke and Schennetten (1951), Mulvaney (1953), and Coats (1956); however, the technique did not progress, mainly because stone fragmentation was accompanied by significant tissue damage.

A system very similar to the first clinical electrohydraulic shock wave generator, patented by Hoff and Behrendt (1976) and described in Sect. 5.2.1, was proposed in the 1940s (Rieber 1947). Shock waves generated by a high-voltage electric discharge at the inner focus of an oil-filled paraellipsoidal metallic reflector were supposed to destroy brain tumors (Fig. 2.1). The device was never used clinically and many years passed until the spark-gap method was proposed once again to produce shock waves for an extracorporeal application.

During experiments with small high-speed projectiles in the early 1960s, which generated shock waves as those produced by micrometeorites and raindrops impinging on satellites and aircraft structures, engineers at the aerospace company Dornier in Friedrichshafen, Germany discovered that pain similar to an electric discharge

Fig. 2.1 Schematic of a spark-gap shock wave generator, patented in 1947. Analogous to modern electrohydraulic shock wave sources, an electric discharge between two electrodes placed at the first focus ($F1$) of an oil-filled paraellipsoidal reflector produces a shock wave which is reflected off the reflecting surface and focused towards the outer focus ($F2$). A flexible membrane couples the shock waves into the patient

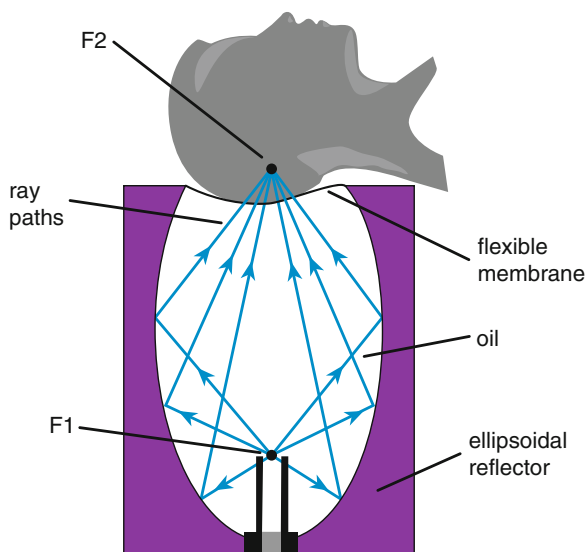


Fig. 2.2 Photograph of Eberhard Häusler (*left*), one of the physicists that did pioneering contributions to the development of extracorporeal lithotripsy, and Francisco Larrondo, the urologist that operated the first Dornier *HM4* lithotripter in Mexico



was felt when touching the target of the experimental setup at the moment of projectile impact. Measurements revealed that this sensation was not due to electricity. The phenomenon stimulated research to better understand the effects of shock waves on living beings.

Pioneering contributions to the development of SWL were done by Eberhard Häusler (Fig. 2.2) from the Technical University of Saarbrücken, Germany (Häusler and Kiefer 1971). It seems that during a lunch at a restaurant in Meersburg, Germany, Häusler commented for the first time the possibility of using shock waves to destroy kidney stones with technicians from Dornier. Initially, the goal of the collaboration between Häusler and Dornier was to study the erosion caused by tiny raindrops on metallic structures (Fig. 2.3). Nevertheless, the idea of crushing kidney stones without surgery was so appealing that not only the physicists and engineers from Dornier, Günther Hoff, Armin Behrendt and Wolfgang Hepp, but also physicians from the University of Munich, such as the urologist Egbert Schmiedt were enthusiastic



Fig. 2.3 Photograph of a ten-penny coin of the former Federal Republic of Germany, perforated by a high-speed water drop at the High Speed Physics Laboratory of the Saarland University, Saarbrücken, Germany. The experimental arrangement was used to show that a single water drop can produce severe damage to solid structures if accelerated at supersonic speed. (Courtesy of E. Häusler)

about it (Wess 2009). In a chapter entitled “Der schwebende Patient” (The floating patient), Othmar Wess, a former employee (1979–1987) at Dornier, commented that good ideas are always simple, at least retrospectively. To perform SWL, shock waves should be generated outside the patient’s body and focused on the kidney stone until it is pulverized. The fragments would be eliminated during urination. Nevertheless, the technological and medical challenges to pass from the idea to reality were immense.

Initially, kidney stones were destroyed *in vitro* inside a closed waveguide using shock waves produced by high-speed (up 2000 m/s) water drops (Häusler and Kiefer 1971). Shortly later, the feasibility of kidney stone destruction by shock waves was demonstrated exposing concrements in a water tank to shock waves produced with a gas gun (Fig. 2.4) (Hepp 1972). Häusler reported his initial results during a conference of the German Physical Society in 1971, leading to studies with Manfred Ziegler, a urological surgeon from the University of Saarbrücken.

A federal research project, sponsored by the West German Ministry of Research and Development, started in January 1974. Hoff and Behrendt developed the principle of generating underwater shock waves by high-voltage electric discharges at the focus of a semiellipsoidal metallic reflector (Hoff and Behrendt 1976). This shock wave source was installed in the first experimental lithotripter, called *TMI*. Christian Chaussy was a staff member at the Institute for Surgical Research of the Ludwig-Maximilian University, headed by Walter Brendel. He started his residency in Urology in 1975. During that time, Egbert Schmiedt, head of the Department of Urological Surgery of the same university, accepted the offer from Dornier to do research on the effects of shock waves on kidney stones. Christian Chaussy, the urologist Ferdinand Eisenberger, and Bernd Forssmann, a physicist at Dornier, studied the *in vitro* and *in vivo* interaction of underwater shock waves with cells and tissue (Chaussy et al. 1976, 1978, 1979b; Eisenberger et al. 1977). Chaussy created a novel model to implant human kidney stones into the renal pelvis of healthy dogs

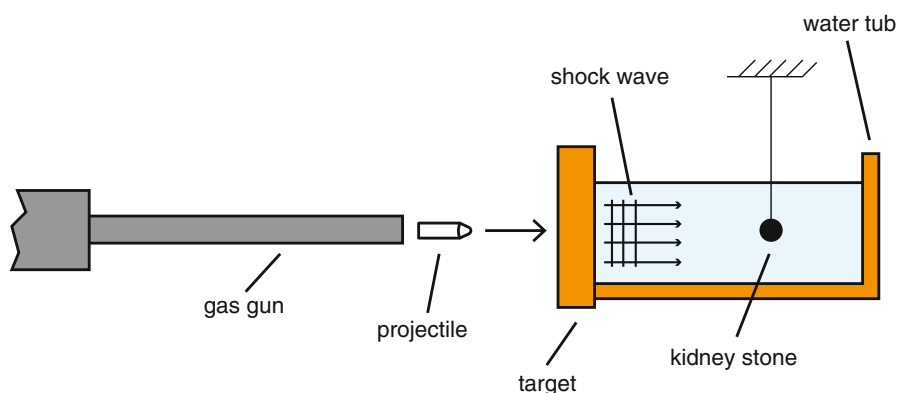


Fig. 2.4 Schematic of an experimental device used to generate underwater shock waves by the impact of a projectile on a target. Shock waves propagated through the water, destroying a kidney stone suspended inside the water tank. (Courtesy of C. Chaussy)

in order to perform the initial *in vivo* SWL treatments (Chaussy et al. 1979a; Chaussy and Staehler 1980). An improved shock wave source and an ultrasound A scanner were tested in the second extracorporeal lithotripter (*TM2*); however, ultrasound imaging did not work satisfactorily and the feasibility of the project was seriously questioned. (In the *A-* or *amplitude-mode* an ultrasound transducer scans through the patient's body and the echoes are displayed on a screen as a function of depth). A further device (*TM3*) was equipped with *B-* or *brightness-mode* ultrasound (also known as *2D mode*). In this mode, an array of transducers is used to obtain a two-dimensional image of a plane through the patient's body. Even if the results with the *TM3* were still not good enough to consider a clinical application, they were crucial to obtain enough funding to keep the research project alive. Further laboratory studies revealed that with two independent, biplane X-ray imaging systems, three-dimensional stone location could be possible. In the *TM4*, ultrasound imaging was replaced by an integrated X-ray system (Chaussy et al. 2007). Initially, the lithotripter had a rubber membrane to couple shock waves into the body of the animal; however, an open water bath was used in the next prototype, because shock wave transmission through the membrane was not as efficient as expected. The first water bath model with a two axis X-ray system for animal studies was finished in 1978. Extensive animal experiments were performed during 1978 and 1979 (Chaussy et al. 1978, 1979b) and finally it was possible to obtain funding to develop the first clinical lithotripter prototype, the Dornier *Human Model 1 (HMI)* shown in Fig. 2.5. Hoff, Hepp, and Forssmann were in charge of the technical developments.

In 1979 the first *HMI* was installed at the Institute of Surgical Research of the Ludwig-Maximilians University, Klinikum Grosshadern in Munich (Fig. 2.6). Patient positioning inside the water tub was tested on a group of stone bearing volunteers (Chaussy et al. 2007). This lithotripter was used to perform the first SWL treatment on February 7, 1980 by Christian Chaussy, Bernd Forssmann, and Dieter

Fig. 2.5 Photograph of the *Human Model 1 (HMI)* lithotripter (Dornier MedTech GmbH, Wessling, Germany), used to perform the first extracorporeal shock wave lithotripsy in 1980, showing (1) the right (as seen from the patient) and (2) the left image intensifier of the biplanar fluoroscopy system, (3) the water tub, and (4) the patient stretcher. The lithotripter was donated to the German Museum (“Deutsches Museum”) in Bonn, Germany. (Courtesy of C. Chaussy)



Fig. 2.6 Christian Chaussy (*right*) supervising patient positioning for SWL with the Dornier *HMI* extracorporeal shock wave lithotripter. The photograph shows the two image intensifiers (1) and (2) of the biplanar fluoroscopy system, the stainless steel water tub (3) and the support of the patient stretcher (4). (Courtesy of C. Chaussy)

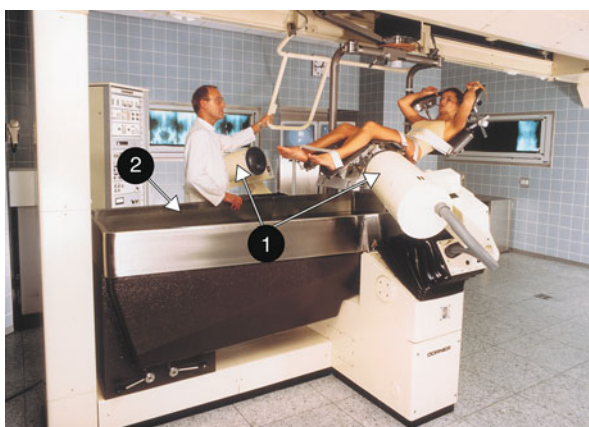


Jocham (Chaussy et al. 1980, 1984, 2014; Brendel 1981). A first trial was actually made at the end of 1979; however, the procedure had to be interrupted before starting the emission of shock waves, because the patient began to float in the water tub, not following the movement of the patient gantry as required. The problem was solved by designing special straps to fasten the patient to the gantry, allowing precise positioning and successful fragmentation of the kidney stone during the memorable SWL in 1980 (Wess 2009). Figure 2.7 is a photograph taken at the tenth anniversary of this first historical treatment.

Fig. 2.7 From left to right: Christian Chaussy, Egbert Schmiedt and the first SWL patient Hans Dworschak, standing next to a *Lithotripter Compact* (Dornier MedTech GmbH, Wessling, Germany), 10 years after the historical treatment with the Dornier *HMI* at the Klinikum Grosshadern in Munich, Germany. (Courtesy of C. Chaussy)



Fig. 2.8 Photograph of the legendary *Human Model 3* (*HM3*) extracorporeal shock wave lithotripter, showing (1) the image intensifiers of the biplanar X-ray system before placing them into the treatment position, and the patient on the stretcher before being positioned inside the water tub (2). (Courtesy of Dornier MedTech GmbH, Wessling, Germany)



The novel technique, published at the end of the same year (Chaussy et al. 1980; Chaussy and Staehler 1980) was received with skepticism by the urological community. An abstract dealing with the first results of SWL, which Chaussy and colleagues submitted to the 1981 meeting of the American Urological Association (AUA) was not accepted. Nevertheless, the first clinical experience with SWL was published in the *Journal of Urology* shortly after (Chaussy et al. 1982). A total of 220 patients were treated with the *HMI*. A second model, the Dornier *HM2* was installed in the first lithotripsy center, headed by Chaussy, at the University of Munich in May 1982. The *HMI* and *HM2* prototypes were followed by the first commercial extracorporeal lithotripter, the *HM3* (Sect. 5.2.1). The first *HM3* (Figs. 2.8 and 2.9) was installed in 1983 at the Department of Urology of the Katharinen Hospital in Stuttgart, under the supervision of Ferdinand Eisenberger (Eisenberger et al. 1983, 1985), and a second device was installed at the Klinikum

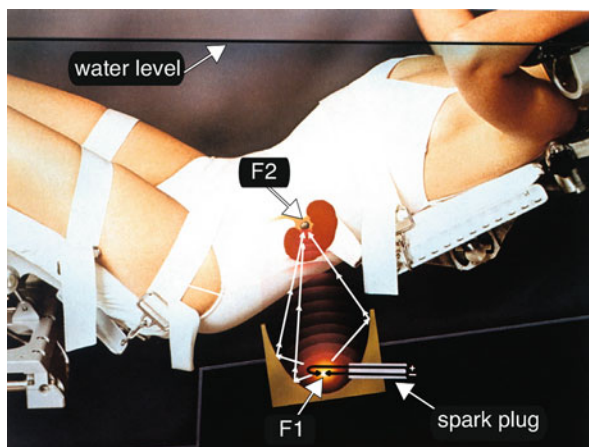


Fig. 2.9 Image of the *Human Model 3 (HM3)* extracorporeal shock wave lithotripter. Shock waves were generated by underwater electric discharges at the inner focus (*F1*) of a paraellipsoidal metallic reflector and focused towards the outer focus (*F2*). A stationary biplanar X-ray system (not shown) guaranteed localization and positioning of the kidney stone at *F2*. (Courtesy of Dornier MedTech GmbH, Wessling Germany)

Grosshadern in October 1983. Until 1985, the *HM3* was the only extracorporeal lithotripter on the market. It was an expensive high-tech system, consisting of a huge water tub, a biplanar fluoroscopy location system, a shock wave generator, a patient-positioning device, a hydraulic supply system, a water treatment unit, and a control cabinet. As of 1986, more than 20 SWL centers had performed more than 26,000 treatments in West Germany. Worldwide, about 200 Dornier lithotripters were installed and more than 250,000 successful treatments had been performed (Drach et al. 1986), causing a revolution in urinary stone therapy. The Dornier *HM3* was considered to be “the gold standard” of SWL by many authors worldwide (Cass 1995; Lingeman and Safar 1996; Graber et al. 2003; Gronau et al. 2003; Gerber et al. 2005), and in 1998 it was still one of the most widely used lithotripters in the USA. After the initial model, Dornier released the so-called *modified HM3*. This model and the *HM4*, a “dry” lithotripter with a water cushion (Fig. 2.10), had lower energy and a slightly larger reflector aperture to produce a tighter focal zone (Sect. 5.2.1).

The first extracorporeal lithotripter in the USA (an *HM3*) was installed in March 1984 at the Methodist Hospital in Indianapolis and operated by James Lingeman and Daniel Newman. Shortly later, Japan purchased an *HM3* that was installed in a lithotripsy center managed by the doctors Tazaki and Higashihara in Sapporo. The FDA (Food and Drug Administration) of the USA pre-market approval was obtained in December 1984 and the approval of the Japanese Ministry of Public Welfare was attained in November 1985. SWL clinics in Houston, Gainesville, Boston, and Charlottesville followed, and were led by Don Griffith, Birdwell Finlayson, Steve Dretler, and Jay Gillenwater, respectively. A report of the United States cooperative

Fig. 2.10 Photograph of the *Human Model 4 (HM4)* extracorporeal shock wave lithotripter, showing (1) the image intensifiers of the biplanar X-ray system, (2) the water cushion, and (3) the patient stretcher. (Courtesy of Dornier MedTech GmbH, Wessling, Germany)



study of SWL was published in 1986 (Drach et al. 1986). In 1989 Chaussy, Schmiedt, and Eisenberger were rewarded by the AUA with the Distinguished Contribution Award. The Acoustical Society of America held the first session devoted to SWL in 1988.

In 1978, a research project called “Ultra Shock Wave” was started at the company Richard Wolf GmbH (Knittlingen, Germany), in collaboration with the University of Saarland and the University of Karlsruhe in Germany. The main goal of the project, led by Herbert Schubert, Helmut Wurster, and Werner Krauss, was to study the feasibility of piezoelectric-based extracorporeal shock wave lithotripsy. After several unsuccessful trials with compact piezoelectric bowls, Günther Kurtze and Rainer Riedlinger from the University of Karlsruhe found a solution by arranging about 3000 small piezoelectric cylinders on a self-focusing spherical bowl made of metal, embedded in a special epoxy resin and activated by a high-voltage pulse (Sect. 5.4.1) (Kurtze and Riedlinger 1988). In December 1985, the first patient with a kidney stone was successfully treated without anesthesia at the University of Saarland Hospital by Manfred Ziegler, Thomas Gebhardt, and Dietmar Neisius with a piezoelectric prototype SWL device. The initial successful treatments lead to the design of the *Piezolith 2200* and *Piezolith 2300* (Richard Wolf GmbH) lithotripters in 1986. These were the first commercially available piezoelectric-based SWL systems (Sect. 5.4.1). The novelty of the *Piezolith 2200* was based on a real-time in-line ultrasound localization system combined with a shock wave source having a large aperture and a narrow shock wave focus for painless treatment without anesthesia and virtually no side effects (Ziegler et al. 1986, 1988; Marberger et al. 1988). The continuous real-time in-line ultrasound imaging concept of the *Piezolith*

2200 was adopted by many other manufacturers. Following models manufactured by Richard Wolf GmbH, such as the *Piezolith 2500*, had an additional X-ray localization system integrated. Almost parallel to the *Piezolith 2200*, a piezoelectric lithotripter called *LT01* (Sect. 5.4.1), with a broader focal zone, was manufactured by EDAP (Vaulx-en-Velin, France) (Vallancien et al. 1988, Miller et al. 1989).

Even if the design of an electromagnetic pressure wave source was published in the beginning of the 1960s by Wolfgang Eisenmenger, flat coil electromagnetic lithotripters (Sect. 5.3.1) were developed until the beginning of the 1980s (Eisenmenger 1962; Wilbert et al. 1987; El-Damanhoury et al. 1991a). The first successful SWL with an electromagnetic lithotripter, developed by Siemens Healthcare GmbH in Erlangen, Germany, was performed in 1986 (Coptcoat et al. 1987). Approximately 3 years after the first SWL with the *HM1*, Eisenmenger patented an electromagnetic shock wave source to produce self-focusing shock waves (Eisenmenger 1983). The system was implemented on a Chinese lithotripter (Sect. 5.3.4) many years later (Eisenmenger et al. 2002).

Because the *HM3* and *HM4* were huge systems, several companies developed smaller, easier to use, and less expensive lithotripters. The *Piezolith 2300* (Richard Wolf GmbH) (Fig. 2.11), the *Lithostar* (Siemens Healthcare GmbH, Erlangen, Germany) (Sect. 5.3.1), the *LT01* and *LT02* (EDAP TMS, Vaulx-en-Velin, France) (Fig. 2.12), and the *Sonolith 2000* (Technomed Medical Systems, Vaulx-en-Velin, France) were the initial competitors of the *HM3*.

At the end of the 1980s, gallstones were successfully treated with a modified kidney lithotripter (Chaussy and Fuchs 1989). This led to the development of a multipurpose device for biliary and urinary stones. Second- and third-generation lithotripters, featuring ultrasonic or fluoroscopic imaging and offering multifunctionality, improvements in patient positioning and decreased anesthesia, were developed; however, according to several authors, it took almost 20 years for the so-called fourth-generation lithotripters to achieve better clinical outcomes than the *HM3* (Rassweiler et al. 2005; Wess 2005; Nomikos et al. 2007).

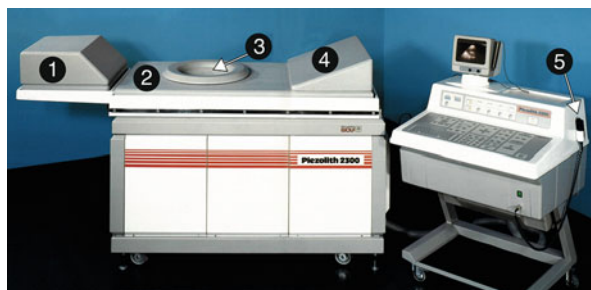


Fig. 2.11 Photograph of the *Piezolith 2300* piezoelectric extracorporeal shock wave lithotripter, showing (1) the cushion for the patient's legs, (2) the fixed treatment table, (3) the open water bath, (4) the cushion for the patient's head, and (5) the manual ultrasound probe. (Courtesy of Richard Wolf GmbH, Knittlingen, Germany)

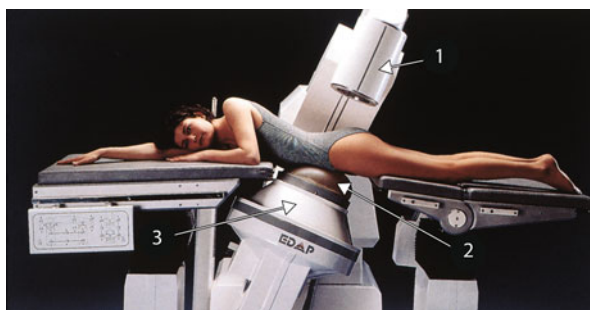


Fig. 2.12 Photograph of the LT02 piezoelectric extracorporeal shock wave lithotripter, showing (1) the mobile C-arm with the fluoroscopy system, (2) the water cushion, and (3) the shock wave generator with integrated ultrasound probe and X-ray source. (Courtesy of EDAP TMS, Vaulx-en-Velin, France)

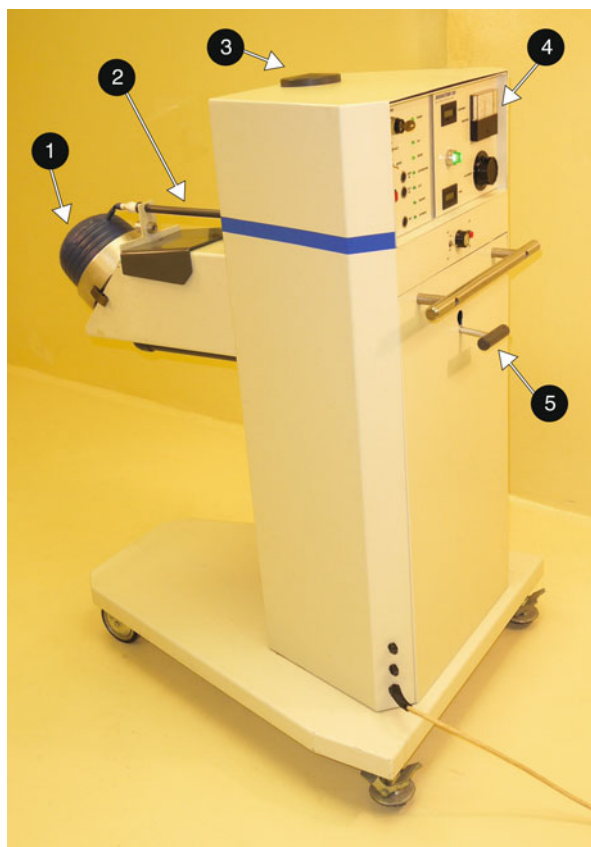
As will be described in Chap. 5, most modern lithotripters can be used without anesthesia, are equipped with both fluoroscopy and ultrasound imaging, and allow multifunctional use. Several of these lithotripters can be installed in a relatively small space.

A first step towards compact extracorporeal shock wave lithotripters was made by Direx Systems Corporation (Canton MA, USA), with the introduction of a modular device called *Tripter Compact* (Servadio et al. 1988). Coupling a C-arm and a treatment table to their shock wave generator resulted in a more versatile and affordable system. The idea was soon adopted by other manufacturers (Fig. 2.13). Another ingenious system, developed by Othmar Wess and Ernst Marlinghaus at Storz Medical AG (Tägerwilten, Switzerland), was an electromagnetic shock wave source based on a cylindrical, instead of a flat coil (Wess et al. 1990). As will be described in Sect. 5.3.2, the cylindrical design uses a parabolic reflector instead of an acoustic lens to focus the shock waves. The first patient was successfully treated with this device in 1989. Since then, about 1700 Storz extracorporeal shock wave lithotripters with a cylindrical coil have been installed worldwide.

The first SWL-patient successfully treated for a salivary gland stone (Sect. 5.8) was exposed to shock waves on a piezoelectric kidney lithotripter, since no shock wave equipment for dentistry was commercially available at that time (Iro et al. 1989).

In Japan, microexplosives were proposed to generate shock waves for biomedical applications (Murata et al. 1977; Watanabe and Oinuma 1977; Kaneko et al. 1979; Watanabe et al. 1983). Initial research was performed in 1975 at the Shock Wave Research Center of the Institute of Fluid Science, Tohoku University. Takayama and his research group suspended small lead azide pellets on thin cotton threads in water, igniting them with a laser beam to produce underwater shock waves. In 1982, the results lead to collaborations with the School of Medicine of the same university to explore the potential of microexplosive SWL (Takayama 1993; Takayama and Saito 2004). After successful in vivo experiments (Kuwahara et al. 1986), the first patients

Fig. 2.13 Photograph of the *Breakstone 100* compact electrohydraulic shock wave lithotripter (Breakthrough Medical Corp., Gaithersburg, Maryland, USA), showing (1) the water cushion of the shock wave source, (2) the air outlet of the water cushion, (3) the water reservoir, (4) the voltmeter that displays the high-voltage setting, and (5) the crank handle to manually move the shock wave source and replace the spark-plug. The device had to be coupled to a patient treatment table and an X-ray C-arm



were treated with a microexplosive extracorporeal lithotripter in 1985 (Sect. 5.2.2). The device was approved for clinical therapy by the Ministry of Health in Japan in 1987 (Kuwahara et al. 1987).

During the early days of SWL, it was not expected that shock waves would be used clinically to treat three other conditions in urology (Chap. 6): the Peyronie's disease (Butz and Teichert 1998), the chronic pelvic pain syndrome (Zimmermann et al. 2005), and erectile dysfunction (Gruenwald et al. 2012). The idea of using shock waves to treat indications other than lithotripsy emerged after incidental observations of a shock wave-induced osteogenic response on living tissue in vivo (Graff et al. 1988a, 1989; Yeaman et al. 1989). One of the first reports indicating that extracorporeal shock wave therapy (ESWT) has the potential to be used prior to revision total hip arthroplasty to facilitate cement and component removal was published by Karpmann et al. (1987). Pioneering studies of ESWT for delayed and nonunion of fractures were reported by Bürger et al. (1991), Valchanou and Michailov (1991), and Schleberger and Senge (1992). The first commercial shock wave source designed specifically for orthopedic and traumatic indications, called *OssaTron* (High Medical Technologies, AG, Lengwil, Switzerland), became available

Fig. 2.14 Photograph of the *OssaTron* shock wave source, designed for orthopedic and traumatic conditions. (Courtesy of High Medical Technologies, AG, Lengwil, Switzerland)



in 1993 (Fig. 2.14). The FDA approved therapy with the *OssaTron* for chronic *plantar fasciitis* and tennis elbow in 2000 and 2003, respectively. During the following years, several clinical applications of ESWT were developed (Thiel 2001). Each application has its own history and the list of conditions is continuously growing. Examples are shock wave therapy to patients suffering from *shoulder tendinopathy* (Rompe et al. 1995b; Haupt 1997), *plantar fasciitis* (Dahmen et al. 1995), tennis elbow (Rompe et al. 1995a), *heel spur* (Cosentino et al. 2001), Achilles tendons (Rompe et al. 2008), ESWT to children with spastic movement disorders (Lohse-Busch et al. 1997), and to patients with cellulite (Siems et al. 2005). ESWT also shows astonishing results in wound healing (Qureshi et al. 2011). The first successful noninvasive shock wave thrombolysis treatment was done in 1998, using a modified *Minilith SL1* (Storz Medical AG) electromagnetic shock wave source (Belcaro et al. 1999). Initial therapies of revascularization with extracorporeal cardiac shock waves were also performed in 1998 (Caspari and Erbel 1999). The *Modulith SLC* (Storz Medical AG), which has a specially modified electromagnetic lithotripter shock wave source, was the first commercial shock wave device to treat ischemic zones of the heart (Sect. 6.17). Today, shock waves are an alternative to treat chronic stable angina pectoris.

Since 1999, not only focused, defocused, and planar shock waves, but also so-called radial shock waves have been used clinically. Radial shock wave sources increased the range of indications of ESWT, although strictly speaking these devices generate radial pressure waves, not shock waves. Nowadays, small desktop

Fig. 2.15 Therapy on the lateral epicondyle with a 5000 SWT Power radial pressure wave unit (BTL Laboratorios de Tecnología, México). (Courtesy of J. Lozano Pardini)



devices are common in doctors' offices to treat ailments in a variety of areas, such as orthopedics (Fig. 2.15), dermatology, odontology, neurology, cardiology, and veterinary medicine.

Writing about the history of biomedical applications of shock waves is getting more complicated as time passes, because the developments are spreading into an increasing variety of fields. An example worthwhile commenting is genetic transformation of fungi. Filamentous fungi are valuable microorganisms to produce compounds, such as antibiotics, insulin, hepatitis vaccines, and anticoagulants; however, the process can only be achieved by inserting foreign DNA into their genomes. Unfortunately, standard methods suffer from a low efficiency of genetic transformation and a bad reproducibility. Surprisingly, a few years ago it was discovered that exposure of fungi to shock waves, as used in clinical applications, is a highly efficient transformation method. The first reports on shock wave-mediated genetic transformation of bacteria (Jagadeesh et al. 2004) and fungi (Magaña-Ortíz et al. 2013) already belong to another chapter of the history of biomedical applications of shock waves, which begun long time before in the aerospace industry with the problem of damage caused by raindrops impinging on supersonic aircraft.

Medical and Biomedical Applications of Shock Waves

Loske, A.M.

2017, XXIII, 378 p. 198 illus., 184 illus. in color.,

Hardcover

ISBN: 978-3-319-47568-4