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# Comparison of treatment of renal calculi by open surgery, percutaneous nephrolithotomy, and extracorporeal shockwave lithotripsy

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## Abstract

This study was designed to compare different methods of treating renal calculi in order to establish which was the most cost effective and successful. Of 1052 patients with renal calculi, 350 underwent open surgery, 350 percutaneous nephrolithotomy, 328 extracorporeal shockwave lithotripsy (ESWL), and 24 both percutaneous nephrolithotomy and ESWL. Treatment was defined as successful if stones were eliminated or reduced to less than 2 mm after three months. Success was achieved in 273 (78%) patients after open surgery, 289 (83%) after percutaneous nephrolithotomy, 301 (92%) after ESWL, and 15 (62%) after percutaneous nephrolithotomy and ESWL. Comparative total costs to the NHS were estimated as £3500 for open surgery, £1861 for percutaneous nephrolithotomy, £1789 for ESWL, and £3210 for both ESWL and nephrolithotomy. ESWL caused no blood loss and little morbidity and is the cheapest and quickest way of returning patients to normal life.

## Introduction

Throughout the 1970s research and skill improved the success rates of open renal surgery for the large staghorn and smaller renal calculi and allowed all stones to be removed with minimal loss of function. The morbidity associated with such procedures was also reduced. In 1980 percutaneous nephrolithotomy was introduced, whereby a radiologically guided track was made through the skin into the renal collecting system, permitting the stones to be extracted under direct vision with an endoscope.<sup>1</sup> This technique reduces mortality and morbidity and entails a short stay in hospital at low cost to the National Health Service.<sup>2</sup>

In November 1984 the first extracorporeal shockwave lithotripter in the United Kingdom was installed by the St Martin's group of hospitals at the London Stone Centre. This apparatus enables

kidney stones to be broken up in situ by using focused shock waves generated by an ultrashort, high tension underwater electrical discharge; it obviates the need for invasive surgery, although an anaesthetic is still required.<sup>3</sup> In all, 750 treatments have now been performed at the London Stone Centre and over 80 000 have been performed world wide (Dornier Systems, West Germany).

With any new and capital expensive treatment three questions need to be answered: What is the difference in mortality? What is the difference in morbidity? Which mode of treatment is the most cost effective? We tried to define the current place of extracorporeal shockwave lithotripsy (ESWL) in the management of renal calculi by comparing 350 cases of open stone removal, 350 cases of percutaneous nephrolithotomy, and 352 cases of ESWL. All patients were treated by the same team of surgeons under the direct supervision of one consultant. Patients in all groups were unselected and treated consecutively over 14 years (open surgery from 1972 to 1980, percutaneous nephrolithotomy from 1980 to 1985, and ESWL in 1985).

## Methods

**Open surgery**—All renal and ureteric calculi were treated by nephrolithotomy, pyelolithotomy, ureterolithotomy, or a combination of these procedures. Many patients had complicated conditions and had been operated on previously. Some complex renal calculi were removed with the aid of regional hypothermia,<sup>4</sup> in some cases intravenous inosine was used to protect function during controlled ischaemia, and in some cases minimal ischaemia or no clamping of the renal pedicle was used. Intraoperative radiography was commonly used, antibiotics were given routinely, and all patients required general anaesthesia.

**Percutaneous nephrolithotomy**—The techniques of one and two stage nephrolithotomy used have been extensively described.<sup>5</sup> This study comprised 150 two stage and 200 one stage nephrolithotomies. All types of stone were treated. In the one stage procedure the tracks were kept patent with an Amplatz sheath and the stones were removed whole or broken up with electrohydraulic lithotripsy or ultrasound.<sup>6,7</sup> All patients were given prophylactic antibiotics and general anaesthesia.

**ESWL**—The technique of ESWL used was based on the German experience of the Dornier lithotripter.<sup>8</sup> The number of shocks was limited to that required to render the stones into particles that could be passed spontaneously (roughly 2 mm in diameter)<sup>7</sup> (G W Drach *et al*, tapes presented at meeting of American Urological Association, 1984). Patients underwent either general or epidural anaesthesia, and all received prophylactic antibiotics. All patients were screened for clotting defects and renal impairment, and urine samples were cultured. Follow up consisted of a plain abdominal x ray examination on the second postoperative day; renal ultrasonography, if clinically indicated by fever or pain; and a plain abdominal x ray examination on the 10th postoperative day and at three

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months. In 25 patients with larger staghorn calculi the portion of the stone in the renal pelvis was removed percutaneously and then ESWL was applied to the residual stone fragments; these patients were considered separately. When patients required unplanned percutaneous nephrolithotomy after ESWL this was recorded as a complication of treatment. In some cases of percutaneous nephrolithotomy and ESWL stones in the upper ureter were manipulated back into the renal pelvis before being treated in the kidney.<sup>9</sup>

**Analysis**—In all groups stones were sent for analysis, and all patients

underwent metabolic stone screening.<sup>3</sup> For the purpose of this study all details of patients were assessed three months after treatment. The procedures were defined as successful if patients were free of stones at three months or, in the case of ESWL, if stones had been fragmented into particles of less than 2 mm. For each type of treatment the patients were considered in two groups: group 1 were those with stones of a mean diameter of less than 2 cm and group 2 those with stones of a mean diameter of 2 cm or more or with multiple stones.

TABLE I—Details of patients in each treatment group

	No (%) of patients with stones		Total	Mean age (range)	M:F (%)
	<2 cm (group 1)	≥2 cm (group 2)			
Nephrolithotomy/pyelolithotomy	13 (6)	218 (94)	231	45 (12-78)	45:55
Pyelolithotomy	31 (41)	45 (59)	76	47 (16-72)	51:49
Ureterolithotomy	43 (100)		43	46 (20-68)	69:31
Percutaneous nephrolithotomy	270 (77)	80 (23)	350	52 (23-72)	68:32
ESWL	204 (62)	124 (38)	328	48 (22-83)	70:30
Percutaneous nephrolithotomy and ESWL		24 (100)	24		

TABLE II—Success rate of treatment\* (figures are numbers (%) of patients)

	Group 1	Group 2	Overall
Nephrolithotomy/pyelolithotomy	12 (92)	154 (71)	166 (72)
Pyelolithotomy	26 (84)	38 (84)	64 (84)
Ureterolithotomy	43 (100)		43 (100)
All open procedures	81 (93)	192 (73)	273 (78)
Percutaneous nephrolithotomy†	234 (87)	55 (69)	289 (83)
ESWL	200 (98)	101 (82)	301 (92)
Percutaneous nephrolithotomy and ESWL		15 (62)	15 (62)

\*Success defined as no stones at three months or stone reduced to particles <2 mm in size.

†52 with electrohydraulic lithotripsy, 69 with ultrasound.

## Results

Table I shows the subgroups of patients by age, sex, operation, and size of stones. The mean age was between 45 and 52 (range 12-83), and two thirds of patients were male. Most open procedures were for stones greater than 2 cm in diameter, whereas most of the closed procedures were performed for smaller stones.

Table II compares the success rate by size of stones and shows that overall ESWL had the best success rate of 90% (98% in group 1 and 82% in group 2).

The proportions of patients who had complications (excluding infective urine) were: after nephrolithotomy/pyelolithotomy 105 patients (46%) (3 (23%) in group 1; 102 (47%) in group 2); after pyelolithotomy 27 (36%) (12 (38%); 15 (33%)); after ureterolithotomy 4 (9%) (0; 4 (9%)); after percutaneous nephrolithotomy 59 (17%) (35 (13%); 24 (30%)); and after ESWL and percutaneous nephrolithotomy 37 (11%) (7 (3%); 30 (20%)).

**Morbidity**—Table III lists the complications that occurred after each type

TABLE III—Complications after each procedure (figures are numbers of patients)

	Nephrolithotomy		Pyelolithotomy		Ureterolithotomy		Percutaneous nephrolithotomy		ESWL	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Cardiac		10					4	4	6	5*
Pulmonary	1	32	4	6	1					1
Gastrointestinal	1	3								
Renal failure		9	1	1	1					1
Septicaemia		8	2	1			20	14		5
Obstruction of upper tract		5	1				6	6		15†
Leak	1	16	2	2	2		5			
Wound infection		19	2	5					1‡	3
More than one complication	2	36	2	3	1		2	2		

\*Transient arrhythmias.

†Treated by needle nephrostomy, percutaneous nephrolithotomy, or ureteroscopy.

‡Includes elective percutaneous nephrolithotomy and ESWL.

Cardiac complications included cardiac arrest, pulmonary embolus and deep venous thrombosis, and cardiac arrhythmias. Pulmonary complications were usually chest infections yielding positive results on sputum culture. Ileus and stress ulcers were the gastrointestinal complications. Renal failure occurred in patients with solitary kidneys; chronic renal failure before treatment was excluded. Septicaemia included transient bacteraemia after operation. Obstruction of the upper tract included obstruction of the pelviureteric junction and ureteric obstruction by calculi but excluded the ureteric calculi that did not obstruct, as is sometimes seen after ESWL (the "Steinstrasse"). Leaks were recorded if urine leaked for more than two days after removal of a drain or nephrostomy tube. Wound infection included abdominal bruising, which sometimes occurs after ESWL.

TABLE IV—Comparative total cost of each part of procedure to NHS

	Inpatient days		Outpatient visit		Cost of procedure	Total cost (range) (£)
	No	Cost (£)*	No	Cost (£)†		
Nephrolithotomy	17-08	2972	2-4	243	469-28	3500 (3324-3660)
Pyelolithotomy	15-15	2636	2-4	243		
Percutaneous nephrolithotomy:						
First	5-63	955	2-5	251	407-84	1861 (1613-2111)
Second	8-3	1453	2-5	251		
ESWL	3-7	643	3	251	800-00	1739 (1689-1789)
ESWL and percutaneous nephrolithotomy	9-92	1726	3	276-44	1207-00	3210

\*NHS bed £174.

†First outpatient visit £165, follow up £55-72.

of treatment. No distinction was made between primary and secondary haemorrhage, and only the total amount of blood required was recorded. During open surgery four patients in group 1 required more than three units of blood, one of whom required 10 units; and 90 patients in group 2 required more than three units of blood, 18 of whom required more than six units and one of whom subsequently underwent nephrectomy. During percutaneous nephrolithotomy no patients in group 1 needed more than three units but two in group 2 did, one of whom required 16 units. No patients who underwent ESWL required blood. Average blood loss was 2.6 units during open surgery and nil during both ESWL and percutaneous nephrolithotomy.

**Mortality**—Mortality with all three modes of treatment was extremely low: three patients (0.9%) died after open surgery, two (0.7%) after percutaneous nephrolithotomy, and none after ESWL.

**Cost of procedures**—A calculation of the overall cost to the NHS (table IV, appendix) showed that ESWL can be the cheapest form of treatment for both large and small stones. The cost to the NHS for sessions on the lithotripter at the stone centre can be further reduced if patients are housed in their referring hospital. The costs do not include the cost of transport to and from the stone centre.

## Discussion

The surgical management of patients with renal calculi has now moved away from operative intervention, but the types of stone do not change. The incidence of stone disease encountered in a major health region is around 1200 cases a year, of which 300-400 will need surgical intervention (this may increase with ESWL by 10-15% (M Blacklock, personal communication)). The economic consequences of this are enormous as most patients are around 45 years old and two thirds are male.<sup>10</sup> ESWL and percutaneous nephrolithotomy, which reduce inpatient stay by 75%, allow patients to return to work far more quickly than open surgery, and with ESWL most patients can resume normal activity within 24 hours of treatment and can return to work in less than a week.<sup>3</sup>

Over 80 000 patients have been treated with ESWL world wide and only two have died. Morbidity with this procedure is minimal, as evidenced by the small amount of analgesia required post-operatively.<sup>11</sup> Complications that arise can be anticipated and treated by a skilled team. Moreover, stones can be cleared in patients who have previously been considered to be unfit for open surgery or technically unsuitable for percutaneous nephrolithotomy. The overall cost of ESWL compares favourably with that of percutaneous nephrolithotomy, and the procedure is far more cost effective than open surgery.<sup>12</sup> Time spent on treatment by the consultant (57 minutes as opposed to 84 minutes for percutaneous nephrolithotomy and 130 minutes for open surgery) and exposure to x rays are considerably less for ESWL, and hence many more patients can be treated. Treatment of one patient an hour is easily realisable.

In overall economic and therapeutic terms, therefore, ESWL is superior to other forms of treatment for most types of stone except cystine and complete staghorn stones. Given the overall incidence of stones in the United Kingdom of 1.2-4.6/10<sup>4</sup>, probably five lithotripters are needed in the United Kingdom. The machines are expensive and, to be used efficiently, should form part of an overall stone service and be grouped in units where all forms of endourological skill are available (American Urological Association ad hoc committee, May 1985). More surgeons need to be trained in percutaneous renal surgery so that they can use their skill in conjunction with ESWL, thus allowing more urologists to participate in a complete stone service.

Previously the aim of treatment has been to eliminate all stones as residual calculus results in a high rate of recurrence requiring treatment.<sup>14</sup> With ESWL gravel may persist in dependent calices with no clinical effect (24% seen on x ray films at three months). It is too early to predict the ultimate fate of these finely fragmented particles as follow up is still less than five years world wide, but because ESWL is so safe further treatment may be undertaken to treat reformed or residual calculi. As yet there is no proved maximum number of treatments that patients may safely undergo, and hence it should be possible to render a patient free of stones and keep him such with repeated ESWL if required.

Our study shows that the size of the stone is a crucial factor in

determining the outcome of treatment. Stones greater than 2 cm in diameter lead to a high failure rate with all forms of treatment, but much less so with ESWL. The prevalence of complications is also increased to up to 46% in this group, and blood loss is always greater. As confidence with ESWL and percutaneous nephrolithotomy increases larger stones are attempted, accounting for the slight increase in morbidity and failure rates as numbers expand. The complete staghorn is still a major challenge, but with a combination of percutaneous nephrolithotomy and ESWL, using repeated treatments, open surgery may be avoided for nearly all stones.

We thank Sisters V Capper, T Raybold, and L Pinker for their help in compiling the cost figures; Larry Watkinson for the use of the institute's computer services; Ian Carswell in the financial department of the Middlesex Hospital; and the London Stone Centre for making its records freely available. We especially thank Professor N Blacklock for access to his lithotripter pilot study for Greater Manchester.

## Appendix

### COMPARATIVE COSTS OF TREATMENT

#### Open surgery

Theatre time (average 2 h 10 min) at £87/h (medical cost £36/h, nursing/portering £26/h, maintenance £25/h)	£188.50
Radiology units (120)	68.76
Disposables	78.02
Special equipment (£10 per case)	10.00
Capital outlay	£3074
Hypothermic equipment RHU101	859
Ortholav	2215
Drugs (inosine at £36.23 for £20; £20 per case)	20.00
Blood (average 2.6 units at £40/unit)	104.00
Cost per case	£469.28

#### Percutaneous nephrolithotomy

X ray department time (average 1 h 24 min) at £74.28/h (medical cost £50.15/h, nursing/portering £24.13/h)	£103.99
Radiology units (180)	103.14
Disposables	157.28
Special equipment (£36 per case)	36.00
Capital outlay	£8983
Wickham operating scope	962
Rigid stone forceps × 2	208
Storz optical triradiate and 0° scope	1230
Wolf electrohydraulic lithotripter	2820
Lithotripter probes × 6	408
Wolf ultrasonic operator	1882
Wolf sonotrode	463
Wolf suction pump	1010
Cost per case	£400.41

#### ESWL<sup>14</sup>

Building to house machine	(£214 000-328 000)
Dornier lithotripter	1 100 000
Ward conversion	243 000
X ray guidance for endourology	150 000
	1.707m-1.821m
Revenue costs (£1000-1250/year for 5 years)	
Medical staff	£81 000
Nursing and ancillary	67 547
Maintenance of building and equipment	
10% depreciation on building	21 400
10% depreciation on machine	110 000
Medical disposables	7 300
Rates	25 000
Electricity	25 000
Electrode (1.7/patient at £200 each, assuming 1000 patients)	340 000
Servicing	100 000
	£777 247
Cost per case*	£777

\*Assuming initial capital outlay is written off, and assuming 1000 patients are treated.



## COMPARATIVE COSTS OF ESWL AT PRIVATE AND NHS HOSPITALS

<i>Private hospital</i>	
Lithotripsy	£1500
Hospital room (£185/day) for 3 days	555
Anaesthetist	200
Pathology	351
	£2606
<i>Cost to NHS</i>	
Lithotripsy (£3500/session with 4.5 patients treated each session)†	778
Single patient treatment including price	950
Room for 3 days	470
	£2198

†Referring hospital would be expected to provide transport and anaesthetist if patient not staying.

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## CLINICAL CURIOS

## Strongyloides stercoralis infection in a former soldier of the Burma campaign: 40 years later

The nematode worm *Strongyloides stercoralis* causes infections that may persist for many years because of autoinfection (larvas penetrate perianal skin and pass via tissues to the gut, where they later reproduce). Infections may be asymptomatic or cause diarrhoea, malabsorption, or a pathognomic rash known as larva currens. This is a rapidly moving, linear, eruptional wheal caused by migrating larvas, which is intensely itchy and affects central areas of the body.

A notable proportion of people who were prisoners of the Japanese during the second world war still have strongyloides infection, and it is common among those who worked on the Thai to Burma railway. British soldiers in the Burma campaign often fought in similar jungle environments to the prisoners of war and contracted the infection through touching soil contaminated with faeces.

A 64 year old man had fought in the jungle during the Burma campaign in 1944-5. In 1984 he attended a reunion at which we drew attention to strongyloidiasis. He immediately recognised the creeping, erupting rash as being identical with his own, which occurred about monthly and affected his body and thighs; it had previously been attributed to nerves. Investigations were performed in 1985. He did not have appreciable blood eosinophilia, but microscopy of stools showed scanty larvas of *S. stercoralis*. He was given mebendazole 200 mg twice daily for two weeks, and his rash cleared.

This man undoubtedly acquired strongyloidiasis in the Far East during the war, and it persisted until treatment 40 years later. The prevalence of strongyloidiasis among prisoners of war who worked on the Thai to Burma railway and were examined 30-40 years later has been variously quoted as 21-37%. As there are about 30 000 men in Britain today who fought in the Burma campaign so the total number with strongyloidiasis is probably considerable.

Advice on suspected strongyloidiasis is available from the Department of Tropical Medicine, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool L3 5QA (tel 051 708 9393).—G V GILL, Arrowe Park Hospital, Merseyside L49 5PE; D R BELL, School of Tropical Medicine, Liverpool L3 5QA; R J PEARCE, Ipswich IP1 3LU.

## Appearance of facial cosmetics as a sign of cerebellar dysfunction

A 26 year old woman presented with difficulty in walking of four years' duration that had deteriorated more rapidly after the birth of each of her three children. Her brother was confined to a wheelchair. In an attempt to appear presentable she had applied facial cosmetics, producing a sadly bizarre appearance that offered an immediate clue to the underlying diagnosis. Her face was smeared with lipstick, and her eyeshadow had a

hopelessly cubist asymmetry. Further examination confirmed the suspicion of cerebellar disease: pale optic discs, absent reflexes, hypotonia, and extensor plantars were found, but no skeletal abnormalities, strongly suggesting Friedreich's ataxia.<sup>1</sup> Electromyography confirmed the clinical suspicion, showing sensory neuropathy and disturbed function of the posterior quadrant.



Does Friedreich's ataxia deteriorate more rapidly after pregnancy or does the physical strain of a child quickly magnify the underlying abnormalities? The clinical sign of bizarre facial make up is unreported, but we suspect that the absence of facial make up is much more common in patients with the condition.—K ANDERSON, W F DURWARD, Institute of Neurological Sciences, Southern General Hospital and Royal Infirmary, Glasgow.

1 Friedreich N. Über degenerative Atrophie der spinalen Hinterstränge. *Virchow's Archiv für Pathologische Anatomie und Physiologie und für Klinische Medizin* 1863;26:391-419.