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How Efficient Is Extracorporeal Shockwave Lithotripsy with Modern Lithotripters for Removal of Ureteral Stones?

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ABSTRACT

Purpose: **To analyze results of extracorporeal shockwave lithotripsy (SWL) for treatment of ureteral stones with two modern lithotripters.**

Patients and Methods: **A consecutive series of 598 patients with ureteral stones was treated with the Modulith SLX Classic and Modulith SLX-F2 lithotripters. The mean (SD) age of the patients was 54 (17) years, and the mean (SD) stone surface area was 42 (34) mm^2. Results were available for 580 patients.**

Results: **Stone-free ureters were recorded in 563 (97.1%) patients. Stone-free rates were 96.1%, 97.8%, and 97.9%, for the proximal, middle, and distal ureter, respectively. The average number of SWL sessions needed was 1.31. For the proximal, middle, and distal ureter, one SWL session was sufficient in 73.1%, 66.7%, and 83.2% of patients, respectively. Assisting auxiliary procedures were used in 102 patients (18%). The total mean (SD) treatment time was 48 (26) minutes and the mean (SD) number of shockwaves was 3266 (2258). SWL for stones located in the proximal, middle, and distal ureter was carried out in the prone position in 38%, 88%, and 9%, respectively. For 90 patients primarily treated with a large focus, the re-treatment rate was the same as for patients treated with a standard focus. A stone treatment index used to assess the efforts, results, and complications was similar for the two lithotripters and for all stone locations. Thus both lithotripters had similar efficacy.**

***Conclusion*: With consistent use of SWL, a stone-free rate of more than 97% can be attained, with a reasonable re-treatment rate and only modest use of assisting auxiliary procedures.**

INTRODUCTION

SINCE THE INTRODUCTION OF EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY (SWL) more than two decades ago, there has been a continuous debate about the best method for removal of ureteral stones. This is an important issue because the annual need for stone removal is approximately 200 to 300 patients per one million population.[1]

Numerous reports have addressed this issue. The wide variation in disintegrating capacity[2] of lithotripters manufactured today has likely been one factor that has stimulated the rapid technological advancements seen recently in endoscopic instruments and techniques. Both ureteroscopy (URS) and extracorporeal shockwave lithotripsy (SWL) have proved to be acceptable alternatives for treating patients with ureteral stones. The major disadvantages generally stated for these two methods are the need for repeated treatment sessions sometimes reported for SWL, and the need for general or regional anesthesia together with greater morbidity for URS. Excellent stone-free rates have been reported with SWL carried out with the Dornier HM3 lithotripter.[3,4] A recent review of the literature also showed that SWL was not inferior to URS when the need for anesthesia was taken into consideration.[5]

In view of the variability in recently reported treatment results, the important question is how effective modern shockwave lithotripters actually are in their capacity to disintegrate and eliminate stones in the ureter. Conclusions are sometimes difficult to draw because of the inconsistent use of SWL, and there are few reports of large groups that were consecutively and consistently treated with SWL as the primary stone removal procedure. In most series, patients have been carefully selected, with referral also to other forms of treatment, usually URS.

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In the author's department SWL has been used as the first-line treatment for all patients with ureteral stones for more than 20 years. This article summarizes the results obtained with the Modulith SLX Classic and SLX-F2 lithotripters in a consecutive series of patients with ureteral stones.

PATIENTS AND METHODS

From October 2004 through December 2006 we treated a total of 598 patients for ureteral stones with the Modulith SLX Classic and Modulith SLX-F2 lithotripters (Storz Medical AG, Tägerwilen, Switzerland). During that period the two lithotripters were operated in parallel at our stone unit. We did not have any special rules governing the use of one or the other lithotripter, and the distribution of patients treated with the two devices thus can be considered as approximately random. Moreover, in cases of repeated treatment we tried to use the same lithotripter as that used for the first treatment session, but due to organizational and logistical factors, this was not always possible.

The SLX Classic and SLX-F2 lithotripters have similar geometric properties, with the exception that the latter device offers the option of using an extended focus. The size of the normal shockwave focus is approximately 6×28 mm, and with the larger focus it is 10×50 mm.

All treatments (except in pediatric patients) were carried out with repeated intravenous administration of small doses of alfentanil and propofol. The patients were awake during this type of conscious sedation. The treatments were carried out on an outpatient basis. Forced diuresis was used in the majority of patients. This was accomplished by intravenous administration of 20 mg of furosemide and high-pressure infusion of about 1000 mL of Ringer's acetate solution during the treatment session. The frequency of shockwave administration was either 1.0 or 1.5 Hz, but the treatment outcomes in this report have not been stratified by shockwave frequency.

The mean (SD) age of the patients was 54 (17) years (range 8–82 years). The mean (SD) duration of the total treatment (including re-treatment if necessary) was 48 (26) minutes. The total mean (SD) number of shockwaves was 3266 (2258), and the energy levels were chosen according to the progress of disintegration.

The mean longitudinal (l) and transverse (w) diameters of the stones as measured on the plain frontal x-ray image were 8.6 and 5.5 mm with ranges of 2 to 29 mm and 2 to 14 mm, respectively. The mean (SD) stone surface area was 42 (34) mm^2 with a range from 6 to 250 mm^2. The stone surface area was calculated using the longitudinal and transverse diameters with the following formula, in which the shape of the stone was considered to project as an ellipse:[6]

$$l \cdot w \cdot \pi \cdot 0.25$$

In those patients in whom the stone composition had been analyzed we derived a hardness index (HI) from the percentage of calcium oxalate monohydrate (*COM*), calcium oxalate dihydrate (*COD*), hydroxyapatite (*HAP*), brushite (*BRU*), magnesium ammonium phosphate (*MAP*), carbonate apatite (*CarbAp*), uric acid (*Ur*), and cystine (*Cy*), by using hardness factors described elsewhere:[7]

$$\left(\frac{COM}{100} \cdot 1.3\right) + \left(\frac{COD}{100} \cdot 1.0\right) + \left(\frac{MAP}{100} \cdot 1.1\right) + \left(\frac{BRU}{100} \cdot 2.2\right) + \left(\frac{MAP + CarbAp}{100} \cdot 1.0\right) + \left(\frac{Ur}{100} \cdot 1.0\right) + \left(\frac{Cy}{100} \cdot 2.4\right)$$

The HI values used in these calculations were derived from a retrospective analysis of treatment requirements in a large group of patients treated with SWL for stones with known chemical composition. For patients in whom stone material analysis had not been performed, an HI of 1.18 was used, which was the average HI in our previous analysis.

In order to summarize in a single expression the treatment efforts and results in relation to the initial stone burden and some other important factors, a stone treatment index (STI) was used. This index describes how effective the treatment was, and thus a high STI indicates efficient treatment and a low STI relatively inefficient treatment. The STI was derived as follows:[8]

$$\frac{N_{SF}(\sqrt{SA} \cdot HI \cdot BMI_r \cdot Age_r)}{(N + N_{RE} + N_{ANE} + N_{AUX[inf\,]} + N_{COM})}$$

In this formula N_{SF} is the number of stone-free patients, *SA* is the stone surface area (in square millimeters), *HI* is the hardness index. BMI_r is the body mass index ratio calculated from BMI/25, and Age_r is an age ratio obtained from Age/50. *N* is the number of first SWL sessions, N_{RE} the number of repeated sessions, and N_{ANE} is the number of patients in whom the treatment required general or regional anesthesia. For patients only given analgesics and sedation N_{ANE} was set to 0; a value was assigned only when general anesthesia had been used.

The auxiliary procedures used in association with SWL were of various kinds. The most important of these steps was the insertion of a ureteral catheter with administration of saline or contrast medium in order to facilitate stone disintegration, passage, or to determine its location, or to place an internal stent to treat obstruction caused by fragments after SWL. Occasionally a Zeiss loop (Rüsch Medical Company, Tüttlingen, Germany) was used to facilitate disintegration by creating a fluid space around the stone. When any of these procedures was used it was referred to as AUX_{ASSIST}, because the intent was to improve disintegration with shockwaves or facilitate fragment elimination. To this category of auxiliary procedures we also classified one patient who was given chemolytic dissolution of uric acid stone fragments through a percutaneous nephrostomy catheter already in place. Some other patients had either a percutaneous nephrostomy or an internal stent inserted before they were referred to us for SWL. The indications for these procedures (AUX_{PRE}) were not obvious, but in many cases this was just a safety step undertaken while the patient was waiting for stone removal. After the successful disintegration of stones in the AUX_{PRE} patients, their internal stents were removed by an endoscopic session (AUX_{PREOUT}). Noninvasive assisting procedures with intravenous administration of contrast medium or antegrade pyelographic examinations were referred to another category ($AUX_{NONINVASIVE}$). For patients in category AUX_{ASSIST}, two procedures were recorded, one each for insertion and removal of an internal stent. For N_{AUX} in the STI

TABLE 1. POSITION OF STONES AT THE PRIMARY TREATMENT SESSION IN 580 PATIENTS WITH URETERAL STONES

	Number	*Mean (SD) surface area (mm²)*	*Range of surface area (mm²)*
Proximal ureter	254	53 (38)	7-250
Middle ureter	90	47 (28)	6-197
Distal ureter	236	38 (21)	6-190

calculation above, the total number of AUX_{ASSIST} procedures was used, whereas for patients in category AUX_{PRE}, N_{AUX} was set to 0. For category AUX_{PREOUT} the individual N_{AUX} was considered to be 1. It needs to be emphasized that all these auxiliary procedures were carried out with only local anesthesia of the urethra, with or without a small amount of conscious sedation.

Evaluation of the treatment result was made by reading plain x-ray films, and when necessary from CT scans or intravenous urographic examinations, usually carried out 4 to 8 weeks after the last treatment session.

Statistical interpretation was carried out using the Student's *t*-test and chi-square analysis.

RESULTS

Of the 598 patients treated during this period, follow-up information was not available for 18 patients, either because these patients did not show up for a planned radiographic examination, or because they had follow-up carried out at a center that did not inform us of the results. Most of these patients probably were free of both symptoms and stones, but they were nevertheless excluded from the evaluation. In the remaining 580 patients treated with SWL with or without auxiliary procedures, stone-free ureters were found in 563 (97.1%). The position and size of the stones in these 580 patients are summarized in Table 1.

At the time of treatment none of the patients had stones at more than one ureteral level. The total number of sessions for the entire group of patients was 760, or an average of 1.31 sessions/patient. The lowest re-treatment rate was recorded for stones in the distal ureter, for which an average of 1.22 sessions was required (Table 2). There were no differences in re-treatment rate between the two lithotripters except for patients with middle ureteral stones, who required 1.58 sessions with the SLX-F2 lithotripter compared with 1.29 sessions with the SLX Classic. This difference can probably be explained by selection bias, because many of the most difficult cases were allocated to the SLX-F2 device. Otherwise the treatment results were very similar regardless of the lithotripter used for the first treatment session (Table 3).

The mean (SD) duration of the total treatment (including re-treatments) was 48 (26) minutes, and the total mean (SD) number of shockwaves given was 3266 (2258). One treatment session was sufficient in 73.1% of the proximal, 66.7% of the middle, and 84.1% of the distal ureteral stones. In this regard there were also no important differences between the two lithotripters, as shown in Table 4. When all patients were considered together 76.6% had been treated with one SWL session, 17.3% with two sessions, 5.7% with three sessions, 1.2% with four sessions, and 0.8% with five or more SWL sessions. There was a positive relationship between the number of treatment sessions and stone surface area. Patients treated with one, two, three, four, or more than four sessions had mean (SD) surface areas of 38 (37), 54 (42), 59 (46), 65 (49), and 102 (20) mm^2, respectively.

Compared with patients sufficiently treated with one session, the stone size was significantly larger in those requiring two ($P < 0.01$), three ($P < 0.01$), or more than four sessions ($P < 0.01$). No significant differences in terms of stone surface area were recorded among the patients treated with more than one session ($P > 0.10$).

Six children with ureteral stones were included in this series of patients. They had an age of 8 to 17 years. Four were treated with general anesthesia, and the other two with analgesics and sedation only. They all became stone-free after one treatment session.

Ninety patients were treated with a large focus during the first treatment session. In 40 of them the large focus was used throughout the entire procedure, and in 50 patients a combination of large and normal foci were used. Re-treatments were necessary in 30 (33%) of these patients. The corresponding re-treatment rate for patients who were treated with the normal focus at the first SWL session was 22.3%. This difference was significantly different, with a lower re-treatment rate for patients treated with the normal focus (chi square 4.54; $P < 0.05$). The surface area was, however, larger in those patients in whom the large focus was used. The mean (SD) surface area was 57

TABLE 2. RESULTS OF SWL TREATMENT IN RELATION TO THE INITIAL POSITION OF THE STONE IN THE URETER

	Number	*Stone-free number (%)*	*Average number of SWL sessions per patient*
Proximal ureter	254	244 (96.1)	1.37
Middle ureter	90	88 (97.8)	1.47
Distal ureter	236	231 (97.9)	1.22

TABLE 3. RESULTS OF SWL ACCORDING TO THE LITHOTRIPTER USED FOR THE FIRST TREATMENT SESSION

	SLX Classic		*SLX-F2*	
	Number of patients	*Stone-free number (%)*	*Number of patients*	*Stone-free number (%)*
Proximal ureter	138	131 (94.9)	116	113 (97.4)
Middle ureter	49	49 (100)	41	39 (95.1)
Distal ureter	143	140 (97.9)	93	91 (97.8)
All	330	320 (97.0)	250	243 (97.2)

(41) mm^2 for patients treated with a large focus, compared with 46 (38) mm^2 for those treated with the normal focus ($P < 0.05$). Both lithotripters, the SLX Classic and the SLX-F2, were apparently efficient in disintegrating ureteral stones. The stone-free rates were almost identical (Table 3). As shown in Table 4, there was no significant overall difference between the two lithotripters in terms of need for repeated treatments (chi-square 3.09; $P > 0.05$). Only for stones located in the proximal ureter was the re-treatment rate slightly higher for stones treated with the SLX-F2 device: 34.5% *v* 20.5% (chi-square 5.77; $P < 0.05$). It should be noted, however, that the STIs for proximal stones was no lower for treatments carried out with the SLX-F2 than for the SLX Classic lithotripter (Table 5). For stones in the middle and distal ureter the chi square values were 0.14 and 0.79, respectively, for the SLX-F2 and SLX Classic devices.

The auxiliary procedures used in association with or after SWL treatment are shown in Table 6. The total number of AUX_{ASSIST} procedures was 142, carried out in 102 patients. This amounts to a total of 18% of patients who had need for auxiliary procedures. Antegrade pyelograms were only carried out to assist in the treatment of patients that already had a percutaneous nephrostomy in place, and to confirm a stone-free ureter before extraction of the nephrostomy catheter. The patients with AUX_{PRE} were referred to our unit from other hospitals, some of which had quite a liberal policy with regard to insertion of nephrostomy catheters in patients with acute stone colic. There were also patients with stents in place that had to be removed (AUX_{PREOUT}), either when the ureter was stone-free, or when the fragments were so small that they were likely to easily pass spontaneously. Stent removal was included in STI calculations only when they had been inserted as part of the stone removal procedure. All auxiliary procedures were, however, carried out either with only local anesthesia or with small doses of analgesics and sedation. Zeiss loops were occasionally placed around stones in association with SWL treatment, and afterwards they were either extracted actively or allowed to pass spontaneously with the gravel. Percutaneous surgery, URS, or any other kind of endoscopic manipulation used to remove stones were all considered to be SWL treatment failures, and these procedures were therefore not recorded as auxiliary procedures. Of those patients who already had stents in place 69% were treated more than once, compared with only 34% of those without stents (chi-square 5.16; $P < 0.05$).

Of patients with stones in the proximal ureter 38% had their first treatment in the prone position. The corresponding figures for middle and distal ureteral stones were 88% and 9%, respectively. When re-treatments were also considered 39%, 80%, and 9% of patients with stones initially located in the proximal, middle, and distal ureter were treated in the prone position. The reason for using a prone approach was to avoid interaction between the shockwave device and skeletal structures.

Seventeen patients for whom SWL with or without auxiliary procedures was unsuccessful had their stones managed as follows: Stone removal by URS was necessary in five patients. A stone basket was used to extract a hard stone in a dilated distal ureter in another patient. One patient with an impacted proximal stone had to be treated percutaneously because all transureteral manipulations were ineffective due to a severe urethral stricture caused by a serious accident. In one seriously ill man the nephrostomy was left in place. In two other elderly and weak asymptomatic patients the non-obstructing stones were left in the ureters. In three patients with nonfunctioning kidneys in whom stone removal was attempted in order to remove ureteral obstruction, nephrectomy became necessary in two cases, and in the third an asymptomatic stone fragment was left in the ureter. One patient with a residual uric acid stone did not complete treatment because of malignant disease. A small nonobstructing intramural stone fragment was left in place in one patient. Two patients died before the treatment was completed. One small asymptomatic stone has to date remained in a ureterocele.

A summary of the treatment in terms of STI is shown in Table 5. There was no significant difference between patients initially treated with the SLX Classic and those treated with the

TABLE 4. PERCENTAGE OF PATIENTS IN WHOM ONE TREATMENT SESSION WAS SUFFICIENT

	SLX Classic (%)	*SLX-F2 (%)*	*All patients (%)*
Proximal ureter	79.5	65.5	73.1
Middle ureter	68.6	63.9	66.7
Distal ureter	81.8	85.5	83.2
All	78.8	72.8	76.3

TABLE 5. RESULTS EXPRESSED AS MEAN STI FOR STONES IN DIFFERENT PARTS OF THE URETER AND FOR THE TWO LITHOTRIPTERS

	SLX Classic	*SLX-F2*	*SLX Classic + SLX-F2*
Proximal ureter	5.10	5.61	5.30
Middle ureter	5.61	4.47	4.59
Distal ureter	5.01	5.27	5.15
All	5.23	5.37	5.35

TABLE 6. AUXILIARY PROCEDURES IN PATIENTS UNDERGOING SWL

	AUX_{ASSIST}		AUX_{PRE}		AUX_{PREOUT}		$AUX_{NONINVASIVE}$	
	P	*N*	*P*	*N*	*P*	*N*	*P*	*N*
Antegrade pyelography	—	—	0	0	0	0	40	45
Intravenous contrast	—	—	0	0	0	0	45	48
Percutaneous nephrostomy	2	2	63	63	0	0	0	0
Internal stent[a]	40	80	62	62	62	62	0	0
Ureteral catheter	49	49	0	0	0	0	0	0
Zeiss loop	10	10	0	0	0	0	0	0
Chemolysis	1	1	0	0	0	0	0	0

[a]Extraction of stents inserted to improve treatment results are recorded as AUX_{ASSIST}, whereas extraction of stents that the patient had placed before referral to SWL are recorded as AUX_{PREOUT}. N = number of procedures; P = number of patients (P).

SLX-F2 lithotripter. An STI of 4.47 was obtained for patients primarily treated for middle ureter stones with the SLX-F2, compared with 5.61 with the SLX Classic, despite a larger stone burden in the patients treated with the SLX-F2. Differences in shockwave transmission might have explained this effect.

DISCUSSION

How ureteral stones most effectively and conveniently should be removed has remained a matter of controversy ever since the introduction of SWL. With the technical improvements in stone disintegration and stone removal methods this debate has been intensified and the choice of treatment accordingly has become even more difficult.

Whereas shockwave lithotripsy carried out with the unmodified Dornier HM3 lithotripter resulted in a very high stone-free rate, treatment with second and third generations of lithotripters has shown a pronounced variability in stone-free rates.[2] This problem is obvious from a representative selection of reports in the literature in which stone-free rates following SWL varied between 42% and 98%.[5,9–26] The stone-free rate of more than 97% recorded in this series of patients thus is among the best found in the literature. This result also should be considered in view of the fact that SWL was used as the primary treatment for all patients with stones in the ureter in whom the indication for active stone removal was fulfilled. None of our patients was referred to any other treatment modality unless SWL failed. Stones with a diameter up to 5 mm (20 mm^2) usually were left for spontaneous passage, and active removal was undertaken only if such small stones caused severe pain or did not pass within a reasonable period of time.

In randomized as well as in other comparative studies the retreatment rates were generally higher for SWL than for URS. Stone-free rates after URS in a selection of articles disclosed a range between 69% and 100%.[5,9–17,19–24,27–37] For our SWL-treated patients the average number of treatment sessions was 1.31. This figure is very similar to that recorded for SWL with the unmodified Dornier HM3 lithotripter as previously reported.[3,4] It needs to be emphasized, however, that many of the comparisons between SWL and URS are based on stone removal from the distal ureter. For such stones almost 98% of our patients became stone-free with an average of 1.22 sessions per patient. Only 16% of these patients required re-treatment.

When the results of SWL treatment were analyzed in relation to the position of the stone in the ureter at the first SWL session, it was demonstrated that the highest re-treatment rate was recorded for stones in the middle (33%) and proximal (27%) ureters. It is of note that these results are very similar to the results that we previously reported for the Dornier HM3 and Dornier/Philips MFL 5000 lithotripters.[3,4,26]

Adjunctive or auxiliary procedures were used to facilitate stone disintegration, stone localization, or fragment passage in 18% of our patients. These measures were in most cases undertaken in association with a repeated SWL session and carried out with local anesthesia of the urethral mucosa, and when necessary with a small dose of analgesics and/or sedation, but always without general or regional anesthesia. The need to use URS or stone basket extraction (the latter of which was used as an exception in one patient) was considered SWL treatment failure, and thus these procedures were accordingly not included in the category AUX_{ASSIST}; neither were patients who had already undergone percutaneous nephrostomy or placement of an internal stent before they came to us for treatment. It was also observed that in patients with a stent in place during the first treatment session, the number of re-treatments required was not reduced, but instead increased. This finding is in accordance with the observations of others.[38] Although such an effect might be explained by larger stones in the stented group of patients with proximal ureteral stones, this was apparently not the case for stones in the middle or distal part of the ureter.

Which auxiliary procedures should be included in the STI is a difficult issue that continues to be a matter of debate. The number of internal stents and percutaneous nephrostomy catheters already in place at the time of referral to our unit will of course influence both the total N_{AUX} and the resulting STI. It might thus seem reasonable to also include these steps in the reported STI. The decision was made, however, to include only those auxiliary procedures that we carried out in our own unit with the aim of improving stone disintegration and stone clearance. Removal of a previously inserted stent was added to the index because its presence required an additional treatment procedure. The removal of a percutaneous nephrostomy catheter on the other hand, was so easy that it was considered unnecessary to include it as a specific auxiliary step. The author is well aware of the problems associated with these different conditions and distinctions. Several STI expressions might be used to circumvent this dilemma, but it is the author's impression that too many expressions of this kind might be more confusing than clarifying. Table 5, however, contains all the necessary data from which readers can derive modified STI expressions if they so desire.

The ability to perform the entire stone removal procedure with only analgesics and sedation is one great advantage of SWL over URS. In our experience general anesthesia is only necessary in children, and none of the children in this series required auxiliary procedures, and they all had stone-free ureters after only one SWL session. These results support previous observations about the effectiveness of SWL for removal of ureteral stones in children.[39]

Our SLX-F2 lithotripter offers the advantage of using either a normal or an extended size of shockwave focus. Whether a large focus is advantageous in the treatment of ureteral stones is difficult to conclude from our data. When a large focus was used either entirely or as part of the first treatment session, we did not see a smaller number of re-treatments. We did not have an experimental setting that allowed any rigorous comparison between our two lithotripters, but at least for the normal focus size, we found no technical differences between the two devices.

Skeletal structures in the minor pelvis as well as along the course of the proximal ureter might shield the stone, and this is why we chose the prone position for as many as 38% of the patients with stones in the proximal ureter. For some of the patients treated in the prone position re-treatment was necessary because of shockwave attenuation caused by intestinal gas.

The ease with which patients can undergo stone removal with SWL, with or without minor auxiliary procedures, makes this therapeutic approach particularly attractive. In the majority of patients there is no need for any specific patient preparation or pre-anaesthetic evaluation. Patients can usually be managed on an outpatient basis and there is no need to occupy an operating theatre for the procedure. It is the author's opinion that in comparison with URS, these properties of SWL compensate for the obviously lower need for repeated treatments with URS.

The reasons for stone removal in patients with nonfunctioning kidneys can of course be questioned. These patients were in poor health, and it was considered worthwhile to attempt to establish a free passage through the ureter to help prevent infections due to stagnated fluid in the kidney, and thereby avoid nephrectomy. These patients still had some production of urine.

It is claimed that URS is superior to SWL in that stones can usually be removed in a single treatment session, and this is true when direct comparison is made between the two techniques.[10,26] However, the price paid for that is the need for general anesthesia, a more invasive procedure, and a higher risk of complications for URS. It should also be noted that as many as 73%, 67%, and 83% of patients with stones in the proximal, middle and distal ureter, respectively, became stone-free after only one SWL session in this series of patients.

In randomized trials[18,40] as well as in retrospective comparative analyses[5,9–17,19–24] patients treated with URS had a higher stone-free rate than patients treated with SWL, at least in the hands of experts. It is of note, however, that the number of patients in URS reports usually is much smaller than that in SWL reports, and one can speculate that perhaps centers with poorer URS results refrain from having them published. One reason for that might be that URS is considered more operator-dependent than SWL, for which result the lithotripter is assumed to play a greater role. Whatever the true stone-free rate is for URS, the results obtained in our study of nearly 600 patients show that it is possible to get stone-free rates comparable to those obtained with URS, and that these results are attainable with SWL when it is used in a consistent manner. Although there is a clear need for both repeated sessions and auxiliary procedures, SWL remains an attractive alternative due to its comparatively noninvasive nature and the ease with which it can be carried out. Despite the ability to more quickly perform stone removal with URS than with SWL, the operating costs are no lower for URS,[40] and studies of patient preference indicate they would choose SWL over URS.[13,40] Moreover, as shown here, the results achieved with the SLX lithotripters seem to be quite similar to those reported 16 years ago with the "gold standard" unmodified Dornier HM3 lithotripter.

In a recent report[41] ureteral stone treatments were carried out with the portable version of the Modulith SLX-F2. Their stone-free rates immediately postprocedure and at 3-months follow-up were 83% and 75%, respectively. The reasons for the lower stone-free rate in that study are not immediately obvious. One possible explanation is that the portable device, which must be attached to a mobile C-arm and sometimes adjusted to the lithotripter's geometry may result in less precise focusing of energy on the stone. Moreover, it is likely that we re-treated our patients with partially disintegrated stones more generously.

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ABBREVIATIONS USED

AUX_{ASSIST} = assisting auxiliary procedures; $AUX_{NONINVASIVE}$ = intravenous or antegrade administration of contrast medium; AUX_{PRE} = auxiliary procedures carried out before referral to SWL; AUX_{PREOUT} = extraction of stents or nephrostomy catheters inserted as AUX_{PRE}; BRU = brushite; CarbAp = carbonate apatite; COD = calcium oxalate dihydrate; COM = calcium oxalate monohydrate; CT = computed tomography; Cy = cystine; HAP = hydroxyapatite; HI = hardness index; MAP = magnesium ammonium phosphate; STI = stone treatment index; SWL = extracorporeal shockwave lithotripsy; Ur = uric acid; URS = ureteroscopy.