Urol Res (1990) 18 [Suppl 1]:S13–S23

Urological Research

ESWL '90 – state of the art

Limitations and future trends of shock-wave lithotripsy

J. Rassweiler and P. Alken

Department of Urology, Mannheim Clinic, Clinical Faculty of the University of Heidelberg, Mannheim FRG

After a decade of clinical experience, extracorporeal shock-wave lithotripsy (ESWL) has proved to be the safest treatment modality for urinary stones with minimal morbidity and side effects. Despite this fact, it is of great importance that the limitations of this procedure be pointed out with the aim of further improving its efficacy.

Limitations of ESWL

Persisting fragments

The follow-up series after 2 and 3 years show a stone-free rate of 67%–78% and a recurrence rate of 6%–11% [61, 81, 82, 97, 98]. The stone-free rate does not exceed 60% for calculi in the lower calix. This correlates with the results ater percutaneous nephrolithotomy (PCNL) plus ESWL for staghorn stones [42].

Most stone remnants are asymptomatic. Therefore, in the majority of cases, no further treatment is recommended. However, residual fragments represent a persisting risk factor for future complications (i.e. infection, fever, colics) and can even cause redevelopment of calculi. In the first instance, the management of persisting fragments (i.e. >6 months) should include a short-interval follow-up. In the case of symptoms and regrowth, percutaneous removal of the stone debris should be performed [16]. A surgical approach might be indicated if additional anatomical disorders exist (i.e. caliceal diverticulum, infundibular stenosis).

Criteria for the selection of adjuvant procedures

Correct patient selection is the main means of avoiding ESWL treatment failure. Although lithotripters have been further improved (i.e. ultrasound stone location), the criteria for patient selection have remained the same: Stone burden/distribution, stone composition/radiodensity, renal function, and collecting system. Of course, the *use of indwelling stents* has contributed to the extension of indication for ESWL monotherapy, even for staghorn calculi, as acute morbidity is reduced. It must be noted, however, that double-J stents do not increase the stone-free rate, and double-J morbidity (4%–10%) should not be neglected [48, 101, 163, 168].

The use of ultrasound probes for stone localization has enabled ESWL treatment of even *non-opaque or slightly opaque calculi* [156]. The follow-up of such patients remains problematic, particularly in cases with larger calculi: it is often difficult to determine the degree of stone disintegration as well as the passage of fragments [42]. Thus, especially for larger non-opaque or slightly opaque stones, PCNL seems to be the method of choice [42].

Decreased renal function is accompanied by reduced urinary outflow and perfusion of the kidney. Additional anatomical disorders and urinary tract infection frequently exist. These factors greatly limit the effectiveness of ESWL due to the increasing risk of complications (i.e. septicemia). The same applies to percutaneous stone removal. Therefore, in most cases such kidneys should be excluded from ESWL [17]. *Stenosis of the collecting system* also reduces the success rate of ESWL. However, calculi in a caliceal diverticulum have a 50% chance of being successfully disintegrated [134]. Therefore, a trial session of shock-wave lithotripsy is indicated. In the case of ESWL failure, percutaneous removal can be performed using a short ureteroscope via a small percutaneous tract (18 F). Open plastic renal surgery is indicated for nephrolithiasis in connection with major anatomical disorders, whereas the effectiveness of percutaneous technique and ESWL should not be overestimated.

In summary, the final success of ESWL cannot be predicted in all cases. The existence of residual fragments in about 30% of cases [95, 97] requires an adequate follow-up. Undesirable failure of this elegant method can be avoided by correct patient selection for ESWL (instead of uncritical "bang and see" [121]) and the use of additional methods (endourology, surgery).

Table 1. Advantages and disadvantages of the different methods of shock-wave generation

Method	Advantage	Disadvantage
Electrode elements	Wide range of energy, twin-pulse technique, flexible size of aperture (15–26 cm)	Short life span (3,000–4,000 SW), only ellipsoid for focussing, no continuous gradation of energy (min. generator volt)
Piezo-electric elements	Very long life span (> 1,000,000 SW), variation of frequency (1–100 Hz) target control	Limited range of energy, large aperture necessary (> 30 cm)
Electromagnetic elements	With range and continuous gradation of energy, flexible size of aperture, long life span (200,000–400,000 SW), multiple focussing principles (membrane + acoustic lens, cylinder + paraboloid, spherical shape)	Metal membrane must be changed

SW = shock waves

Future lithotripter technology

The technical progress of second-generation lithotripters has involved all of the basic principles of ESWL such as shock-wave generation, focussing, energy coupling and stone localization [8, 60, 64, 65, 69, 76, 80, 91, 93, 102–106, 112, 127, 133, 135, 139, 141, 144, 148, 152, 166, 170, 176, 180, 187, 189, 193, 196, 197]. In the meantime, with respect to general clinical experience with second-generation lithotripters, the results of the first series have been reproduced by other centers on most of the machines. The successful stone-disintegration rate ranges between 80% and 95%. Unfortunately, this sometimes includes a considerable retreatment rate (Wolf Piezolith 2300 = 45%). Some common principles could be implemented in future lithotripters, despite the various technical disadventages involved (Table 1).

Shock-wave generation

Electromagnetic elements [81, 112, 143, 144, 184, 190] may be preferred as the shock-wave source in the future, as they are more durable than electrodes, enable continuous graduation of shock-wave energy and provide sufficient shock-wave pressure, even with a smaller aperture in the focussing system They can therefore be integreated in multifunctional tables. The shape of the electromagnetic membrane can be modified and enables different focussing principles. The fact that the *electrodes* must be changed after each treatment, causing inconvenience to the operator and higher maintenance costs, poses a major disadvantage. The twin-pulse technique compensates for the time lost during renewal of the electrodes between treatments [65].

The greatest disadvantage of *piezo-electric elements,* despite technical improvement (Wolf Piezolith 2500), is the restricted energy of each element [148], affording a large aperture for the focussing system. An adjustable frequency scale is of minor importance for lithotripsy, as high frequencies (> 2.5 Hz) are less effective and cause severe tissue damage. A theoretically possible "hit control", which converts the echo signal of the stone that is recorded by one of the piezo-electric elements, has not yet been realized in clinical lithotripters [93, 152].

An *electromagnetic cylinder for shock-wave generation together with a paraboloid metal reflector* is an interesting modification of an electromagnetic element. As a self-focussing system without an energy-absorbing acoustic lens, it produces a high range of shock-wave pressure. In contrast electrohydraulic systems, the cylinder in this system enables the coaxial integration of an ultrasound probe that does not lie in the blast path [143, 144, 149]. No advantage is gained from other modifications to shock-wave generation, such as pulsed laser or microexplosion with lead acetate pellets and these can be disregarded for future use [91, 106].

Shock-wave coupling

As with the shock-wave source, there are some technical alternatives, but the coupling of shock-wave energy will be carried out only via a *water cushion* and *ultrasonic gel* in all future lithotripters. Only one of the new machines [176] has retained a partial water bath (Sonolith 3000). Owing to the membrane of the water cushion, the attenuation of shock-wave energy amounts to approx. 15% as compared with that obtained using a water bath [45, 80], and this can easily be compensated by an increase in generator voltage. The result is an enormous reduction in the size of lithotripters and more favourable maintenance costs.

Table 2. Demands and characteristics of third-generation lithotripters

Demand	Characteristic
Biliary and urinary calculi	Fluoroscopy and ultrasound
Better efficacy than Dornier HM3	Wide energy range of the shock-wave source
Anesthesia-free treatment (max. i.v. analgesia)	Large aperture in the focussing system
Multifunctional use of table	Integrated fluoro-table for endoscopy
Economical machine	Low costs and maintenance

Positioning

Because of the water cushion, the energy source can be included in an ordinary treatment table. As a result, special positioning techniques (i.e. sitting position for distal ureteral stones) have become less important. The patient must be in the supine position, as for a normal intravenous pyelogram (IVP), if *fluoroscopic stone localization* is used for renal and upper calculi. A prone position is recommended for mid- and lower ureteral stones [113, 114, 116, 138]. Oblique positioning of the patient is favourable for the *purely ultrasonic localization* of upper ureteral stones and prone positioning with the patient's bladder being semi-filled, for that of distal ureteral stones [128, 141].

Stone localization

Many of the new lithotripters use *ultrasound* for stone localization. The reasons for this are: (1) the large aperture of the focussing system has prevented easy integration of the X-ray, (2) cost reduction, and (3) to enable the treatment of gallbladder stones. A major advantage of *ultrasound* is real-time monitoring, which avoids radiation exposure during treatment and enables "autofocussing" of the stone by the patient's own breathing [141]. This regulation of the patient's breathing is much more effective and far cheaper than a computerized respiratory gating or even a "hit control" by a piezo-electric element [8, 80, 93, 189].

Despite its low cost and wider range of indications for ESWL (i.e. radiolucent calculi, biliary stones), ultrasound also has some disadvantages. Ultrasound localization of calculi in the mid-ureter is almost impossible, and multiple stones can be problematic. The lengthy learning curve is another disadvantage. A sonographically experienced urologist requires considerable time to distinguish between actual fragmentation of secondary artifacts and intrarenal gas formation such as air bubbles released by shock waves or cavitation [94].

Fluoroscopic stone localization is much safer, as the chance of missing radiopaque calculi is minimal. This results in a shorter learning curve. Furthermore, fluoroscopy guarantees a wide range of indications for in situ treatment (eventual application of contrast dye) and enables multifunctional use of X-rays (diagnostic, endourologic). Fluoroscopic localization of stones close to the vertebral column and of radiolucent calculi is especially difficult. The adequate treatment of gallbladder stones, in particular, is not possible.

The highest demand on future interdisciplinary lithotripters ("third-generation lithotripters") is the *combination of ultrasound and fluoroscopy* (Table 2). The following are the present technical alternatives to this localization method (Table 3):

1. In-line ultrasound probe with integrated C-arm for fluorescopic localization using a virtual focus (F_v) and moving the patient on the shock-wave source (Storz Modulith SL20, Diasonics Therasonic Lithotripter); parallel to ultrasound, with oblique coupling of the shock-wave source (Dornier MPL 9000); and using an in-line C-arm integrated in the shock-wave source (Wolf Piezolith 2500)
2. One rotating X-ray tube with an integrated lateral computer-assisted ultrasound scanner (Dornier MFL 5000-u, Medstone 1000-s)
3. Two fixed X-ray tubes with two independent shock-wave sources and an overhead module consisting of a third shock-wave source with coaxial ultrasound probe (Siemens Lithostar Plus)

The compact form of a unit that uses a *virtual focus* (F_v), enabling easy handling and multifunctional use of the lithotripter, is very advantageous [144]. Unfortunately, real-time fluoroscopy during treatment is not possible. It should be stressed that due to accurate mechanical design and calibration, exact focussing is possible unless the patient is moved on the shock-wave source after fluoroscopy. Simultaneous fluoroscopy and ultrasound can be carried out by *parallel use of a C-arm* [139]. The combination of two C-arms (shock-wave head and fluoroscopy), however, makes handling complicated (i.e. treatment is not possible with the patient in the prone position). *Integration of the fluoroscopic system in the large aperture of the shock-wave generator* provides an interesting and compact lithotripter design [128]. On the other hand, this type of machine cannot be used for multifunctional purposes.

Both of the basically X-ray-guided systems provide the widest spectrum for multifunktional use. The implementation of a *lateral computer-assisted ultrasound probe* [8] enables easy handling, but focussing is restricted due to (1) deviation of lateral ultrasound owing to diffraction and declination, amounting to approx. 5 mm on the x- and y-axes; and (2) the inadequate precision of computer-assisted positioning of the patient after ultrasound determination of the stone coordinates. Alternatively, the installation of an *independent ultrasound-guided overhead module* is a quite expensive solution [185]. Almost all types of stones can be treated on such a machine, but there is no provision for the simultaneous use of ultrasound and fluoroscopy. The most appropriate concept for interdisciplinary lithotripsy will be determined in the time to come.

Comparison of lithotripters

The introduction of new lithotripters has made comparison of the different machines necessary [133, 148]. Where-

Table 3. Third-generation lithotripter: comparison of the main technical concepts combining ultrasound and fluoroscopy for stone localization

Localization concept	Multifunctional use	Simultaneous X-ray and ultrasound	Real-time fluoroscopy	Handling	Machine	Reliability of focussing
1. In-line ultrasound with integrated C-arm:						
External fluoroscopy with virtual focus (Modulith SL20)	++	No	No	Easy	Compact	++[b]
Parallel fluoroscopy (MPL 9000-x)	++	Yes	Yes	Complicated (positioning)	Complex	+++
In-line fluoroscopy (Piezolith 2500)	+	No[a]	Yes	Easy	Compact	+++
2. One rotating X-ray tube with lateral ultrasound (MFL 5000-u)	+++	Yes	Yes	Easy	Expensive (space required, computer-assisted ultrasound)	++[c]
3. Two X-ray converters plus independent shock-wave head with coaxial ultrasound (Lithostar plus)	+++	No	Yes	Easy	Expensive (3 shock-wave sources)	+++

+ = insufficient; ++ = sufficient; +++ = excellent; [a] inflation of X-ray ballon necessary; [b] with respect to integrated C-arm; [c] with respect to lateral ultrasound

as the technical differentiation of the lithotripters, i.e. shock-wave generation, focussing, coupling and localization, is simple, classification of the disintegrative efficacy remains problematic. The development of new shock-wave sources, in particular, requires a *standardized classification* to determine the range of shock-wave pressure (or generator voltage) that is safe for clinical use. This can be accomplished by physical measurements, stone models, and animal studies.

Physical measurements

Ideally, shock-wave generators should be classified with acoustic measurements [25–27, 45, 73]. Theoretically, they can be defined by the rise time, peak positive pressure, peak negative pressure, duration of impulse, spectrum of frequencies, size of the focal area, and acoustic energy of each impulse.

At present *no standardized hydrophones* are available. Accurate measurement requires a durable and sensitive pressure probe with adequate rapid response time to record the fast-rising peak pressures. Previously, shock-wave measurement was carried out using a narrow band width and was therefore, less accurate [65]. The use of a broad-band (PVDF) needle probe ensures more reliable data [184]. Recently, Coleman et al. demonstrated significant differences in frequency response between needle probes, even between those from the same manufacturer, leading to varying statistics in the focal zone [26]. As Coleman and Saunders have shown, this unreliable measurement method is of minor importance when different shock-wave sources are tested using the *same* hydrophone [27]. Nevertheless, it is understood that a significant comparison of lithotripters can be made only using a reliable, well-defined standard for measuring shock waves. The laser hydrophone could possibly become such a standard instrument [45].

Stone models

The problem of physically classifying shock waves is the main reason why the exact impact of each of the different paramenters for stone disintegration with minimal tissue traumatization has not been adequately defined and, as a result, is not yet completely understood. Standardized in vitro stone models have therefore, become important for the classification and comparison of shock-wave efficacy [148, 149].

Stones, chalk pieces, plaster cubes and pellets made of dental cement were used in preliminary studies to measure both the number of impulses for complete disintegration and the cavity produced after a defined number of shock waves. The possibility of determining a characteristic curve plotting impulses vs generator voltage for different shock-wave sources was demonstrated. The movement of the curve (to the left of right) along the x-axis was caused by the hardness of the stone tested or by shock-wave attenuation (use of a water cushion). These characteristic curves could be useful for determining the optimal generator-voltage range for effective stone fragmentation and comparing the therapeutic broad band of different shock-wave sources [143, 184].

An easy check of the actual machine power can also be made, particularly in less successful clinical cases. Any decrease in disintegrative efficacy, i.e. owing to defective transducers, can be demonstrated on a standardized stone model by increasing the impulses for fragmentation. Plaster cubes can also be used for the exact regulation of

Table 4. Comparison of clinical results obtained with the most important second-generation lithotripters using the efficiency quotient[a]

	SFR	RE-TX	AUX	EQ
Stones measuring < 1 cm:				
Dornier HM3	77%	5%	12%	0.66
Dornier HM4	85%	38%	4%	0.60
Direx	75%	24%	7%	0.57
EDAP	72%	29%	2%	0.55
Siemens	74%	7%	16%	0.60
Technomed	81%	13%	7%	0.68
Wolf	86%	16%	4%	0.72
Stones measuring 1–2 cm:				
Dornier HM3	75%	10%	11%	0.62
EDAP	64%	68%	6%	0.37
Siemens	65%	12%	12%	0.52
Wolf	69%	27%	2%	0.53

[a] From [133]
SFR = Stone-free rate; RE-TX = retreatment rate; AUX = percentage of auxiliary measures; EQ = efficiency quotient

the focussing and localization system It is important that a considerable deviation of shock-wave focus and geomentrical focus, amounting to approx, 2–3 mm in the electrode ellipsoid system as well as in the electromagnetic membrane-acoustic lens device, is possible [184]. This deviation is less important in shock-wave sources with a large focal zone (12 or 9 mm, respectively, on the x- or y-axis) than in those with a small focal area (3 or 5 mm on the x- or y axis) [164]. In comparison with the geometrical focus determined by fluoroscopic localization, the focal zone of the shock wave can be depicted by means of a plaster cube, making time-consuming pressure measurements unnecessary.

Animal studies

At present, the degree of tissue trauma produced by shock waves cannot be predicted by physical measurements or in vitro stone models, as pertinent standards are missing. It has been well documented that only focal and reversible intrarenal hematomas occur when a medium range of shock-wave energy is applied [1, 3, 5, 13, 19, 32–34, 53, 56, 74, 90, 99, 123, 124, 130, 143, 173, 185, 188]. The introduction of shock-wave sources that produce higher pressure levles (i.e. Storz Modulith SL20, Lithostar overhead, Dornier MPL 9000, Piezolith 2500) has made the characterization of renal trauma that occurs at higher energy levels a matter of great importance in avoiding severe clinical complications.

Three animal models can be used (canine, New Zealand rabbit and mini-pig), and at least two of them should be standardized with respect to the experimental design (i.e. number of shocks, localization, positioning) for future studies [56, 143]. Nevertheless, a well-defined standard of physical measurements should be achieved using standardized, reliable hydrophones. The correlation of this standard to in vitro and in vivo studies should finally make animal experiments unnecessary.

Clinical trials

Despite the fact that in vitro stone models have been correlated with clinical experience (i.e. the number of impulses and the retreatment rate vs the number of shocks for disintegration of a test stone), only clinical trials can estimate the exact capability of a lithotripter. A prospective, randomized phase III study at one center would be the best method of clinically comparing different stone machines. Unfortunately, very few centers have more than one lithotripter. Diverse stone distribution and the treatment strategies of each ESWL unit make a simple comparison of the available clinical data difficult. As phase III studies cannot be performed in most cases, the following represents a suitable method for comparing clinical results:

1. Definition of treatment strategy (i.e. in situ ESWL for ureteral calculi or "push and bang")
2. Determination of stone size and localization and adjustment procedures before ESWL.
3. Definition of success (i.e. degree of disintegration and stone-free rate after 3–6 months)

Taking these criteria into consideration, it is possible to make a reasonable comparison of clinical results obtained using different lithotripters. The *"efficiency quotient"* EQ, (Table 4) recently defined by Preminger and Clayman [133] enables the determination of a specific figure that expresses the clinical efficacy of a stone machine:

$$EQ = \frac{\%\text{ of stone-free patients}}{100\% + \%\text{ retreated patients} + \%\text{ secondary procedures}}$$

It is interesting to compare the similarity of EQs obtained for small stones between the most important second-generation lithotripters and the Dornier HM3. The EQ obtained for larger calculi using the Dornier HM3 is much higher (Table 4). Future clinical trials based on the above-mentioned criteria must confirm the theoretical advantages of the new (third-generation) interdisciplinary lithotripters in clinical practice.

Choice of lithotripters

The rapid development of new lithotripters has initiated a worldwide boom of these machines. This mainly the case in the *United States and West Germany* and has led to an abundance of stone machines. In West Germany, 22 urologic ESWL centers were installed in 1986 and this number was considered to be sufficient. At present, > 75 lithotripters are being used for interdisciplinary ESWL, and additional installations are planned. In the United States > 25 stone machines are in use in Los Angeles alone. This increase In ESWL centers has led to a marked change in the indications. Whereas ureteral stones were treated in 15% of all ESWL patients in 1984, ureteral calculi were treated in 45% of ESWL cases in 1989, In general, most larger stones were disintegrated [18, 22, 42].

As a result, decentralization of ESWL will become established in the future and an increasing number of urologists will treat fewer stones. This could affect the quality of treatment for the following reasons: (1) an increase in the use of *mobile lithotripters* would make necessary retreatment on the following day difficult, and (2) *out-patient treatment of ESWL* would complicate follow-up [168]. Moreover, as a result of this trend toward decentralization urologists will no longer be classified into two groups (those with and those without a lithotripter).

In *developing countries* (e.g. India, South America, Africa), ESWL has just started and a very large number of patients require stone treatment. Thus, ESWL and endourology will be the chief means of stone management in such countries. Financial problems will limit the number of lithotripters available in these countries for the next few years.

For these reasons, it is obvious that no specific choice among lithotripters can be made. The following are the important factors to be considered:

1. The *size of the unit,* allowing for the number of patients, the financial support, and the choice of a urological or an interdisciplinary stone center
2. The *distribution of calculi,* i.e. the localization (renal vs ureteral) and size of stones
3. *Experience of the urologist* with ESWL and ultrasound

Small urology units can choose from three alternatives: (1) a "low-cost lithotripter" based mainly on ultrasound stone localization; (2) a more expensive multifunctional table based on fluoroscopy, which could also be used for other urological purposes; and (3) a mobile lithotripter with the above-mentioned disadvantages. The aim of *larger urology units* with a substantial number of patients should be a third-generation lithotripter encompassing all ESWL requirements. If necessary, interdisciplinary lithotripsy could also be performed. A third-generation lithotripter should also be the first choice of an *interdisciplinary stone center.* However, if the center has a standard lithotripter with fluoroscopic stone localization (i.e. Dornier HM3, MFL 5000 or Siemens Lithostar), an ultrasound-based stone machine could be a good addition; 7–10 patients/day must be treated at such "two-machine stone centers" before the acquisition of both lithotripters is worthwhile [139].

Further applications of shock waves

Clinically, the most interesting extension of indications for ESWL is the treatment of *pancreatic duct and salivatory duct stones* [72], as extensive surgery can be avoided in both cases. To date, the treatment of stones in the salivary gland (i.e. submandibular, parotid gland) has been performed by glandectomy, with the possibility of significant injury and postoperative complications (i.e. paresis of the facial nerve).

Another possible clinical application of shock waves involves the treatment of *pseudoarthrosis.* In 1989, Valchanov et al. [179] presented their first experience with 53 patients who had suffered from pseudoarthrosis of fractures for an average of 20 months. On shock-waves treatment, the pseudoarthrosis was brought to a stillstand for an average of 81 days; this therapy was successful in 88% of the patients.

In contrast, the *treatment of tumors with shock waves* remains at an early experimental stage. The clinical relevance of such treatment is unknown, despite the fact that early investigations demonstrated that significant dose-dependent damage was caused by high-energy shock waves. Only a temporary effect was determined in most studies, and very little information exists on the tumor-specific effect of shock waves [6, 9, 10, 12, 14, 15, 20, 21, 55, 59, 70, 100, 132, 159, 160, 191]. Shock waves will have to be modified for any future treatment of neoplasms. Whereas shock waves were developed for ESWL sources with the aim of minimal tissue trauma, maximal traumatization is the aim of tumor treatment. The increase in cavitation and the use of higher frequencies are important factors in this respect. Using normal tissue, in 1989, Peschke et al. [132] demonstrated that 5-Hz impulses caused more distinct damage to Dunning Ly/Lu prostate carcinoma of the rat than did 1-Hz impulses. Due to essential differences in shock-wave quality, all experimental studies concerning the treatment of tumor cells – including chemotherapy – are elementary. The same applies to *shock-wave treatment of benign prostatic hypertrophy* [46].

Aiming shock waves at drug carriers could be another interesting application. In 1989, Jones et al. loaded autologus erythrocytes with [^{3}H]-methotrexate and demonstrated a 107% increase in the cytotoxic drug in the shocked area [183]. Such techniques could reduce the toxic side effects of cancer chemotherapy. All of the above-mentioned methods are far from being ready for clinical application.

References

1. Abrahams C, Lipson SB, Ross LS (1988) The effects of shock wave lithotripsy (ESWL) on canine kidneys. J Urol 139:324A
2. Alken P, Rassweiler J (1989) Complications of ESWL. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. L4)
3. Baumgartner BR, Dickey KW, Ambrose SS, Walton KN, Nelson RC, Bernardino ME (1987) Kidney changes after extracorporeal shock wave lithotripsy: appearance of MR imaging. Radiology 163:531
4. Becopoulos T, Karayannis A, Mandalaki T, Karafoulidou A, Markakis C (1988) Extracorporeal lithotripsy in patients with hemophilia. Eur Urol 14:343
5. Begun FP, Lawson RK (1988) Renal injury resulting from focused electrohydraulic shock waves. J Urol 139:323A
6. Berens ME, Schostock C, Hart L, Barshira Z, McCullough DL (1988) Effect of cell cycle and temperature on the antiproliferative effects of acoustic shock waves (SW) against human tumor cells. J Urol 139:304A
7. Bomanji J, Boddy SA, Britton KE, Nimmon CC, Whitfield HN (1987) Radionuclide evaluation – pre- and postextracorporeal shock wave lithotripsy for renal calculi. J Nucl Med 28:1284

8. Brandl H, Chaussy C, Thüroff S, Leser C (1989) First results with the multifunctional lithotripter MFL 5000. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. 02–2)
9. Bräuner T, Brümmer F, Hülser DF (1989) Histopathology of shock wave treated tumor cell suspensions and multicell tumor spheroids. Ultrasound Biol 15:451
10. Brendel W, Conzen P, Goetz AE, Königsberger R (1987) Experimentelle Tumortherapie mit Schockwellen – Erste Ergebnisse. In: Vereinigung der Bayerischen Chirurgen. 64. Tagung vom 16.–18. Juli 1987, Bad Reichenhall
11. Brendel W, Delius M, Goetz AE (1987) Effect of shock waves on the microvasculature. Prog Appl Microcirc 12:41
12. Brendel W, Wilmer A, Delius M (1987) Effekt von Stoßwellen auf Tumorzellen in Suspension. In: Vereinigung der Bayerischen Chirurgen. 64. Tagung vom 16.–18. Juli 1987, Bad Reichenhall
13. Brewer SL, Atala AA, Ackerman DM, Steinbock GS (1988) Shock wave lithotripsy damage in human cadaver kidneys. J Endourol 2:333
14. Brümmer F, Bräuner T, Brenner J, Hülser DF (1988) Effects of lithotripter-generated shock waves on L1210 mouse leukemia cells detected by flow cytometry. Eur J Cell Biol 46:12
15. Brümmer F, Brenner J, Bräuner T, Hülser DF (1989) Effect of shock waves on suspended and immobilized L1210 cells. Ultrasound Biol 15:229
16. Bush W, Gibbons RP, Lewis GP, Brannen GE (1986) Impact of extracorporeal shock wave lithotripsy on percutaneous stone procedures. Am J Radiol 147:89
17. Charig CR, Webb DR, Payne SR, Wickham JE (1986) Comparison of treatment of renal calculi by open surgery, percutaneous nephrolithotomy, and extracorporeal shockwave lithotripsy. Br Med J 292:879
18. Chaussy CG, Fuchs G (1980) Erfahrungen mit der extrakorporalen Stosswellenlithotripsy nach 5 Jahren klinischer Anwendung. Urologe [A] 24:305
19. Chaussy CG, Schmied E, Jocham D, Fuchs GJ, Brendel W, Forssmann B, Hepp W (1986) In: Chaussy C (ed) Extracorporeal shock wave lithotripsy. Karger, Basel
20. Chaussy C, Randazzo RF, Fuchs GJ (1988) The effects of extracorporeal shock waves on human renal carcinoma cells and normal human embroyonic kidney cells. J Urol 139:320A
21. Chaussy C, Randazzo RF, Fuchs GJ (1988) The effects of extracorporeal shock waves on FANFT bladder tumors in C3H/He mice. J Urol 139:289A
22. Chaussy CG (1988) ESWL: past present and future. J Endourol 2:97
23. Chinn SKB, Michaels EK, Fowler JE, Behnia R, Linde HW, Ray V (1988) Hemodynamic and adrenal response to shock wave energy. J Urol 139:324A
24. Chuong CJ, Zhong MS, Preminger GM (1988) Pressure measurements in a Wolf Piezolith 2200 lithotripter. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 395
25. Coleman AJ, Saunders JE (1987) Comparison of extracorporeal shock wave lithotripters based on measurements in the acoustic field. In: Coptcoat MJ, Miller RA, Wickham JEA (eds) Lithotripsy II. BDI Publishing, London, p 121
26. Coleman AJ, Saunders JE (1989) A comparison of PVDF hydrophone measurements in the acoustic field of a shock waves source. In: Proceedings of Med Tech '89, 6–11th November 1989, Berlin
27. Coleman AJ, Saunders JE (1989) A survey of the acoustic output of commercial extracorporeal shock wave lithotripters. Ultrasound Med Biol 15:213
28. Coptcoat MJ, Webb DR, Kellett MJ, Fletcher MS, McNicholas TA, Dickinson IK, Whitfield HN, Wickham JE (1986) The complications of extracorporeal shock-wave lithotripsy: management and prevention. Br J Urol 58:578
29. Coptcoat MJ (1987) The steinstrasse: classification and management. In: Coptcoat MJ, Miller RA, Wickham JEA (eds) Lithotripsy II. PDI Publishing, London, p 133
30. Das G, Birch B, Samuel C, Whitfield HN, Wickham JEA (1988) Enzymuria as a marker of tubular recovery following extracorporeal shock wave lithotripsy or extracorporeal piezoelectric lithotripsy. In: Lingeman JE, Newman DM (eds) Shockwave lithotripsy – State of the art. Plenum Press, New York London, p 369
31. Delius M (1987) Extracorporeal shock wave lithotripsy of gallstones. In: Baethmann D, Messmer K (eds) Surgical research: recent concepts and results. Springer, Berlin Heidelberg New York
32. Delius M, Enders G, Heine G, Stark J, Remberger K, Brendel W (1987) Biological effects of shock waves: lung hemorrhage by shock waves in dogs – pressure dependence. Ultrasound Med Biol 13:61
33. Delius M, Enders G, Xuan Z, Liebich HG, Brendel W (1988) Biological effects of shock waves: kidney damage by shock waves in dogs – dose dependence. Ultrasound Med Biol 14:117
34. Delius M, Jordan M, Eizenhoefer H, Marlinghaus E, Heine G, Liebich HG, Brendel W (1988) Biological effects of shock waves: kidney haemorrhage by shock waves in dogs – administration rate dependence. Ultrasound Med Biol 14:689
35. Di Silverio F, Gallucci M, Gambardella P, Alpi G, Benedetti R, La Mancusa R, Pulcinelli FM, Romiti R, Gazzaniga PP (1990) Blood cellular and biochemical changes after extracorporeal shock wave lithotripsy. Urol Res 18:49
36. Dretler SP (1990) An evaluation of ureteral laser lithotripsy: 225 consecutive patients. J Urol 143:267
37. Eisenberger F, Fuchs G, Miller K, et al. (1985) Extracorporeal shock wave lithotripsy and endourology: an ideal combination for the treatment of kidney stones. World J Urol 3:41
38. Eisenberger F, Gumpinger R, Miller K, Horbaschek H, Sklebitz H (1985) Stereo-Röntgen in der Endourologie. Urologe [A] 24:342
39. Eisenberger F, Rassweiler J (1986) Extrakorporale Stoßwellenlithotripsie im Wandel. Aktuel Urol 17:229
40. Eisenberger F, Miller K, Fuchs G, et al. (1987) Urologische Steintherapie. Thieme, Stuttgart New York
41. Eisenberger F, Schmidt A (1989) ESWL – What is proven and what remains controversial? Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. L7)
42. Eisenberger F, Rassweiler J, Kallert B, Bub P (1989) Die Behandlung des Ausgußsteines. Strategien und Ergebnisse des kombinierten Einsatzes neuer Techniken. Urologe [A] 28:138
43. Eisenmenger W (1961) Eine elektromagnetische Impulsschallquelle zur Erzeugung von Druckstössen in Flüssigkeiten und Festkörpern. In: Cremer L (ed) Proceedings of the 3rd International Congress on Acoustics. Elsevier Amsterdam, p 326
44. Eisenmenger W (1962) Elektromagnetische Erzeugung von ebenen Druckstössen in Flüssigkeiten. Acustica 12:185
45. Eisenmenger W (1988) Physikalisch-medizinische Aspekte selbstfokussierter elektromagnetisch erzeugter Stoßwellen. Verh Ber Dt Ges Urol 39:69
46. Erlich N, Lobel B, Guille F, Cipolla B, Leveque JM, Olivo JF, Ramee MP (1989) Influence of high energy shock waves on benign prostatic hypertrophy. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. P13–13)
47. Erturk E, Streem S, Stower NT, Pestana J, Nally JV, Lorig R, Gephart G, Novick AC (1988) The effects of ESWL on renal function and systemic blood pressure: preliminary report of an experimental study. In: Lingeman JM, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 383
48. Fetner CD, Preminger GM, Kettelhut MC, Elkins SL (1989) Morbidity of ureteral stenting during ESWL. J Urol 141:270A (Abstract No. 402)

49. Fischer N, Rübben H, Hofsäss S, et al. (1987) Alternative Stosswellenerzeugungsverfahren mit dem Dornier Lithotripter HM3. Urologe [A] 26:29
50. Fischer N, Müller HM, Gulhan A, Sohn M, Deutz FJ, Rübben H, Lutzeyer W (1988) Cavitation effects: possible cause of tissue injury during extracorporeal shock wave lithotripsy. J Endourol 2:215
51. Fritz KW, Reimann P, Schröder D, Allhoff E, Spangehl-Meridjen P, Jonas U (1989) Extrakorporale Stoßwellenlithotripsie (ESWL) mit dem modifizierten HM3-Lithotriper. Eine klinische Untersuchung zum Anästhesiemanagement. Klinikarzt 18:363
52. Fuchs J, Miller K, Rassweiler J, Eisenberger F (1985) Extracorporeal shock wave lithotripsy: one year experience with the Dornier lithotripter. Eur Urol 11:145
53. Fuchs AM, Coulson W, Fuchs GJ (1988) Effect of extracorporeally induced high-energy shock waves on the rabbit kidney and ureter: a morphologic and functional study. J Endourol 2:341
54. Fuchs GJ, Fuchs AM, Royce PL, Stenzl A, Chaussy CG (1988) Staghorn stone treatment with extracorporeal shock wave lithotripsy: the fate of residual stones. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 101
55. Fuchs GJ, Randazzo RF, Fuchs AM, Stenzl A, Chaussy CG (1988) The in vitro and in vivo effects of extracorporeal shock waves on tumor cells. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 351
56. Fuchs GJ, David RM, Wolfson B, Barbaric Z (1989) Comparative morphological and functional study of the bioeffects of open surgery, percutaneous surgery and ESWL on renal morphology and function: creation of an animal model. Proceedings of the 7th World Congress on Endourology and ESWL, Noevember 27–30, 1989 Kyoto, Japan (Abstract No. 04–7)
57. Gilbert BR, Riehle RA, Vaughan Jr ED (1988) Extracorporal shock wave lithotripsy and its effect on renal function. J Urol 139:482
58. Gleeson MJ, Griffith DP (1989) Extracorporeal shockwave lithotripsy monotherapy for large renal calculi. Br J Urol 64:329
59. Goetz AE, Königsberger R, Feyh J, Conzen PF, Lumper W (1987) Breakdown of tumor microcirculation induced by shock waves or photodynamic therapy. In: Baethmann D, Messmer W (eds) Surgical research: recent concepts and results. Springer, Berlin Heidelberg New York, p 82
60. Graff J, Pastor J, Herberhold D, et al. (1987) Technical modifications of the Dornier HM3 lithotripter with an improved anesthesia technique. World J Urol 5:202
61. Graff J, Pastor J, Funke P-J, Mach P, Senge T (1988) Extracorporeal shock wave lithotripsy for ureteral stones: A retrospective analysis of 417 cases. J Urol 139:513
62. Graff J, Richter KO, Pastor J (1988) Wirkung von hochenergetischen Stoßwellen auf Knochengewebe. Verh Ber Dtsch Ges Urol 39:76
63. Grote R, Döhring W, Aeikens B (1986) Computertomographischer und sonographischer Nachweis von renalen und perirenalen Veränderungen nach einer extrakorporalen Stoßwellenlithotripsie. Fortschr Röntgenstr 144:434
64. Grunberger I, Laungani GB, Armel H, Mykulak D, Irwin M, Godec CJ, Macchia RJ (1989) Initial experience with the therasonic lithotripter. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. 02–3)
65. Hepp W, Heine G, Schneider W, et al. (1987) The Dornier lithotripter (Dornier GmbH): HM3, HM4, HM5. In: Coptcoat MJ, Miller RA, Wickham JEA (eds) Lithotripsy II. BDI Publishing, London, p 15
66. Higashihara E, Horie S, Takeuchi T, Kameyama S, Asakage Y, Hosaka Y, Honma Y, Minowada S, Aso Y (1990) Laser ureterlithotripsy with combined rigid and flexible ureterorenoscopy. J Urol 143:273
67. Hofmann R, Hartung R, Schmidt-Kloiber H, Reichel E (1990) Laser-induced shock wave lithotripsy. Urol Res 18:45
68. Holl R (1982) Wellenfokussierung in Fluiden. Dissertation der Fakultät für Maschinenwesen, Rheinisch-Westfälische Technische Hochschule Aachen
69. Holm HH, Hald T, Kristensen J, Holm-Bentzen M, Schultz A (1988) The Danish extracorporeal lithotripter. In: Lingemann JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 301
70. Holmes RP, Yeaman LD, Taylor RG, Lewis JC, McCullough DL (1988) Enhanced adriamycin uptake by neutrohils exposed to shock waves. J Urol 139:304A
71. Holmes RP (1990) Tumor growth suppressed by shockwaves and cisplatin. AUA Today 3:12
72. Iro H, Wessel B, Benzel W, Zenk J, Meier J, Nitsche N, Wirtz PM, Ell C (1990) Gewebereaktionen unter Applikation von piezoelektrischen Stoßwellen zur Lithotripsie von Speichelsteinen. Laryngo-Rhino-Otol 69:102
73. Ison K (1987) Physical and technical introduction to lithotripsy. In: Coptcoat MJ, Miller RA, Wickham JEA (eds) Lithotripsy II. BDI Publishing, London, p 7
74. Jaeger P, Redha F, Uhlschmid G, Hauri D (1988) Morphologic changes in canine kidneys following extracorporeal shock wave treatment. J Endourol 2:205
75. Jaeger P, Redha F, Alund G, Uhlschmid G (1989) Schadet die Stosswelle der Niere? Schweiz Med. Wochenschr 119:944
76. Jenkins A (1986) ESWL: alternative technologies. Presented at 44th Annual Meeting of the Mid-Atlantic Section of the AUA, Bermuda, September 28–October 2, 1986
77. Jenner R, Rassweiler J, Bub P, Eisenberger F (1989) Ureterkatheter-Dilatationsset – eine wertvolle Ergänzung des endourologischen Instrumentariums. Urologe [B] 29:112
78. Jocham D, Chaussy C, Schmiedt E (1986) Extracorporeal shock wave lithotripsy. Urol Int 41:357
79. Jocham D (1987) Die extrakorporeale Stoßwellenlithotripsie: Indikationen, Grenzen, Resultate. Medwelt 38:766
80. Jocham D, Liedl B, Chaussy CG, et al. (1987) Preliminary experience with the HM4 bath-free Dornier lithotripter. World J Urol 5:208
81. Jocham D, Liedl B, Ludwig W, Jaenicke U, Hofstetter A (1989) Clinical experience with a Dornier lithotripter using electromagnetic shock wave generation. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. 02–5)
82. Jocham D, Liedl B, Lunz Ch., Schuster C, Chaussy C (1989) Langzeiterfahrungen nach ESWL von Harnsteinpatienten. Urologe [A] 28:134
83. Jones BJ, Ryan PC, Fenton D, Nowlan P, Voorheis HP, Butler MR (1989) Targetting of drug carriers using piezo-electric shock waves. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. P13–11)
84. Kaude JV, Williams CM, Millner MR, Scott KN, Finlayson B (1985) Renal morphology and function immediately after extracorporeal shock-wave lithotripsy. Am J Radiol 145:305
85. Kishimoto T, Yamamoto K, Sugimoto T, Yoshihara H, Maekawa M (1986) Side effects of extracorporeal shock wave exposure in patients treated by extracorporeal shock wave lithotripsy for upper urinary tract stones. Eur Urol 12:308
86. Kitada S, Kuramoto H, Kumazawa J, Yamaguchi A, Nakasu H, Hara S (1989) Effects of extracorporeal shock wave lithotripsy on urinary excretion of N-acetyl-beta-D-glucosamidase. Urol Int 44:35
87. Kramolowsky EV, Kratz C (1988) Extracorporeal shock wave lithotripsy for the treatment of bulbous urethral stones. J Urol 139:362
88. Krongrad A, Saltzman B, Tannenbaum M, Droller MJ (1988) Enzymuria following extracorporeal shock wave lithotripsy (ESWL). J Urol 139:324A

89. Kroovand RL, Harrison LH, McCullough DL (1987) Extracorporeal shock wave lithotripsy in childhood. J Urol 138:1106
90. Kurzweil SJ, Smith JE, Van Arsdalen K (1988) Effects of extracorporeal shock waves on skeletal and renal growth in the infant rabbit. J Urol 139:325A
91. Kuwahara M, Kambe K, Kurosu S, et al. (1986) Extracorporeal stone disintegration using chemical explosive pellets as an energy source of underwater shock waves. J Urol 135:133a
92. Kuwahara M, Kambe K, Kurosu S, Kageyama S, Ioritani N, Orikasa S, Takayama K (1987) Clinical applications of extracorporeal shock wave lithotripsy using microexplosions. J Urol 137:837
93. Kuwahara M, Ioritani N, Kambe K, Saitoh T, Taguchi K, Igorashi M, Shirai S, Orikasa S, Takayama K, Aida S (1989) A new overhead-type ESWL machine with an anti-miss shot control device. Proceedings of the 7th World Congress on Endourology and ESWL, November, 27–30, 1989, Kyoto, Japan (Abstract No. 01–6)
94. Kuwahara M, Ioritan N, Kambe K, Shirai S, Taguchi K, Saitoh T, Orikasa S, Takayama K, Aida S, Iwama N (1989) Hyperechoic region induced by focused shock waves in vitro and in vivo: possibility of acoustic cavitation bubbles. J Lithotrip Stone Dis 1:282
95. Liedl B, Jocham D, Lunz Ch, Schuster C, Chaussy C (1989) Prävalenz und Inzidenz der arteriellen Hypertonie bei ESWL-behandelten Nierensteinpatienten. Urologe [A] 28:130
96. Lin P-J, Hrejsa AF (1987) Patient exposure and radiation environment of an extracorporeal shock wave lithotriptor system J Urol 138:712
97. Lingeman JE, Newman D, Mertz J, Mosbaugh PG, Steele RE, Kahnoski RJ, Coury TA, Woods JR (1986) Extracorporeal shock wave lithotripsy: the methodist Hospital of Indiana experience. J Urol 135:1134
98. Lingeman JE, Sonda LP, Kahnoski RJ, Coury TA, Newman DM, Mosbaugh PG, Mertz J, Steele RE, Frank B (1986) Ureteral stone management: emerging concepts. J Urol 135:1172
99. Lingeman JE, McAteer JA, Kempson SA, Evan AP (1987) Bioeffects of extracorporeal shock wave lithotripsy. J Endourol 1:89
100. Loening SA, Mardan AH, Holmes J, Lubaraoff DM (1988) In vivo and in vitro effects of shock waves on dunning prostate tumors. J Urol 139:303A
101. Lupu AM, Fuchs GJ, Chaussy CG (1986) Calcification of ureteral stent treated by extracorporeal shock wave lithotripsy. J Urol 136:1297
102. Marberger M, Türk C, Steinkogler I (1988) Painless piezoelectric extracorporeal lithotripsy. J Urol 139:695
103. Marshall F, Makofski RA, Mark F, et al.: Shock wave destruction of renal calculi (1984) New technical modifications. J Urol 131:133A
104. Marshall F, Weiskopf F, Singh A, Mark F, Leo F, Sanders R, Makofski R, Walsh PC, Smith N (1988) A prototype device for nonimmersion shock wave lithotripsy using ultrasonography for calculus localization. J Urol 140:249
105. Martin X, Mestas JL, Cathignol D, Margonari J, Dubernard JM (1986) Ultrasound stone location for extracorporeal shock wave lithotripsy. Br J Urol 58:349
106. Mayo ME, Chapmann WH, Anwell JS (1986) Progress report on the lasertripter. J Urol 135:160A
107. McCullough DL, Yeaman LD, Bo WJ, Assimos DG, Kroovand RL, Griffin AS, Furr EG (1988) Do extracorporeal shock waves affect fertility and fetal development? A study of shock wave effects on the rat ovary and fetus. J Urol 139:325A
108. McCullough D, Yeaman LD, Bo WJ, Kroovand RL, Assimos DG, Griffin As (1988) Experimental effects of extracorporeal shock waves on the rat ovary and fetus. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 327
109. McMurty JM, Clayman RV, Sicord GA, Anderson CB (1988) Pulmonary embolism and deep venous thrombosis following extracorporeal shock wave lithotripsy. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 177
110. McNicholas TA, Ramsay JWA, Crocker PR, Webb DR, Wickham JEA (1986) The effects of extracorporeal shock wave lithotripsy on urological prostheses and endoprostheses. Urol Res 14:309
111. Meyer WW, Michels-Maisch B, Jonas D (1989) The effect of shock waves on MDCK-cells. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. P13–4)
112. Meyer WW, Jonas D (1989) First experiences with the Storz Modulith lithotripter. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. 02–1)
113. Miller K, Hautmann R (1987) Treatment of distal ureteral calculi with ESWL: experience with more than 100 consecutive cases. World J Urol 5:259
114. Miller K, Bachor R, Hautmann R (1988) Extracorporeal shock wave lithotripsy in the prone position: technique indications, results. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 43
115. Miller K, Bachor R, Hautmann R (1988) Percutaneous nephrolithotomy and ESWL versus ureteral stent and ESWL for the treatment of large renal calculi and staghorn calculi: Preliminary results of a prospective randomized study. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 89
116. Miller K, Bachor R, Sauter T, Hautmann R (1989) Aktuelle Therapie des Harnleitersteins. Urologe [A] 28:148
117. Mininberg DT (1989) Extracorporeal shock wave lithotripsy in children: an overview. J Endourol 3:385
118. Mueller SC, Wilbert D, Thueroff JW, Alken P (1986) Extracorporeal shock wave lithotripsy of ureteral stones: clinical experience and experimental findings. J Urol 135:831
119. Müller M (1987) Stoßwellenfokussierung in Wasser. Dissertation der Fakultät für Maschinenwesen, Rheinisch-Westfälische Technische Hochschule Aachen, 1987
120. Müller-Klieser W (1987) Multicellular spheroids. A review on cellular aggregates in cancer research. J Cancer Res Clin Oncol 113:101
121. Mulley Jr. AG, Carlson KJ, Dretler SP (1988) Extracorporeal shock wave lithotripsy: slam-bang effects, silent side effects? Am J Radiol 150:316
122. Muschter R, Kutscher KR, Bohle A, et al. (1987) Die ESWL mit dem Dornier Lithotripter HM3 mit modifiziertem Stosswellengenerator. Urologe [A] 26:33
123. Muschter R, Schmeller NT, Kutscher KR, Reis M, Hofstetter AG, Lohrs U (1988) Histological findings in renal parenchyma after extracorporeal shock wave lithotripsy. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 405
124. Muschter R, Schmeller NT, Scheu W, Hofstetter AG, Krech R, Löhrs U (1988) Reduktion der ESWL-bedingten Nierenparenchymschädigung - der modifizierte Dornier HM3 im Tierexperiment. Verh Ber Dtsch Ges Urol 39:72
125. Nakatsuka S, Kinoshita H, Ueda H, Araki T, Tanaka H (1988) Combined treatment of medullary sponge kidney by EDTA potassium citrate and extracorporeal shock wave lithotripsy. Eur Urol 14:339
126. Neisius D, Gebhardt T, Seitz G, Ziegler M (1989) Histological examination of the liver and gallbladder after application of extracorporeal shock wave to the gallbladder with the Piezolith 2200. J Lithotrip Stone Dis 1:26
127. Neisius D, Zwergel U, Becht E, Ziegler M (1989) Extracorporeal piezoelectric lithotripsy (EPL) of urinary calculi in children. J Urol 141:270A
128. Neisius D, Zwergel T, Moll V, Kanokogi M (1989) Extracorporeal lithotripsy of ureteral stones in situ. Proceedings of the 7th

World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. P2–20)
129. Newman DM Coury T, Lingeman JE, Mertz JH, Mosbaugh PG, Steele RE, Knapp PM (1987) Extracorporeal shock wave lithotripsy experience in children. J Urol 138:238
130. Newmann R, Hackett R, Senior D, Brock K, Feldman J, Sosnowski J, Finlayson B (1987) Pathologic effects of ESWL on canine renal tissue. Urology 29:194
131. Pastor J, Graff J, Senge T, et al. (1987) New development in ESWL without invasive anesthesia. Dornier User Lett 2:10
132. Peschke P, Hahn EW, Lorenz WJ, Debus J, Zabel HJ, Iffländer H, Lorenz A, van Kaick G, Pfeifer M (1989) Pulsed high energy ultrasound shock waves: biological effects on the dunning prostate rat tumor. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. P13–7)
133. Preminger GM, Clayman R (1989) The changing face of lithotripsy: impact of "second generation" machines. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. P7–18)
134. Psihramis KE, Dretler SP (1987) Extracorporeal shock wave lithotripsy of caliceal diverticula calculi. J Urol 138:707
135. Puppo P, Bottino P, Germinale F, Caviglia C, Ricciotti G (1988) Extracorporeal shock wave lithotripsy using double-J stents: technique, pitfalls, results and complications. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 35
136. Puppo P, Bottino P, Germinale F, Giuliani L (1989) Lithoring multi one: experimental studies and clinical applications. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. 01–7)
137. Rambow A, Staritz M, Klose P, Thelen M, Meyer zum Büschenfelde K-H (1989) Extrakorporale Stoßwellenlithotripsie von Gallenblasensteinen: Wie viele Patienten sind geeignet? Dtsch Med Wochenschr 114:895
138. Rassweiler J, Bub P, Eisenberger (1987) The role of ESWL for ureteric stones. In: Coptcoat MJ, Miller RA, Wickham JEA (eds) Lithotripsy II. BDI Publishing, London, p 135
139. Rassweiler J, Bub P, Seibold J, Schmidt A, Fehring K, Jipp P, Eisenberger F (1988) Dornier MPL 9000: urologic use in an interdisciplinary stone center. J Endourol 2:375
140. Rassweiler J, Buch J, Miller K, Fuchs G (1985) Computertomographische Steindichtemessungen zur Steinanalyse vor extrakorporaler Stoßwellenlithotripsie (ESWL). Aktuel Urol 16:30
141. Rassweiler J, Gumpinger R, Mayer R, Kohl H, Schmidt A, Eisenberger F (1987) Extracorporeal piezoelectric lithotripsy with modified Dornier HM3: a cooperative study. World J Urol 5:218
142. Rassweiler J, Gumpinger R, Miller K, Hölzermann F, Eisenberger F (1986) Multimodal treatment (extracorporeal shock wave lithotripsy and endourology) of complicated renal stone disease. Eur Urol 12:294
143. Rassweiler J, Köhrmann KU, Berle B, Pfenninger T, Marllinghaus EH, Alken P (1989) Experimental classification of a newly-designed electromagnetic shock wave source for lithotripsy. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. 01–2)
144. Rassweiler J, Köhrmann KU, Heine G, Wess O, Alken P (1989) Modulith SL 10/20 – First clinical experience with a new interdisciplinary lithotripter. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. P7–19)
145. Rassweiler J, Lutz K, Gumpinger R, Eisenberger F (1986) Efficacy of in situ extracorporeal shock wave lithotripsy for upper ureteral calculi. Eur Urol 12:377
146. Rassweiler J, Miller K, Fuchs G, Eisenberger F (1985) Kosten und Nutzen der berührungsfreien Nierensteinlithotripsie. Lebensversicherungsmedizin 3:80
147. Rassweiler J, Schmidt A, Gumpinger R, et al. (1987) Experimental basis of ESWL using different principles of shock wave generations. J Urol 137:278
148. Rassweiler J, Westhauser A, Bub P, Eisenberger F (1988) Second-generation lithotripters: a comparative study. J Endourol 2:193
149. Rassweiler J, Löbelenz M, Köhrmann U, Eisenberger F, Alken P (1990) In vitro comparison of second-generation lithotriptors using two stone models. In: Vahlensieck W, Gasser G, Hesse A, Schöneich G (eds) Proceedings of the 1st European Symposium on Urolithiasis, Bonn 1989. Excerpta medica, Amsterdam Hongkong Princeton, p 133
150. Recker F, Hofstadter E, Daus HJ, Rubben H, Bex A, Deutz FJ, Lutzeyer W (1988) Morphological pathomechanism following extracorporeal shock wave lithotripsy in rat kidneys. In: Lingeman JM, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 357
151. Recker F, Konstantinidis K, Jaeger P, Knönagel H, Alund G, Hauri D (1989) Der Nierenbeckenausgußstein: Anatrophe Nephrolithotomie versus perkutane Litholapaxie und ESWL versus ESWL Monotherapie. Ein Bericht über 6 Jahre Erfahrung. Urologe [A] 28:152
152. Riedlinger R, Ueberle F, Wurster H, Krauß W, Vallon P, Konrad G, Kopper B, Stoll HP, Goebbels R, Gebhardt T, Ziegler M (1986) Die Zertrümmerung von Nierensteinen durch piezoelektrisch erzeugte Hochenergie-Schallpulse. Physikalische Grundlagen und experimentelle Untersuchungen. Urologe [A] 25:188
153. Riedlinger R, Ueberle F (1986) Berührungsfreie piezoelektrische Nierensteinzertrümmerung. In: Proceedings of the 12. Gemeinschaftstagung mit Kolloquien der deutschen Arbeitsgemeinschaft für Akustik, 10.–13. März 1986
154. Rigatti P, Colombo R, Centemero A, Francesca F, Di Girolamo V, Montorsi F, Trabucchi E (1989) Histological and ultrastructural evaluation of extracorporeal shock wave lithotripsy-induced acute renal lesions: preliminary report. Eur Urol 16:207
155. Roth RA, Beckmann CF (1988) Complications of extracorporeal shock wave lithotripsy and percutaneous nephrolithotomy. Urol Clin North Am 15:155
156. Royce PL, Fuchs GJ, Lupu AN, Chaussy CG (1987) The treatment of uric acid calculi with extracorporeal shock wave lithotripsy. Br J Urol 60:69
157. Rubin JI, Arger PH, Pollack HM, Banner MP, Coleman BG, Mintz MC, Van Arsdalen KN (1987) Kidney changes after extracorporeal shock wave lithotripsy: CT evaluation. Radiology 162:21
158. Ruiz-Marcellán JR, Servio LI (1986) Evaluation of renal damage in extracorporeal lithotripsy by shock waves. Eur Urol 12:73
159. Russo P, Mies C, Huryk R, Heston WDW, Fair WR (1987) Histopathologic and ultrastructural correlates of tumor growth suppression by high energy shock waves. J Urol 137:338
160. Russo P, Stephenson RA, Mies C, Huryk R, Heston WDW, Melamed MR, Fair WR (1986) High energy shock waves suppress tumor growth in vitro and in vivo. J Urol 135:626
161. Ryan PC, Seery J, Colhoun E, Kiely EA, Nowlan P, Kaye E, Murphy B, Gaffney E, Butler MR (1988) Functional, morphological and microbiological effects of piezoelectric shock wave lithotripsy (EDAP LT91): an experimental and clinical study. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 399
162. Sackmann M, Delius M, Sauerbruch T, Holl J, Weber W, Ippisch E, Hagelauer U, Wess O, Hepp W, Brendel W, Paumgartner G (1988) Shock wave lithotripsy of gallbladder stones. N Engl J Med 318:393
163. Saltzman B (1989) Ureteral stenting during extracorporeal shock wave lithotripsy – friend or foe. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. L4)

164. Saunders JE, Coleman AJ (1987) Physical characteristics of the Dornier extracorporeal shock wave lithotriptor. Urology 29:506
165. Schulze H, Falkenberg F, Mondorf AW, Engelmann U, Senge T (1988) Enhanced excretion of kidney-derived antigens in the urine of patients after ESWL treatment. J Urol 139:323A
166. Seibold J, Rassweiler J, Schmidt A, et al. (1988) Advanced technology in extracorporeal shock wave lithotripsy: the Dornier MPL 9000 versus the upgraded Dornier HM3. J Endourol 2:173
167. Servadio C, Livne P, Winkler H (1988) Extracorporeal shock wave lithotripsy using a new compact and portable unit. J Urol 139:685
168. Shore N, Somers W, Riehle Jr RA (1990) Evolution of pre-treatment stenting and local anesthesia for extracorporeal shock wave lithotripsy at a single university center. J Urol 143:257
169. Sigman M, Laudone VP, Jenkins AD, Howards SS, Riehle Jr R Keating MA, Walker RD (1987) Initial experience with extracorporeal shock wave lithotripsy in children. J Urol 138:839
170. Sonda LP, Lipson S, Ross L, Hammond G, Drake D, Bowers G (1988) Report on safety and efficacy of the Medstone 1050 lithotripter. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 255
171. Sutherland RM (1988) Cell and environment interactions in tumor microregions: the multicell spheroid model. Science 240:177
172. Tanaka M, Matsumoto T, Kitada S, Kumazawa J, Hara S, Yamaguchi A (1988) Endotoxemia in patients who underwent ultrasonic lithotripsy and extracorporeal shock wave lithotripsy. Eur Urol 14:173
173. Thibault Ph, Dory J, Cotard JP, Moraillon JY, Vallancien G, André-Bougaran J (1986) Lithotripsie à impulsions ultracourtes. Etude expérimentale sur une lithiase rénale du chien. Ann Urol 20:20
174. Thomas R, Harmon E, Sloane B, Hurwitz G, Figueroa TE (1989) Effect of extracorporeal shock wave lithotripsy in children. J Urol 141:272A
175. Thomas R, Sloane B, Roberts J (1988) Effect of extracorporeal shock wave lithotripsy on renal function. J Urol 139:323A
176. Tomera KM, Benson RC, Martin X (1987) Sonolith 2000. In: Coptcoat MJ, Miller RA, Wickham JEA (eds) Lithotripsy II. BDI Publishing, London, p 65
177. Ueberle F (1988) Ein Konzept für Ultraschall-Ortung und Erkennung von Zielen für Schallpulse hoher Amplitude. Dissertation der Fakultät für Elektrotechnik der Universität Karlsruhe 1988
178. Vahlensieck Jr. W, Kürz H-J, Steinhauer H, Friedburg H, Sommerkamp H (1990) Side effects of extracorporeal piezoelectric shock wave lithotripsy (EPL). Urol Res 18:53
179. Valchanov V, Michailov P, Patrashkov T (1989) New possibilities of HM3 lithotripter for treatment of disturbed bone union. In: Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. P13–14)
180. Vallancien G, Aviles J, Munoz R, Veillon B, Charton M, Brisset JM (1988) Piezoelectric extracorporeal lithotripsy by ultrashort waves with the EDAP LT01 device. J Urol 139:689
181. Vallancien G, Brisset JM, Veillon B, et al. (1987) Clinical results with piezoelectric second generation LT01 lithotripter. J Urol 137:144
182. Vandeursen H, Baert L (1990) Extracorporeal shock wave lithotripsy monotherapy for bladder stones with the second generation lithotriptors. J Urol 143:18
183. Vandeursen H, Baert L (1990) Extracorporeal shock wave lithotripsy monotherapy for staghorn stones with the second generation lithotriptors. J Urol 143:252
184. Vergunst H, Terpstra OT, Schröder FH, Matura E (1989) Assessment of shock wave pressure profiles in vitro: clinical implications. J Lithotrip Stone Dis 1:289
185. Vergunst H, Terpstra OT, Schröder FH, Matura E (1989) Assessment of shock wave pressure profiles in vivo. Proceedings of the 7th World Congress on Endourology and ESWL, November 27–30, 1989, Kyoto, Japan (Abstract No. 01–4)
186. Wess OJ, Marlinghaus EH, Katona J (1989) A new design of an optimal acoustic source for extracorporeal lithotripsy. Presented at the Second Interdisciplinary International Symposium on Biliary Lithotripsy, Vancouver, April 24–26, 1989
187. Wilbert DM, Hutschenreiter G, Schärfe T, Riedmiller H, Alken P, Hohenfellner R (1988) Zweite Generation der berührungslosen Nierensteinzertrümmerung – klinische Ergebnisse der lokalen Stoßwellenlithotripsie. Aktuel Urol 19:93
188. Wilbert DM, Jungbluth A, Rosenkranz T, Reichenberger H, Rumpelt HJ, Riedmiller H, Alken P, Hohenfellner R (1987) Experimental evaluation of a new electromagnetic shock wave source. In: Jacobi GH et al. (eds) Investigative Urology, 2. Springer, Berlin Heidelberg New York
189. Wilbert DM, Reichenberger H, Hutschenreiter G, et al. (1987) Second generation shock wave lithotripsy: experience with the Lithostar. World J Urol 5:255
190. Williams CM, Kaude JV, Newman RC, Peterson JC, Thomas WC (1988) Extracorporeal shock wave lithotripsy: long-term complications. Am J Radiol 150:311
191. Wilmer A, Gambihler S, Delius M, Brendel W (1988) Shock waves enhance the cytotoxicity of Cisplatin but not of Adriamycin. Eur Surg Res 20:89
192. Wu W, Wu H, Zhou X-M (1990) "Dry lithotripsy" by a simple modification of the Chinese lithotripter KDE-1. Urol Res 18:57
193. Wurster H, Ziegler M, Marberger M (1987) Piezolith 2200 (Richard Wolf GmbH). In: Coptcoat MJ, Miller RA, Wickham JEA (eds) Lithotripsy II. BDI Publishing, London, p 91
194. Yeaman LD, McCullough DL, Jerome CP (1988) Effects of extracorporeal shock waves on immature bone growth of the rat. J Urol 139:324A
195. Yokoyama M, Kitahara K, Yanagizawa R, Shoji F, Osaka M (1988) Tissue damage by extracorporeal shock wave lithotripsy treatment in patients with urolithiasis: Clinical evaluation. In: Lingeman JE, Newman DM (eds) Shock wave lithotripsy – State of the art. Plenum Press, New York London, p 377
196. Ziegler M, Mast G, Neisius D, Zwergel T, Kopper B, Zwergel U, Wurster H, Riedlinger R (1988) Results in the use of extracorporeal piezoelectric lithotripsy (EPL) for treatment of urinary calculi. Urol Int 43:35
197. Zwergel U, Neisius D, Zwergel T, et al. (1987) Results and clinical management of extracorporeal piezoceramic lithotripsy (EPL) in 1,321 consecutive treatments. World J Urol 5:213

Dr. J. Rassweiler
Urologische Abteilung
Klinikum Mannheim der Universität Heidelberg
Theodor-Kutzer-Ufer
W-6800 Mannheim 1
Federal Republic of Germany