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Treatment of ureteric stones. Comparison of laser and pneumatic lithotripsy

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Objectives To study the treatment of ureteric stones by laser lithotripsy (LL) and pneumatic lithotripsy (PL), and to evaluate the results of the two treatment modalities to assess effectiveness, complications and cost benefits.

Patients and methods Between January 1993 and February 1994 200 ureteric stones in 194 patients were fragmented intracorporeally, 48 by LL and 152 by PL. The ages of the patients ranged from 31 to 40 years with a male to female ratio of 2 : 1. All procedures were performed under general/regional anaesthetic in a day-care set-up. Patients were followed at weekly intervals. Re-treatment was carried out at 4 weeks where necessary.

Results The majority of the stones treated (84%) were in the lower third of the ureter, 69% measured 7–12 mm in diameter, and 61% were composed of calcium oxalate. Ninety-three per cent of the stones were fragmented in one treatment session. The overall stone-free status at 4 weeks was 95% for PL and 84% for LL. The non-fragmentation rate was 10% for LL and 1% for PL. Post-treatment complications were encountered in 8% of the patients treated by LL and 7% by PL.

Conclusions Our experience shows that PL and LL both provide a safe and effective means of performing intracorporeal lithotripsy for smaller ureteric stones. However, PL is more effective in fragmenting larger and harder stones. Moreover, PL is more user-friendly and highly cost-effective compared with LL.

Keywords Ureteric stones, laser lithotripsy, pneumatic lithotripsy

Introduction

The mainstay of treatment of impacted ureteric stones up until the early 1980s was either open surgery [1] or extraction with loops or baskets under fluoroscopic control [2]. Today, with the advent of *in situ* extracorporeal shock wave lithotripsy (ESWL) and an array of intracorporeal endoscopic techniques, up to 95% of ureteric stones can be successfully treated by minimally invasive methods [3–5]. Although *in situ* ESWL has been found to be effective for ureteric stones in the upper third of the ureter [6], the treatment of choice for those in the middle and lower third is less clear. Electrohydraulic, ultrasound and laser lithotripsy (LL) have been used in increasing numbers of centres [7–9]. Pneumatic lithotripsy (PL) is a relatively new treatment modality, especially for ureteric stones in the middle and lower ureter [10]. The selection of these modalities in a particular set-up is dictated by several factors. First, the effectiveness in fragmentation and the stone-free rates achieved; second, the overall complications; and third, cost benefits, especially capital outlay and the subsequent cost of consumables. This paper describes our experience of treatment of ureteric stones using LL and PL, and compares the efficacy, effectiveness and cost differentials of the two modes of therapy.

Patients and methods

One-hundred and ninety-four patients with 200 ureteric stones, treated between January 1993 and February 1994, were included in the study. The age and sex distribution are shown in Fig. 1. The majority of the

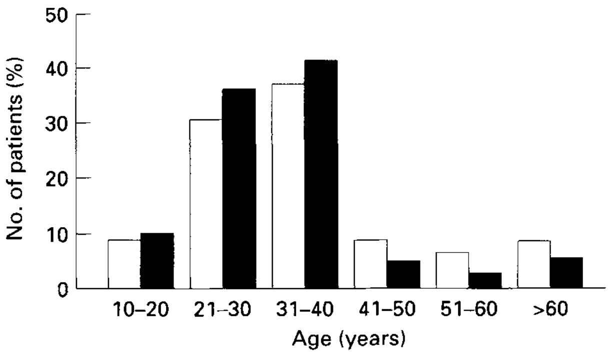

Fig. 1. Age distribution of patients treated by laser (□; M:F ratio, 1.7 : 1) and pneumatic lithotripsy (■; M:F ratio, 2.2 : 1).

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patients (74%) were in the age group 21–40 years, and the male to female ratio was 2 : 1. The patients' age and sex distribution were similar in both treatment groups and patients' ages ranged from 15 to 65 years.

Intravenous urograms were performed in all patients for the diagnosis, localization and determination of size of stones. Forty-five patients had either received initial conservative treatment or had failed *in situ* ESWL. Prior to treatment routine biochemistry and haematology, and coagulation profiles were also performed.

All procedures were carried out under general/regional anaesthesia on a Uroskop urological table (Siemens, Germany) with the facility for fluoroscopic screening. A 0.38 in. guide wire was passed prior to insertion of the ureteroscope. A 7 F ureteroscope (Wolf, Germany) with a straight channel to accommodate the pneumatic probe as well as a laser fibre was used in all patients. The ureteric orifice was dilated by a Uretomat (West, Germany) which employs hydraulic dilation of the ureteric orifice. Patients were treated with an Alexanderite Laser Impact (Dornier, Germany) with a 250 μm single-use fibre and/or a Lithoclast (EMS, Switzerland) with a 1 mm probe.

Treatment time and energy varied with the size and location of stones. All treatments were performed as a day-care procedure. Patients who developed complications, either immediate or post-treatment, were hospitalized for further management. Post-treatment, 4.7 F ureteric stents were placed whenever the stone burden after fragmentation was large or the treatment time was prolonged due to difficult ureteroscopy. Urine collection bags were connected in 54 patients for collection of stone fragments. All patients were followed-up routinely at weekly intervals or earlier if indicated. Ultrasound examination, plain abdominal film of the kidney, ureter, bladder and urine culture were repeated as warranted by the patients' condition. Patients with inadequately fragmented stones were subjected to subsequent treatment sessions within 4 weeks of the initial treatment. All patients were followed up until they were stone-free. Intravenous urography was performed at 3 months in selected patients where difficulty was encountered during the procedures.

The cost of the procedure was estimated on the average annual treatment load of 200 ureteric stones. The capital outlay of $200 000 for the Alexanderite (Dornier) Laser, $45 000 for the EMS Lithoclast and $150 per laser fibre was taken into consideration as all other cost parameters were the same for the two procedures.

Stone fragments were collected from the bags, were dried at room temperature and analysed by infra-red spectroscopy. Fragments (2–4 mg) were mixed with 200–400 mg of KBr powder. A pellet was made under a pressure of 8 tons and was scanned from 4000–600 cm^{-1} in an infra-red spectrophotometer (Shimadzu, Japan). The scans obtained were compared with characteristic spectra of known compounds and compound mixtures. Statistical analysis was carried out using the Z test for proportions.

Results

Of the 200 stones, 48 were treated by LL and 152 by PL. The first 28 consecutive stones were treated by LL and the following 70 by PL. Thereafter the two modalities were used concurrently. PL tended to be used for larger and radiologically harder stones. The majority of the stones (84%) were in the lower third of the ureter, 13% were in the middle third and 3.0% were in the upper third (Table 1). Of the stones treated, 66.5% were 7–12 mm in diameter, 13.0% were ⩽6 mm and 4% were >20 mm. For both PL and LL, all stones <12 mm in diameter were treated successfully in one session. In the size range 13–18 mm, 82% required one and 18% two treatment sessions. Of those measuring >20 mm, 38% required two, 12% three and the remaining (50%) one. One-session fragmentation rates for PL and LL were evaluated according to the site of the stones, i.e. above and below the pelvic brim. Above the pelvic brim the rates were 90% for PL and 80% LL, while below the pelvic brim they were 96% for PL and 89% for LL. Figure 2 shows the fragmentation sequence of a 25 mm lower ureteric stone.

Non-fragmentation rates were significantly higher ($P<0.001$) (10%) in the LL group compared with the PL group (1%) (Table 2). Stone-free rates at 4 weeks or less showed a statistically significant ($P<0.01$) higher

Table 1 Site and size distribution of ureteric stones

	Size							
	⩽6 mm (n=26)		*7–12 mm (n=133)*		*13–18 mm (n=33)*		*>20 mm (n=8)*	
Site	*PL*	*LL*	*PL*	*LL*	*PL*	*LL*	*PL*	*LL*
Upper third (*n*=6) % of total (3)	–	–	2	1	–	1	1	1
Middle third (*n*=26) % of total (13)	3	2	8	2	5	2	3	1
Lower third (*n*=168) % of total (84)	13	8	96	24	20	5	1	1
Total no.	16	10	106	27	25	8	5	3
%	11	21	70	56	16	17	3	6

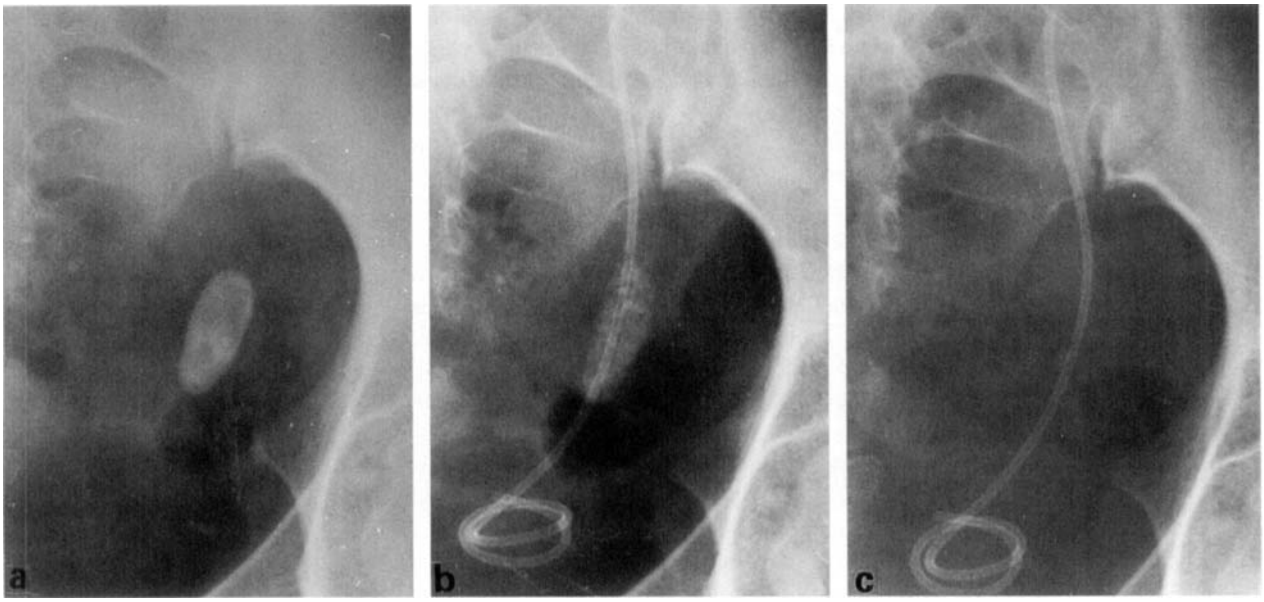

Fig. 2. **a**, Impacted, 25 mm stone in the pelvic ureter of the left kidney. **b**, Same stone fragmented after a single PL session. **c**, Complete stone clearance a week after PL session.

Table 2 Overall results of intracorporeal fragmentation of ureteric stones

	Lasertripsy		*Pneumatic lithotripsy*	
Results	n	*% of total*	n	*% of total*
Non-fragmentation	5	10.4	2	1.3 ($P<0.01$)
Stone-free status				
<4 weeks	40	83.3	144	94.7 ($P<0.01$)
>4 weeks	3	6.2	6	3.9

rate of 95% in the PL group compared with 84% in the LL group. All five stones where LL failed were >12 mm and were successfully fragmented by PL in the same treatment session. The two stones that were not fragmented by PL were removed by open ureterolithotomy.

The treatment time was marginally higher for LL, while more energy was required for PL (Table 3). The cost per procedure was eight times higher for LL when equipment depreciation and laser fibre costs of $150/procedure were incorporated into the calculations. On average, one fibre was used for each stone fragmentation. In three patients with large stone burdens, two fibres were used while in two sets of two patients with a small stone burden, a single fibre generated sufficient energy to disintegrate their two stones. Overall, complications were observed in 8% of the patients (Table 4). These were comparable in the two modes (LL 8% and PL 7%). The mean length of hospital stay in patients with no complications in both groups was 8 h (range 6–12). In patients who developed complications, the mean hospital stay was 2.5 days in the LL group (range 1–6) and 2.7 days (range 1–7) in the PL group. Infrared spectroscopic analysis of stone fragments was possible in nine stones treated by LL and 36 treated by PL. The majority of the stones in both groups were composed of calcium oxalate monohydrate (LL 56% and PL 61%). The frequency of other stone types, pure or combined, was struvite 22%, uric acid 21% and apatite 19%. No stones comprising cystine were found. Of the five stones

Table 3 Treatment data and cost differentials

Results	*Lasertripsy*	*Pneumatic lithotripsy*
Times of treatment (min)	15–20	10–15
Energy (MJ)	35–65	75–100
Cost/procedure ($)	200	45
Fibre costs ($)	150	—

Table 4 Complications following intracorporeal fragmentation

	Lasertripsy		*Pneumatic lithotripsy*	
Complications	n	*% of total*	n	*% of total*
Urosepsis	2	4	5	3
Haematuria	1	2	4	3
Perforations	1	2	2	1

where LL failed, three were analysed by infra-red and these were found to be composed of calcium oxalate monohydrate.

Discussion

Minimally invasive techniques for the treatment of ureteric stones should be evaluated from the standpoints of efficacy and the ultimate success rate of the various procedures. These include the ease of performing the procedure, the number of sessions required to render the patient stone-free, and the time required to achieve stone-free status. However, the popularity of any particular method will be equally determined by the cost of stone removal, particularly in developing countries where the constraints of cost are crucial determinants in the evaluation of treatment modalities.

Over the years advances in technology have seen an evolution in ureteroscope design enabling the treatment area to be reached safely and easily. This improvement in design, with better illumination and a wider working channel, has brought about the addition of newer options to the intracorporeal modalities of stone fragmentation. In the last decade, electrohydraulic, ultrasound and, more recently, LL have been used in increasingly large numbers of patients with better results [11]. No single therapeutic modality for all middle and lower ureteric stones has demonstrated superior results. PL is the most recent modality in the armamentarium for treatment of ureteric stones [10].

This study reports our experience of intracorporeal lithotripsy for the treatment of ureteric stones in the clinical setting of a developing country. LL and PL, two of the most promising methods currently used in the West, have followed the use of electrohydraulic and ultrasound lithotripsy which have been available in this centre for many years, but aspects of safety and technical difficulties precluded them from becoming the treatment of choice for ureteric stones.

The patient populations in the two groups were comparable in terms of the ureteric stones. Moreover, the age and sex distribution of the patients was representative of a previous group of patients with ureteric stones [12], and is in general agreement with other reports in the literature where the patients ranged in age from 40 to 45 years [13].

Both modalities were used predominantly for stones located in the middle and lower ureter. The main indication for treatment was failure of conservative management, in the presence of symptoms, or patients who underwent a failed *in situ* ESWL. Sometimes, failure of ancillary procedures to dislodge the stone was considered an indication for intracorporeal lithotripsy. There is broad consensus amongst workers in the use of *in situ* ESWL for upper ureteric stones, and the results have been rewarding [3,11]. Twenty-six patients with stones located in the middle ureter, an area sometimes referred to as 'no man's land', have been treated in this clinic. The first treatment option in this group was *in situ* ESWL, but those whose stones failed to fragment were treated subsequently with either PL or LL.

Three quarters of the patients had stones lodged in the lower third of the ureter. Intracorporeal lithotripsy has been used more often in this population as results of *in situ* ESWL can be equivocal and exposure to radiation, particularly in women is considered unacceptable. The intracorporeal methods offered good results (94%) in one session in this series making it a very suitable option. Smaller stones are likely to impact in the pelvic ureter resulting in obstruction of the affected renal unit. In these situations ureteroscopic methods, particularly LL or PL, hold great promise as day-care procedures. Not only do they reduce the cost of hospitalization but the patient can resume work within 2–3 days.

Under direct vision both LL and PL have shown good results at fragmenting ureteric stones. The laser energy generated through an alexandrite crystal and delivered through a 250 μm fibre was sufficient to completely fragment all of the smaller stones (<12 mm in the first session). There was, however, a fall in the first session fragmentation rate with increased stones size, i.e. 75% in stones >12 mm and 33.3% in stones >20 mm. Moreover, the composition and compactness of stones affected the success rate; poorer results being obtained for harder stones. Five stones were not fragmented by LL but all were disintegrated by PL in the same sitting. These were >12 mm and the three that were analysed by infra-red spectroscopy were found to be composed of calcium oxalate monohydrate.

PL fragmented virtually all the stones (99%), including the five that were not fragmented by LL. Ninety-seven per cent were fragmented in a single treatment session. PL has therefore become the treatment of choice in this setting for larger and harder ureteric stones. However, the fragments produced following LL were smaller and finer than those produced by PL. Moreover, the fragments produced following PL tend to advance upwards due to the irrigants' pressure and this requires turning down the flow or chasing the fragments in the proximal ureter before disintegrating them further to facilitate their downward course.

Several workers have advocated the use of ureteroscopic methods for the treatment of middle and lower ureteric stones [13,14]. The use of LL and PL has found more support compared with that of electrohydraulic lithotripsy and ultrasound lithotripsy for reasons of safety and ease [15]. Although the results of different groups vary due to differing criteria of success, there is a consensus that once a stone is visualized, the fragmentation rate of LL and PL is in excess of 95%.

The use of stents in patients with a large stone burden or in those in whom the procedure was difficult enabled patients undergoing intracorporeal lithotripsy to be treated as day-cases. Stents were also employed in patients who came from long distances away, especially those from rural areas where access to medical care is difficult. The stent prevents obstruction in the post-operative period permitting the patient to return home early. This was demonstrated by our study on the use of ureteric stents in relation to ESWL [16].

In the present series the incidence of complications was marginally higher than that observed by other groups [10,17]. This may reflect a higher proportion of larger stones as well as a greater percentage of calcium oxalate monohydrate stones in our series.

The final question that remains to be answered when choosing one modality over the other is the cost effectiveness of the method. When the capital outlay and the cost of consumables are considered, PL is far more cost effective than LL. Furthermore, PL also has the advantage of better visual targeting while fragmenting the calculus compared with the rapid flashes of light emanating from discharges from the laser. This sometimes interferes with targeting even in the presence of a pilot light. LL also requires the operator to wear protection.

In conclusion, PL offers cheap, safe and effective clearance of stones rendering the majority of patients stone-free after one session. This is particularly relevant for developing countries especially in areas where stone disease remains endemic.

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