

# Extracorporeal shockwave lithotripsy, endourology and open surgery: the management and follow-up of 200 patients with urinary calculi

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**Key words:** EXTRACORPOREAL SHOCKWAVE LITHOTRIPSY; PERCUTANEOUS NEPHROSTOMY; PERCUTANEOUS NEPHROLITHOTRIPSY; URETERORENOSCOPY; URETEROLITHOTRIPSY; NEPHROLITHOTRIPSY; ENDOUROLOGY; LITHOTRIPSY; UROLITHIASIS

## Summary

*The management and follow up of 200 consecutive patients with renal and ureteric calculi are presented. The primary treatment of 185 (92.5%) was by extracorporeal shockwave lithotripsy (ESWL), of whom three (1.6%) with large calculi underwent percutaneous nephrolithotripsy (PCNL) prior to ESWL as a planned combined procedure. Twelve (6%) were treated by PCNL or ureterorenoscopy (URS) as their definitive treatment and three (1.5%) by conventional open renal and ureteric surgery. The average in-patient stay was 3.8 days and most returned to normal activity within one day of discharge. Of the 185 patients 102 (55%) required no analgesia after treatment by ESWL, 29 (15.6%) required parenteral analgesia and the rest were comfortable with oral non-narcotic medication. Thirty (16%) required auxiliary treatment by percutaneous nephrostomy (PCN), PCNL and URS following ESWL for obstructive complications from stone particles. Two required further ESWL and one PCNL at three months for large fragments. Overall, open surgery was required for only 1% of renal calculi and 13% of ureteric stones. These results are consistent with the extensive West German experience confirming that most urinary calculi are now best managed by ESWL and endoscopic techniques. Where these facilities are available open surgery should only be necessary for less than 5% of upper urinary tract stones.*

## Introduction

The management of urolithiasis has undergone revolutionary changes since 1980. This common condition causes considerable morbidity and is prone to recurrence (1). Conventional treatment involves extensive and often repeated open surgery which necessitates a prolonged convalescent period and may result in a significant loss of renal function or in nephrectomy (2).

Since the introduction of percutaneous nephrostomy (PCN), percutaneous nephrolithotripsy (PCNL) and ureterorenoscopy (URS) and the development of extracorporeal shockwave lithotripsy (ESWL), the role of open surgery has been greatly reduced. The combination of ESWL and endourological techniques (PCN, PCNL and URS) allows for either non or minimally invasive management of the majority of upper tract stones.

The Dornier Company, in collaboration with urologists from the University of Munich, developed and investigated the techniques of shockwave generation and the precise focusing of the shockwaves for the treatment of renal calculi over a period of 8 years prior to clinical introduction. Since the first report of the treatment of upper urinary tract calculi by ESWL in 1980 (3), over 35 000 patients have been treated worldwide, (Personal communications, D. Denzinger, The Dornier Co).

A shockwave is generated by passing an ultrashort high tension electrical discharge underwater to form an arc between two electrodes. The fluid surrounding the arc path vaporizes to produce a rapidly expanding gas bubble. As a result of this rapid expansion a shockwave is created in the surrounding fluid which radiates from the focus in a circular manner. The shockwave is generated by an electrode placed in the first focus of an ellipse in a hemi-ellipsoidal reflector. The shockwaves are accurately focused to produce a high tensile pressure precisely at the small area of the second focus (Fig. 1). For treatment by ESWL, the patient's calculus is localised at the second focus using biplanar radiography. The patient is suspended in a warmed water bath to facilitate transmission of the shockwaves. After ESWL, the resultant fine fragments of stone are passed in the urine with minimal discomfort over the following weeks.

The Devonshire Hospital Lithotripter Centre provides a combination of endourological techniques and ESWL in a purpose designed suite. This allows ESWL and endourology

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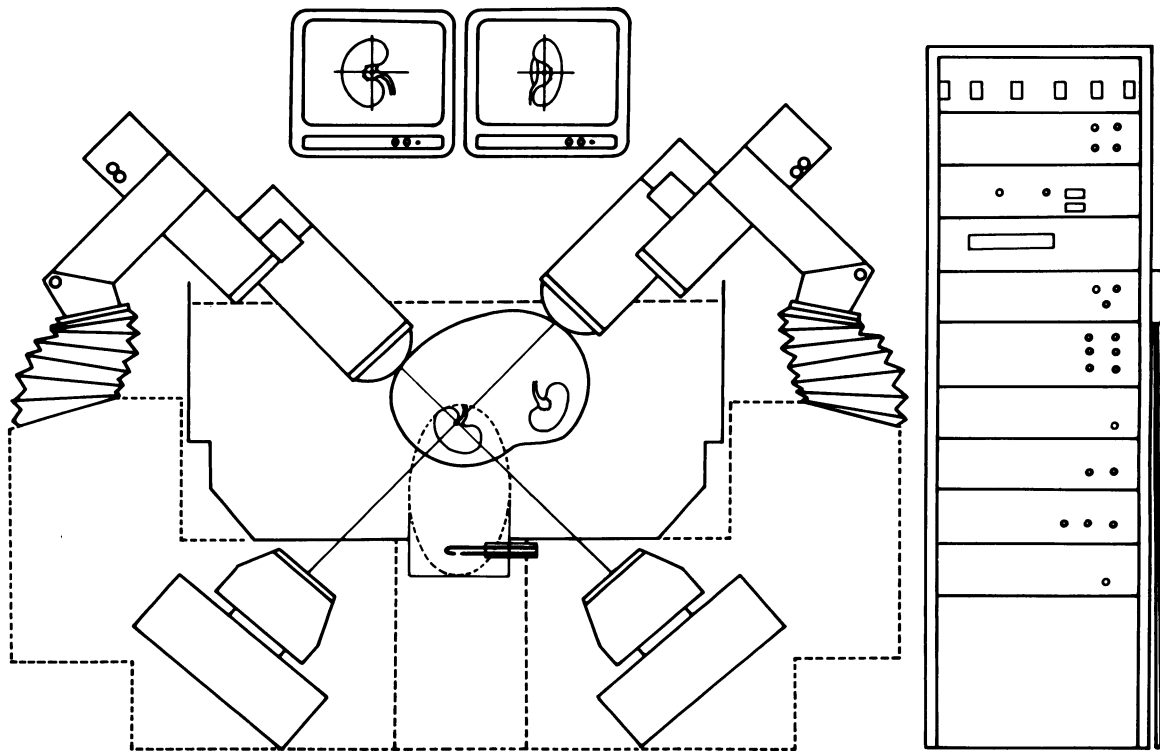


FIG. 1 Schematic cross section of lithotripter showing biplanar X-ray localization of the calculus at the shockwave focus, image intensifier screens and remote control panel.

to be carried out independently or as combined procedures under the same anaesthetic. This paper analyses the management and follow up of the first 200 consecutive patients presenting to the centre with urolithiasis.

#### Patients and methods

Since the first treatment in November 1984 (4) over 200 consecutive patients have been treated at the Devonshire Hospital Lithotripter Centre. Their primary management is shown in Table 1. Fifty-four were National Health Service patients and 146 were private. One hundred and eighty five (92.5%) underwent ESWL as their primary treatment.

TABLE 1 Primary management of 200 patients

ESWL	182
PCNL and ESWL	3
PCNL	9
URS	3
Open (4 renal units)	3

Suitability for ESWL was decided by a panel of urologists and radiologists. Suitable stones were those within the renal collecting system that could be localised radiologically and where the debris could pass spontaneously after fragmentation via an unobstructed urinary system. Of the 185 receiving ESWL, 3 (1.6%) with very large stone masses (mean diameter 6 cm) underwent PCNL prior to ESWL to debulk the stone mass and provide an alternative conduit for drainage of both urine and the stone particles following ESWL. Of those unsuitable for ESWL, 9 (4.5%) were treated by PCNL, 3 (1.5%) by URS and 3 (1.5%) by open surgery. Patients with an inconvertible clotting disorder or who are too heavy or too short for the supportive cradle (ie, weight above 135 kg and height below 130 cm) or whose calculus cannot be radiologically localised due to poor opacity or anatomical abnormalities are not suitable for ESWL.

The average age of the 185 patients was 44.7 years (range 13–83 years). One hundred and thirty-five patients (73%) were male and 50 (27%) were female. The left kidney

required treatment in 57% and in 43% the right. Sixty-five (35%) had undergone previous open renal surgery for calculi on the affected side. Forty-one had multiple ipsilateral calculi, 40 had solitary symptomatic calyceal calculi and 18 had partial or complete staghorn calculi. Ten had ureteric stones above the iliac crest. These were manipulated transurethrally under fluoroscopic control back into the renal pelvis and then treated by ESWL under the same anaesthetic (known as the "push-bang" procedure). The remaining 76 (41%) had renal pelvic stones. Eleven patients (6%) had calculi in a solitary kidney.

All patients underwent plain abdominal radiography (KUB), renal ultrasonography, routine biochemical testing, urine analysis and a full clotting profile before treatment. After induction of anaesthetic, a urethral catheter was inserted. Treatment was performed by a urologist using the Dornier System's Extra Corporeal Shockwave Lithotripter. After manoeuvring the stone into the shockwave focus, a series of shockwaves were triggered by the R wave of the patients electrocardiogram. This coupling ensures passage of the shockwave during the refractory period of the myocardium. The position of the calculus and progress of the disintegration were monitored radiologically every 100 shockwaves. All patients received a 5 day course of an appropriate oral antibiotic.

After treatment, the urine was strained and fragments sent for biochemical analysis. All symptoms and intake of analgesics were recorded. Forty-eight hours after treatment the patients were reviewed by KUB and renal ultrasound and were discharged provided they were comfortable, afebrile, mobile and showed radiological evidence of satisfactory progression of the stone debris without significant ureteric obstruction. Patients were similarly reviewed at 7–10 days after treatment. Further follow-up was arranged at 3 months either at the stone centre, or by arrangement with their practitioner so that both a report on progress and follow-up X-rays could be forwarded to the centre.

#### Results

Localisation was satisfactory in all patients. Two cases of lucent urate calculi were treated by administering contrast

medium either intravenously or via a retrograde catheter to locate their stones. The positioning of the patient on the frame was critical for accurate stone localisation.

One hundred and seventy (87%) were treated under general anaesthetic, 25 (13%) receiving epidural anaesthesia. Five patients developed a cardiac arrhythmia. Three ventricular and one supraventricular settled spontaneously or after the administration of intravenous Lignocaine. In one case it was necessary to terminate ESWL due to persistence of an arrhythmia and he later underwent PCNL. One patient with a sinus bradycardia responded to intravenous atropine and completed his treatment. All other treatments were completed without incident. All patients developed macroscopic haematuria during treatment by ESWL and occasionally passed clots per urethra. A few developed mild bruising at the entry and exit sites of the shockwaves on the body wall.

The average treatment time (excluding anaesthesia), was 25 minutes (range 7–65 minutes), which is approximately half that for percutaneous extractions (5). All calculi disintegrated satisfactorily except for one large calcified cystine stone. Thirty-eight calculi broke particularly easily and on analysis these proved to be composed entirely or predominantly of calcium oxalate. The cystine stones were the most difficult to fragment. The average number of shockwaves per treatment was 944 (range 300–2000). The average diameter of the calculi was 2.28 cm with a range from 0.3 to 8 cm in two patients with large staghorn calculi. The patients spent an average of 3.8 days in hospital (range 2–30). One hundred and two (55%) required no postoperative analgesia. Seventeen (9.2%) required parenteral opiates within the first 24 hours and a further 12 (6.5%) beyond that period. Fifty-four patients (29%) required occasional or regular oral mild analgesics, mainly paracetamol. Six (3%) were readmitted following treatment with flank pain for a maximum of 48 hours of parenteral analgesia. Twelve developed pyrexias of over 37.5°C, of whom two required a temporary fine PCN. One proved to have a viral upper respiratory tract infection and the remainder settled on antibiotic therapy alone.

At discharge, 29 (15.7%) had a "Steinstrasse", a radiological description of stone fragments in the ureter, making a fine cast of the ureteric lumen. Sixty-nine patients collected fragments for biochemical analysis. Of these, 59% were calcium oxalate, 12% mixed triple phosphate, 23% mixed calcium oxalate and calcium phosphate, 3% uric acid and 3% cystine.

At the first follow up visit, nearly all of those not requiring an auxillary procedure had resumed normal activity within 24 hours of discharge. Five were restricted in their activities beyond 24 hours, the maximum being 5 days. Auxillary procedures were required in 30 (16.2%) patients (Table II).

TABLE II. Auxillary procedures following primary treatment by ESWL 185 patients

PCN/PCNL	17
URS	7
Dormia basket	3
Repeat ESWL at 3 months	2
Open ureterostomy	1
	30 (16.2%)

Seventeen (9.2%) required PCN or PCNL to relieve obstruction or to remove stone fragments. Seven (3.8%) underwent URS for persistent lower ureteric steinstrasse with dilatation above and three required Dormia basket extraction. A 65-year-old man with a single kidney devel-

oped obstructive anuria and underwent open ureterostomy-in-situ to treat his renal failure as PCN facilities were unavailable at his local hospital. His condition resolved rapidly after drainage. The average stone mass diameter in those requiring auxillary procedures was 5 cm (range 1.4–8 cm).

At 48 hours, 8 (4.3%) were completely free of stone and 57 (31%) were stone free at 7–10 days. One hundred and six (76%) of those who attended follow up or furnished X-rays as requested (140) were stone free at a mean follow up time of 14.5 weeks (9–26 weeks). Thirty-four had residual fragments, 2 required repeat ESWL at 3 months and one a PCNL at 3 months for large fragments. Thirty (21%) patients who had persisting small amounts of calcific debris that could be expected to pass spontaneously and were uncomplicated, were observed further. In total, 45 (24%) failed to fulfill follow up arrangement. Of those with a follow up period of 3 months or greater, 80% were clear of stone.

## Discussion

ESWL has been shown to be safe and effective, and where available has become the primary treatment for the majority of stones (6,7). In the early reports of ESWL, 60–70% of stones were thought suitable for Lithotripsy (8). As experience has increased and with the addition of endourological techniques, it is now reasonable to expect to treat 85% or more of all stones by ESWL (6,7).

As with any procedure, appropriate patient selection is essential for the best results. The single most important feature in the absence of distal obstruction is stone mass diameter. Our auxillary procedure rate of 16% compares well with the German series (6–28% according to the size of stone) (6). Our acceptance rate for ESWL as primary therapy was marginally higher (92.5%) than a recent representative series (85%) (8). Previous experience has shown that stones below 2 cm diameter are suitable for ESWL as the treatment of choice with minimal complications. Above this size complications are more likely (7). Our auxillary interventions were performed for stones averaging 5 cm diameter (range 1.6–8 cm). Complications can be anticipated in this group of patients with larger calculi and therefore PCNL should be performed prior to ESWL in order to reduce the stone mass and to provide an alternative conduit for drainage of urine and stone debris as well as to decompress the upper urinary tract during the subsequent stone passage.

At 3 months, 34 (24%) had residual stone fragments. This appears initially a high figure. However, only 3 of these had fragments that were symptomatic or of a size that required retreatment by ESWL or PCN. The remainder were finely fragmented, uncomplicated and likely to undergo spontaneous passage. They therefore constituted no special problems. It remains to be seen what the ultimate fate of these small stones will be. There have not been reports of increased stone recurrence following ESWL since its introduction in 1980 but probably at least another 5 years is required before the true recurrence statistics are available. However, by conventional open renal surgery complete removal of all stones from the collecting system could only be accomplished in 80–90% of cases in the best reported series (6). Residual fragments after open surgery can only be observed and result in a high recurrence rate that requires further open surgery (9). Also, after PCN, significant residual fragments are left in 9% of cases (10).

What is reassuring following ESWL is that the incidence of large residual fragments in small and compares very favourably with PCNL and open surgery. Recurrences can be easily and safely retreated if necessary by ESWL before attaining a large size. Open surgical procedures and their attendant morbidity are no longer necessary for recurrent or residual calculi.

Patients with solitary kidneys are a high risk group whatever treatment is used. In this study, 5 (46%) required

intervention (3 PCN, 1 URS and 1 open ureterostomy-in-situ) although all made a satisfactory recovery. They are a group that obviously require extremely close postoperative monitoring and PCN expertise to avoid serious complications. This was clearly demonstrated by the case undergoing open ureterostomy-in-situ where ureteric obstruction occurred and PCN facilities were not available.

In institutions practising both ESWL and endourology, over 95% of urinary calculi can be removed without open surgery as demonstrated by this series and others (6,7). The indications for PCNL as the primary treatment in our group of patients were when stone localisation in the shockwave focus was impossible due to obesity, a low anterior horseshoe kidney and large parapelvic cyst displacing the kidney. A combined pelvi-ureteric junction stricture and calculus were treated by synchronous PCNL and percutaneous pyelolysis (11). Lucent calculi may be treated by PCN or alternatively by ESWL if localisation with contrast is possible and the stone is of suitable size.

PCNL prior to ESWL allows the safer management of larger stones and those complicated by infection. Finally, endourological methods are vital for the management of complications that may occur after ESWL of any stone as demonstrated by the 16% auxillary procedure rate in this series.

Certain circumstances will still demand open surgery. Of the three patients requiring open surgery, one underwent a combined ureterolithotomy and correction of a 2 cm ureteric stricture. A second presented with 2 large (3 cm and 2 cm) calculi which had been wedged in the pelvic ureter for over 6 months with severe obstruction and dilatation. In addition, she had lower pole renal calculi. It was necessary to perform ureterolithotomy as these stones were impacted in the ureteric mucosa making manipulation impossible and endoscopic lithotripsy dangerous. Ureteric calculi below the iliac crest cannot be successfully treated by ESWL as the energy cannot be conveyed to the stone through the bones of the pelvis (12). Ureteric stones accounted for 7.5% of all our stones and open surgery was required in 13% of these, whereas open surgery was the primary treatment for only 1% of renal calculi. These figures closely resemble the Stuttgart experience with 1340 patients (6) of whom 7% had ureteric stones of which 15% required open surgery compared with 1% of renal stones. The third patient undergoing open surgery was a young thin lady with bilateral complete staghorn calculi with a predominantly peripheral calyceal stone mass who had not undergone previous surgery. The kidneys were small and scarred. In view of her age, large stone mass and intrarenal anatomy she underwent straightforward, bilateral open, extended pyelolithotomies and multiple radial nephrolithotomies. In this patient a single procedure on each kidney resulted in rapid complete stone clearance. Whilst ESWL with PCNL could have been expected to clear these kidneys of stone, our experience of such large bilateral stone masses is that they may require multiple procedures and prolonged operating, anaesthetic and inpatient time. However, another patient with recurrent bilateral infective calculi and a history of multiple surgical procedures on each side on at least two previous occasions was rendered stone free by a combination of ESWL, PCNL and URS. Though his inpatient stay was prolonged, bilateral repeated open surgery would have been extremely difficult and would have carried a high risk of

operative complications, loss of renal function and possibly even nephrectomy.

It is not clear at present what the ideal initial management of every staghorn calculus should be. Guidelines as to those most suitable for open surgery or ESWL and endourology are still to be established. However, once a primary staghorn stone has been removed, close follow up will allow early treatment of recurrences by ESWL or endourology and prevent large and complicated stones from reforming. What is clear is that open stone surgery in the kidney now holds a minor place in primary management. It should be reserved for the removal of stones from poorly or non-functioning kidneys, the correction of anatomical deformities (eg, pyeloplasty) and the removal of a proportion of complex staghorn stones only.

In the ureter, large impacted stones and those associated with a ureter that requires repair or reimplantation are best treated by open surgery. Otherwise, those above the iliac crest are best treated by replacement in the kidney and simultaneous ESWL or PCNL and those below by ureteroscopic extraction or lithotripsy (12).

This series confirms that ESWL is an effective, safe and non-invasive treatment and confirms the early European experience. ESWL has become the primary treatment for most stones in our practice. Advanced endourological expertise must be available within any department managing these patients. We are particularly impressed by the low morbidity and by the ready acceptance by patients of this technique.

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