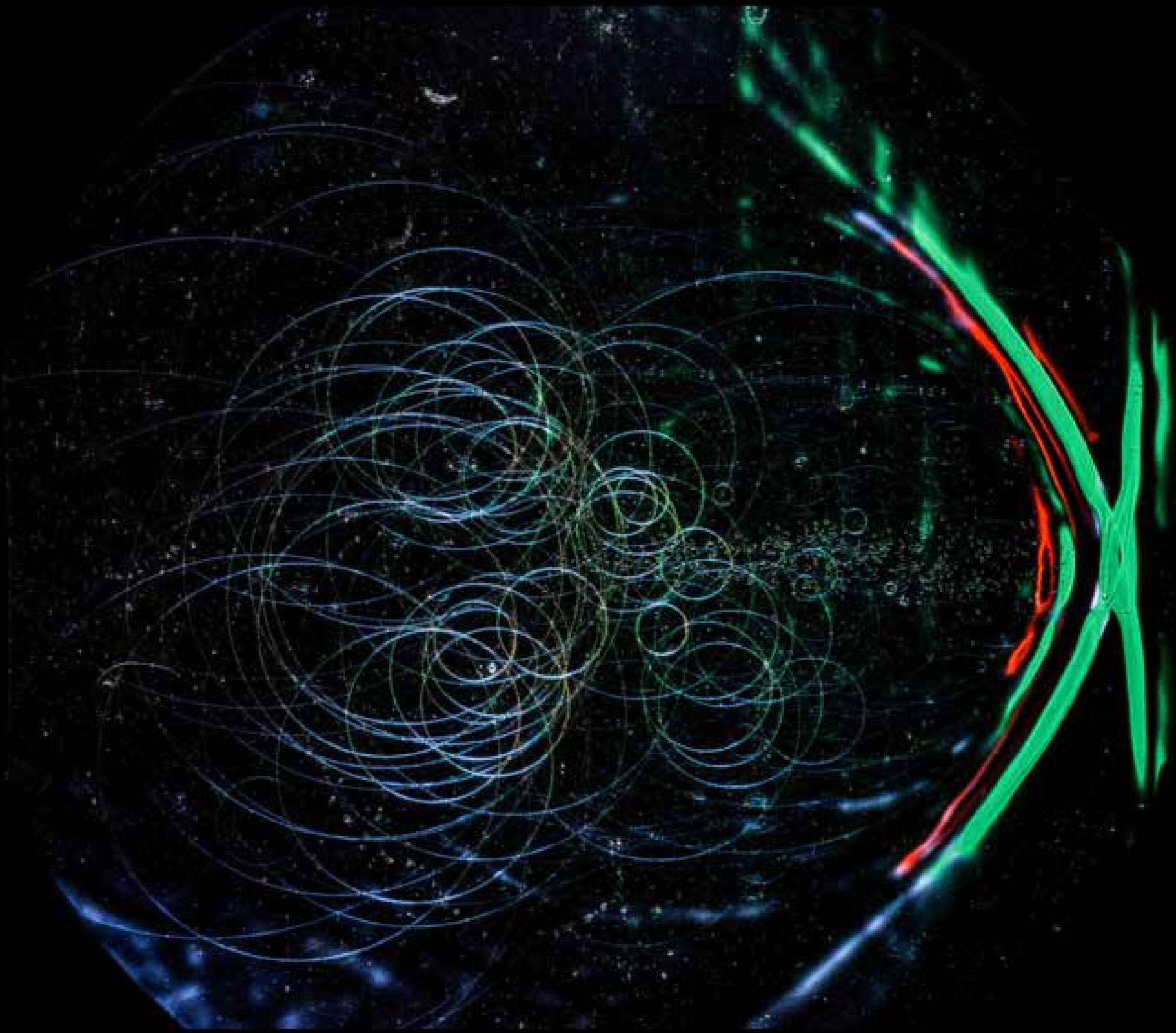

Four decades with Extracorporeal Shock Wave Lithotripsy

Lessons learnt

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Christian Chaussy

1st Edition February 2023

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Design: BAMBERG kommunikation GmbH
Cover photo: Othmar Wess and Jürgen Mayer
Printing and bookbinding: Schweikert Druck
Wieslensdorfer Str. 36, 74182 Obersulm-Eschenau
Printed in Germany

ISBN

Four decades with Extracorporeal Shock Wave Lithotripsy

Lessons learnt

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Hans-Göran Tiselius, 1985

Hans-Göran Tiselius

Hans-Göran Tiselius was born in Stockholm in 1945. His medical studies started at Karolinska Institutet, Stockholm, in 1965 and continued in Lund from 1967 until 1972. after which he achieved the M.D.-degree. A growing interest in surgery brought him to Linköping where clinical education in general surgery was started in 1973.

He began research in medical/clinical chemistry already in 1964 at Karolinska Intitutet/Karolinska hospital. This activity subsequently was run parallel with the medical studies and during the time in Lund, he also simultaneously had intermittent employment as assistant at the department of Medical Chemistry. Ph.D thesis with the title "Metabolism of vitamin B6" was presented and defended in Göteborg in 1974.

The connection between medical chemistry and urology might appear weak, but vitamin B6 is involved in the metabolism of oxalate and this vague association was one factor that contributed to a change from general surgery to urology in 1977 with the aim of focusing on urolithiasis. In 1980 he became Associate Professor of urological surgery in Linköping. Advances in the understanding of the biochemical background to stone formation was one factor that contributed to the national decision to install the first ESWL unit in Linköping in 1985. During the following 13 years in Linköping and 15 years in Stockholm Hans-Göran Tiselius spent most of his clinical and scientific efforts on ESWL, other stone removing modalities and stone recurrence prevention. This work resulted in considerable experience and expertise in non-invasive and least-invasive stone removal.

Hans-Göran Tiselius was head research supervisor for five young urologists in Linköping who were examined with Ph.D.-degree between 1984 and 1998. Hans-Göran Tiselius became Professor of urology first in Linköping 1992 and in Stockholm 1999 (Karolinska Institutet).

He was given the Fernström Award to young scientists in 1984, Curt Engelhorn Award, European Foundation of Advancements in Medicine, in 1998, Life-time achievements Award by the International Society of Urolithiasis in 2016.

Between 1989 and 1992 he was Managing Editor of Scandinavian Journal of Urology and Nephrology and since 1998 Associate Editor of Urolithiasis. He was invited as honorary member of the European Association of Urology in 2011, the Swedish Association of Urology 2012 and EULIS in 2017. He is also a senior honorary member of Societé International Urologie.

Hans-Göran Tiselius formally retired in 2010 but continued to work part time in the stone unit in Stockholm/Huddinge until 2013 after which he has been scientific advisor to colleagues in Guangzhou and Wuhan and has been the author of Comments to ESWL articles for Storz Medical since 2011.

The number of publications is around 400 and the oral presentations amounts to approximately the same number.

Editors

Christian G Chaussy, 1982

Christian G Chaussy

studied medicine in Munich, Germany. He spent several years as staff member at the Institute for Surgical Research, University of Munich where he did mainly research in the field of Transplantation/Xenotransplantation. Together with Walter Land he started 1976 the Transplant Center at the Dept. of Surgery, Univ. Munich. During his residency at the Dept. of Urology, Univ. of Munich, he began 1975 (together with Ferdinand Eisenberger and Bernd Forssmann) the pre-clinical and clinical research for Extracorporeal Shock Wave Lithotripsy (ESWL) and treated on February 7th 1980 the first patient worldwide with ESWL.

In 1981 he became Professor for Urology, University of Munich. 1984 Chaussy accepted a tenure position at UCLA as Professor of Urology and Head of the Stone Center which he left in 1986 to accept the position as Chairman of the Department of Urology of the University Associated Klinikum Harlaching in Munich from which he retired in February 2010. In 1996 he had started at his Department, together with Stefan Thueroff, the use of High Intensity Focused Ultrasound (HIFU) for the treatment of localized Prostate Cancer. They treated 3,000 patients until 2010.

Besides his regular memberships in numerous Medical Societies and International Committees he is honorary member of several National and International Surgical and Urological Societies. Among these are the Honorary Fellowship Royal College of Surgeons Edinburgh, the Honorary Membership of the Brazilian College of Surgeons, the Professorship of the Medical University of Beijing, the Honorary Membership of the Georgian Urological Association, the Honorary Membership of EULIS, the Honorary Membership of the Urological Association Republic of China, the Honorary Membership of the AUA and the Honorary Membership of the Endourological Society.

From 1995–2010 he was President of the German Lithotripsy Society and became their Honorary President in 2011. In 2009 he served as Scientific Chairman of the 27th WCE in Munich. 2011 he was President of the Endourological Society.
Besides his professorship at the Ludwig-Maximilians-Univ. Munich C. Chaussy is also Professor at the Department of Urology, University of Regensburg and was after his Retirement for a few years Clinical Professor of Urology at the Keck School of Medicine, USC.

Throughout his career, Dr. Chaussy has received many Awards among which are the von-Langenbeck Award of the German Surgical Society, the Ritter-von-Frisch Award of the German Urological Society, the Distinguished Contribution Award of the AUA, the Lifetime Achievement Award of the Endourological Society, the Innovators in Urology Award of the EAU, the Lifetime Achievement Award of EULIS and European Science Award, the Lifetime Achievement Award of the IAU and the Presidential Citation Award of the AUA. He was also honoured with the Federal Cross of Merit on Ribbon of the FRG.

Abstract

Extracorporeal shock wave lithotripsy (SWL) undoubtedly revolutionized the treatment of patients with urolithiasis in 1980 and this treatment subsequently has been applied in several millions of patients. This treatment modality, however, has been and is still used with different levels of ambition and accordingly with variable results. Consequent use of SWL with attention paid to the details required for a satisfactory outcome offers a least-invasive treatment for stone disintegration. Handled with appropriate care, the results can be better than what comparative studies with endoscopic procedures usually indicate, and this is particularly true for ureteral stones. SWL provides a treatment that not only is least-invasive, economic, and possible to complete without general or regional anesthesia, it also can be carried out in an out-patient setting without access to an operating theatre. Moreover, this anesthesia-free method was found to be an excellent way of stone treatment while simultaneously avoiding aerosol exposure of staff members to covid-virus. Gentle auxiliary procedures not requiring anesthesia can be helpful for dealing with problems encountered in some patients who are not entirely and successfully treated with SWL.

In this review we have summarized different clinical routines that have emerged from consequent use of SWL in the past approximately four decades. The main purpose was to provide practical, hands-on information on how to handle patients in the SWL process with attention to treatment results and safety.

1. Introductory comments

The first clinical disintegration of a kidney stone with shock wave lithotripsy (SWL) was carried out in Munich, Germany in 1980 [1–3]. This successful event proved that the technology that had been developed and experimentally tested over a period of approximately 10 years, was possible to use for non-invasive disintegration and elimination of stones in humans. The fruitful collaboration between the Dornier company and the Grosshadern urological clinic in Munich had resulted in an outstanding treatment modality that dramatically and for ever changed the principles of stone surgery. After few years the technique disseminated worldwide. In Linköping, Sweden, the first SWL was carried out in April 1985.

Subsequently different SWL devices were developed and introduced clinically with the aim of non-invasive stone disintegration. Accordingly, several electro-hydraulic, piezoelectric, and electromagnetic lithotripters of various kinds were used with varying treatment capacities and results. The devices commonly were called shock wave machines, a description that erroneously gave the impression that the lithotripter automatically can accomplish satisfactory stone disintegration and successful clearance of stone material. This is a serious misinterpretation, and it is important to emphasize that successful SWL needs careful attention to many details. In previous publications we have emphasized the advantages of SWL and how to optimize its clinical use. Simultaneously and partly attributable to great variations in SWL results with common occurrence of residual fragments, there has been an impressive technical development of low-invasive endoscopic techniques: ureterorenoscopy (URS), percutaneous nephrolithotomy (PCNL), flexible URS and retrograde intrarenal surgery (RIRS). Although the latter technical achievements undoubtedly are very effective and preferred by many urologists it stands to reason that SWL still is the dominating and least invasive treatment modality for stone patients worldwide.

A search in PubMed in May 2022 showed that approximately 9,000 articles had their focus on SWL and the intention with the present article was not to summarize the great clinical experience reported in these publications or to review comparisons between non-invasive and invasive, treatment modalities, but rather to emphasize how important it is to pay attention to numerous details before, during and after SWL to be successful with this non-invasive treatment. Literature results as well as extensive personal experience have taught us how SWL can be carried out to give successful results without jeopardizing patient safety.

Figure 1 shows important factors necessary to consider by every SWL operator and the different points will be briefly discussed below. As mentioned, this has been done before, but the intention with this review was to give clear and detailed straightforward advice on how to carry out SWL, as close to a “manual of SWL” as possible. There always are some gaps between general advice and how to translate them into a clinically working strategy. There are numerous questions that need an answer: For whom? When? Why? How? How often? How long? How many? How much? All recommendations in this article are based on personal clinical experience which together with literature reports helped us to formulate clinically useful and successful least-invasive regimens for different stone situations and patients with specific features.

Undoubtedly, the authors have an accumulated extensive clinical experience with different lithotripters on the market and subsequently applied that knowledge to continuously modify and improve treatment principles. The aim was to establish clinical routines that were effective, easy to follow, least-invasive, safe, and with treatment results that satisfied the expectations of all involved parts. Because of the many technically different lithotripters on the market, the handling of any specific lithotripter was not the scope of this review. In that regard each manufacturer usually has clear recommendations to which the reader is referred.

Introductory comments

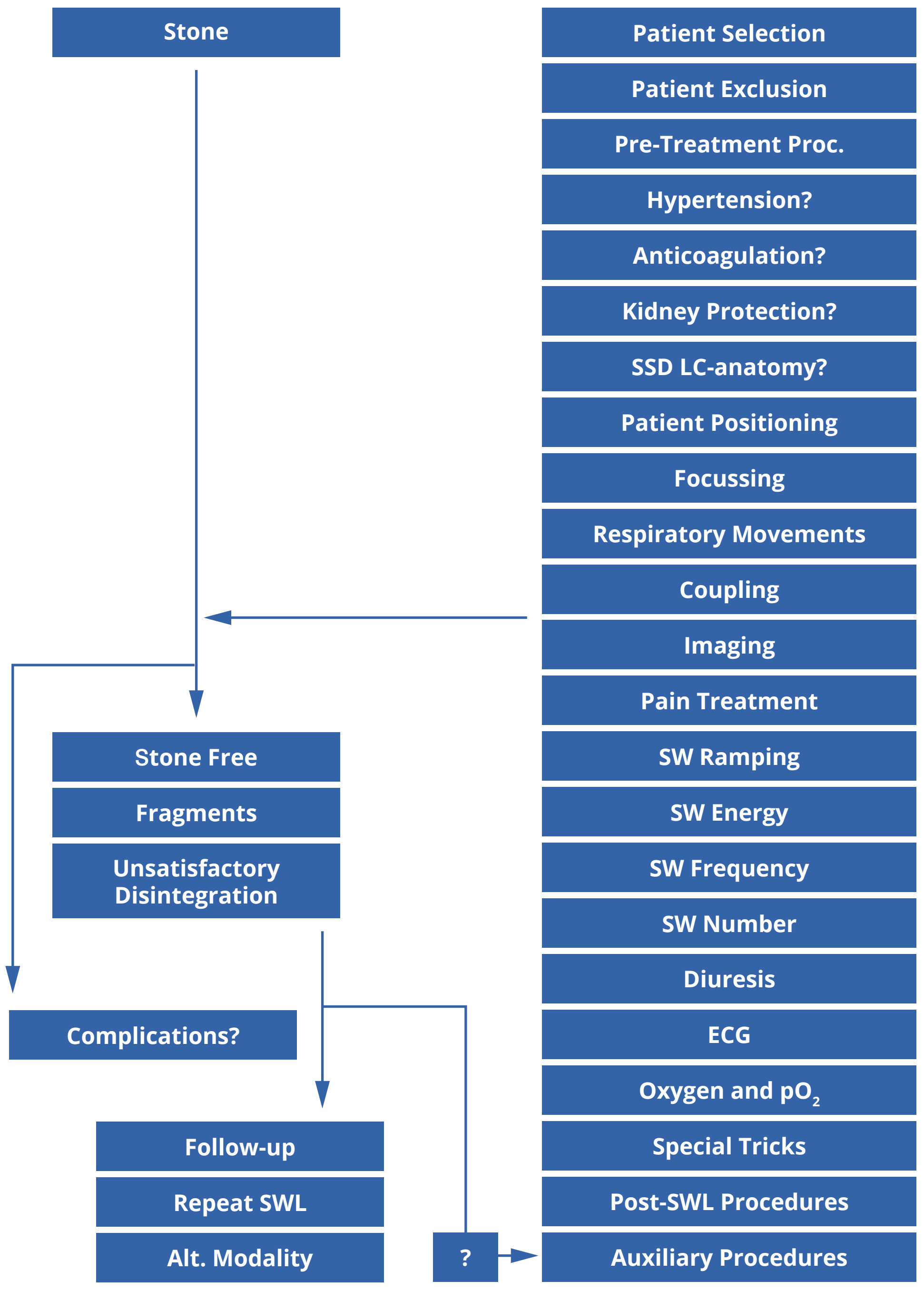

Figure 1
Overview of the SWL procedure and different factors of importance for best treatment outcome.

Our impression from numerous scientific reports, as well as from many visits to national and international stone clinics, is that SWL is carried out with highly variable levels of ambition. Whereas some centres for instance use powerful pain treatment, others seem to have as goal to disintegrate the stones by using no pain treatment or only marginally effective analgesic agents. High diuresis, respiratory control, administration of oxygen, ECG recording, and careful patient positioning dictated by the shock wave path are applied variably. Moreover, insufficient attention is paid to details so important for success and in many centres stereotypic standard protocols are followed uncritically. This decrease in treatment ambitions has occurred parallel with the increasingly popular and attractive, albeit invasive, endoscopic treatment.

It is important to know, however, that what is summarized below, is not in every aspect supported by or the result of strict scientific analyses, but the methodology and treatment strategies were slowly introduced over time under strict medical control. In long-term perspective the recommendations have shown to be effective and safe in the treatment of thousands of patients.

Finally, it must be said that SWL not always gives successful results. Like in all surgical and medical treatments there are shortcomings, but the outcome is much better than generally expected and much better than what sometimes is shown in the literature. The latter statement is particularly true for treatment of ureteral stones.

Below follows a sequence of considerations aiming at optimal application of SWL in clinical practice. The details and recommendations presented in this text have been discussed in several previously published review articles where the reader also can find additional information and necessary supporting references [2–18].

2. Patient selection

It is repeatedly emphasized in the literature that appropriate selection of patients is one important pre-requisite for successful SWL. The determining factors in this regard are stone size, stone location and stone composition (hardness). The literature is rich of data to be applied in terms of patient selection. It is of fundamental importance, however, to distinguish between stones in the kidney and stones in the ureter. Practical clinical updated recommendations for SWL have been published by EAU, AUA and recently by IAU [19]. The recommendations are slightly different but can roughly be summarized as follows.

SWL is most appropriate for stones in the upper, middle calyces and the renal pelvis when the largest stone diameter is ≤ 20 mm (~200–250 mm^2), for lower calyx stones with a largest diameter of ≤ 15 mm (~100–150 mm^2) and for ureteral stones measuring ≤ 10–15 mm (~50–150 mm^2). For stones in the lower calyx a favourable anatomy is mentioned as another prerequisite. Four factors determine the lower calyx anatomy: calix length, calix height, calyx width and outflow angle. Measurements in our patients showed that calix height and length are sufficient variables for calculation (not measurement) of the calyx outflow angle. The angle together with the calix height were useful estimates of the geometry. In the literature, measurement of the outflow angle has been defined and carried out in different ways and it can be concluded that such estimates were easier to obtain from pyelography with contrast than from NCCT examinations. It is possible that application of AI in the future can be helpful in this regard. Before the first SWL session, however, it is seldom necessary to include these anatomical variables in the selection of patients. The clearance can be predicted reasonably well from inspection of the calyces on the NCCT images. To improve elimination of lower calix residual fragments, inversion therapy can be very helpful. Other auxiliary treatment procedures are discussed below.

It is well-recognized that disintegration of stones in the kidney might be associated with residual fragments. Such fragments are in most cases found in the lower calix, either because the treated stone initially was located there, or because disintegrated stone material from another part of the kidney moved to the lower part of the kidney because of gravity. From such observations it can be concluded that patients' mobility is of importance not only for stone clearance but also for how stone fragments move within the kidney. Accordingly stone clearance generally is much better in young than in old patients. Why the stone size is important for lower calyx clearance is not easily explained, but one assumption is that larger stones in the lower calyx may have destroyed or weakened the contractile power of the calyx musculature and thus negatively affected the fragment clearance in that part of the kidney. Such a mechanism might occur also in the other calyces, but without a similarly disturbed elimination of fragments.

The situation is completely different for SWL of ureteral stones. Once disintegrated, the stone material has a straightforward way for elimination. It is thus of no surprise that the occurrence of residual fragments following SWL of ureteral stones is much less than that for kidney stones. When problems are encountered, they are usually associated with impacted stones and ureteral oedema, but most of those problems can be dealt with by applying gentle auxiliary procedures. Only the most therapy resistant residual stones might require ureteroscopy.
Stones located in the ureter, however, might present different problems for transmission of the shock wave power from the therapy head to the stone. It thus stands to reason that successful disintegration and elimination of ureteral stones cannot be obtained unless combined with careful topographical three-dimensional thinking. This issue is further discussed below. The current urological literature apparently often favours endoscopic removal of ureteral stones and particularly so for distal stones. The arguments for that are difficult to understand because in a review of 600 consecutively treated patients with ureteral stones more than 83 percent of distal stones were successfully disintegrated with only one session and without anaesthesia. Further details of ureteral stone treatment results are shown in Table 11a.

It is important to consider that when anaesthesia-requiring endoscopic procedures are impossible for one reason or another, the indications for SWL can be

expanded provided repeated sessions and low-invasive auxiliary procedures can be accepted. Other factors to consider is the stone composition and the stone hardness. Stones composed of COM, brushite and cystine are more SWL resistant than COD, HAP, MAPCarbAp and uric acid stones. With an effective lithotripter, however also hard stones (HU>1000) can be disintegrated. The skin-to-stone distance (SSD) might be important for selecting the most appropriate shock wave energy, but if the stone can be placed in focus this measure usually has been of minor importance in our hands.

In view of the low degree of invasiveness SWL is an excellent method for stone removal in children. Although individual tolerant children can be treated with only analgesics and sedatives, general anaesthesia has been the rule.
Presence of pacemakers or defibrillators is not a contraindication, but it is wise to consult the patient's cardiologist and literature information before SWL.
Importantly, some patients should or must be excluded from SWL. Pregnancy is an absolute contraindication. In patients with coagulation diseases, SWL might be an option provided necessary precautions and preparations have been made. In those cases, it is of utmost importance to plan the treatment strategy in close collaboration with coagulation experts. Large stones, partial or complete staghorn stones composed of cystine, brushite and COM might be associated with problems both regrading disintegration and fragment elimination and for such patients, endoscopic stone removal is recommended. But these patients comprise a relatively small group. In case of infection staghorn stones, the least invasive approach is to combine stone disintegration and chemolysis. This strategy, however, is time consuming and demanding for the patients and although the method is extremely gentle, it requires insertion of two percutaneous nephrostomy catheters. It is today applied only exceptionally.

Stones located in calyx diverticula and calyx cysts can be disintegrated, but although that might render the patient pain-free for some time, the recurrence risk is high and for those patients, endoscopic procedures are recommended. There are also patients in whom anatomical abnormalities present a wide range of problems, but in those cases the most appropriate treatment modality must be decided and planned individually.

3. Pre-treatment steps.

Careful patient information

Of course, it is mandatory to inform every patient what SWL is, how it is carried out and how the individual plan is. This step is best accomplished by printed and illustrated as well as verbal information. Today many patients are well informed because they seek information on the web, but contradictory conclusions are not unusual. In addition to careful information, one of the most important pre-treatments steps is to tell the patient what can be expected from the treatment and to mention the rare complications that might occur. It is well spent time if the patient is aware of the possibility of repeated treatment sessions. Patients should be carefully informed that if more than one SWL session becomes necessary, this is part of the procedure and should not be considered as a failure, but rather as a consequence of how SWL works. In this regard the patient should be told that although repeated sessions for various reasons might be necessary, also repeated treatments, in contrast to endoscopy, can be completed with only analgesics and sedatives. It is important to emphasize, however, that there is no guarantee that only one treatment session is sufficient even if strict selection criteria are used.

Prediction of risk of serious complications and how to avoid them.

It is before SWL that the efforts should aim at reduced or eliminated risk of complications. The most serious complications are subcapsular renal hematomas, renal injuries of other kinds and infection leading to septicaemia. In patients with hypertension, shock waves never should be directed to stones in the kidney or to the proximal ureter if there is risk that some shock waves will pass through the renal tissue. Never proceed to SWL unless the hypertension has been adequately treated! Our experience has shown that it is wise to be particularly careful with shock wave energy, number of shock waves and shock wave frequency also in normotensive patients but who have a history of hypertension. The basic rule is that it is better to repeat SWL than to overtreat the patient on one occasion. The definition of hypertension may be different in different clinics, but even the suspicion of high blood pressure should result in an internal medicine consultation for appropriate treatment.

How to deal with patients on anticoagulation treatment.

There is increased risk of bleeding complications in patients on treatment with thrombocyte aggregation inhibitors (for instance salicylates, aspirin, Plavix and other agents with similar action). There should be no SWL unless such medication has been stopped for at least 7 days. Our principle has been to wait 10 days for kidney stones, which is the approximate time required for new thrombocytes to form. There are special rules for other agents with effect on coagulation. For those situations it is recommended to consult the patient's internist before proceeding to treatment. The basic principles for handling patients with anticoagulation treatment is summarized in Table 1.

For patients on treatment with salicylate (Aspirin and other similar thrombocyte aggregation inhibitors).

Stop treatment **(7–)10 days** before planned SWL.

Discuss need of bridging therapy with the patient's internist!

Warfarin: Stop treatment 3 days before SWL.

For modern anticoagulating agents (**NOAK**) the experience is limited and in all these patients, consultation with anticoagulation experts should be carried out.

Except for salicylates, it is always wise to give bridging therapy for these patients: **Fragmin** (Dalteparin®) or **Inohep** (Tinxaparin®) 2500–5000 IE per day, INR < 1.2. Do not administer low-molecular heparin agents until after the SWL-session.

Table 1
General principles for dealing with anticoagulation treatment in patients planned for SWL.

Moreover, it is important to know if there is any risk associated with short-term or intermittent arrest of anticoagulation treatment. Although the bleeding risk is much lower for treatment of stones in the ureter it is recommended to apply these principles for all patients irrespective of stone location. When bridging therapy with low-molecular heparin compounds (Fragmin®, Inohep® or similar agents) is necessary, never give more than 2500–5000 IE per day! Always administer this agent after SWL, never administer these agents before the treatment! If anticoagulation treatment cannot be stopped, ureteroscopy or RIRS should be considered.

Avoiding infection complications
Patients with symptomatic and culture verified urinary tract infection should be adequately treated with antibiotics before SWL. All patients should have a bacteria test carried out immediately before the treatment also when they are asymptomatic. In case of a positive test our experience has shown that administration of a broad-spectrum antibiotic agent 1–2h before SWL has been effective to prevent infection complications. (Table 2)

Table 2
Pre-SWL antibiotic treatment of patients with asymptomatic positive bacteria test.

If the bacteria test is positive but the patient is without infection symptoms:

Give an appropriate broad spectrum antibiotic agent one hour before SWL.

In case of urinary tract bacteria demonstrated by positive urine culture:
Pre-treat with appropriate antibiotics until the infection is cured.
If possible, wait 2 weeks before SWL.

For all patients one suppository of Diclofenac 30–60 minutes before SWL-start as complement to the pain-treatment.

Protection of kidney tissue.
In patients with advanced reduction in renal function it is wise to avoid SWL. In patients with moderately reduced renal function, it might be of value to give the patient some tissue protective treatment. Several agents have been ascribed tissue protection for instance allopurinol and verapamil. Table 3. There is no consensus on such a regimen, but it might be worthwhile in patients at risk of further reduced renal function.

Table 3
Administration of tissue protective agent in patients with moderately elevated creatinine.

Allopurinol 300 mg or **Isoptin 40 mg** (Verapamil®) before SWL

Moreover: **Small number** of shock waves at **low frequency** (1Hz) and with **low levels of energy.**

Premedication
Early attention to the pain treatment might be rewarding and reduce the doses of analgesics and sedatives during the SWL session. Already 30–60 minutes before start of SWL the patient will benefit from a suppository of 50 mg diclofenac, Table 2.

4. Patient positioning

For SWL of stones in the kidney most patients advantageously can be treated with shock waves transmitted from the back. The exception is when the shock wave hits a rib. In such cases the pain can be intolerable and administration of shock waves from the abdominal side is superior. For SWL of stones in the ureter there is no absolute best position. Each patient and stone location must be subject to an individual decision. Distal ureteral stones might be best approached from the abdominal side, whereas some stones are better treated with shock waves delivered transgluteally. Interference between the shock wave and skeletal structures are common and need to be carefully observed. It is important to make sure that there is no hinder for shock wave transmission and adjust patient position accordingly. The spine, transverse processes, and the pelvic skeleton are obvious obstacles. For adequate conclusions of the best patient position, it is necessary to be aware of the direction of the shock wave path.

For determination of the direction of the shock wave path, see below under "Special tricks".

5. Coupling

When the water tub used in the Dornier HM3 lithotripter was abandoned, the important problem was to get transmission of the shock waves with as little loss of power as possible. Ultrasound gel is the most used medium for shock wave transmission, but it is important that this medium is free from air bubbles. It is important that the amount of gel is sufficient to enable optimal shock wave transmission. Special ultrasound quality gel should be used, and a suitable aliquot stored in tubes before clinical use to allow bubbles to disappear. The medium should be carefully applied to avoid introducing air bubbles. Recent optical systems in some lithotripters might be useful to detect and remove air under visual control.

When water is part of the transmission medium, as in the Storz Modulith lithotripters, it is essential that the water is degasified before use. This goal can be accomplished by boiling the water before storage in bottles at 37°C.

It is of course also highly important to make sure that the water in the therapy head is free of air bubbles. If not, that problem also needs to be dealt with. In case of hairy skin at the entrance point for the shock wave, shaving is necessary. Air bubbles will attach to hair with attenuation of the shock wave power.

6. Imaging

Radiology

Fluoroscopy is an excellent way for detecting stones, to place the stone(s) in focus and to follow the treatment progress. One important rule is, however, that when the stone has been identified, always use the collimators to reduce the radiation field! This is very often neglected and in too many departments that we have visited worldwide, the fluoroscopic field has been wide open! Reduction of a fully open window will reduce the radiation dose dramatically. There are several other tricks that have been recommended such as frozen fluoroscopic images. Unfortunately, appropriate focusing requires dynamic information and it is uncertain whether that technique really will reduce the total radiation dose. The assumption is that the hit-rate will decrease and that is undesirable.

Ultrasound

Stone localization by ultrasound is of course ideal to avoid radiation and should be preferred in children. Unfortunately, ultrasonography is difficult to learn and impossible to use in some parts of the urinary tract. This is the reason why fluoroscopy in most clinics so far has remained the standard method. Nevertheless, US should be more commonly used in the future.

7. Focussing

To position the patient so that the stone is in focus with a high hit-rate is only one part of the initial step. The other and equally important step is to make sure that the shock wave path does not interfere with anatomical structures. Transverse processes of the spine, the spine itself, the sacroiliac and pelvic skeleton as well as the ribs are anatomical structures of great importance in this regard. The same is true for intestinal gas if shock waves are administered transabdominally. Intestinal gas might negatively affect the shock wave power and reduce the quality of the fluoroscopic image.

When intestinal gas can be an expected problem, pre-treatment of patients with Dimeticon (Minifom®) five days before SWL might at least occasionally be beneficial. Some other methods are also presented in Table 4. Laxatives as a general preparation should be avoided because such a regimen often makes the situation worse. During the early days of SWL laxatives was part of the patient preparation, but in Sweden that kind of preparation was abandoned in 1998, almost 25 years ago.

Table 4
Methods aiming at removal of intestinal gas before SWL.

These principles should be applied for patients with lots of intestinal gas in whom it is necessary to administer shock waves transabdominally and it is assumed that the treatment otherwise would be without effect.
Dimethicon (Minifom®) **100 mg/mL 3 ml x 3** during **FIVE days** preceding SWL When necessary give an enema before SWL: **Docusate/Sorbitol 120 mL** or occasionally in difficult cases early on the SWL-day: Pretreatment with **1 L** of **Macrogol** to which is added **~10 mL** of **Dimethicon**. KUB on the day of SWL is recommended to determine the gas situation!

8. Respiratory movements

One annoying feature commonly encountered during SWL is that respiration moves the stones out of focus. This focus instability might result in significantly reduced number of shock waves that actually hit the stone. Although most literature reports give data on the total number of delivered shock waves, it is very seldom mentioned how many of them that actually did hit the stone. For stones in the ureter such movements are usually less common except for the uppermost part of the ureter that usually moves together with the kidney.
It was early shown that technical solutions with respiratory triggered shock waves failed to solve the problem in awake patients. The most successful approach were belts or abdominal compressing devices. Our routine in most patients was to use belts whenever possible with the important note that the belt should not compromise respiration and oxygen tension must be measured! It was early discovered that an increased hit-rate can be further achieved by adjusting patient position so that the stone remains in focus during the longer expiratory phase.

When the shock wave path is directed towards or passes the lungs it is necessary to protect the lung-field with polystyrene. This step is particularly important when treating children.

9. Pain treatment

One thing that has become quite clear is that if patients feel pain or discomfort during SWL, the outcome will be disappointing. Over time different pain treatment methods have been applied. Initially it was assumed that SWL required regional or general anaesthesia and this view is still held by some operators.
It was shown, however, that with appropriate analgesics and sedatives, it was possible to use also the original unmodified Dornier HM3 lithotripter without general or regional anaesthesia. In Sweden use of general anaesthesia and peridural anaesthesia was abandoned in 1987 and subsequently treatments were carried out with only analgesics and sedatives and the unmodified Dornier HM3 lithotripter for additionally 10–11 years.

With the introduction of modern lithotripters based on electromagnetic and piezoelectric generation of shock waves, patients' pain experience was decreased, and regional and general anaesthesia were generally abandoned worldwide. Subsequently a series of pharmacological pain treatment models were introduced, most of them efficient. But according to our own experience one of the winning concepts was intermittent administration of small doses of alfentanil and propofol or alfentanil alone. These two agents are powerful, but when handled with care it was proven that they have been used without problem in several thousands of patients. The common dosage is shown in Table 5. The recommendation is always to give these patients oxygen on mask or via nose catheters, 2 L per minute and to measure pO_2.

Table 5
Recommended analgesics and sedatives for SWL.

The regimen below has been rewarding in our hands. It needs to be emphasized, however, that these recommendations may not be allowed in all clinics. For those situations it is necessary to follow the local regulations!

Average doses based on recordings from 3500 consecutive SWL sessions.

Alfentanyl (Rapifen®) 0.9 mg
Propofol (Diprivan®) 74 mg

The two agents are given in small intermittent doses intravenously during the treatment to keep the patient free of pain.

Suggested start doses:

Alfentanyl [0.5 mg/mL]: **~ 0.5 mL** (–1 mL)
Propofol [10 mg/mL]: **~ 2 mL**.

If **bradycardia** appears with this treatment regimen, give **0.5 mg of atropine!**

In case of raised blood pressure during SWL additional analgesics are usually necessary but if that step does not help, it is wise to stop the treatment. Practical limit of 160/95.
It is recommended to measure the blood pressure intermittently during the treatment, but too frequent blood-pressure measurement is disturbing to the patient and might result in patient movement and lost focus. For propofol adapted dosed are recommended for old and weak patients. In very weak, old and brittle patients it is recommended to only use alfentanyl.

It is necessary to carefully educate nurses and colleagues on how to handle alfentanil and propofol and how this form of pain treatment should be applied without loss of safety. With appropriately educated nurses and urologists there may be no absolute need of an anaesthetist. But in this regard, it is necessary to adhere to the local and national regulations.

10. ECG-recording

With the pain-treatment regimen in Table 5 it is important to follow the heart rate with ECG-registration because bradycardia occasionally might require administration of atropine (Table 5). Moreover, the initial experience with SWL, mainly with the Dornier HM3 device showed that the electromagnetic field sometimes resulted in ventricular extra heart beats or ventricular electrical complexes (VES). Because this side effect might be dangerous, shock waves were triggered by the R-wave of the ECG signal. But because VES mainly disappeared with use of electromagnetic shock wave generation, the need of ECG-triggered shock waves became less necessary. It is important, however, always to use ECG recording to discover any VES or other arrythmias that might occur. Moreover, it might be worthwhile to consider ECG-triggering when treating very small children.

11. Administration of shock waves

How important is the frequency of shock wave administration? How many shock waves should ideally be given? The answers to these questions depend on which aspect that is considered. Basically, the important point is that we need a strategy resulting in optimal stone disintegration while avoiding negative effects on surrounding tissues. In this regard it is important to keep in mind that overtreatment in terms of energy, frequency and number of shock waves always should be avoided!

So, how can the appropriate energy level be determined? In most situations clinical experience is an outstanding guide. In other cases, detection of early haematuria is helpful. For that purpose, administration of a diuretic agent and high-pressure infusion of fluid can be worthwhile for treating patients with stones in the kidney (Table 6). Many patients might, however, find the need of a bladder catheter inconvenient. When used, the bladder catheter is removed immediately after SWL.

Table 6
Forced diuresis during SWL.

In patients for whom forced diuresis is considered of value, insert a bladder catheter attached to a transparent urine collection bag.

Give Furosemide intravenously 20 mg.

Administer a Ringer-Acetate solution as high pressure infusion of 1000 mL during the treatment. Use a blood-pressure cuff!

It is expected to get 1000 mL in and 1000 mL out during a normal treatment session of 30–50 minutes.

The energy level at which the first appearance of blood in the catheter is noted corresponds to the shock wave power required for disintegration. Choosing an energy level slightly above that (one or possibly two steps) is recommended for the remaining part of the treatment. The important rule is that the patients should be given sufficient pain relief so that the course of stone disintegration and not the patient's pain reaction determine how the treatment should continue!

Experimental studies have shown that starting the treatment with a series of low energy shock waves is advantageous to avoid kidney injuries. Either a long series of low energy shock waves during approximately 5 minutes or 100 shock waves followed by a 2–3 minutes pause will result in vasoconstriction and signi-ficantly reduced risk of bleeding. That regimen has been followed for treatment of stones in the kidney and ureter close to the kidney. Subsequently the energy should be increased stepwise in a way termed ramping. Such a regimen enables determination of the power necessary for disintegration and is important for the patient's adaptation to the shock waves.

There is no need for a pause or similar precautions when treating stones in the ureter, but ramping is useful for patient adaptation.

It has been rewarding to administer shock waves to stones in the kidney at a frequency of 60 per minute (1Hz). For ureteral stones 90 shock waves per minute has been the rule (1.5Hz). A frequency of 120 per minute (2 Hz) used by some operators was almost never used in our clinical work. In contrast it occasionally was necessary to reduce the frequency to 60 from 90 for better disintegration. Such an effect on stone disintegration often was surprising to younger colleagues.

How many shock waves should be administered during one session? There is no clear answer to that question and in the literature, it is obvious that up to 5000 shock waves or even more have been applied. The basic rule in our own experience was, however, that it is better to repeat the treatment than to take the risk of consequences of overtreatment. But it is important to continue with shock wave administration no longer than is required for satisfactory stone disintegration. This point sometimes might be difficult to determine. The appropriate number of shock waves during one session therefore seldom exceeded 2000. The practical limit was set to 2000–2500, the same as was used with the original Dornier HM3 lithotripter, but that does not exclude that for occasional patients up to 3000 shock waves might be relevant. It is important to consider that this threshold might vary from one lithotripter to another, but in those electromagnetic lithotripters that were in our hands during the past two to three decades the guidelines above have proved useful and safe.

The associated question is: how soon can a repeated SWL be carried out? There is no clear answer to that question either, but for experimental contusions in the renal tissue the healing process took approximately 2 weeks. Therefore, when treating stones in the kidney the general rule was to plan for another SWL session not earlier than after 2 weeks. That long period is not necessary for repeated treatment of ureteral stones, but it is recommended to let one- or two-days pass between two successive treatment sessions for ureteral stones. It always is beneficial to get rid of fragments on the stone surface before proceeding with a new SWL session. It must be emphasized that for treating stones located in the proximal part of the ureter when the kidney temporarily is hit by shock waves, the same principles should be applied as for treatment of stones in the kidney!

12. Special tricks

When the distance to the stone exceeds the penetration depth of the shock wave (because of long SSD) it is possible to achieve satisfactory disintegration if the stone is placed in line with the shock wave propagation with so called blast path technique. This trick is most easily applied in lithotripters with imaging and shock wave paths in line. This requirement, however, is not met in all lithotripters and in such cases, it is necessary to know the direction of the shock wave path on the imaging screen. All lithotripters are equipped with a device the purpose of which is to check the position of the focal point. That device can be used to show the blast path direction which accordingly can be determined and marked on plastic film (over-head sheets) placed on the imaging screens. Knowledge of the direction of the shock wave path is necessary also for excluding interference between the shock wave and skeletal structures as discussed above.

In thin patients and in small children the opposite situation might occur in which it is impossible to establish a satisfactory contact between the shock wave therapy head and the body. That unusual problem might be overcome by placing an air-free plastic urine collection bag filled with degasified water between the shock wave head and the body surface, of course with rich application of transmission mediums on both sides.

Auxiliary procedures

13. Auxiliary procedures

In some patients the final success of SWL might require additional supporting measures. The purpose is to improve the outcome by low-invasive auxiliary tools. Thereby it is understood that the various additional procedures in such cases can be carried out while maintaining the least invasive concept. The auxiliary procedures referred to do not need general or regional anaesthesia. Accordingly, follow-up URS is not included in the set of auxiliary procedures, because in most cases URS cannot be carried out without anaesthesia and if URS or PCNL become necessary it means that SWL has failed.
The auxiliary procedures used were internal ureteral stents, ureteral catheters, percutaneous nephrostomies, chemolysis and inversion/percussion. All these procedures can be completed with surface mucosa anaesthesia of the urethra without or with mild analgesic-sedation whereas inversion treatment does not require any form of pain-treatment.

Internal stents
Internal ureteral stents or pig-tail catheters should be inserted before SWL when the stone burden is large, for which stones there is risk of ureteral obstruction caused by accumulated stone fragments in the ureter (steinstrasse). Clinically important steinstrasse occurs when the fragment/stone-accumulation results in obstructed urine flow. Indications for stenting are summarized in Table 7. In these patients the stent is inserted immediately before SWL. The normal stent dimension is 6–7Ch and 24–26 cm. Stents always should be inserted over guidewires.

Table 7
When is an internal stent beneficial?

In patients with large stone burden: largest stone diameter 20 mm, stone surface area >~ 300 mm², or stone volume >~4000 mm³.
In patients with ONE kidney.
In patients with obvious risk of infection complication.
In old and brittle patients in whom ureteral obstruction might be deleterious!

Moreover, it is helpful to use the extraction thread and tie a loop, 2–3 cm before insertion. The loop should be left in the bladder-part of the stent. Leaving the whole thread out through urethra occasionally might be associated with accidental stent extraction. The great advantage with the loop is that if the stent is retracted, which might happen, the loop-threads can be caught by a special self-constructed hook described elsewhere. This step can be carried out without anesthesia.

Successful treatment of steinstrasse in most cases can be carried out with repeated SWL. Thereby it might be useful to insert a stent. To facilitate its passage through the fragment column, lubrication of ureter and fragments can be accomplished by instillation of a gel mixture (e.g., Instillagel®) 50% and saline 50%. That mixture can be administered via a ureteral catheter. The purpose of dilution is to reduce the viscosity and facilitate gel installation.
In patients with ureteral stones in whom a stent already is in place, stone disintegration can be facilitated by stent extraction before SWL.

Ureteral catheter
Retrograde injection of contrast medium occasionally is of value to visualize the intrarenal configuration of the collecting system and when it is difficult to identify a stone in more than one projection.
Manipulation of impacted ureteral stones can be accomplished by the gel-mixture installation mentioned above.

Percutaneous nephrostomy catheter.
Diversion of urine from obstructed kidneys when catheterization from below has failed is necessary when there is simultaneous infection. Insertion of at least two nephrostomy catheters is necessary when percutaneous chemolysis is planned.

Chemolysis
Administration of chemolytic solutions via a ureteral catheter is never successful and should not be attempted!

Table 8
Chemolytic solutions suitable for stones of different composition.

Stone composition	Solution	Preparation	
Magnesium ammonium phosphate, Carbonate apatite, Brushite HAP	Renacidin, Hemiacidrin 10 %	Solution ready to use!	
Uric acid Cystine	THAM solution 0.3 mol/L	Sterile water Addex-THAM 3.3 mmol/mL NaCL KCl	800 mL 90 mL 30 mmol 5 mmol
Uric acid Cystine	THAM solution 0.6 mol/L	Sterile water Addex-THAM 3.3 mmol/mL NaCL KCl	800 mL 180 mL 30 mmol 5 mmol
Cystine	Acetylcystein	Acetylcystein 200 mg/ml Tribonate Sterile water	100 mL 500 mL 400 ml

For some stone compositions, SWL with advantage can be combined with intrarenal irrigation of solutions with stone dissolving properties. For such purpose it is necessary to have two percutaneous nephrostomy catheters (7Ch) in place with the end-loops at some distance from each other. For chemolytic treatment it is helpful, albeit not necessary, to have an internal ureteral stent in place.

Chemolytic agents must be chosen based on knowledge (or informed assumption) of stone composition. Suitable chemolytic solutions are given in Table 8. When chemolytic irrigation causes pain and there is no sign of obstruction, percutaneous instillation of a local anesthetic solution (e.g. Citanest®) is helpful. When finishing chemolysis it might be of value to install heparin in the

renal collecting system to re-establish the protective muco-polysaccharide surface layer. It should be noted that if a patient has a nephrostomy catheter in place and has been SWL-treated for a soluble stone, follow-up irrigation with an appropriate chemolytic agent might be useful also when the patient is considered stone-fee. Such an additional step might eliminate invisible minor or microscopic fragments and result in a better stone clearance and reduced risk of recurrent stone formation.

Important: All patients with nephrostomy catheter must be treated with antibiotics pre-SWL (Table 2).

Procedures aiming at facilitated fragment elimination from the kidney.
Percussion or vibration with patient inversion is sometimes helpful to mobilize and eliminate fragments residing in the lower calyces. For this procedure it is recommended to have a high diuresis by administration of a tablet of furosemide (40 mg) and intake of at least one liter of water 30–40 minutes before the procedure (DIVE; Diuresis Inversion Vibration Elimination). Repeated sessions of that kind can be of value for stone clearance although it is difficult to predict the result.

Several special devices have been constructed for this treatment, but a simple tipping board together with some kind of vibration device might be sufficient. Other instructions to the patients for mobilization of fragment should be given with attention paid to the age and mobility of the patient.

14. Medication after SWL

After the treatment it has proven useful to prescribe diclofenac suppositories (50 mg) twice daily during one week to 10 days. That is an excellent way to counteract pain during periods with fragment passage and this regimen will in most cases make it possible to avoid visits to the emergency departments. (Table 9).

Table 9
Recommended pharmacological treatment after SWL.

Diclofenac suppositories 50 mg	1 x 2	for 7–10 days
Alpha-receptor antagonist Tamsulosin 0.4 mg or Doxazosin (Afluzosin) 4 mg	1 x 1 1 x 1	for 2–4 weeks (or longer) for 2–4 weeks (or longer)
Alternatively: **Calcium channel blocker** Nifedipine 10 mg	1 x 2	for 2–4 weeks (or longer)

Medication after SWL

One way to facilitate passage of fragments through the ureter is to prescribe an alpha-receptor antagonist or a calcium-receptor antagonist during a period of 2–4 weeks.

All patients are recommended to increase fluid intake to get a high urine flow. A dose of diuretic agent (e.g., furosemide 40 mg per day) during 3–5 days might be rewarding.

To prevent recurrent stone formation in patients treated for infection stones, acidification might be of value (Table 10). For stones with other composition recurrence prevention requires metabolic risk analysis. This issue, however, is beyond the scope of this booklet.

Table 10
Fragment dissolution and recurrence prevention in patients SWL treated for infection stones.

After adequate treatment of struvite infection stone, with or without residual fragments.
Long-term treatment with appropriate oral antibiotic agent according to the sensitivity pattern. **3– (6) months.** Acidification with **Ammonium chloride 500 mg** 2 x 3 **ONE** or **TWO** days a week. Alternatively: **Methionine** (Acimethine) 500 mg 1–2 x 3

What can be expected from SWL in a consecutive series of patients?

15. What can be expected from SWL in a consecutive series of patients?

It does not make sense to report the overall achievements in the huge population of patients primarily treated with SWL for ureteral and kidney stones in our stone units. Tables 11a and 11b below show what was achieved in a consecutive series of patients with stones treated with SWL. Only a very small number of patients with large brushite stones, large cystine stones and staghorn stones were referred to endoscopic procedures, all other patients were treated with SWL without or with gentle auxiliary procedures without general or regional anaesthesia.

Although the results shown in Table 11a and 11b only comprise approximately 1000 patients consecutively treated with SWL, they very well represent what was achieved in the whole cohorts of patients. For correct interpretation of these data, it also should be noted that although all ureteral stones had a surface area of less than 250 mm^2, as many as 34 percent of stones in the kidney had surface areas exceeding 250–300 mm^2. It is of note that the best results were recoded for patients treated for stones in the distal ureter of whom 97.6 percent became stone free and as many as 86.3 percent had their stones satisfactorily disintegrated with only one SWL session.

Number of patients	580
Mean (SD) age	54 (17)
Mean stone (SD) surface area mm^2	42 (34)
Location of stone in the ureter	
Number of patients	580
Mean stone (SD) surface area mm^2	42 (34)
Stone surface area range mm^2	6–250
Stone-free %	97.1
Average number of sessions	1.31
Treated with ONE session %	76
Auxiliary procedures %	16.9
Complications %	7.0
Stone treatment index	5.35

Table 11a
Data recorded for 580 patients consecutively treated with SWL for stones in the ureter. All treatments were carried out with Storz Medical SLX Classic or Modulith SLX-F2 lithotripters [11]

Table 11b
Data recorded for 420 patients consecutively treated with SWL for stones in the kidney. All treatments were carried out with Storz Medical SLX Classic or Modulith SLX-F2 lithotripters.

Number of patients	420
Mean (SD) age	54 (16)
Stone surface area mm^2mean (SD)	94 (172)
Number of SWL sessions	624
Average number of sessions /patient	1.49
Shock waves from the back %	81.7
Shock waves via abdomen %	17.2
Shock waves from both directions %	1.1
Completely stone-free % SF	57
Fragments < 1mm % miniFR	17
Fragments 1–4 mm % FR	20
Residual stones > 4 mm % RES	6
Very good result % SF + miniFR	74
Satisfactory disintegration %	94
Auxiliary procedures %	22.4
Treated with ONE session %	64
Complications %	10.0

What can be expected from SWL in a consecutive series of patients?

The stone treatment index in Tables 11a and 11b was calculated with the following formula [20]:

$$\frac{Num_{SF} \text{ x mean}(\sqrt{SA} \text{ x HI}) \text{ x meanAge}_R \text{ x meanBMI}_R}{Num_{SESSIONS} + Num_{AUX} + Num_{ANE} + Num_{COMP}}$$

In this formula N_{SF} is the number of stone-free patients, SA the stone surface area and HI is the stone hardness index [15], BMI_R is the quotient BMI/25 and Age_R the quotient age/50. N is the total number of treated patients. $Num_{SESSIONS}$ is the total number of SWL sessions, Num_{ANE} number of patients treated with general or regional anaesthesia Num_{AUX} the number of auxiliary procedures and Num_{COM} number of patients with complications.

Epilogue

16. Epilogue

Worldwide, SWL still is the most common treatment modality for stone removal. But there is little support in the current literature for choosing this non- or least invasive treatment instead of endoscopic surgery. The recommendations in numerous reports as well as in the modern guidelines are in favour of URS, RIRS and PCNL. The two major reasons for that recommendation are the more common occurrence of residual fragments in the lower calyces after SWL and the relatively high requirement of repeated treatments associated with SWL. The latter problem usually can be dealt with by appropriate patient selection, and it is of note that in most patients, SWL results in adequate stone disintegration followed by relief of pain and/or elimination of other stone-related symptoms.

Accordingly, there is a well-documented ongoing shift from SWL to endoscopy. When Global Trend analysis was carried out to get information on web-searches for stone treatment, not surprisingly there was a rise in visits to websites on RIRS, URS and PCNL. There was a decline for SWL but search on SWL nevertheless remained at the highest level!

We are aware of the outstanding technical development of endoscopic instruments, and it is clear, that among many urologists SWL today is much less popular than the low-invasive endoscopic procedures. Despite decades of successful results with SWL applied in millions of patients, it is both surprising and difficult to understand that SWL is considered as a partially outdated treatment method. But why have invasive endoscopic methods unchallengedly been given the place as preferred procedure for stone removal?

There are several explanations for that. Many urologists consider SWL as boring and have receded from active participation in this treatment modality. The common transfer of the responsibility for SWL to sometimes insufficiently educated members of the staff might be a problem, because when SWL is managed entirely by non-urologists and when technicians, nurses and less well-informed residents run the lithotripter service, it stands to reason that there is an obvious risk that the treatment becomes very stereotypic. This organisation undoubtedly works well in many places, but special tips, tricks, and specific considerations necessary for difficult stone cases, are seldom applied. Moreover, it is accepted too often that SWL has failed without analysing why. Recent systematic reviews of comparative studies between SWL and URS for ureteral stones and between SWL and RIRS and PCNL have demonstrated the lower stone-free rates with SWL. But it also is important to realize that none of the endoscopic methods resulted in complete stone clearance. As mentioned above the advantages of endoscopic surgery are the higher stone-free rates and a lower rate of repeated treatment session sessions. But there are other advantages with SWL, such as the possibility to complete the treatment without general or regional anaesthesia, in an out-patient setting and without access to an operating theatre.

For adequate decision on the most appropriate treatment, it is necessary to consider a reasonable balance between the treatment goal and the efforts required to reach that goal. One factor that also must be accounted for is the cost of the treatment. Different data have been reported in this regard, but several recent reports have shown that the cost is lower for SWL than for endoscopic procedures. In a recent report it was clearly shown that the cost of SWL was lower than that of URS. The baseline is that whereas several factors speak in favour of endoscopy, there are others in support of SWL.

Adequate knowledge of what can be accomplished with SWL unfortunately has become low among urologists and there is an apparent discrepancy between what can be achieved with SWL and what urologists in general believe and expect. Isolated notes from urological clinics in Sweden indicated that SWL very often was described to the patients as an “attempt” to deal with the stone problem. Generally, however, SWL should be much better than only an “attempt”. Methodological improvements and technical development of SWL cannot take place unless a qualified urologist more directly is involved in the treatment or at least is sufficiently familiar with the method to give qualified advice. But in many clinics, it is a shortcoming that experienced urologists because of the internal organisation, very often lack insight and understanding of what SWL can give. Although it repeatedly is emphasized in the literature that endoscopy requires well-educated endoscopic surgeons, it is seldom mentioned that successful SWL also requires special expertise. Studies have shown that extensive education and training of SWL operators resulted in significantly improved treatment results. Nevertheless, SWL might result in considerable cost savings.

One of the intentions by presenting the principles of SWL outlined in this booklet was to increase urologists' insights in SWL and increase the awareness of factors important for successful outcome.

It is obvious that endoscopic surgery is more attractive particularly among young urologists than is SWL. That factor cannot be neglected but should not be important for selection of treatment. The invasiveness of endoscopic methods is not always beneficial for the patients and although there is no doubt that endoscopic stone removal in the hands of experts is very successful, carried out by less experienced urologists/surgeons, invasive treatment might be associated with both injuries, failures, and high cost. Although arguments for the shift of stone removal from SWL to URS/RIRS in many patients can be understood, it is difficult to fully support the dramatic change in principles of stone removal that has taken place during past years. One explanation that seldom is mentioned is that in many countries there is a significant driving force in endoscopic direction by more favourable reimbursement for the latter treatment modality. Such differences are problematic, because most economic calculations of the real cost show favourable data for SWL.

It repeatedly has been claimed that after the Dornier HM3 lithotripter, that was used for the first clinical shock wave lithotripsy in 1980 and forward, there has been no or only marginal methodological progress of shock wave lithotripsy. This conclusion is not correct. Albeit there definitely was an early period during which lithotripters with inferior capacity to disintegrate stones were developed and manufactured, currently available lithotripters generally have a high technical standard and although modern lithotripters have different technical features, differences in treatment results to a large extent can be explained by how the devices have been handled.

Technical modifications together with increased knowledge on how to deal with SWL-related pain, has resulted in a method for stone disintegration that almost always can be completed without general or regional anaesthesia. There is no doubt that anaesthesia-free treatment today is one of the greatest advantages of SWL, but this does not mean that the treatment can or should be carried out without pain treatment. With limited need of patient preparation and ease of pain treatment, SWL has become extremely versatile.

Details of the progress in SWL methodology might be difficult to discern in the shadow of the extremely powerful Dornier HM3 lithotripter. That device had a large focal volume and lithotripters subsequently have been developed with different shapes and volumes of the shock wave focus. Large low energy focal volume and small high energy focal volumes have been compared, but there is still no consensus on which focal geometry that is optimal.

The problem with shock wave transmission that became evident when the water tub of the Dornier HM3 was abandoned has been subject to careful experimental and clinical research. The achievements thereby emphasized the importance of bubble-free transmission media. It was discovered that also a very small percentage of bubbles resulted in a dramatic reduction in shock wave power. It was noted that in many treatments, the quantity of transmission gel applied on the therapy head too often was insufficient, a factor that might have explained of treatment failures. Today, some modern lithotripters are equipped with video cameras for detection of air bubbles in transmission gel.

With the improvement in pain treatment followed the possibility to carry out SWL as an outpatient procedure without need of an operating theatre. This meant that for most patients there was no need of in-patient hospital care. Many patients with stone disease seek medical advice because of acute renal colic caused by obstructing stones in the ureter. For these patients the advantage of non-invasive or least-invasive treatment is obvious with the possibility to directly give emergency treatment with limited patient preparation, and without general or regional anaesthesia.

Research on how shock waves might interfere with the heart activity and tissues around the stones have resulted in valuable knowledge and several important precautions to increase patient safety. Accordingly, it was found that attention to and control of the patient's blood pressure is of fundamental importance for avoiding bleeding complications. Moreover, the benefit of starting the treatment at a low energy level and introducing a short pause to cause vaso-constriction before the power is further increased by ramping became obvious. Experience showed that excesses in terms of shock wave number and energy should be avoided. It was also clear that administration of shock waves at low frequencies were superior to high-frequency SWL.

Recent developments with high-frequency SWL, burst-wave lithotripsy and histotripsy so far not consistently have been introduced in the clinical routine. Methods to control target stability by abdominal compression were developed and these methods have become highly important for increasing the shock wave hit rate. The early appearance of haematuria as a sign of stone disintegration has proved clinically valuable.

Numerous articles have been published on the presence of asymptomatic residual fragments (CIRFs) after SWL. Although residual fragments are a potential risk for development of new stones, it is important to keep in mind that there is an obvious risk of recurrent stones also in patients with completely stone/fragment-free renal collecting systems after all kinds of stone removal. A more than 7-year follow-up of residuals in 140 patients SWL treated for calcium stones in Sweden showed that there was an annual need of re-intervention in three percent of the patients. At follow-up of after at least 7 years, 20 percent had been retreated. In those cases, repeated intervention was carried out with SWL.

Another point that needs attention is how the x-ray exposure might differ between SWL and endoscopic procedures. Whereas data usually are reported for SWL, x-ray exposure during endoscopy is not consistently found in the literature. Moreover, it is our impression that in endoscopic surgery the collimators are used in a highly variable way. With the integrated x-ray and ultrasound available in some modern lithotripters and with strict collimation during fluoroscopy, it seems a lot easier to reduce the x-ray exposure in SWL than it is in endoscopy. It also is possible to further reduce the radiation dose by using computerized systems for auto-positioning of the stones when such options are available.

The advantage of SWL in the COVID-pandemic has been emphasized in several recent reports. When there is no need of tracheal intubation the aerosol spread of virus can be markedly reduced.

In an environmental perspective, recent research has shown that the construction of ureteroscopes is associated with considerable release of CO_2. For a similar reason, negative effects on the environment can be anticipated with single-use endoscopes.

If we consider stone disintegration to be the goal of the treatment, taking care of disintegrated residual fragments is a second problem for which other non-invasive methods currently are available or in progress.

Our conclusion, based on more than 35–40 years of clinical experience with SWL, is that this least-invasive treatment still is an excellent first line therapeutic approach for a large number of patients and that the success rate is high when appropriate attention is given to the important details of patient selection and how SWL should be carried out. This conclusion is particularly relevant for patients with ureteral stones. There is no doubt that SWL applied in the way described in this booklet is economically advantageous compared with endoscopy. Only inappropriate reimbursement principles might violate this conclusion.

Bottomline:
It is important to realize that successful SWL is hidden in the details!

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Based on accumulated and considerable experience of Extracorporeal Shock Wave Lithotripsy for four decades, the authors of this booklet have summarized their clinical routines and advice on how this treatment can be carried out to get clinically successful results. Undoubtedly, there have been numerous lessons learnt over this long period and with the purpose of avoiding unnecessary failures, the text contains many practical recommendations. The booklet therefore can be considered as a kind of “guideline” for shockwave lithotripsy in clinical practice.

It is of note that all recommendations in this booklet are based on clinical observations and outcome in several thousands of patients and the rules are applicable to Extracorporeal Shock Wave Lithotripsy irrespective of which lithotripter that is used. The importance of attention to treatment details is emphasized.

Both Christian Chaussy, who performed the first Extracorporeal Shock Wave Lithotripsy in 1980, and Hans-Göran Tiselius are Professors of Urology, and they still believe in “renaissance” of this treatment method for patients with urinary tract stones.

ISBN