AUSTRALIA

Renal stone therapy

A report by the

Australian Health Technology Advisory Committee

June 1991

National Health and Medical Research Council

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This report was initiated by the National Health Technology Advisory Panel (NHTAP) and finalised by the Australian Health Technology Advisory Committee (AHTAC). Any comments or information relevant to the subject matter of the report would be welcome. Correspondence should be directed to:

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Executive summary

- Ten years ago the main treatments for renal stones were open surgery and medical therapy. Since then, radical changes have occurred with the introduction of percutaneous nephrolithotomy (PCN), extracorporeal shock wave lithotripsy (ESWL) and transurethral procedures using lithotripsy.
- It remains true that not all cases of kidney stones require intervention.

PCN

- While PCN can be used to remove most kidney and upper ureteral stones, its main role, when ESWL is available, is in the preliminary debulking of large or staghorn stones, and in the removal of cystine stones which are often resistant to ESWL.
- In Australia, public hospital stays following PCN are longer (eight to twelve days) than those reported overseas (three to nine days).

ESWL

- ESWL has made a major impact on renal stone treatment, and is being used to treat 80 to 90 per cent of stones in several other countries. It is used to treat the majority of renal stones and many ureteral stones.
- Several issues relating to its use and effects are still being debated, in particular the possibility of ESWL leading to renal hypertension in some cases, and its use in the treatment of staghorn and very large stones.
- In Australia, ESWL (where available) has replaced many open surgical operations and some transurethral procedures. Australian experience with ESWL is similar to that overseas in terms of factors such as length of hospital stay, complications, number of shocks per session and energy levels.
- Recent advances in lithotripters include features such as multipurpose treatment tables, stone localisation alternatives and improvements in patient positioning, rather than significant changes in the technology itself. A number of different units are now available, with capital costs ranging from $430,000 (excluding localisation device) to $2.2m.
- Fewer referrals have come to the two public hospital ESWL units in Sydney and Melbourne from the country than from the surrounding metropolitan areas. Even fewer cases have come from interstate, with practically none travelling east from Western Australia.
- Recent and pending acquisitions are expected to result in at least three ESWL units in Sydney, and one in each of Melbourne, Brisbane and Perth. These six units would be able to treat the estimated national caseload of 4,800 to 6,400 with capacity to spare, although problems of access and equitable distribution would need to be addressed.

Transurethral procedures

- Laser ureteroscopy is a new technology with much wider application than either electrohydraulic or ultrasonic ureteroscopy, although it is more costly. Developments in ureteroscopes have increased the potential usage of lasers in this application.
- Most ureteral stones can be treated, and indications are still evolving. Information on morbidity, mortality, success rates and cost-effectiveness is still limited.
- Several suitable laser-based systems are available, with capital costs in the range $250,000 to $380,000.

Open surgery

- Levels of open surgery for renal stones in Australia are considerably higher than those reported for other countries which have ESWL.

Costs and savings

- Hospital costs per patient (including machine costs) for ESWL depend on the type of lithotripter, re-treatment rate and patient throughput ($1,860 to $3,000). ESWL is still the least costly method of treating stones.
- Open surgery is the most expensive method of treating stones ($4,962 to $6,062).
- PCN is expensive on the basis of the average length of public hospital stay ($6,450). For uncomplicated cases with shorter stays, costs drop to $3,700 to $4,750 per patient.
- The cost of transurethral procedures depends on the method of stone fragmentation or extraction, and on patient throughput; costs are relatively low at $2,591 to $2,949 per patient.
- The introduction of ESWL to Australia has resulted in an estimated annual saving to the health care system of approximately $3.9m, according to the model used in this report.

Health outcomes

- ESWL has few complications, and patients normally return to usual activities within a week.
- Convalescence following PCN or transurethral procedures is usually longer at one to two weeks.
- The reduction in convalescence periods due to ESWL has reduced post-treatment illness by an estimated 69 person years a year in Australia, a significant saving from the point of view of both patients and employers.
- Complications of laser ureteroscopy relate mainly to ureteroscopy, and decrease as the operator becomes more experienced.
- Open surgery is associated with longer periods of convalescence (four to six weeks), with higher morbidity and with some mortality.
- The long-term effects of ESWL on renal hypertension, the growing kidney, and the ovaries (when used on mid ureteral stones) are not yet established.

Recommendations and suggestions

The Committee:

- does not support any further increase in the number of ESWL units in Australia beyond those needed to provide a realistic distribution of services between States without generating significant over-capacity. This would imply no more than seven ESWL units in Australia;
- urges caution in treating patients with high numbers of shocks, high energy levels, or several treatment sessions in quick succession, until the question of whether or not ESWL leads to hypertension is resolved;
- suggests that State governments should address the issue of ensuring equitable access to ESWL;
- sees a need for further investigation of the use of PCN in Australia, in particular the long hospital stays associated with its use, and its application in combination with ESWL;
- considers that the level of open surgery for kidney stones in Australia remains unacceptably high;
- considers there is a need for further data on laser ureteroscopy, including comparison with ESWL for the treatment of ureteral stones;
- suggests that laser ureteroscopy might prove to be an effective way of treating many ureteral stones in Australia.

Introduction

Stones (known as calculi) can form in the kidney and ureter by the deposition of substances which are normally dissolved in the urine. In about 80 per cent of cases, stones pass naturally. The remainder are usually treated to remove the stone. Ten years ago the primary treatment was removal of stones by open surgery, but as a result of recent developments open surgery is now only used in a small proportion of cases. Instead, stones are removed using extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PCN) or transurethral procedures.

In 1985 the National Health Technology Advisory Panel (NHTAP) produced a report which discussed the new technology of ESWL and made recommendations for its introduction in Australia(1). An updated report on ESWL technology was produced in 1987(2).

The present report, rather than focusing on a specific technology, reviews renal stone therapy as a whole, including the roles of the various technologies involved. The impact of the new technologies on treatment strategies in Australia is also examined.

Occurrence and types of renal stone disease

The prevalence of renal stone disease in United States and United Kingdom populations has been reported at between two and four per cent[3,4]. Middle aged men are the most affected, with the prevalence in this group reported as high as 13.7 per cent in Sweden[5]. The incidence in the United Kingdom has been estimated at about 250 per million population, with regional rates varying from 150 to 470 per million population[6]. The recurrence rate is high. Coe et al reported a recurrence rate of 43 per cent within three years in the United States, and Ljunghall and Hedstrand reported an overall recurrence rate of 42 per cent in Swedish men[7,5].

Calcium stones are most common, with 70 to 80 per cent of patients having calcium oxalate stones and five to ten per cent calcium phosphate stones[8]. Another five to ten per cent have struvite (or infection) stones, and a similar proportion uric acid stones. Cystine stones occur in one to five per cent of patients, while silicate and xanthine stones are rare. Renal stones can be caused by metabolic disorders such as hyperparathyroidism and cystinuria, dietary or vitamin excesses, or by drugs such as analgesics and calcium antacids (Table 1).

Table 1: Common causes of renal stones

	Common causes		
Type of stone	*Metabolic*	*Dietary*	*Drugs*
Calcium	Hypercalcemia eg hyperparathyroidism Hypercalcuria eg idiopathic, renal leak Hypocitraturia eg renal tubular acidosis Hypomagnesuria	Excess use of condiments eg curry Milk plus alkali	Vitamins A and D Analgesics Amphotericin Calcium antacids Lithium Acetazolamide Corticosteroids
Oxalate	Hyperoxaluria eg idiopathic, enteric	Oxalate excess	Vitamin C Ethylene glycol
Silicate			Magnesium trisilicate
Urate	Hyperuricemia eg gout Hyperuricosuria	Protein excess	Uricosuric agents eg probenecid Antineoplastics Ammonium chloride Thiazide diuretics
Xanthine			Allopurinol
Struvite or infection	Urease-producing bacteria		Orthophosphates in presence of urinary tract infection
Cystine	Cystinuria		

Source: References 8, 9

Therapy options

Medical treatment

Metabolic evaluation and medical treatment are used to identify the cause of stone formation, inhibit stone growth and prevent further stone formation, rather than to dissolve existing stones. Current medical treatment strategies include increasing fluid intake, dietary modification and drug therapy (Appendix A).

Percutaneous procedures

In percutaneous nephrolithotomy (PCN), stones are removed through a small incision. PCN involves four steps: establishment of the percutaneous tract, dilation of the tract, stone extraction and postextraction drainage of the kidney. Small stones may be extracted by mechanical techniques or chemolysis, while large stones are usually fragmented by electrohydraulic, ultrasonic or laser lithotripsy before extraction.

With electrohydraulic lithotripsy a spark creates a hydraulic shock wave that fragments stones. Ultrasonic lithotripsy converts electrical energy into high energy sound waves that are transmitted along a probe, causing vibrations at its tip. When a stone is in direct contact with the probe, fragmentation occurs. Laser lithotripters generate pulses of light at a particular wavelength and transmit them via quartz fibres. The light is absorbed by the stone and a shock wave produced, which fragments the stone.

PCN can be used to treat renal stones, and upper and mid ureteral stones. It is sometimes used in combination with ESWL, or as an alternative when ESWL is unsuccessful, inappropriate or not available.

A number of studies have investigated the effectiveness of PCN in removing renal stones, and report success rates ranging from 72 to 100 per cent, with most between 85 and 95 per cent(10-15). Use of different criteria for success accounts for some of the cross-study variation. Success rates have decreased in recent years as more complicated cases with complex stones are now being referred for PCN(16). PCN has been performed on an out-patient basis, but hospital stays averaging four to six days, with a range of three to nine days, are more usual(12,14,17-20). Anesthesia is required for PCN, but can generally be limited to epidural or assisted local anesthesia(11). Convalescence time is one to two weeks(11,21,22). Major complications include renal colic, infection and septicemia(14,19). Further details about PCN are provided in Appendix A.

Extracorporeal shock wave lithotripsy

In extracorporeal shock wave lithotripsy (ESWL), a shock wave is generated outside the patient's body and focused on the stone. Repeated shocks reduce the stone to many small fragments that can be passed naturally. The indications for ESWL have widened since its initial introduction and it can now be used in the treatment of the majority of renal stones and many ureteral stones.

There has been debate on a number of issues relating to the use of ESWL. The first of these is the most appropriate way of treating impacted ureteral stones, whether in situ or by pushing the stone back into the kidney. The second is the treatment of large or staghorn stones. ESWL monotherapy is generally regarded as unsuitable for complete staghorn stones, but some regard it as suitable for partial staghorn or large renal stones, at least in certain cases(23,24). Others prefer a combination of PCN and ESWL(25). A third issue concerns the use of ureteral stents after ESWL. 'Steinstrasse' (accumulation of multiple fragments within the ureter) can develop after treatment of large stones, and lead to ureteral obstruction. Ureteral stents are placed to facilitate the passage of fragments. However, their use after treatment of smaller stones is more controversial in view of the discomfort they cause.

There is considerable concern and debate over the long-term effects of ESWL, in particular whether or not it causes new-onset hypertension(25). Questions such as the effect of energy levels, numbers of shocks, frequency of shock waves, and number and spacing of ESWL sessions on the patient's long-term health status need answering. Other issues are the effect of ESWL on the growing kidney, and on the ovaries during treatment of mid ureteral stones.

Reported success rates for 'first generation' ESWL range from 72 to 98 per cent for most stones[10,19,26] but can be as low as 26 per cent for staghorn stones[15]. Smaller stones require an average of 1.2 sessions per stone for successful treatment, but staghorn stones can take up to eight sessions[27,28]. The average number of shocks per session ranges from 1,100 to 2,000[11,27]. Hospital stays following first generation ESWL range from one to 7.9 days, but average two to four days[10,12,14,19,26]. Anesthesia is normally used with first generation lithotripters, but frequently is limited to epidural anesthesia. Transient gross hematuria occurs in most patients, and other complications include renal colic, fever, infection and obstruction[14]. Complication rates are less than for PCN.

There have been a number of developments since production of the first generation lithotripters. Different systems can be used to produce the shock waves, and in general the shock wave energy is lower in more recent machines, which decreases the pain of treatment but increases the number of shocks needed for stone fragmentation. Ultrasound as well as fluoroscopic localisation is now available. Recent model lithotripters are easier to use, with more mobile shock wave applicators and treatment tables. A wider range of stones can be treated, and other urological procedures can be performed on the lithotripter's treatment table.

Reported success rates for second generation ESWL range from 53 to 94 per cent, with most being over 84 per cent[13,29-32]. Re-treatment rates are higher than for first generator lithotripters, and for some models reach 62 per cent[29]. The average number of shocks per session is also higher, and ranges from 1,600 to 3,600[13,30]. Hospital stays are much shorter, and with some models treatment is usually done on an out-patient basis. Less anesthesia is used, with a number of patients not needing any at all. Further information is provided in Appendix A.

Transurethral procedures

Transurethral ureteroscopy involves passing a long thin endoscope into the ureter through the ureterovesical junction. Ureteral stones can then be removed mechanically or fragmented using electrohydraulic, ultrasonic or laser probes. Ureteroscopes vary in diameter, and can be rigid, semi-flexible or flexible. The smaller diameter flexible ureteroscopes cause fewer complications. Major complications of ureteroscopy are more frequent early in the operator's experience, and include ureteric perforation, avulsion, stricture and infection[33]. Minor complications include mucosal tears and creation of a false passage[34].

Once visible ureteroscopically, non-impacted stones can be extracted mechanically using different types of baskets, forceps or graspers. Reported success rates (see Appendix A) range from 74 to 96 per cent[11,12]. Das et al report an average hospital stay of about three days[12]. The period of convalescence is one to two weeks[11,35].

Electrohydraulic lithotripsy is not used to treat impacted stones and stones close to the ureteral wall since there is a risk of perforating the wall. Other complications include fever and sepsis, as well as those of ureteroscopy[36]. Reported success rates range from 50 per cent (for staghorn stones in the kidney) to 91 per cent[36,37].

Ultrasonic lithotripsy is restricted to use with rigid ureteroscopes. It is particularly useful for cystine and very hard stones, for which other lithotripters are not effective. The main complication, other than those of ureteroscopy, is ureteral injury. Success rates of 80 to 100 per cent have been reported[18,38].

Laser lithotripters are a recent and promising development. Those available are the Nd:YAG, pulsed dye and Q-switched alexandrite laser lithotripters, the difference between them being in the laser medium which determines the wavelength of the light produced. Stones absorb light from pulsed dye lasers more readily than light from Nd:YAG lasers, and the energy density is much higher[39]. Pulsed dye laser devices also have a much narrower fibre and can be used with newly-developed small diameter flexible and semi-flexible ureteroscopes, so that they can be applied more safely in a wider range of cases. For these reasons, pulsed dye lasers are considered more promising than other types of lasers.

Table 2 summarises technical data for several commercially available laser lithotripters. A disadvantage is their cost compared with electrohydraulic and ultrasonic lithotripters.

Lasers can be used for all but cystine and very hard stones. They are particularly useful in the treatment of impacted stones and steinstrasse because they do not cause ureteral wall injury[40]. Their potential use is growing as new ureteroscopes become available and operators become more experienced. Upper ureteral stones can be treated with laser lithotripsy, and there is a possibility of limited use in the kidney. Reported success rates range from 55 to 100 per cent, with most being over 85 per cent[41-44]. Coptcoat et al report an average length of hospital stay of 2.4 days, and some patients have been treated on an out-patient basis[43,45].

Table 2: Technical specifications of laser lithotripters

	Q-switched Nd:YAG	*Q-switched Alexandrite*	*Pulsed dye*	
	Storz Calculas SL2	*Dornier Laserlithotripter*	*Candela MDL200 Lasertripter*	*Technomed Pulsolith*
Wavelength (nm)	1,064	755	504	504
Pulselength	25nsec	150-800nsec	1.2μsec	–
Pulse repetition frequency (Hz)	1-20	1-10	1-10	1-10
Maximum output energy (mJ) Fiber diameter:				
200μm	–	80	80	80
320μm	–	–	140	135
600μm	100	–	–	–
Weight (kg)	–	120	326	290
Capital cost ($)(a)	375,000	250,000	(b)327,230	380,000
Maintenance cost ($)(a)	37,500	–	24,010	75,000

(a) Costs are at September 1990.
(b) The Candela Miniscope is an additional $12,830.

Source: N Stenning and Co, Dornier Medical Systems, Solus Medical Imaging and GEC Australia Ltd

Open surgery

Since the advent of lithotripsy and PCN, open surgery is used to remove only five per cent of stones in the United States(46). It is indicated in a few cases, but complications are more severe and convalescence much longer than for other procedures. Complications include infection, fever, nerve damage, excessive bleeding, and partial or total loss of kidney function(1). A mortality rate of 0.38 per cent has been reported(47). Average lengths of hospital stay range from eight to twelve days and convalescence is four to six weeks(11,21,26,48). If stones recur, repeated surgery becomes more difficult.

Australian experience

The developments described in the previous section have made an impact on the treatment of renal stones in Australia. PCN was introduced in the Royal Melbourne Hospital as early as 1982, and has since become widespread(49). Dornier HM3 lithotripters (first generation ESWL) were acquired by the Charles Wentworth Private Hospital, Sydney and St Vincent's Hospital, Melbourne in 1986, and by the Prince Henry Hospital, Sydney in 1987. Advances in transurethral procedures have also been adopted, with electrohydraulic and ultrasonic lithotripters being available.

The distribution of the different types of procedure used in Australia is shown for public hospital patients for 1988–89 in Table 3, and for recipients of Medicare benefits for 1988–89 and 1989–90 in Table 4. Information pertaining to the source of these data, their area of coverage and limitations is presented in Appendix B.

Table 3: Number (percentage(a)) of patients with renal stones treated in public hospitals

Type of procedure	*1988–89* *NSW*	*Vic*	*SA*	*1988* *Qld*	*WA*	*Tas*	*1987–88* *ACT*
Surgery(b)	482 (21.3)	387 (21.4)	134 (59.6)	290 (64.4)	125 (28.9)	32 (53.4)	29 (30.8)
ESWL	1210 (53.3)	948 (52.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Percutaneous(c)	127 (5.6)	181 (10.0)	45 (20.0)	99 (22.0)	196 (45.3)	1 (1.7)	54 (57.4)
Transurethral removal of obstruction(b)	442 (19.5)	281 (15.5)	45 (20.0)	61 (13.6)	105 (24.2)	27 (45.0)	11 (11.7)
Ultrasonic fragmentation	8 (0.4)	14 (0.8)	1 (0.4)	0 (0)	7 (1.6)	0 (0)	0 (0)

(a) Percentage of all patients treated that year.
(b) Includes some other procedures, eg evacuation of renal cysts (see Appendix C for details).
(c) Incomplete data for Queensland; remaining percutaneous procedures coded under surgery.
Source: State health authority data

Table 4: Payments for stone treatment under Medicare benefits items

Type of procedure	*1988–89* *Number*	*Percentage(a)*	*1989–90* *Number*	*Percentage(a)*
Surgery	737	16.0	607	13.6
ESWL	1,396	30.3	1,481	33.3
Endoscopic manipulation or extraction	1,671	36.3	1,567	35.2
Ureteroscopy plus extraction	630	13.7	591	13.3
Ureteroscopy plus lithotripsy	166	3.6	207	4.6

(a) Percentage of all payments for stone treatment that year.
Source: Commonwealth Department of Community Services and Health

Comparison of these data with overseas experience is of interest. For example, 1,500 consecutive cases were treated from 1984 at the London Stone Clinic. Of these, 78 per cent of stones were removed with ESWL, seven per cent with PCN, 13 per cent with ureteroscopy, and only two per cent with open surgery(12). In the United States, ESWL is considered the appropriate modality for 80 to 90 per cent of stones, with five per cent being removed by open surgery, and the remainder by percutaneous or transurethral procedures(11,46). However, a number of countries appear to be over-supplied with ESWL unit(50).

In Australia, patterns of use of the various technologies proportions are different. ESWL is used in a much lower proportion of renal stone procedures, and proportions of all other procedures are higher. In particular, the proportion of open surgery is higher in States without an ESWL unit; over the past few years PCN does not appear to have replaced as many surgical procedures as has ESWL. The higher reliance on open surgery in these States is of great concern, given the higher morbidity, mortality, recovery time, costs and renal scarring associated with open surgery.

Possible reasons for the low levels of PCN include reluctance to use a lengthy procedure on limited operating lists in public hospitals, general surgeons rather than urologists removing stones in country areas, difficulties in training urologists and radiologists already practising outside the major cities, and insufficient caseloads to maintain expertise (Cameron-Strange, Lenaghan, personal communications).

Even in the major States, levels of open surgery remain considerably higher than those reported for most other countries which have used ESWL. Table 5 shows the geographic distribution of patients treated by the two public hospital ESWL units in New South Wales and Victoria. Approximately half of the estimated public hospital caseload is treated by ESWL in New South Wales and Victoria, so even in these States far fewer stones are treated with ESWL than is the case overseas. The proportion is much smaller in the remaining States.

Table 5: Geographic distribution of ESWL patients in public hospitals in 1988-89

State of of origin of patient	*Estimated ESWL caseload*	*No. of ESWL treatments(a)*			*Percentage of estimated caseload*
		NSW	*Vic*	*Total*	
NSW	2,260	1,184	18	1,202	51.1
Vic	1,700	0	833	833	47.0
Qld	460	19	8	27	5.6
WA	440	0	5	5	1.1
SA	270	2	44	46	16.4
Tas	80	0	15	15	18.0
Not specified	–	5	25	30	–
Total	5,210	1,210	948	2,158	39.8

(a) Assumes re-treatment rate of four per cent(51).

Source: State health authority data

The bulk of interstate referrals to the New South Wales Lithotripter Centre come from Queensland, and represent approximately six per cent of the renal stone procedures performed on Queensland patients in public hospitals.

Interstate referrals to the Victorian Lithotripsy Service come primarily from South Australia, and represent approximately 17 per cent of the renal stone procedures performed on South Australian patients in public hospitals. Further referrals come from Tasmania and New South Wales. The Tasmanian referrals are about 19 per cent of the renal stone procedures performed on Tasmanian patients in public hospitals. Few West Australians travel east for ESWL. The Medicare data show a similar pattern of interstate referrals (Table 31).

In 1988-89 64 per cent of renal stone procedures done on patients from Melbourne used ESWL, compared with 39 per cent for patients from the rest of Victoria. In the same year, 61 per cent of renal stone procedures done on patients from Sydney used ESWL, compared with 43 per cent of patients from the rest of New South Wales. The lower referral rate for patients outside Melbourne and Sydney (whether from the same or another State) could be due to a number of factors, such as additional costs, lack of access to the ESWL services, not being referred to the ESWL units, or the patient preferring to have an alternative treatment in a hospital closer to home.

Data for the number of PCN procedures performed over several years have been obtained from individual hospitals and are incomplete (see Appendix E). The Victorian data show an increase in the number of PCN procedures since 1986, despite the introduction of ESWL, whereas in New South Wales there was a small decrease. PCN procedures in Queensland have remained relatively constant.

The total number of procedures to treat renal stones has increased in the past six years (Tables 30 and 33). The increase is largest in Victoria, with public hospital procedures doubling, although the increase in Medicare payments is not large. The increase in renal stone procedures in Tasmania is also large. Smaller increases occurred in New South Wales, Queensland and the Australian Capital Territory. The remaining States show little change or a small decrease. In a number of States there was apparently a drop in the number of renal stone procedures performed in 1985 or 1986.

In 1988–89, 977 renal stone procedures were performed in New South Wales private hospitals (State health authority data), corresponding to 42 per cent of services eligible for Medicare benefits payments being performed in private hospitals. In the same year, 177 renal stone procedures were performed in South Australian private hospitals (65 per cent of the services eligible for Medicare benefits payments). These percentages have been used to estimate the total renal stone caseload for Australia (Table 6).

Table 6: Estimated 1989 caseload for all renal stone therapeutic procedures

State	*Estimated caseload*
New South Wales	3,245
Victoria	2,190–2,480
Queensland	665–795
Western Australia	490–520
South Australia	405
Tasmania	115–145
Other	85–100
Total	7,195–7,690

The 1989 caseload suitable for ESWL has been estimated at 4,700 to 6,200 procedures (65 to 80 per cent of all renal stone procedures). This estimate is considerably higher than the estimate of 2,530 to 2,955 in the earlier NHTAP report on ESWL, due to the better data available to the Committee through the Australian Institute of Health and an overall increase in renal stone procedures done since 1983(1).

Assuming that the growth of renal stone procedures is the same as the population growth projected by the Australian Bureau of Statistics (ABS), the 1991 ESWL caseload can be estimated as 4,800 to 6,400 procedures(52). This assumption may not be valid. The prevalence of renal stones in the population may be increasing or decreasing, the backlog of treatable patients at the advent of ESWL may or may not have all been treated, and it is possible that ESWL is being used to treat patients who were previously not treated, such as asymptomatic patients. Treatment by ESWL has certainly increased from the first year it was introduced to Australia (Table 34).

The number of procedures per capita shows a different pattern (Tables 7 and 8). In general this measure has remained reasonably constant, except for procedures in public hospitals in Victoria, which have almost doubled since 1984. The per capita procedure levels are higher in New South Wales than in the other States, although the Victorian public hospital level has climbed to a comparable level in recent years. The Australian Capital Territory levels are also higher. Levels in the other States have remained steady and are similar. Western Australia has a higher level of public hospital procedures, matched by a lower level of procedures funded through Medicare (all private and some public hospital procedures).

State health authority data (Table 35) show a dramatic decrease in the number of surgical procedures to remove kidney stones in New South Wales and Victoria. Surgical procedures to remove ureteral stones have also decreased in New South Wales, but not significantly in Victoria (Table 36). The Australian Capital Territory shows a similar pattern. In all other States except Western Australia, the numbers of surgical procedures have remained constant or increased. On the other hand, Medicare data (Table 32) show a decrease in surgery to remove kidney stones in all States. Removal of ureteral stones by surgery has only decreased in New South Wales and Victoria.

Table 7: Renal stone procedures per capita ('m) performed in public hospitals

Year of treatment(a)	*NSW*	*Vic*	*Qld*	*WA*	*SA*	*Tas*	*ACT*
1984	370	–	170	270	90	150	330
1985	270	230	120	290	140	180	240
1986	340	190	190	250	150	120	370
1987	–	300	150	290	140	100	–
1988	400	440	160	280	160	130	340
1989	390	420	–	–	160	210	–

(a) Some data refer to financial years rather than calendar years; see Appendix B.

Source: State health authority data, reference 53

Table 8: Number of payments per capita ('m) for treatment of renal stones under Medicare benefits items

	1984-85	1985-86	1986-87	1987-88	1988-89
New South Wales	380	330	360	390	410
Victoria	250	190	250	270	270
Queensland	180	180	210	180	190
Western Australia	160	130	100	80	80
South Australia	230	200	200	210	190
Tasmania	120	200	190	240	230
Other	150	160	160	170	140
Total	270	230	260	270	280

Source: Commonwealth Department of Community Services and Health, reference 53

Medicare data (Table 32) show an increase in the removal of stones by ureteroscopy (followed by mechanical extraction or lithotripsy) in all of Australia. Removal of stones by endoscopy decreased in New South Wales, Victoria and the Australian Capital Territory over the same period, but changed little in the rest of Australia. The State health authority data do not separate the two procedures, but show a decrease in both combined in New South Wales and Victoria, with little change or an increase for the other States (Table 37).

State health authority data for hospital admissions in New South Wales, Victoria, South Australia and the Australian Capital Territory indicate that about 55 per cent of stones occur in the kidney, and about 45 per cent in the ureter (Table 38). Only 50 to 54 per cent of public hospital admissions for kidney stones in New South Wales and Victoria actually have procedures to remove the stones (Table 39). The percentage is even lower in South Australia at 30 per cent. Overseas experience prior to introduction of ESWL is comparable; Rous reports 57 per cent of hospital admissions in the United States being treated with observation only, with the remanding 43 per cent having stones removed surgically(54).

In 1988-89, 27 to 32 per cent of admissions to public hospitals in New South Wales and Victoria were discharged without any procedures for either diagnostic or therapeutic reasons being done (Table 39). Reasons for this include the stone passing naturally, or a private patient being discharged and re-admitted to a private hospital (Cameron-Strange, personal communication). Of those Victorian patients whose primary procedure was diagnostic, 68 per cent had an X-ray of the urinary system, and 29 per cent transurethral endoscopy. In most cases the X-ray was the only procedure. Of those New South Wales patients whose primary procedure was diagnostic, 68 per cent had transurethral cytoscopy, and only 29 per cent had an X-ray of the urinary system. During the period of hospital admission, approximately one quarter of the cystoscopy procedures were followed by an X-ray, and another quarter by stone removal.

An interesting feature of the State health authority data is that very few combined ESWL/PCN procedures are recorded for the same hospital admission– only six in New South Wales in 1987-88 and six in Victoria in 1988-89. The combined procedure has been used by Brooks and Yeaman with the PCNs being performed at the Westmead Centre and ESWL at the Charles Wentworth Private Hospital(55). Twenty-five patients with staghorn stones were treated in the 12 months to April 1988. Brooks and Yeaman report a stone-free rate of 62 per cent after three months(55). A number of patients developed recurrent urinary tract infection. Some developed new stones, so that after two years 36 per cent of the group had persisting stones.

Comparison with overseas experience is difficult, since most studies compare success rates of ESWL and PCN as separate procedures. However, Rigatti et al report performing combined procedures on 1.6 per cent of patients in their study, while Das et al report using them with 5.5 per cent of patients in their series(26,12). The combined procedure is seen as important in the treatment of staghorn stones, although its use for smaller stones is still being debated(23-25,56-58).

Table 9 contains information on the average length of stay in public hospitals of New South Wales and Victorian patients whose principal procedure was the removal of kidney or ureteral stones. Length of stay for patients undergoing surgical procedures was comparable with overseas experience (Table 29). PCN in Australia involves much longer hospital stays (eight to twelve days compared with three to nine days reported overseas (Table 21)). This is in part due to other procedures being done as well as the PCN, whereas the overseas data may refer to PCN and any resulting complications alone. When the only procedure performed was PCN, the length of stay was reduced, although it was still considerably higher than overseas experience (Table 10). Taylor et al also report a higher average length of stay in Western Australia of seven days(59).

Table 9: Average length of stay (days) in public hospitals for different principal procedures, New South Wales and Victoria

	1987-88		*1988-89*	
Type of principal procedure	*NSW*	*Vic*	*NSW*	*Vic*
Surgical procedures:				
- nephrotomy	12.0	6.2	9.1	10.1
- pyelotomy	14.4	10.4	11.9	13.5
- ureterotomy	10.5	8.6	9.2	8.1
Percutaneous procedures:				
- without fragmentation	11.7	8.4	11.5	10.6
- with fragmentation	9.2	12.4	7.7	9.0
Transurethral procedures	4.6	5.3	3.4	4.9
ESWL	2.9	2.3	2.6	2.1

Source: State health authority data

Table 10: Average length of stay (days) in public hospitals where the only procedure was percutaneous, New South Wales and Victoria

	1987-88		*1988-89*	
Type of principal procedure	*NSW*	*Vic*	*NSW*	*Vic*
Percutaneous procedures:				
- without fragmentation	7.9	7.4	8.4	9.4
- with fragmentation	7.8	9.4	5.4	7.7

Source: State health authority data

Reasons for the longer stays might be related to a higher incidence of post-operative fever and complications or to the size of the stones treated. For example, the majority of PCN procedures carried out in metropolitan Melbourne are on large or difficult stones, many being staghorn stones (Johnson, personal communication). Delayed surgery due to unavailability of theatre time when the patient is admitted as an emergency is also a factor, as is delayed removal of the nephrostomy tube due to ureteric obstruction(59). However, in view of the high cost of hospital beds, it would be productive to investigate these longer hospital stays after PCN to determine their causes. Transurethral procedures in Australia also involve longer stays, but the difference is not as marked (three to five days compared with one to three days overseas (Tables 25 and 26)).

ESWL in Australia generally requires shorter hospital stays than those reported for first generation lithotripters elsewhere (two days compared to one to seven days overseas (Table 22)), although these are long compared with those reported for later generation lithotripters. Hospital stays are shortening as experience with ESWL increases. They were shorter in 1988-89 than in 1987-88 for both New South Wales and Victoria, and are much shorter now than the 3.6 days reported for the initial use of the ESWL unit at the Charles Wentworth Private Hospital(60). At the New South Wales Lithotripter Centre, the 133 patients treated in 1987-88 stayed an average of four days after ESWL, whereas the 507 patients treated in 1988 stayed an average of only two days.

Experience with the technology has had other effects on ESWL procedures. The average duration of treatment at the New South Wales Lithotripter Centre dropped from 59 minutes in 1987–88 to 51 minutes in 1988. The percentage of patients requiring post-ESWL treatment such as nephrostomy or ureteroscopy dropped from 11.3 per cent to three per cent in the same period. In the nine months from December 1988, the percentage of patients at the Victorian Lithotripsy Service requiring repeat ESWL was seven per cent, and one per cent had other procedures. Instead of using general anesthesia, as occurred with a number of centres overseas which used first generation lithotripters, at least 93 per cent of Victorian lithotripsy patients received an epidural. Use of anesthesia might be reduced further if this first generation lithotripter is replaced by a later model.

At the Victorian Lithotripsy Service, seven per cent of patients underwent PCN prior to ESWL, and three per cent underwent transurethral procedures. An attempt was made to push ureteral stones back into the kidney in 20 per cent of patients, with success in three quarters of these cases. A stent or catheter was placed in 34 per cent. Most shocks (72 per cent) were given at 21kV or 22kV, with 52 per cent of patients receiving 1,000 shocks or less, 21 per cent between 1,000 and 1,500 shocks, and the remainder over 1,500 shocks. The average number of shocks would appear to be comparable to overseas experience (Table 22). As with overseas experience, complications were few (less than one per cent), and comprised hematomas and high temperatures. Steinstrasse occurred in 1.3 per cent of patients.

The re-treatment rate of 11 per cent reported by the Charles Wentworth Private Hospital ESWL Unit is comparable to overseas experience (Table 22)(61). Fifty-six per cent of patients with multiple renal calculi are reported as stone-free after three to 12 months, compared with 78 per cent of patients with solitary renal calculi(61).

As has occurred overseas, the application of ESWL in Australia has widened to include ureteral stones. Ten to 20 per cent of stones treated with ESWL are ureteral stones (Table 40), although 45 per cent are diagnosed as ureteral. The New South Wales Lithotripter Centre has treated distal ureteric calculi by modification of the patient's position, with a success rate of 69 per cent(62). More energy was needed to fragment these stones than for kidney stones, with the number of shocks ranging between 1,600 and 4,000. The unit has been used to treat impacted ureteral stones, with a success rate of 73 per cent(63). Both upper and lower ureteral stones have also been removed successfully at the Charles Wentworth Private Hospital ESWL Unit(63). The ease and availability of suitable patient positioning in later types of lithotripter would increase the number of ureteral stones able to be treated by ESWL.

Costs

Several studies have examined the costs of ESWL using first generation lithotripters and compared these to other renal stone procedures. ESWL is regarded as a cost-effective way of treating smaller kidney and ureteral stones[10,19,64,65]. Larger stones are more effectively treated with PCN[64,65]. Mays has concluded that some of the earlier calculations of the cost-effectiveness of the Dornier HM3 may not have been accurate, and suggests that there is probably no significant difference between the cost-effectiveness of ESWL using second generation lithotripters and that of PCN[66].

ESWL and PCN are both regarded as more effective than open surgery for a number of reasons, such as lower cost, decreased morbidity and shorter convalescence[19]. Few analyses of the costs of transurethral procedures versus ESWL exist. Liong et al determined direct costs for these procedures, and concluded that they were similar[11].

In the present study the total cost per patient has been estimated for each type of procedure, making the following assumptions:

- the urologist requires an assistant for open surgery and PCN, but not for transurethral procedures or ESWL;
- the urologist, anesthetist, radiologist and assistant are paid at the rate of Medicare Benefits Schedule fees;
- hospital stays are costed at $370 a day;
- there are no complications requiring additional procedures;
- the useful life of all lithotripters and lasers is seven years (annual depreciation 14.3 per cent). They do not have a resale value;
- the discount rate for determining the opportunity costs of capital and calculating net present value is five per cent;
- where maintenance costs for ESWL units and lasers were not provided by suppliers, they are assumed to be five per cent of the capital cost. Maintenance costs for ultrasonic and electrohydraulic lithotripters are small and have not been included;
- insurance for all lithotripters and lasers is two per cent of the capital cost; and
- costs are as at September 1990.

ESWL

The total cost per patient of ESWL has been estimated for a range of lithotripters. Table 11 gives estimates of the operating costs per procedure (all costs except equipment costs). There is now a range of lithotripters available, with prices varying from $430,000 (excluding localisation device) to $2.2m. The cost per treatment of the equipment used depends on the type of lithotripter and patient throughput. Table 12 includes these equipment costs and gives estimated costs per session for a range of treatment options. Due to the lower shock wave energies, re-treatment rates when the first procedure fails are higher for piezoelectric lithotripters than for electromagnetic and electrohydraulic lithotripters[67]. Re-treatment rates for electrohydraulic lithotripters are reported by some to be lower than for electromagnetic lithotripters, although others disagree (Cameron-Strange, personal communication)[51]. Taking re-treatment into account, Table 13 estimates the total cost per patient for different treatment options.

Table 11: Estimated operating cost of ESWL per procedure (excluding equipment costs)

Item	*Cost ($)*
Urologist's fee	435
Anesthetist's fee	138
Diagnostic procedures(a)	242
Medication	40
Bed day costs - piezoelectric(b)	185
- other lithotripters	925
Staff costs(c)	31-63
Other costs(d)	77
Total - piezoelectric	1,148-1,180
- other lithotripters	1,888-1,920

(a) Diagnostic procedures used are plain film X-ray and intravenous pyelography preoperatively, and two plain film X-rays postoperatively.

(b) Assumes piezoelectric lithotripsy done on an out-patient basis.

(c) Assumes a lithotripsy unit set up with a full-time receptionist and use of the services of a hospital radiographer as required. Cost per patient depends on patient throughput.

(d) Placement of a stent in 35 per cent of patients.

Table 12: Total cost of an ESWL session for different treatment options

Treatment options		*Costs per session ($)*		
Type of lithotripter	*Patients per year*	*Equipment(a)*	*Operation(b)*	*Total*
High cost	1,500	280	1,888	2,168
	1,000	480	1,896	2,376
	500	960	1,920	2,880
Medium cost	1,500	190	1,888	2,078
	1,000	320	1,896	2,216
	500	640	1,920	2,560
Low cost	1,500	100	1,888	1,988
	1,000	160	1,896	2,056
	500	320	1,920	2,240
Piezoelectric	1,500	180	1,148	1,328
	1,000	300	1,156	1,456
	500	600	1,180	1,780

(a) Equipment costs include capital, maintenance and insurance costs, and a space maintenance charge.

(b) Assumes piezoelectric lithotripsy done on an out-patient basis, and length of stay of 2.5 days for all other lithotripsy.

Table 13: Total cost per patient of different treatment options

Treatment option	*Cost per ESWL session ($)*	*Re-treatment rates (per cent)(a)*	*Cost per patient ($)*
Electrohydraulic lithotripter			
- high cost	2,168-2,880	4	2,255-2,995
- low cost	1,888-2,240	4	1,964-2,330
Electromagnetic lithotripter			
- medium cost	2,078-2,560	15	2,390-2,944
- low cost	1,988-2,240	15	2,286-2,576
Piezoelectric lithotripter	1,328-1,780	40	1,859-2,490

(a) Source: References 51, 67

These results show the sensitivity of cost per patient to patient throughput and re-treatment rates. The lower capital cost of piezoelectric units is thus off-set to a large extent by the higher re-treatment rate. The re-treatment rate of electrohydraulic lithotripters has been found by some to be higher (10 to 15 per cent) than Tung et al have reported, which increases the cost of treatment by electrohydraulic lithotripters relative to the others (Cameron-Strange, personal communication)(61). Costs are also sensitive to changes in length of hospital stay; reducing the length of stay from 2.5 days to one day decreases the per patient cost by $577 for electrohydraulic lithotripters, and by $638 for electromagnetic lithotripters.

Percutaneous procedures

Table 14 shows estimates of costs for PCN with mechanical extraction or lithotripsy on smaller stones, and for all PCN done on larger stones. Hospital stays were taken to be five days for the former and six days for the latter, giving a range of costs per patient from $3,700 to $4,750 for uncomplicated cases. The length of stay recorded in the State health authority data is longer at ten days, and increases the cost range to $6,450.

Table 14: Cost of percutaneous procedures

	Cost ($)		
Item	*With lithotripsy*	*With mechanical extraction*	*Large stones(a)*
Surgeon's fee	525	435	670
Assistant's fee	105	87	134
Anesthetist's fee	150	126	300
Radiologist's fee	350	350	350
Theatre costs(b)	600	600	700
Medication	60	60	90
Hospital costs(c)	1,850	1,850	2,220
Equipment costs	–	30	30
Diagnostic procedures(d)	199	199	199
Total	3,707	3,920	4,744

(a) For large stones, the tract was assumed to be established the day before the stone was removed; otherwise it was assumed the tract was established immediately prior to stone removal.

(b) The radiologist establishes the tract (nephrostomy) before the urologist removes the stone. This might be done immediately prior to stone removal, or on the previous day (which increases theatre costs).

(c) Number of days in hospital was assumed to be six for large stones and five otherwise.

(d) Diagnostic procedures used are plain film X-ray and intravenous pyelography preoperatively, and one plain film X-ray postoperatively.

Open surgery

Table 15 gives estimated costs for using open surgery to remove ureteral and large kidney stones. The cost to remove small kidney stones is a little lower than the cost to remove large stones.

Table 15: Cost of open surgery

	Cost ($)	
Item	*Kidney stones*	*Ureteral stones*
Surgeon's fee	815	525
Assistant's fee	163	105
Anesthetist's fee	138	126
Theatre costs	600	600
Medication	120	120
Hospital costs(a)	4,070	3,330
Diagnostic procedures(b)	156	156
Total	6,062	4,962

(a) Number of days in hospital was assumed to be nine days for removal of ureteral stones and 11 days for removal of kidney stones.

(b) Diagnostic procedures used are plain film X-ray and intravenous pyelography.

Transurethral procedures

Transurethral procedures include mechanical extraction, electrohydraulic and ultrasonic lithotripsy. There are also several different lasers now available for lithotripsy, including the Stortz Nd:YAG laser, the Dornier alexandrite laser, and two pulsed dye laser systems, the Candela Lithotripter and the Technomed Pulsolith. Costs of these are provided in Table 2.

The electrohydraulic and ultrasonic lithotripters are considerably cheaper than laser lithotripters. Electrohydraulic lithotripters are about $10,000 each, with an additional cost of $130 to 180 per probe. Ultrasonic lithotripters are approximately $14,000, and probes $100. An ultrasonic probe can be used on a number of patients, but an electrohydraulic probe is replaced after each patient. Assuming a throughput of 20 patients a week for 50 weeks a year, the per treatment cost of lithotripsy equipment ranges from $13 to $157 (Table 16).

Table 16: Cost of transurethral lithotripters

Type of lithotripter	*Total annual cost(a)($)*	*Cost per patient ($)*
Candela MDL200 Lasertripter(b)	107,773	108
Technomed Pulsolith	148,272	148
Dornier Laserlithotripter	60,705	61
Stortz Calculas SL2	109,807	110
Stortz Calcutript (electrohydraulic)	1,928	157
Stortz Ultrasonic Lithotrite System	2,699	13

(a) Excluding probe costs for electrohydraulic and ultrasonic lithotripters.

(b) Includes cost of Candela Miniscope; an average of 2,000 pulses per patient was assumed to determine maintenance costs.

Source: Solus Medical Imaging, N Stenning and Co, Dornier Medical Systems, GEC Australia Limited

Table 17 gives estimated costs for three types of transurethral procedure. These costs are sensitive to throughput and length of hospital stay. A throughput of ten rather than 20 patients a week will increase costs, to $2,949 per patient for the Candela laser and $2,785 per patient for the ultrasonic lithotripter. In practice the throughput could be considerably lower, in which case the equipment life should be longer than seven years, and the per patient cost would be higher.

Table 17: Cost of transurethral procedures

		Cost ($)	
Item	*Mechanical extraction*	*Ultrasonic lithotripter*	*Candela laser lithotripter*
Surgeon's fee	410	525	525
Anesthetist's fee	104	126	126
Theatre costs	400	400	400
Medication	40	40	40
Hospital costs(a)	1,480	1,480	1,480
Diagnostic procedures(b)	157	199	199
Equipment costs	-	13	108
Total	2,591	2,783	2,878

(a) Number of days in hospital was assumed to be four days.

(b) Diagnostic procedures used are plain film X-ray and intravenous pyelography preoperatively. Another plain film X-ray is done after lithotripsy.

As expertise grows and instruments improve, hospital stays may shorten. Overnight stays have already been reported (Lenaghan, Cameron-Strange, personal communications). As hospital stays shorten, costs will be reduced. For example, an average hospital stay of three days after treatment by a Candela laser reduces the cost from $2,878 to $2,508.

Comparison of costs

Table 18 compares the cost ranges of the different types of treatment. Despite the high capital costs, ESWL is the least expensive of the procedures considered in terms of cost per session, the main reason being the reduced hospital stay. Transurethral procedures are less expensive than the remaining procedures, with the possibility of costs falling as techniques and instruments improve and hospital stays shorten. The cost of PCN varies considerably depending on the complexity of the case and the length of hospital stay. Open surgery remains on average the most costly option.

Table 18: Comparison of costs per patient of different treatments

Type of treatment	*Cost ($)*
ESWL	1,859-2,995
PCN	3,700-6,450
Open surgery	4,952-6,062
Transurethral procedures	2,591-2,949

Re-treatment rates due to failed procedures should be taken into account when considering costs. Open surgery removes all the stone, so there is no re-treatment unless stones recur. PCN sometimes leaves fragments in calyces; these may clear naturally, or need further treatment. Large fragments are usually removed mechanically after transurethral lithotripsy, but small pieces are left to clear and will sometimes require further treatment. All fragments are left to clear after ESWL, so re-treatment is more frequent. ESWL has a re-treatment rate ranging from four to 40 per cent, depending on the type of lithotripter(51). Since the cost of two ESWL treatments is similar to the cost of a PCN, the cost-effectiveness of this approach is questionable, particularly when the long-term effects of such intensive ESWL are not clear.

Hatziandreu et al have performed a detailed analysis of the cost-effectiveness of ESWL in the United States and have concluded that it is preferable to PCN for small stones, but that ESWL is preferred for large stones(65). Overseas experience would suggest that the use of PCN only, or a combination of ESWL and PCN, is a safer and more cost-effective option for treatment of large and staghorn stones in Australia.

There are considerable differences between the various procedures in terms of costs to the community through delayed recovery and consequent loss of productivity. Because it is minimally invasive, most patients having ESWL return to work within a week. After open surgery, four to six weeks' convalescence is needed, representing considerable loss of productivity(21,48). The effects of PCN and transurethral procedures are less severe, with a one to two week recovery period(11,18,21,22,35).

Cost savings due to ESWL

The State health authority data and Medicare data have been used to obtain a rough estimate of the minimum savings ESWL has made to the health care system. The data indicate that ESWL has replaced at least 850 open operations to remove kidney stones, 350 to remove ureteral stones, and 300 endoscopic procedures. The lithotripters used fall into the high cost range, with an estimated cost per patient of approximately $2,500. The cost savings of ESWL over open surgery to remove kidney stones is then $3,560 per patient (Tables 13 and 15). The cost savings of ESWL over open surgery to remove ureteral stones is $2,460 per patient (Tables 13 and 15). Finally, the cost savings of ESWL over endoscopy is $100 per patient (Tables 13 and 17). With the model used in this report, the total savings to the health care system over a year is estimated at $3.9m; the introduction of ESWL would appear to have been an effective strategy in the treatment of renal stones.

Additional savings have occurred in the cost to patients themselves and the community as a whole, although these are more difficult to quantify. The reduction of convalescence times represent considerable savings in terms of productivity, as well as a significant reduction in patient discomfort. Carlsson and Tiselius report that ESWL reduces short-term illness after treatment by three weeks compared with open surgery(64). On this basis ESWL in Australia has resulted in a reduction of annual short-term illness of 69 person years. In fact, the reduction is probably higher, since others report shorter convalescence periods after ESWL(10,11). Other possible savings from the use of ESWL include fewer visits to general practitioners after discharge from hospital, and fewer patients needing dialysis at a later date due to less traumatic stone removal(6).

Role of each therapy

Open surgery for kidney stones has decreased markedly, but will continue to have a role in the treatment of stones, albeit a small one. Because the caseload for open surgery will be very low, urologists might have difficulty maintaining expertise and providing training in the procedure. For this reason it might be appropriate to concentrate this expertise in one or two centres in each State.

Most stones can be treated by ESWL, PCN or transurethral procedures, but the role of the different procedures is still the subject of some debate. While ESWL is used by some to treat large and staghorn stones, the more common treatment is PCN alone, or a combination of ESWL and PCN. Since large stones require more shocks, it might be safer to avoid ESWL monotherapy, especially with high energy units such as electrohydraulic lithotripters, until the effect of ESWL treatment on the incidence of hypertension is clear.

Distal ureteral stones can be treated with ESWL, although ureteroscopic procedures are considered by many to be more appropriate for such stones. Ureteroscopy is commonly used on lower ureteral stones, and can be used on some stones higher in the ureter. Once under direct vision, stones can be extracted mechanically if not too large and not impacted(68). Ultrasonic lithotripsy is of particular use for very hard stones, and electrohydraulic lithotripsy cannot be used near the ureteral wall. The new laser lithotripters are more generally useful. They can be used on most ureteral stones, including those in the upper ureter, and in experienced hands might possibly have some limited use in treating kidney stones.

ESWL is popular with patients because of its high profile, lack of invasiveness and the short recovery period. The latter decreases costs, despite the high capital cost of the equipment, especially in Australia where lengths of hospital stays associated with PCN are quite long.

The trend overseas has been that, once there are sufficient ESWL units to meet demand, most kidney and a number of ureteral stones are removed with ESWL. However, although percutaneous techniques are now being used for alternative upper urinary tract surgery such as pyeloplasty, tumour resection, marsupialisation of cysts and diverticula, and removal of foreign bodies, the trend of treating kidney stones with ESWL rather than PCN may still create problems in terms of caseloads being insufficient to maintain expertise and train new urologists(69). This is of concern since PCN has a role to play in the treatment of very large and staghorn stones.

Number and distribution of ESWL units

As Table 19 shows, the supply of ESWL units in Europe and the United States has expanded rapidly since the first unit was placed in clinical practice in 1983. However, some countries now have an over-supply of ESWL units. For example, the Netherlands is considered over-supplied, and a number of lithotripters in Germany are underutilised(50). Only 45 per cent of lithotripters in the United States are profitable, while 27 per cent lose money(70).

Table 19: Supply of ESWL units in selected countries, May 1989

Country	*Total ESWL units*	*No. of inhabitants per unit (millions)*
Belgium	11	0.90
West Germany	57	1.07
United States	225	1.13
Sweden	5	1.67
Netherlands	8	1.86
France	29	1.90
Denmark	2	2.55
United Kingdom	12	4.72
Australia	3	5.57
(At June 1991)	(6)	(2.79)

Source: Reference 71

There may be a tendency in such a situation to treat asymptomatic patients or patients whose stones would pass naturally, or alternatively to use ESWL alone when another procedure or combination of procedures might be more appropriate. In the Netherlands, the introduction of ESWL has led to preventative treatment of asymptomatic patients, an approach that is somewhat controversial(72,73). In one of the counties of Sweden, the number of kidney stone procedures has increased from 25 to 58.6 per 100,000 inhabitants since the introduction of ESWL(50). Whether this increase is due to a back-log of untreated renal stone patients, a widening of the indications to include previously-untreatable stones, or any of the above factors is not clear.

Two questions arise: how many ESWL units does Australia need, and where should they be located? Until mid 1990 Australia had three ESWL units, two in Sydney and one in Melbourne. St Vincent's Private Hospital in Sydney has since purchased a Direx lithotripter capable of treating both kidney and biliary stones. A Siemens lithotripter has been acquired by a Sydney gastroenterologist. This machine was intended for gallstone use, but is also being used on kidney stones. The Holy Spirit Hospital in Brisbane has installed a Dornier lithotripter. The Queensland Department of Health has reached an agreement with the hospital to pay a set fee for the treatment of up to 650 public patients in the first three years of operation of the lithotripter. Royal Perth Hospital is to purchase a lithotripter in 1991, and the possibility of acquiring one in South Australia is being discussed. The second lithotripter in Melbourne is at present being used exclusively for the gallstone treatment trial being undertaken there. In summary, there are five lithotripters in use for renal stone ESWL, with one more being purchased. Of another two acquired for biliary ESWL only, one is also treating kidney stones. Purchase of a seventh machine for renal stones is being investigated.

Since the mean time for an ESWL procedure is 45 minutes (Table 22), it should be possible to schedule six to eight ESWL treatments in a standard working day. Allowing for maintenance and other breaks, a lithotripter has a potential capacity of 1,500 to 1,900 treatments per year. In fact, some German ESWL centres have treated up to 1,700 patients in a year, and in their early experience United States lithotripters were treating approximately 1,500 a year(50,74), with more than 2,000 a year being treated at the first unit in that country (Newman, personal communication).

The 1991 ESWL caseload is estimated at 4,800 to 6,400 treatments. Four lithotripters are sufficient to handle this caseload, provided some effort is put into scheduling to achieve a patient throughput of at least 1,500 per year. Four units represents one per 4.3 million inhabitants, which is comparable to the United Kingdom level. As a result, the requirement for open surgery in Australia should be reduced to the small percentage of cases for which all other procedures are contraindicated(53).

Geographic factors justify acquisition of one or two more lithotripters. Very few Western Australian patients have been referred to eastern States for ESWL. An additional two lithotripters in Australia would, if suitably located, overcome many of the access problems, even if they would also result in an over-capacity of at least 2,600 treatments per year.

A further access problem is that country patients do not make as much use of ESWL as those living close to such facilities. This problem might be able to be addressed by use of a mobile lithotripter, although there are alternative strategies which might be more realistic for Australia.

However, a problem with the six ESWL units presently in Australia or about to be acquired is the inequitable distribution. The siting of units in Perth and Brisbane as well as Sydney and Melbourne is appropriate in terms of providing access to the smaller States. The unit being considered in South Australia might also be justifiable for this reason, although it will add to the existing over-capacity. On the other hand, three units in Sydney is a gross over-supply in this region, and likely to result in considerable under-utilisation and possibly preventative treatment of asymptomatic patients, particularly since two of these machines are not accessible by public patients.

The possibility exists of using ESWL units for biliary lithotripsy as well as renal lithotripsy. Biliary lithotripsy is at present being trialled at St Vincent's Hospital, Melbourne. However, the recently developed procedure of laparoscopic cholecystectomy is diffusing rapidly as a primary method of treating gallstones. This procedure appears to have low morbidity, is much less invasive than open cholecystectomy, requires no long-term post-operative treatment, and is predicted to replace at least 80 per cent of current gallstone procedures(75). This procedure is likely to considerably reduce the potential demand for biliary ESWL. Until studies have been completed and the respective roles of ESWL, open and laparoscopic cholecystectomy in the treatment of gallstones have been determined, it is suggested that estimates of throughput based on biliary ESWL treatments in addition to renal ESWL treatments should not be used to justify purchase of an ESWL unit.

The estimates of adequate numbers of ESWL units considered so far do not take account of recent developments in laser technology and ureteroscopy. ESWL, where available, has been replacing some transurethral procedures using mechanical extraction or electrohydraulic or ultrasonic lithotripsy. This situation may change once the indications, safety and morbidity of transurethral laser lithotripsy is well documented, and the technique becomes more widespread. While it is more invasive than ESWL and is followed by longer hospital stays, the capital cost is lower, it allows easy access to the lower and mid ureter, further procedures are less frequent, and success rates are higher(76). There is a need for studies comparing the success rates, complications, morbidity, re-treatment rates, long-term effects and cost-effectiveness of ESWL and laser ureteroscopy for ureteral stones.

Laser ureteroscopy could have a significant effect on the treatment of ureteral stones and the use of ESWL to treat such stones. Since PCN can be used to remove most kidney and some upper ureteral stones, the combination of laser ureteroscopy and PCN is sufficient to treat almost all stones. In some cases it might be more appropriate to buy a laser and suitable ureteroscope than an additional ESWL unit, and to ensure that PCN is available. On the other hand, purchase of a laser and ureteroscope may be difficult to justify in areas where there are high numbers of ESWL units relative to the population level. The ideal situation would be to have ESWL, PCN and laser lithotripsy available, so that the urologist could use the most appropriate treatment strategy in each case. This would avoid the problem of multiple treatments to remove a single stone, with resultant higher complication rates. While this might be possible in two or three hospitals around the country, the problem of access for the remainder of the population would remain.

Future developments in Australia

There is now a range of lithotripters on the market, with capital costs of some models considerably less than that of the original Dornier HM3. These reduced costs are one reason for additional lithotripters being acquired at centres remote from Sydney and Melbourne. With several lithotripters dispersed throughout the country the problems of access will diminish. A consequence should be replacement of many of the remaining open surgery cases and a number of endoscopy cases by ESWL. Based on the previous cost estimates, this will reduce Australian health care costs further, by up to $32m a year, and also reduce post-treatment illness further, by up to 58 years.

Another effect of additional lithotripter acquisitions is that a large over-capacity of ESWL will result in this country. Only 50 per cent of public hospital admissions with a principal diagnosis of renal stones are treated for these stones, presumably because in some cases the stones pass naturally before treatment can be performed. Stones can also be asymptomatic and only discovered as a result of diagnostic procedures undertaken for other conditions. If the over-capacity is used to treat some of these patients, it could have a considerable effect on health care costs without necessarily benefiting patients in the long term. For example, treating an additional 1,000 patients per year would cost an additional $2m to $3m.

The Dornier HM3 lithotripters originally acquired for Australia will eventually need replacement. Options range from replacement with later models at comparable prices, to replacement with cheaper models such as piezoelectric lithotripters. Capital costs of replacement lithotripters may be significantly lower than the purchase cost for the original HM3 machines. Treatment costs will not decrease to the same extent, since ESWL costs per patient range from $1,900 to $3,000, with the Dornier HM3 at the top of this range. The advantage of replacing the original lithotripters acquired with later models lies in the ease of use and greater flexibility in patient positioning, which allows treatment of a wider range of patients and types of stone. Timing of such replacement needs careful consideration, given the high cost of lithotripters.

PCN does not appear to have diffused as widely or replaced as much open surgery as might have been expected. The advent of ESWL has directed attention away from this procedure, and recent ESWL purchases are likely to continue this trend.

The new transurethral procedure using lasers is likely to have an impact on the treatment of ureteral stones, provided it is proven to be safe and effective. It provides an alternative for ureteral stones difficult to reach with ESWL. It may also decrease the number of multiple treatments done on ureteral stones, with consequential decreases in morbidity, hospital stays and costs.

One difficulty is the integration of the new laser procedure and PCN with ESWL. A possible solution is the formation of 'stone centres' in different States, in which all renal stone procedures are available. These could have several advantages. Urologists would have the full range of treatment options available to them, and could select the most appropriate one for each case. Caseloads should be sufficient for urologists to maintain expertise in open surgery for stone removal, PCN and the new laser technology. Such centres could also act as training centres in these procedures for future urologists.

However, if such centres do emerge, the problem of equitable access for all stone sufferers will need to be addressed with some urgency, since the data presented earlier in this report indicate that access to existing ESWL units is not equitable at present. Providing all urologists with access to the treatment options offered by such a centre might also be a problem.

Conclusions

The introduction of ESWL to Australia has had a marked impact on the treatment of renal stones. Where it is available, ESWL has replaced a large number of open surgical procedures to remove stones. Use of ESWL in Australia is similar to overseas. With experience, length of hospital stay, operation times and the number of post-ESWL procedures have decreased. The average length of hospital stay is 2.5 days, at the lower end of the range predicted by NHTAP(1). Indications for ESWL are widening to include a higher proportion of ureteral stones. There are a number of issues relating to ESWL treatment that are still being debated, such as the usefulness of placement of a stent or catheter prior to ESWL, and its use in the treatment of staghorn and very large stones.

Follow-up of all patients is important, as a possible complication is silent obstruction leading to renal damage. Metabolic assessment is also important to reduce the rate of stone recurrence.

The six lithotripters already purchased give Australia an over-capacity of ESWL facilities. Further acquisitions will worsen this situation and could lead to treatment of asymptomatic stones, with increased cost to the health care system but little additional benefit to patients. On the other hand, geographic factors are important. Available data indicate that distance is a barrier to use of ESWL facilities given current referral and funding patterns. Recent and current acquisitions should reduce this problem to a large extent, although distribution of lithotripters is by no means equitable with three in Sydney, and only one servicing Victoria, South Australia and Tasmania.

The long-term effects of ESWL have not been determined, and the possibility of ESWL treatment leading to development of hypertension has been raised. The influence of factors such as number and spacing of treatments, number of shocks, shock wave frequency and energy on the development of hypertension needs investigation. Until such time as these questions are clarified, some care is indicated in applying extensive ESWL to a patient.

PCN has had a lesser impact on open surgery for renal stones than has ESWL. The average length of stay in public hospitals is longer than overseas experience; the reasons for this are not clear from the data available and need investigation.

Transurethral procedures are changing with the advent of lasers suitable for treating ureteral and some kidney stones, and of small diameter flexible and semi-flexible ureteroscopes. While lasers are more expensive than electrohydraulic or ultrasonic lithotripters, they can be used on a much wider range of ureteral stones. There is a learning curve, and complications are more frequent during the learning phase. Use of lasers is in the early stages, and indications are still evolving. There is a need for studies investigating the success and complication rates, morbidity, mortality, long-term effects and cost-effectiveness of laser ureteroscopy, and comparing these with those of ESWL on ureteral stones.

Despite its high capital cost, ESWL is cheaper than other forms of renal stone treatment, with a cost per session of $1,328 to $2,889 and a cost per patient of $1,859 to $3,000. Transurethral procedures are not much more expensive, at $2,591 to $2,949 per session, and costs may decrease if lengths of hospital stays shorten as techniques and equipment improve.

PCN is more costly ($3,700 to $6,450), in part due to the long hospital stays. Open surgery is on average the most expensive option ($4,962 to $6,062). Given its morbidity, mortality and long-term effects on the kidney as well, open surgery is best restricted to those cases where the alternatives are contraindicated.

In terms of cost savings, introduction of ESWL to Australia has been an effective method of treating renal stones. The model used in this report estimates minimum cost savings to the health care system at $3.9m per year and annual reduction of post-treatment illness by over 69 person years.

The Committee:

- does not support any further increase in the number of ESWL units in Australia beyond those needed to provide a realistic distribution of services between States without generating significant over-capacity. This would imply no more than seven ESWL units in Australia;

- urges caution in treating patients with high numbers of shocks, high energy levels, or several treatment sessions in quick succession, until the question of whether or not ESWL leads to hypertension is resolved;
- suggests that State governments should address the issue of ensuring equitable access to ESWL;
- sees a need for further investigation of the use of PCN in Australia, in particular the long hospital stays associated with its use, and its application in combination with ESWL;
- considers that the level of open surgery for kidney stones in Australia remains unacceptably high;
- considers there is a need for further data on laser ureteroscopy, including comparison with ESWL for the treatment of ureteral stones; and
- suggests that laser ureteroscopy might prove to be an effective way of treating many ureteral stones in Australia.

Appendix A: Description of therapies

Medical treatment

Current medical treatment strategies include increasing fluid intake, dietary modification and drug therapy. Treatment is aimed at inhibiting the growth of stones and preventing the formation of new stones, rather than dissolving existing stones. The exceptions are urate and cystine stones, some of which can be dissolved if they are not calcified.

Patients with all types of stones benefit from increasing urinary volume. An increase to two litres per day or more is recommended, but smaller increases can be beneficial. Dietary modification and drug therapy depend on the type of stone and its cause. Table 20 shows the effectiveness of the major treatment modalities in use. A number of others may also be effective, for example, increasing dietary fibre (calcium stones), cholestyramine (oxalate stones caused by enteric hyperoxaluria), urinary alkalisation (calcium stones caused by distal renal tubular acidosis), and magnesium (calcium stones caused by hypomagnesuria)[8,9].

Table 20: Effect of various treatment modalities on renal stone disease

	Therapy					
Type of Stone	*Low calcium, low sodium diet*	*Thiazide diuretic*	*Citrate*	*Allopurinol*	*Cellulose phosphate*	*Other interventions*
Calcium stone associated with:						
- absorptive hypercalciuria	(a)	(b)	(b)	(d)	(a)	
- resorptive hypercalciuria	(c)	(b)	(c)	(d)	(d)	Parathyroidectomy
- renal hypercalciuria	(b)	(a)	(a)	(d)	(d)	
- hyperoxaluria	(b)	(a)	(b)	(d)	(b)	Low oxalate diet, pyridoxine
- hyperuricosuria	(c)	(c)	(b)	(a)	(d)	Low purine diet
- hypocitraturia	(d)	(c)	(a)	(d)	(d)	
Uric acid stone	(d)	(d)	(b)	(a)	(d)	Urinary alkalinisation, low purine diet
Struvite stone	(d)	(d)	(d)	(d)	(d)	Treatment of infection, urinary acidification, acetohydroxamic acid
Cystine stone	(d)	(d)	(b)	(d)	(d)	Urinary alkalinisation, low methionine diet, tiopronin, D-pencillamine

(a) Significant benefit.
(b) Moderate benefit.
(c) Possible benefit.
(d) No benefit.

Source: References 9,46

Percutaneous procedures

PCN involves four steps: establishment of the percutaneous tract, dilation of the tract, stone extraction, and postextraction drainage of the kidney. To establish the tract, the renal collecting system is visualised using either ultrasound or fluoroscopy. The tract is normally established antegradely (via a fine needle), but can also be established retrogradely by passing the needle through a ureteral catheter and out through the skin[77]. A balloon dilator or graded dilators are used to dilate the tract to approximately one centimetre in diameter. A nephroscope with saline irrigation is passed along the tract into the kidney or ureter.

The methods available for removing the stone are mechanical extraction, chemolysis, and electrohydraulic, ultrasonic or laser lithotripsy. Very small stones or fragments remaining after lithotripsy are removed by suction. Small stones can be removed with a variety of grasping tools. Chemolysis can be used to remove fragments of struvite, cystine and uric acid stones after lithotripsy[40]. Large stones are fragmented using lithotripsy. The lithotripters in common use are electrohydraulic or ultrasonic, with laser lithotripters being a new development. The resulting fragments are removed by irrigation, mechanical extraction, or in some cases chemolysis. A second procedure using either the original tract or a second tract is sometimes required for large stones(78).

Once the procedure has been completed, a stent can be placed in the ureter if necessary. Then the working sheath is removed and the tract allowed to heal. Antibiotic prophylaxis is required. Operative difficulties can include inadequate access or inability to remove the stone. Major complications include renal colic, infection and septicemia(14,19). Bleeding can occur during the operation, but is not common post-operatively. Multiple tract PCN does not appear to affect renal functioning(79).

PCN can be used to treat renal stones, and upper and mid ureteral stones. While ESWL is less invasive, there are instances when PCN or a combined approach are indicated(80). The combined approach can be used for large stones (greater than two to three centimetres), or staghorn stones. PCN is used when other modalities such as ESWL have been unsuccessful or are not available. It provides an alternative to ESWL when there is an impacted upper ureteral stone, an obstruction distal to the stone, the stone is dense and hard or composed of cystine, or when treating children. PCN can be used when certain removal of the stone is important or when the individual's size precludes the use of ESWL.

The only absolute contraindication to PCN is an uncontrolled bleeding disorder. However, caution is needed if a urinary tract infection is present. Some patients have anatomic abnormalities, such as marked scoliosis, that prevent adequate tract placement. Another problem that can occur, especially in obese patients, is an inability to dilate the tract safely(81). Retrograde tract placement is also contraindicated in the presence of ureteral obstruction, full staghorn or large volume calculi(77). Lithotripsy may not be possible if the stone is too hard or cannot be visualised. Stones in the upper pole calyx are inaccessible to PCN (Cameron-Strange, personal communication). Staghorn stones with a small central stone burden and a large peripheral stone mass in the calyces require multiple tracts and might be more appropriately treated by other means.

Table 21 summarises the results of several studies using PCN alone to treat renal and ureteral calculi. Success is normally defined as the patient being stone-free at three months or reduction of the stone into particles of less than two millimetres, which would be expected to pass spontaneously. Some studies use different definitions, so that care is required in making comparisons. Success rates for PCN are consistently high, but have decreased in recent years as more complicated patients with complex stones are now being referred for PCN(16).

The lengths of hospital stays are variable, ranging from three to nine days and more normally four to six days (Table 21). Preminger et al have also reported performing PCN in the out-patient setting for patients with a solitary small calculus in the renal pelvis, with the advantage of reduced costs(17). Anesthesia is required for PCN, but can generally be limited to epidural or assisted local anesthesia(11). Convalescence time is one to two weeks(11,21,22,82).

Table 21: Clinical results of treating stones with percutaneous procedures

	Studies										
	Das et al	*Netto et al*	*Liong et al*	*Streeme t al*	*Mays et al*	*Aronne et al*	*Carlsson et al*	*Charig et al*	*Segura et al*	*Reddy et al*	*Tailly*
Number of patients	103	16	19	25	195	29	300	270	1,000	4,000	300
Success rate (%)	94	87.5	100	80	86	72	91	83	96	(a)98	97
(Mths after operation)	(3)	(3)	(6)	(0)	(3)	(0)	(3)	(3)	(0)	(?)	(?)
Mean days in hospital	4.2	3	-	(b)5.1	9	6.4	9.5	5.6	5.2	7.9	5
Mean operation time (mins)	-	60	90	-	-	-	151	-	48	-	55

(a) Instruments were reinserted in the percutaneous tract following the first procedure in half the patients.

(b) Post-operative.

Source: References 10-15, 18-20, 78, 82

Since its advent, attention has focused on ESWL rather than PCN. Taylor et al have performed a criteria audit of PCN which demonstrates the surgeons' learning curve, the current standards achieved and changes in patient admission rate in an Australian hospital(59). They report post-operative urinary tract infection in 12 per cent of patients and post-operative temperature greater than 38°C in 21 per cent. Access to the stone was inadequate or inappropriate in five per cent, and a further eight per cent required a second operation due to the large stone mass.

Extracorporeal shock wave lithotripsy

In ESWL, a shock wave is generated outside the patient's body and focused on the stone. The shock wave is transmitted through a coupling medium and the patient's body. When it reaches the stone it creates tensile stress and fragmentation along the stone's surface. Repeated shocks reduce it to many small fragments that can be passed naturally. The two basic types of energy sources for generating shock waves are point sources and extended sources. Point sources include underwater spark gap (electrohydraulic), laser-induced and microexplosive ignition generators(83). Extended sources are the electromagnetic and piezoelectric shock wave emitters. The previous reports by NHTAP discuss the mechanisms involved in more detail(1,2).

The indications for ESWL have widened since its initial introduction and it can now be used in the treatment of the majority of renal and upper ureteral stones. ESWL monotherapy can be used on 70 per cent of patients, including those with single or multiple stones less than two centimetres and selected ureteral stones(83,84). Combining ESWL with PCN or stenting allows most of the remainder to be treated.

The treatment of ureteral stones has been the subject of some discussion. Most authors consider treatment of upper ureteral stones in situ much less effective than treatment of renal stones, although Holden and Rao and Tung et al have reported success in this area, particularly with smaller stones(85,51). The reason is that ureteral stones are often impacted. Ureteral stones treated with ESWL fracture on the surface but do not always fragment because they cannot expand.

To improve fragmentation, several strategies have been developed. The first is the 'push bang' technique, where the stone is pushed back into the kidney using either a ureteral stent, an occlusion balloon catheter, irrigation through a ureteral catheter, or manipulation through a ureteroscope. ESWL is then applied as for any renal stone. The second approach is to pass a stent or catheter up past the stone, which provides an artificial expansion space adjacent to the stone. ESWL is then applied. Alternative methods involve removing the outer layer of particles during treatment by ESWL (eg every 400 to 500 shocks). These include use of a stone brush, or flushing away particles using an end-hole catheter(86,87).

Treatment of large renal pelvic or staghorn stones has also been the subject of some debate. ESWL monotherapy is generally regarded as unsuitable for complete staghorn stones(23,58). Such stones are removed by PCN alone, by using PCN to debulk the stone prior to application of ESWL to the residue, or by open surgery. Treatment for partial staghorn or large renal stones varies; Lingeman et al prefer a combination of PCN and ESWL, Constantinides et al prefer ESWL monotherapy after placement of a ureteral stent, whereas Chaussy and Fuchs and Puppo et al suggest the former when the collecting system is dilated and the latter when it is not dilated(25,24,83,57).

After ESWL a number of small stone fragments remain to pass naturally. 'Steinstrasse' (accumulation of multiple fragments within the ureter) can develop from ESWL treatment of large stones, with the possible complication of ureteral obstruction. Indwelling ureteral stents can be placed before ESWL to facilitate drainage and passage of fragments. The presence of the stent also causes the ureter to relax and dilate, so that on removal of the stent larger fragments can pass unimpeded.

However, stenting causes patient discomfort, such as constant urinary urgency, flank ache and voiding disabilities. The use of ureteral stents with ESWL has become somewhat controversial. While most agree that ureteral stenting plays a useful role in treating large stone burdens (over three centimetres) and patients with solitary kidneys, its role in other cases is less clear. Shabsigh et al report a considerably reduced complication rate with the use of stents for stones between 1.5 centimetres and three centimetres, but no change in re-treatment rates for these stones(88). On the other hand, Preminger et al report greater success and fewer problems for similar stones when stents were not placed before ESWL(89). The use of stents and contrast medium allow ESWL to be used on radiolucent and small semiopaque stones when the lithotripter has an X-ray (rather than an ultrasound) localisation system.

Because it is non-invasive, patients normally prefer ESWL to PCN. However, there are some instances where ESWL is not an appropriate method of treatment. Concern has been expressed as to the effect of ESWL on the growing kidney (Cameron-Strange, personal communication). By varying the patient's position (eg sitting rather than lying), lower ureteral stones can be treated with ESWL rather than transurethral procedures[90,91]. Similarly, mid ureteral stones can also be treated, provided fluoroscopic stone localisation is available. Whether or not women in their child-bearing years should have these stones treated by ESWL is a matter of debate; animal studies indicate possible damage to the ovaries, but the evidence is by no means conclusive (Cameron-Strange, personal communication).

Accurate stone localisation may not be possible in very large or very small patients, or in patients with anatomic abnormalities such as scoliosis. These cases and children can sometimes be treated with ESWL by modifying the patient's position.

Another difficulty in treating children is the necessity to protect the lungs (which are closer to the kidneys than in an adult). Patients with cardiac pacemakers can be treated safely when certain precautions are taken[92]. Other contraindications include untreated bleeding disorders, uncorrected hypertension, pregnancy, and anatomic defects and functional disorders that may prevent proper elimination of debris[46]. ESWL monotherapy is not suitable for infection stones, since such stones regrow from small fragments. Stone composition is also a consideration; calcium, oxalate and struvite stones respond well to ESWL, whereas cystine stones respond poorly.

In early ESWL treatments, cardiac dysrhythmias occurred in most patients when the shock wave was produced. This is now avoided by timing the shock waves to the refractory cardiac period, reducing the percentage of patients experiencing dysrhythmias to 0.8 per cent[93]. Ureteral obstructions can occur in seven to 15 per cent of patients, especially if a steinstrasse is present[12,14]. A major problem is that obstructions can be silent and lead to irreversible renal damage. To prevent this, close follow-up of all ESWL patients is needed. Transient gross hematuria due to intrarenal hemorrhage occurs in most patients. Other complications of ESWL include renal colic, fever and infection[14].

New-onset hypertension in eight per cent of patients and increased diastolic blood pressure in another 15 per cent of patients have been reported as long-term complication of ESWL[94-97]. This has raised the question of whether or not ESWL causes renal damage.

Urinary levels of enzymes used as markers for renal damage increase after ESWL, as does urinary protein excretion[98,99]. Increases in such markers appear to be larger when more shock waves are used[100]. Observed morphologic changes include loss of corticomedullary differentiation, perineal fluid, hematomas and enlargement of the kidney[101]. Such renal injury usually disappears within three months of ESWL, although some long-term decreases in renal function have been observed and may be responsible for increases in blood pressure[95].

On the other hand, excessive numbers of shocks have not decreased renal function or led to the development of hypertension in some animal models, and Karlin et al report that levels of enzyme markers return to normal within seven days[102,103]. Renal damage may also be limited to the electrohydraulic and electromagnetic lithotripters, with no significant damage occurring after treatment by piezoelectric lithotripters[104]. Further studies are needed to gain a good understanding of the long-term effects of ESWL. In particular, questions such as the effect of energy levels, number of shocks, frequency of shock waves, and number and spacing of ESWL sessions on the patient's long-term health status need answering.

Table 22 summarises the results of several studies using first generation lithotripters (Dornier HM3) to treat kidney and ureteral stones. As discussed earlier, definitions of success rates differ, which may account for some of the variability in these rates, as may the number of large or staghorn stones in a sample.

As Table 23 illustrates, success rates for staghorn stones are considerably lower than overall success rates. The overall success rate of Sofras et al of 68.4 per cent breaks up into success rates of 83.5 per cent for stones less than one centimetre, but 33.4 per cent for staghorn stones[105]. The much higher rate for ESWL used with a stent for staghorn stones (see Table 23) shows the usefulness of this procedure for such large stones. The number of ESWL sessions for patients with staghorn stones is higher than for other patients; staghorn stones can take up to eight sessions, whereas other stones take 1.2 sessions per stone[27,28]. Because ESWL leaves fragments to be passed naturally, stone-free rates generally improve after a few months; a stone-free rate of 35.2 per cent on discharge from hospital can increase to 72.2 per cent in approximately 19 months[106]. In one study the observed re-treatment rate for ESWL was 20 per cent[27].

Table 22: Clinical results of treating stones with first generation lithotripters

	Studies								
	Das et al	*Liong et al*	*Mays et al*	*Aronne et al*	*Carlsson et al*	*Petersson et al*	*Sofras et al*	*Charig et al*	*Rigatti et al*
Number of patients	1,172	75	933	29	300	1,677	2,000	328	1,830
Success rate(%) (Months after operation)	91.3 (3)	75 (6)	88 (3)	72 (0)	83 (1)	90 (0)	68.4 (1)	98 (3)	72 (3)
Mean days in hospital	3	–	7.9	2.6	4.8	–	1	3.7	4.1
Mean operation time (mins)	–	47	–	–	44	40	–	–	40
Mean number of shocks	1,220	1,102	–	–	–	1,971	–	–	1,780
Range of shocks	100–4,000	–	–	300–1,800	–	–	600–2,800	–	300–3,000
Use of anesthesia	–	100	–	100	93	–	–	–	–

Source: References 10–12, 14, 15, 19, 26, 27, 105

Table 23: Clinical results of treating staghorn stones with ESWL

	Studies					
	Sofras et al	*Carlsson et al*	*Gleeson & Griffith*	*Constantinides et al*		*Vandeursen and Baert*
	ESWL	*ESWL*	*ESWL*	*ESWL with stent*	*ESWL without stent*	*ESWL with stent(a)*
Number of patients	386	147	199	24	37	50
Success rate (%) (Months after operation)	33.4 (1)	26 (1)	43.2 (3)	83.3 (6)	48.6 (6)	56 (3)
Mean number of shocks	–	–	2,996	2,766	2,598	–
Range of shocks	2,200–2,800	–	1,050–5,650	–	–	2,000–36,000

(a) 82 per cent of patients were stented.

Source: References 15, 24, 30, 105, 107

Operation times and hospital stays are in general short (Table 22). The average convalescence time of three to five days is also short, although Carlsson and Tiselius report a range of one to over ten days[10,11,64]. Not surprisingly, more shocks are required for larger stones (Table 23). Most patients are anesthetised for ESWL using first generation lithotripters, although one study used no anesthesia (but with analgesia) and reported 96 per cent of patients prepared to undergo a repeat procedure without anesthesia[108].

Epidural anesthesia is frequently used instead of general anesthesia (epidural anesthesia used for 83 per cent and 63 per cent of patients for Aronne et al and Liong et al respectively)[10,11]. Complication rates are less than for PCN.

There have been several developments since production of the first Dornier lithotripter. The 1987 NHTAP report discusses advances made in second generation lithotripters. These use coupling devices such as water cushions and columns instead of the water bath used by the first lithotripter[2]. Shock waves can be produced by piezoelectric elements rather than electrohydraulic systems. The energy of piezoelectric shock waves is lower than that of electrohydraulic shock waves, resulting in potentially pain-free treatment that requires a larger number of shocks.

Some second generation lithotripters have ultrasound rather than biplanar X-ray localisation systems. Ultrasound localisation has several advantages, such as reduced cost, increased portability, real time imaging, easy targeting of radiolucent stones and no exposure of patient and staff to ionising radiation[109,110]. However, it does not allow the same accuracy as the biplanar X-ray systems, cannot be used for mid ureteral stones, and requires more time for localisation and greater operator experience[83,110].

Developments in the most recent lithotripters available have been in their flexibility and ease of use rather than in the way shock waves are produced. Mobility of both the shock wave applicator and the treatment table has improved. The treatment table of models such as the Dornier MFL5000, EDAP LT.01, Direx Tripter Nova and Siemens Lithostar Plus allow other urological procedures, such as PCN and ureterorenoscopies, to be performed easily on the same patient.

Compact versions such as the Technomed Sonolith 3000 Transportable Model, Dornier Lithotripter Compact and Direx Tripter X1 can be used in mobile treatment units. Siemens have produced an independent overhead unit (the Lithostar Ultra) containing both shock wave applicator and localisation system, that can be added to most diagnostic and therapeutic suites. Direx provide a shock wave applicator and table alone, with localisation being done by existing equipment at the hospital.

Some models, for example the Siemens Lithostar Plus, Direx Tripter Nova and Wolf Piezolith 2500, provide both X-ray and ultrasound localisation. Suppliers have addressed specific problems with later models. For example, Dornier have halved the radiation dose to patient and operator, and provided variable shock wave pressures, while Siemens have increased shock wave frequency to minimise operation times.

The greater flexibility of recent lithotripters has led to their use on distal ureteral stones as well as upper ureteral stones. ESWL is being used by some as a replacement for transurethral procedures because it is less invasive. This is not without problems; if ESWL is not effective, it can add to the inflammatory response that the following transurethral procedure might induce[111].

In second generation lithotripters the shock wave pressure and focal region have been reduced, which reduces the requirement for anesthesia (compare Table 24 with Table 22). When anesthesia is used it is more likely to be local rather than general or epidural[84]. Hospital stays are shorter, and ESWL can be used on an out-patient basis. For example, Neerhut et al treated 69 per cent of patients with a Wolf Piezolith as out-patients[112]. The trade-off is a reduction in stone fragmentation efficiency. More shocks are required per treatment, and the re-treatment rate is higher than with first generation lithotripters. With re-treatment, success rates appear comparable (compare Tables 22 and 24).

The reported experience with second generation lithotripters (summarised in Table 24) represents the initial experience with these machines, and may change as operators become more experienced. For example, Baert et al used general anesthesia on 14 per cent of their first 200 patients, and some form of anesthesia on the remainder, whereas for their third 200 patients, they used general anesthesia on two per cent and no anesthesia on 87 per cent[30]. Similarly, hospital stays dropped from 2.4 days to 1.4 days in this time, operation times dropped from 50 minutes to 36, and the percentage of adjuvant procedures dropped from 45 per cent to 14 per cent.

Table 24: Clinical results of treating stones with second generation lithotripters

	Studies									
	Baert et al	*Bowsher et al*	*Neerhut et al*	*Miller et al*	*Lipson et al*	*Grace et al*	*Sandhu and Rao*	*Rigatti et al*	*Valente et al*	*El-Damanhoury et al*
Number of patients	600	398	384	442	50	145	573	174	400	3,278
Type of lithotripter	Siemans lithostar	Wolf piezolith	Wolf piezolith	EDAP LT-01	Medstone 1050	Siemans lithostar	Siemans lithostar	Wolf piezolith	Direx tripter X1	Siemans lithostar
Success rate (%) (Months after operation)	85 (3)	(a)53 (2)	(b)65/87 (1)	64 (?)	(b)46/90 (1-3)	88 (3)	(b)65/84 (4-18)	78 (3)	87 (?)	(a)63.8 (3)
Mean days in hospital	1.9	–	–	–	–	–	–	–	–	–
Mean operation time (mins)	42	–	40	53	–	–	–	52	40	–
Mean number of shocks	1,593	–	2,600	–	1,581	1,724	–	3,500	1,850	1,850
Range of shocks	400-4,000	3,000-4,000	1,000-6,000	–	400-2,000	–	–	500-7,000	?-4,000	?-5,000
Use of anesthesia or analgesics (%)	64	1	0.5	57	100	98	80	0	–	–
Re-treatment rate (%)	13.2	62	–	21	–	19	–	–	–	7.8

(a) Completely stone free.
(b) Completely stone free/stone free or very small fragments.

Source: References 26, 29-32, 65, 112-115

Comparison of Tables 21, 22 and 24 shows that ESWL and PCN have similar success rates for most stones. ESWL has lower operation times, use of anesthesia and lengths of hospital stays. The reduced hospital stays of second generation lithotripsy have the effect of reducing overall ESWL charges, but increased rates of re-treatment have the opposite effect. Most prefer ESWL for treatment of smaller stones but, as already mentioned, opinions differ as to the effectiveness of ESWL monotherapy, PCN, or a combination of the two for treating large or staghorn stones.

Transurethral procedures

Ureteroscopy

Transurethral ureteroscopy (or endoscopy) involves passing a long thin endoscope into the ureter through the ureterovesical junction. A ureteroscope is passed up the urethra, into the dilated ureter and then visually guided up the ureter. If necessary, the ureteric orifice is dilated using rigid metal or plastic dilators, balloon dilation catheters or short-term ureteric catheters[34]. Anatomic abnormalities such as mucosal flaps, ureteral rings or ureteral narrowing due to previous operations may preclude passage of the ureteroscope. Ureteroscopy is normally performed with the patient under spinal or general anesthesia, although local anesthesia with sedation had been used[116].

Ureteroscopes vary in diameter, and can be rigid, semi-rigid or flexible. Rigid ureteroscopes give better visualisation than flexible ones, but are more difficult to place in men because of the greater curvature of the male ureter[40]. Some of the flexible and semi-rigid ureteroscopes can be passed into the kidney, allowing treatment of selected kidney stones as well as ureteral stones. Some of the newer ureteroscopes, such as the Candela Miniscope, have a very small diameter and can be passed up the ureter without dilation, thus avoiding many of the complications of ureteroscopy.

Once a ureteroscope is in place, ureteral stones can be removed mechanically or fragmented using electrohydraulic, ultrasonic or laser probes. These procedures provide an alternative to the 'push-bang' technique or in situ ESWL for impacted upper ureteral stones. They are used for most mid and distal ureteral stones, although ESWL (by modification in patient position) is now being used to treat some of these stones. Endoscopic procedures are also used as an adjunct to other procedures. They are used to remove stents after ESWL and PCN, and to push stones back into the renal pelvis for fragmentation by ESWL.

Most complications of ureteroscopy are minor, and include mucosal tears and creation of a false passage in the intramural ureter during dilation[34]. Major complications are more frequent early in the operator's experience. They include ureteric perforation (five to 12 per cent), infection (three to eight per cent), stricture (one per cent), avulsion (one per cent) and breakage of instruments (one per cent)[33,117,118]. Contraindications for ureteroscopy are previous surgery or trauma that has left the ureter fibrosed, tortuous or kinked, and urethral structure or prostatic obstruction that cannot be relieved[117].

Mechanical extraction

Once a stone is visible ureteroscopically, if it is not impacted and not too large it can be extracted using different types of wire baskets, forceps or graspers[68]. Loop retrievers, forceps and graspers can also be used to remove foreign bodies such as stents and wires. Blind basketing can be used if the ureteroscope cannot reach the stone, but the risk of perforating the ureter is higher[40].

Table 25 summarises the results of several studies investigating mechanical extraction of stones via a ureteroscope. Success rates are high. The period of convalescence is one to two weeks, which is considerably longer than for ESWL[11,35].

Electrohydraulic lithotripsy

Electrohydraulic lithotripsy works through creation of a hydraulic shock wave that fragments stones. The probe needs to be about one millimetre from the stone. The energy of the shock wave is high, so that operating the probe close to the ureteral wall can perforate it[40]. For this reason impacted stones or fragments close to the ureteral wall are best not treated with this lithotripter.

Table 25: Clinical results of removing stones mechanically via a ureteroscope

	Studies					
	Liong et al	*Olsen et al*	*Chan et al*	*Das et al(a)*	*Weinberg et al*	*Bagley et al(b)*
Number of patients	21	112	61	101	941	70
Success rate (%)	74	89	78	96	82	80.5
(Months after operation)	(6)	(?)	(0)	(3)	(?)	(?)
Mean days in hospital	-	-	-	3.2	-	-
Mean operation time (mins)	115	50	57	-	-	-

(a) 25 per cent underwent electrohydraulic or ultrasonic fragmentation rather than mechanical extraction.

(b) 30 per cent underwent electrohydraulic or laser fragmentation rather than mechanical extraction.

Source: References 11, 12, 116-119

The safety of this device has been improved by recent advances such as decreased probe size and greater operator control over discharge energy, pulse and duration(37). For example, Storz provide an electrohydraulic lithotripter with probes of one millimetre and 600 μm in diameter. A modification that converts the electrical discharge to a mechanical impulse may allow the lithotripter to be operated without direct vision and without anesthesia; this modification is under investigation(40). Electrohydraulic lithotripters are relatively cheap at around $10,000. The probes cost $130 to $180, and one is needed for each patient.

Electrohydraulic lithotripsy is generally used to fragment stones, and basket extraction used for the remainder of the procedure. The main complication, other than those of ureteroscopy in general, is ureteral wall perforation. Small probe sizes and operating the probe under direct vision have decreased this complication markedly. Published clinical results are few, and are summarised in Table 26. Flexible ureteroscopes and an electrohydraulic lithotripter have recently been used to treat partial and complete staghorn stones(36). The stone-free rate of 50 per cent was obtained after an average of 1.5 sessions of 40 to 200 minutes (average 95 minutes). The main complications were fever and sepsis, and occurred in 42 per cent of patients, particularly those with complete staghorn stones. A major difficulty is preventing elevation of the intrapelvic pressure due to the irrigation required.

Table 26: Clinical results of treating stones with electrohydraulic lithotripsy

	Studies			
	Green and Lytton	*Denstedt and Clayman*	*Begun et al*	*Aso et al*
Number of patients	35	22	18	(a)34
Success rate (%)	89	91	90	50
(Months after operation)	(?)	(3)	(0)	(?)

(a) Partial and complete staghorn stones only.

Source: References 36, 37, 120, 121

Ultrasonic lithotripsy

Ultrasonic lithotripsy converts electrical energy into high energy sound waves that are transmitted along a probe, causing vibrations at its tip. When a stone is in direct contact with the probe, fragmentation occurs. Constant irrigation is required to prevent thermal injury.

Probes can be hollow or solid. Hollow probes produce longitudinal vibrations, which necessitates basketing the stone beforehand. Fragments are removed by suction through the probe(40). Solid wire probes are smaller and produce transverse vibrations, so the stone does not need to be basketed. Fragments are extracted mechanically unless small enough to pass naturally.

Ultrasonic lithotripters are used with rigid ureteroscopes. They cost approximately $14,000, and the probes approximately $100. However, unlike the electrohydraulic lithotripter, the probes need replacing infrequently.

Ultrasonic lithotripsy is particularly useful for dense calcium oxalate monohydrate stones or cystine stones, since these are more difficult to fragment with electrohydraulic or laser lithotripsy. It is also useful for treating steinstrasse. Other than those of ureteroscopy, the main complication is ureteral injury due to the pressure needed to fragment hard stones. Table 27 presents results of studies on ultrasonic lithotripsy.

Table 27: Clinical results of treating stones with ultrasonic lithotripsy

	Studies			
	Streem et al	*Higashihara and Aso*	*Chaussy et al*	*Fuchs*
Number of patients	25	16	118	125
Success rate (%) (Months after operation)	80 (0)	(a)87.5 (0)	96.6 (0)	100 (3)
Mean days in hospital	(b)3.38	-	1.8	-

(a) Adjunctive electrohydraulic lithotripsy used in some cases.

(b) Post-operative.

Source: References 18, 38, 56, 122

Laser lithotripsy

Laser lithotripters are the most recent development in the treatment of ureteral stones. They generate pulses of light at a particular wavelength and transmit them via quartz fibres. The light is absorbed by the stone, but not by surrounding material, producing rapidly expanding plasma on the stone surface. Surrounding fluid acts as an incompressible medium that directs the resultant shock wave into the stone, which fragments it(123).

Both continuous wave and pulsed lasers have been investigated for treatment of ureteral stones. Continuous wave lasers were discarded since the process resulted in generalised charring with molten stone running into tissue(124). Pulsed lasers tested include the Q-switched Nd:YAG laser, the Q-switched alexandrite laser and the pulsed dye laser.

The laser medium for the Nd:YAG laser is a neodymium doped yttrium garnet crystal, which generates light at 1.064 nm. Q-switching results in pulses ranging from 10 to 25 ns. They are transmitted through fibres with core diameters of 60 µm or more. The resultant shock waves have an extremely steep shock wave front and a high-pressure amplitude.

The medium of pulsed dye lasers is an organic dye dissolved in alcohol; the dye substance determines the wavelength of the light. The pulse length depends on the flash duration of the exciting xenon lamp and varies between 500 and 3,000 ns. The longer pulse lengths give a smaller peak power than the Nd:YAG laser, so smaller diameter quartz fibres (200 µm) can be used to transmit the energy. Watson and Wickham report a laser emitting at 504 nm in one µsec duration pulses to be the optimum(39). This wavelength also optimises the difference between maximum stone absorption and minimum tissue absorption of the light.

The fibre tip is placed on the stone using direct vision via a ureteroscope(43). Fibre manoeuvrability can be improved by use of a catheter or a specially designed basket(41). Baskets can also be used to hold stones and fragments in place during lithotripsy. Small diameter flexible and semi-flexible ureteroscopes have been developed which make laser access possible to most ureteral stones.

A Q-switched alexandrite solid state laser has recently become available. Light is generated by a flash lamp, and the wavelength determined by an alexandrite crystal.

Commercially available laser lithotripters include the Dornier Laserlithotripter, the Candela MDL 2000 Laser Tripter, the Stortz Calculas SL2 and the Technomed International Pulsolith. Table 2 summarises technical data for these devices. The laser fibre and, in the case of the pulsed dye lasers, the dye solution, need replacing at regular intervals.

Stones absorb light from pulsed dye lasers more readily than light from Nd:YAG lasers, and the energy density of pulsed dye lasers is 185 J/cm^2, compared with 24 J/cm^2 for Nd:YAG lasers(39). Pulsed dye lasers also have a much narrower fibre, so that they can be used for a wider range of cases. For these reasons, pulsed dye lasers are generally preferred over Nd:YAG lasers.

Unlike electrohydraulic lithotripsy, laser lithotripsy does not generate heat or cause thermal injury. Inadvertent firing of the laser at the ureteral wall is limited to a tiny mechanical rupture and does not produce a hole in the ureteral wall nor cause any significant side effects(125,126). Irrigation is required during treatment to keep vision clear of debris, bubbles and any blood resulting from ureteral wall injuries. Looking directly at the laser tip during firing can cause retinal damage, so safety precautions are needed to prevent inadvertent optical damage.

Lasers can be used for all but cystine and very hard stones. They are particularly useful in the treatment of impacted stones and steinstrasse because they do not cause significant ureteral wall injury(40). Table 28 summarises early results in the use of lasers. Success rates are generally high. Coptcoat et al report an average hospital stay of 2.4 days, and Govier et al treated 70 per cent of their patients on an out-patient basis(43,45). One day hospital stays have occurred for some cases in Australia (Lenaghan, Cameron-Strange, personal communications).

The potential use of lasers is growing as new ureteroscopes become available and operators become more experienced. It is now possible to treat upper ureteral stones with transurethral laser lithotripsy, and there is the potential for limited use in the kidney. For example, in a series of 450 patients with impacted ureteral stones, 20 per cent of the stones treated in the first 100 patients were upper ureteral stones whereas 56 per cent were upper ureteral stones in the last 100 patients (Watson, personal communication). Holden et al have also suggested that lasers may be able to be used to identify stone composition in vivo(130). Both Nd:YAG and pulsed dye lasers have potential application to biliary stones(131,132).

Open surgery

Since the advent of lithotripsy and PCN, open surgery is used to remove only five per cent of stones in the United States(46). Indications for open surgery include extremely large dense stones, staghorn stones with a large peripheral stone mass in the calyces, some large impacted ureteral stones, anatomic considerations necessitating open repair, diseased kidneys not worth preserving and extreme obesity (Cameron-Strange, personal communication)(133).

Complications are greater and convalescence much longer than other procedures (see Table 29). Complications are more severe than other forms of stone treatment, and include infection, fever, nerve damage, excessive bleeding, and partial or total loss of kidney function(1). The complication rate is high (estimated by Liong et al as 30 per cent) and is accompanied by a mortality rate of 0.38 per cent(11,47). Hospital stays range from eight to 12 days (Table 29), and convalescence four to six weeks(21,48). If stones recur, repeated surgery (unlike less invasive procedures such as ESWL) becomes more difficult.

Table 28: Clinical results of treating stones with laser lithotripsy

	Studies									
	Watson and Wickam	*Coptcoat et al*	*Hofmann et al*	*Segura and Patterson*	*Beck et al*	*Govier et al*	*Thomas et al*	*Dretler et al*	*Gautier et al*	*Bagley et al*
Number of patients	32	120	56	36	46	50	31	222	278	56
Success rate (%)	100	86	93	75	91	96	(a)55	(b)92	98	100
Type of laser	pulsed dye	pulsed dye	Nd:YAG	pulsed dye	pulsed dye	pulsed dye	Nd:YAG	pulsed dye	pulsed dye	pulsed dye
Mean operation time (mins)	–	78	–	–	–	–	60	–	–	–
Mean days in hospital	–	2.4	–	–	–	(c)0	–	–	2–3	–

(a) A further 29 per cent of stones were partially fragmented.
(b) Includes 13 per cent treated by laser lithotripsy and ESWL combined.
(c) In 70 per cent of cases.

Source: References 41–45, 111, 123, 127–129

Table 29: Clinical results of removing stones by open surgery

	Studies			
	Liong et al	*Das et al*	*Rigatti et al*	*Boyce*
Number of patients	27	24	23	951
Success rate (%)	100	100	100	99
Mean days in hospital	12	10	8.7	9.6
Mean operation time (min)	78	–	90	–

Source: References 11, 12, 26, 47

Appendix B: Source and scope of data

The Medicare data have been obtained from the Commonwealth Department of Community Services and Health. They cover payments made to private patients in either private or public hospitals, and do not include:

- services rendered free of charge in recognised hospitals;
- services covered by third party or worker's compensation provisions or serves rendered to repatriation beneficiaries or defence personnel;
- services to 'non-eligible' persons such as foreign diplomats and their families.

In relation to the Medicare data, 'State' refers to the State of origin of the patient.

State health authority data are collected on the basis of discharges from hospitals. They were obtained directly from the South Australian Health Commission, Queensland Department of Health and Health Department of Western Australia. Data were also obtained from files supplied by the New South Wales Department of Health, the Health Department, Victoria, and the Australian Capital Territory Community and Health Service. The Tasmanian Department of Health Services could not supply any data; instead individual hospitals were approached for the Tasmanian data. The data from Launceston General Hospital are incomplete for 1987 and 1988. The State health authority data presented in this report includes public hospitals only; private and repatriation hospitals have been excluded.

Data are available on a calendar year basis for Queensland, Western Australia and Tasmania, for New South Wales and the Australian Capital Territory prior to 1987, and for South Australia prior to 1986. They were available on a financial year basis for Victoria, New South Wales and the Australian Capital Territory from 1987-88, and South Australia from 1985-86. Early data are provided using ICPM codes; New South Wales and Tasmania changed to ICD-9-CM codes in 1987-88, Victoria in 1986-87, South Australia in 1985, and Western Australia in 1988. ESWL and PCN can only be identified through the ICD-9-CM coding scheme.

ESWL has been understated in the State health authority files for the first year (1987-88) it was recorded in Victoria. The number of ESWL treatments in 1987-88 was obtained directly from the Victorian Lithotripsy Service. Length of stay information for ESWL was taken from the State Health Authority data and should be regarded as representative only for 1987-88. Similarly, there are some uncertainties associated with the New South Wales data for 1987-88, which should be regarded as indicative only.

Data on PCN are not available from Medicare, and were only available from the State health authorities when the ICD-9-CM codes had been used. Some PCN data were obtained from individual hospitals, but are incomplete.

The ICPM and ICD-9-CM codes for surgery and transurethral procedures include some procedures done for other reasons. For example, the ICD-9-CM code 55.01 includes nephrotomy done to evacuate renal cysts or explore the kidney as well as to remove stones. In the cases of nephrotomy, pyelotomy and ureterotomy (ICD-9-CM codes 55.01, 55.11 and 56.2) the proportion of non-stone procedures is not large in comparison with those done to remove stones, so over-estimation of surgery figures due to this factor is minor (Cameron-Strange, Lenaghan, personal communications). The situation is less clear cut with transurethral procedures (ICD-9-CM code 56.0), since the removal of stents falls under this item as well as stone removal. Consequently the public hospital data for transurethral procedures to remove stones overestimate the actual procedures done.

Removal of stones by means of nephrectomy (excision of kidney) has not been included in the statistics, since it cannot be distinguished from nephrectomies performed for other reasons.

Appendix C: Medicare data

The Medicare data comprise the number of payments for services under Medicare benefits items. The items used to compile statistics were:

5691 nephrolithotomy or pyelolithotomy, or both, through the same skin incision, for one or two stones;

5699 nephrolithotomy or pyelolithotomy, or both, extended, for staghorn stone or three or more stones;

5700 extracorporeal shock wave lithotripsy;

5705 ureterolithotomy;

5842 ureteroscopy, plus one or more of extraction of stone, biopsy or diathermy;

5843 ureteroscopy, plus destruction of stone with ultrasound, electrohydraulic shock waves, or laser, with extraction of fragments;

5885 endoscopic manipulation or extraction of ureteric calculus.

Percutaneous procedures were not separated out until recently, so statistics for these procedures were not available.

Table 30: Number of payments for services to treat renal stones under Medicare benefits items

Origin of patient	*1984-85*	*1985-86*	*1986-87*	*1987-88*	*1988-89*	*1989-90*
NSW	2,065	1,797	1,991	2,232	2,350	na
Vic	1,009	798	1,028	1,155	1,171	na
Qld	447	455	544	477	517	na
WA	225	192	142	116	125	na
SA	319	275	283	289	272	na
Tas	54	89	86	109	105	na
Other	57	65	67	73	60	na
Total	4,176	3,671	4,141	4,451	4,600	4,453

na - not available

Table 31: Number of payments for ESWL under Medicare benefits item 5700 by State and year

State	*1986-87*	*1987-88*	*1988-89*
New South Wales	269	601	832
Victoria	210	448	452
Queensland	31	43	46
Western Australia	(a)	(a)	(a)
South Australia	7	17	34
Tasmania	(a)	10	15
Northern Territory	(a)	(a)	(a)
Australian Capital Territory	(a)	8	11
Total	525	1,132	1,396

(a) Confidential.

Table 32: Number of Medicare payments for removal of stones by region

Procedure (Item No.) *Region*	*1984-85*	*1985-86*	*1986-87*	*1987-88*	*1988-89*
Removal of kidney stones by surgery (5691, 5699)					
NSW and Victoria	752	603	325	182	149
Rest of Australia	362	289	182	174	124
ESWL (5700)					
NSW and Victoria	–	–	479	1,049	1,284
Rest of Australia	–	–	46	83	112
Removal of ureteral stones by surgery (5705)					
NSW and Victoria	636	483	386	281	234
Rest of Australia	264	247	246	206	230
Endoscopy (5885)					
NSW and Victoria	1,686	1,398	1,423	1,343	1,256
Rest of Australia	476	501	517	452	415
Ureteroscopy (5842, 5843)					
NSW and Victoria	–	111	406	532	598
Rest of Australia	–	39	131	149	198

Appendix D: State health authority data

The State health authority data were compiled using ICD-9-CM codes where available, and ICPM codes otherwise. The ICPM procedure codes used were:

5-550 nephrotomy and nephrostomy, for drainage, exploration, or removal of calculus or foreign body;

5-551 pyelotomy and pyelostomy, for drainage, exploration, or removal of calculus in renal pelvis, and excluding removal of calculus via ureter (5-560);

5-560 transurethral clearance of ureter and renal pelvis: removal of blood clot, calculus, foreign body;

5-562 ureterotomy for exploration, implantation of electronic stimulater, removal of calculus or ureteral splinting.

The ICD-9-CM procedure codes used were:

55.01 nephrotomy for evacuation of renal cyst, exploration of kidney, or nephrolithotomy;

55.03 percutaneous nephrostomy without fragmentation: percutaneous (nephroscopic) nephrostolithotomy or pyelostolithotomy, percutaneous removal of kidney stone(s) by basket or forceps extraction;

55.04 percutaneous nephrostomy with fragmentation: percutaneous nephrostomy with disruption of kidney stone by ultrasonic energy and extraction (suction) through endoscope;

55.11 pyelotomy for exploration of renal pelvis, pyelithotomy;

56.0 transurethral removal of obstruction from ureter and renal pelvis: removal of blood clot, calculus or foreign body from ureter or renal pelvis without incision;

56.2 ureterotomy: incision of ureter for drainage, exploration, reinsertion of ureteral stent or removal of calculus;

59.95 ultrasonic fragmentation of urinary stones;

59.96 extracorporeal shock wave lithotripsy (ESWL): disintegration of stones by extracorporeal induced shock waves or lithotripter tank procedure.

The ICD-9-CM diagnosis codes used were:

592.0 calculus of kidney: nephrolithiasis NOS, renal calculus or stone, staghorn calculus, or stone in kidney;

592.1 calculus of ureter: ureter stone, ureterolithiasis;

592.9 urinary calculus, unspecified: calculus pyelonephritis.

Table 33: Number of patients with renal stones treated in public hospitals by any procedure

Year of treatment(a)	*NSW*	*Vic*	*Qld*	*WA*	*SA*	*Tas*	*ACT*
1984	1,996	–	426	380	118	66	82
1985	1,495	938	316	407	188	78	61
1986	1,900	787	487	371	205	53	96
1987	–	1,277	411	435	190	47	–
1988	2,271	1,870	449	433	226	60	94
1989	2,269	1,811	–	–	225	94	–

(a) Some data refer to financial years rather than calendar years; see Appendix B.

Table 34: Number of stones treated by ESWL in public hospitals(a)

Year of treatment	*NSW*	*Vic*
1986–87	–	537
1987–88	700	922
1988–89	1,210	948

(a) ICD-9-CM code 59.96.

Table 35: Number of stones removed surgically from the kidney in public hospitals(a)

Year of treatment(b)	*NSW*	*Vic*	*Qld*	*WA*	*SA*	*Tas*	*ACT*
1984	718	–	92	183	81	30	39
1985	559	424	118	212	101	29	34
1986	714	281	156	179	111	20	73
1987	–	196	170	275	84	15	–
1988	357	238	172	71	87	7	18
1989	204	131	–	–	80	25	–

(a) ICPM codes 5-550 and 5-551, or ICD-9-CM codes 55.01 and 55.11.
(b) Some data refer to financial years rather than calendar years; see Appendix B.

Table 36: Number of stones removed surgically from the ureter in public hospitals(a)

Year of treatment(b)	*NSW*	*Vic*	*Qld*	*WA*	*SA*	*Tas*	*ACT*
1984	602	–	109	105	24	29	20
1985	438	306	83	94	45	35	14
1986	454	273	136	89	51	25	7
1987	–	271	113	81	47	21	–
1988	416	290	134	54	58	25	11
1989	278	256	–	–	54	38	–

(a) ICPM code 5-562, or ICD-9-CM code 56.2.
(b) Some data refer to financial years rather than calendar years; see Appendix B.

Table 37: Number of stones removed endoscopically from the ureter in public hospitals(a)

Year of treatment(b)	*NSW*	*Vic*	*Qld*	*WA*	*SA*	*Tas*	*ACT*
1984	676	–	63	92	13	7	23
1985	498	306	46	101	42	14	13
1986	732	273	87	103	43	8	16
1987	–	271	50	79	59	10	–
1988	618	290	61	105	59	27	11
1989	442	256	–	–	45	20	–

(a) ICPM code 5-560, or ICD-9-CM code 56.0.
(b) Some data refer to financial years rather than calendar years; see Appendix B.

Table 38: Principal diagnosis of renal stone patients admitted to public hospitals in New South Wales and Victoria

	Principal diagnosis			
Year and State	*Kidney stone*	*Ureteral stone*	*Unspecified urinary stone*	*Total*
1987–88				
NSW	1,882	1,617	46	3,545
Victoria	1,755	1,266	34	3,055
South Australia	338	393	19	750
ACT	97	72	11	180
Total	4,072	3,348	110	7,530
(Per cent)	(54)	(45)	(1)	
1988–89				
NSW	2,346	1,809	65	4,220
Victoria	1,844	1,309	36	3,189
South Australia	385	362	20	767
Total	4,575	3,480	121	8,176
(Per cent)	(56)	(43)	(1)	

Table 39: Principal procedures (percentages) undertaken on public hospital patients with a principal diagnosis of renal stones in New South Wales and Victoria, 1988–89

Type of principal procedure	*NSW*	*Vic*
Removal of stone from urinary system	50	47
Diagnostic procedures on the urinary system	19	15
Other procedures on the urinary system	4	5
Other procedures	0	1
No procedure done	27	32

Table 40: Percentage of different stone types treated by ESWL, New South Wales and Victoria

	1987–88		*1988–89*	
Type of stone	*NSW*	*Vic*	*NSW*	*Vic*
Kidney	97	81	90	86
Ureteral	3	19	10	14

Appendix E: Hospital data

Since the Medicare data and much of the State health authority data do not contain figures for PCN, individual hospitals were approached to obtain this information. Responses from the following hospitals were received:

New South Wales
Bexley Private
Prince Henry
Royal North Shore
St Luke's
St Vincent's Private
Westmead

Victoria
Alfred
Austin
Ballarat
Fairfield
Geelong
Monash Medical Centre
Royal Melbourne
St Vincent's Private

Queensland
Mater Misericordiae Adult
Princess Alexandra
Royal Brisbane
St Andrew's War Memorial

Western Australia
Repatriation General– Hollywood
Royal Perth
Sir Charles Gairdner

Tasmania
Launceston General
North West Regional
Royal Hobart

PCN data are on a calendar year basis for Queensland, Western Australia, Tasmania, and for New South Wales prior to 1987. They are on a financial year basis for Victoria, South Australia, and for the Australian Capital Territory and New South Wales from 1987–88.

Table 41: Number of percutaneous procedures performed in selected hospitals

Year of treatment(a)	*NSW(b)*	*Vic*	*Qld*	*WA*	*SA(c)*	*Tas*	*ACT(b)*
1984	2	–	–	7	–	–	–
1985	63	21	85	11	–	–	–
1986	71	13	97	8	–	–	–
1987	–	16	112	2	–	1	–
1988	54	53	99	–	14	1	54
1989	41	61	–	–	42	11	–

(a) Some data refer to financial years rather than calendar years.
(b) Plus an additional 132 procedures for 1984 to 1986.
(c) From State health authority data.

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NSW Department of Health
Health Department, Victoria
Queensland Department of Health
South Australian Health Commission
Health Department of Western Australia
Commonwealth Department of Community Services and Health
Royal Hobart Hospital
North West Regional Hospital, Tasmania
Launceston Public Hospitals District
The hospitals listed in Appendix E
Solus Medical Imaging, Sydney
N Stenning and Co, Sydney
Downs Surgical (Aust) Pty Ltd, Sydney
Medical Applications Pty Ltd, Canberra
Hahn and Kolb Pty Ltd, Melbourne
Turrella Industries Pty Ltd, Sydney
GEC Australia Ltd, Sydney
Australian Medical Imaging, Sydney
Dornier Medical Systems, Sydney