Holmium laser cystolithotripsy in children: initial experience

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RAMAKRISHNAN PA, MEDHAT M, AL-BULUSHI YH, GOPAKUMAR KP, SAMPIGE VP, AL-BUSAIDY SS. Holmium laser cystolithotripsy in children: initial experience. The Canadian Journal of Urology. 2005 12(6):2880-2886.

Introduction: *Management of vesical calculi in children poses an interesting challenge to the urologist. The treatment options currently available include open surgery, transurethral pneumatic cystolithotripsy, percutaneous suprapubic cystolithotomy and shockwave lithotripsy (SWL). Holmium: YAG (Ho: YAG) laser cystolithotripsy represents a novel modality of treatment that is minimally invasive.*

Materials and methods: *From July 1999 to January 2003 we treated 23 children with vesical calculi using transurethral Ho: YAG laser lithotripsy. The indications for cystolithotripsy were stone size ≤ 4 cm (N=19), or multiple stones with combined stone burden ≤ 4 cm (N=4). The mean patient age was 7.8 (range 2-12) years and the mean stone size was 2.7 (range 0.9-4) cm. Access was obtained with an 8F ureteroscope and holmium laser energy (0.6-1.8 J/pulse at 5-12 Hz) was applied through a 550-μm. end-firing fibre under video guidance. The calculi were pulverized to tiny fragments about 2-3 mm in size. An 8F urinary catheter was placed for one night in all patients. Post-operatively the children were evaluated at 3 and 18 months with radiological imaging and uroflowmetry to confirm stone-free status and exclude urethral stricture formation.*

Results: *The mean duration of the endoscopic procedure was 38 (range 19-62) minutes while the mean length of hospital stay was 2.2 (range 2-3) days. All the children were rendered stone-free following a single operative session. Laser-induced major complications were not observed in any of the children. At the mean follow-up of 42 (range 26-69) months none of the children developed stone recurrence, urinary tract infections or urethral strictures.*

Conclusions: *Transurethral Ho: YAG laser lithotripsy was found to be an efficient and safe modality for the treatment of vesical calculi in children.*

Key Words: holmium laser, bladder stones, calculi, pediatric urolithiasis, cystolithotripsy

Accepted for publication October 2005

Acknowledgement
We would like to acknowledge Miss Pamela Bryant for her secretarial support.

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Introduction

Minimally invasive endourological techniques are widely employed to manage vesical calculi in adults.[1,2] However, the application of these techniques was restricted in children until recently, primarily due to the difficulty in adapting the relatively large adult endoscopes to the narrow calibre of the pediatric

urethra. Recent improvements in the design of endoscopes and fibre-optic engineering have enabled the development of thin instruments that facilitate easy and relatively atraumatic access to the lower urinary tract in children. Simultaneously, advances in intracorporeal lithotriptor technology have led to the introduction of small-calibre, flexible probes that are especially suited for use through these slender endoscopes. The holmium: yttrium-aluminum-garnet (Ho: YAG) laser is one such technical innovation that is rapidly becoming an integral part of the endourological armamentarium. The Ho: YAG laser is a solid state, holmium-doped, YAG pulsed laser system that operates at a wavelength of 2,150 nm, which is readily absorbed by water resulting in a microscopic vaporization bubble at the fibre tip.[3] The laser energy is transmitted through this vapor cavity, the so-called "Moses effect"; the energy absorbed by the water content of the stone leads to thermal disintegration rather than fragmentation of the stone.[4]

Traditionally, our referral unit has managed vesical calculi in children with open cystolithotomy. Although it is a reliable form of treatment, open surgery is associated with complications such as wound infection, suprapubic urinary drainage and catheter blockage.[5] In an effort to reduce the morbidity associated with open surgery, in recent years we have employed Ho: YAG laser cystolithotripsy as an alternative therapeutic option. We report our initial experience with this treatment modality in 23 children.

Materials and methods

Between July 1999 and January 2003, 23 children with vesical calculi underwent trans-urethral Ho: YAG laser cystolithotripsy at our institution, which is a tertiary referral centre for pediatric urolithiasis. The indications for transurethral cystolithotripsy were stone size ≤ 4 cm (N = 19) or multiple stones with a total stone burden of ≤ 4 cm (N = 4). Children with a stone burden > 4 cm and those who had undergone bladder or urethral surgery in the past were excluded from this study. All children were evaluated preoperatively by standard history and physical examination, renal function studies, urine culture, ultrasound and excretory urography. Metabolic investigations, including estimates of serum calcium, phosphorus and uric acid concentrations were performed routinely in all the children.

All patients received a single dose of broad-spectrum intravenous antibiotic preoperatively. Under general anesthesia, preliminary diagnostic cystourethroscopy was carried out using a 10F cystoscope sheath to examine the urethra and assess the calculus endoscopically. After distending the bladder, a 14 gauge venous canula was inserted through the suprapubic route to provide continuous bladder drainage during the procedure. Subsequently, an 8F rigid ureteroscope with a 5F working channel (Richard Wolf, Knittlingen, Germany) was introduced transurethrally into the bladder. Lithotripsy was applied using a pulsed 80 W. Ho: YAG laser generator (Versa Pulse Select, Coherent Corp; Paulo Alto, CA, USA) through a 550-μm end-firing flexible quartz fibre under video guidance. The laser fibre was stabilized with a 5F open-ended catheter and placed 1-2 mm from the stone surface. A red helium-ion aiming beam facilitated accurate visualization and placement of the fibre-tip. Laser lithotripsy was performed employing the technique described by Grasso.[6] Initially, at a low laser energy setting of 0.6 J/pulse and frequency of 5 Hz a cavity was created centrally in the stone mass. Using the surrounding stone as a thermal shield, higher energy and frequency was then applied to quickly debulk the stone down to a thin shell-like remnant. The laser energy was then decreased and the thin shell was powdered to tiny fragments 2 mm - 3 mm in size. The size of the stone fragments was judged by comparing with the diameter of the 550-μm laser fibre. Particular care was taken not to inadvertently place the fibre tip through the calculus and damage the bladder wall beyond the stone during lasertripsy. Visualization during stone fragmentation was facilitated by manually controlled pulsatile irrigation using a 20 mL syringe attached to the outlet port of the ureteroscope and refilled from an irrigant bag attached to the opposing inlet port. After completion of stone fragmentation the 10F cystoscope sheath was reintroduced and the tiny stone fragments were completely washed out using a 20 mL syringe connected to the side port of the cystoscope sheath. Following endoscopic confirmation of stone clearance and careful assessment for any laser-induced trauma to the urinary bladder, an 8F urethral catheter was inserted and the suprapubic canula was removed. The stone fragments were collected and analyzed.

All patients had a plain film of the kidneys, ureters and bladder (KUB) on the following morning to confirm stone clearance, before the urethral catheter was removed. We were able to discharge 16 patients on the same day after voiding successfully. All the remaining children could also have been discharged but stayed an extra night primarily for family and social convenience. They were clinically assessed and followed up with KUB, ultrasound, urine culture and

uroflowmetry at 3 months and at 18 months after the procedure. Uroflowmetry was performed using the Dantec Urodyn 1000 Flowmeter (Dantec Medical, Santa Clara, California, USA). Further follow-up was scheduled annually with clinical evaluation, urine culture and ultrasound.

Results

Patient demographics

There were 16 boys and 7 girls between the ages of 2 and 12 years (mean age 7.8 years). There were 12 children under the age of 5 years, 7 children between 5 and 10 years and the remaining 4 were older. Three boys (13%) presented with acute urinary retention due to stone impaction in the posterior urethra. For these patients, a preliminary suprapubic 10F cystocath was inserted. The remaining 20 (87%) presented with lower urinary tract symptoms of dysuria and hematuria. In all, there were 27 radiopaque calculi from 23 children; four children each had two calculi in the urinary bladder. The calculi varied in size from 0.9 cm to 4 cm in diameter (mean size 2.7 cm). One child had a co-existing partial staghorn calculus that was treated with SWL while another patient had a co-existing lower ureteric calculus that was treated with ureteroscopy and Ho: YAG laser lithotripsy in the same session. Anomalies of the urinary tract were noted in two patients, which included a megaureter and a duplex collecting system in one child each.

Outcome

A single attempt at lasertripsy with the Ho:YAG laser was performed in all cases. The mean operative time was 38 (range 19-62) minutes. The mean laser pulse energy, frequency and total energy required for fragmentation were 1.0 (range 0.6-1.8) J/pulse, 8.5 (range 5-12) Hz and 4.6 (range 2.2-13.6) kJ respectively. In all, 23 transurethral procedures were employed in 23 children in an attempt to clear 27 vesical calculi. Stone disintegration was easily accomplished in all patients with almost negligible stone vibration or movement. All patients were rendered stone-free after a single endoscopic session. The mean length of the hospital stay was 2.2 (range 2-3) days.

All patients had an uneventful recovery with no major complications related either to access or intracorporeal lithotripsy. Two children had transient, mild haematuria that settled within 24 hours. At the time of discharge, all the children were voiding clear urine spontaneously. Stone fragments were available for analysis in all the children; the stones were composed of ammonium acid urate in 17, calcium phosphate in 4 and calcium oxalate monohydrate in two children. From our investigations, none of the children were detected to have any metabolic lithogenic disorders. The results from a 9-year-old child with a single vesical calculus are shown in Figure 1a-1f.

Follow up

Six children were lost to follow-up after treatment. The rest were compliant and all data was available in 17 children that included 13 boys and 4 girls. The follow-up period ranged from 26 to 69 months, with a mean of 42 months. At follow-up, none of the 17 children developed stone recurrence or urinary tract infections. In addition, none reported new onset obstructive voiding symptoms. The mean maximum urinary flow rates at the 3-month and the 18-month follow-up periods were 18.6 ± 7.4 and 18.1 ± 8.1 ml/sec respectively. The corresponding mean average urinary flow rates were 11.4 ± 4.6 and 11.0 ± 4.7 ml/sec respectively. These flow parameters were comparable to the established nomograms for children in a similar age group.[7]

Figure 1a. KUB from a 9-year-old boy with a vesical calculus.

Figure 1b. IVU confirms the presence of the calculus.

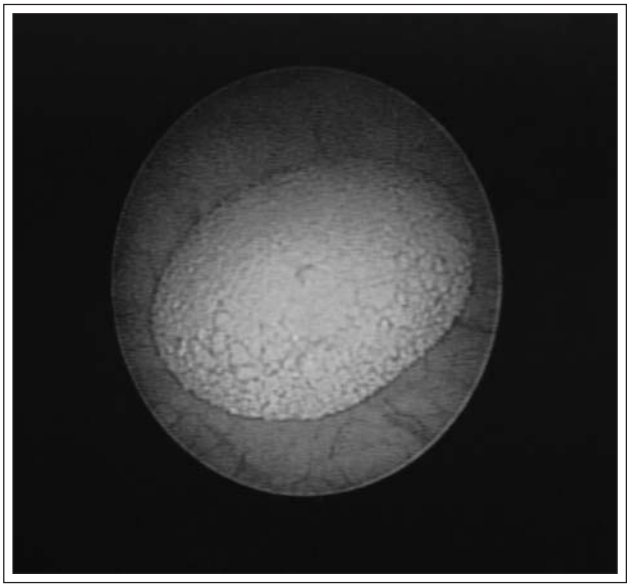

Figure 1c. Endoscopic view of the calculus before Holmium laser cystolithotripsy.

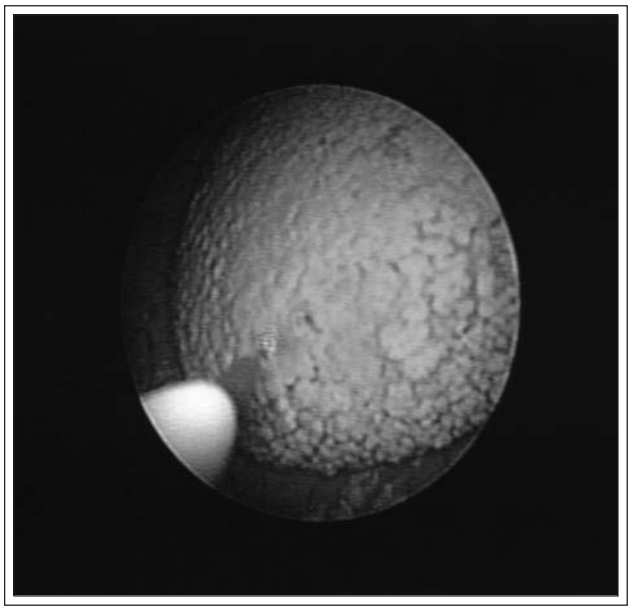

Figure 1d. Endoscopic view at the beginning of Holmium laser cystolithotripsy.

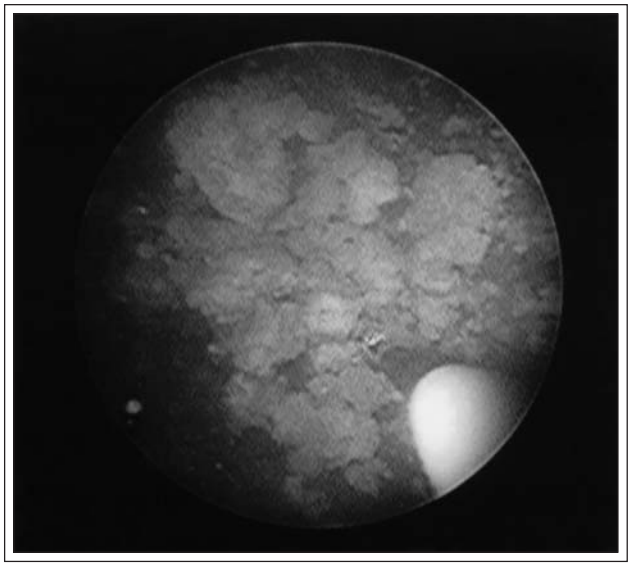

Figure 1e. Endoscopic view with partial fragmentation of the calculus.

Discussion

Childhood vesical calculi are uncommon in developed countries, but continue to be endemic in the third world, particularly the Middle East, northwest India and Indonesia.[8] The main components of these calculi are ammonium acid urate and/or calcium oxalate.[9] Feeding pattern in infants, including a diet high in calcium oxalate and depleted in phosphate, has been

Figure 1f. KUB after Ho: YAG lasertripsy shows complete stone clearance.

implicated in the etiology of these endemic bladder stones.[9] Water intake, water composition, social economic level and infections associated with malnutrition represent additional risk factors.[9] Furthermore, repeated attacks of diarrhea and dehydration, common in these countries, leading to the passage of concentrated, acidic urine could also be contributory.[8] In non-endemic areas, such as the developed countries, other causative factors, namely infective, metabolic and anatomical, are more common.

The current treatment options include open surgery, percutaneous suprapubic cystolithotomy, transurethral pneumatic cystolithotripsy and SWL.[5,10,11] Transurethral Ho: YAG laser cystolithotripsy is potentially viewed as a further advance. In 1996 McIver et al[12] were the first to specifically address the issue of Ho: YAG laser cystolithotripsy for managing vesical calculi. Subsequently other investigators also employed Ho: YAG laser cystolithotripsy obtaining excellent stone-free rates, although most of these reports described experience with adult patients, Table 1.[6,12-18] In the present study that was comprised of vesical calculi exclusively in the pediatric age group, we obtained comparable results with a 100% stone-free rate after a single operative session.

The excellent results achieved with the Ho: YAG laser cystolithotripsy could be explained by the physical properties of the laser and its photothermal mechanism of action. Firstly, because the holmium

TABLE 1. **Holmium laser cystolithotripsy - overview**

	References	No. patients	Stone size range (cm)	Large fibre (μm)	Success after one procedure, n (%)	Significant complications (No.)
*	Reddy et al[13]	2	♦	200	2 (100)	Nil
**	McIver et al[12]	3	4 - 5	500	3 (100)	Nil
***	Lipke et al[14]	3	1 - 5	1000	3 (100)	Nil
**	Costello et al[15]	6	Not specified	550	6 (100)	Nil
**	Grasso[6]	12	1.5 - 15	1000	12 (100)	Nil
*	Cain et al[16]	13	Not specified	Not specified	12 (92)	Bladder perforation (1) Hypothermia (1)
**	Teichman et al[17]	14	4 - 5.5	365 & 550	14 (100)	Nil
**	Gould[18]	15	1.5 - 4	550	15 (100)	Nil
*	Present study	23	0.9 - 4	550	23 (100)	Nil

* Describes pediatric series
** Describes adult series
*** Describes experience in renal transplant recipients
♦ Both calculi measured 170 mm^2 in surface area

energy is absorbed by all stone compositions, this laser has the unique ability to fragment all stone types, including the harder cystine and calcium oxalate monohydrate stones.[19] Secondly, studies have demonstrated that Ho: YAG lasertripsy yields smaller stone fragments than those produced by pneumatic lithotripsy, pulsed-dye laser or electrohydraulic lithotripsy.[20] Finally, the absence of a strong shockwave avoids significant stone movement during lasertripsy, and this facilitates rapid debulking of the calculus.[20]

Ho: YAG laser cystolithotripsy involves a photothermal mechanism and there is therefore a genuine concern as to whether it risks thermal injury to the bladder urothelium and, if so, whether this risk is increased in the smaller pediatric anatomy.[21,22] In the present study bladder wall injury was not observed in any of the children despite using high laser energy (> 1.5 J/pulse) in some. From a cumulative experience of nine studies involving 91 patients bladder perforation was documented in only one patient thereby confirming the safety of Ho: YAG laser, Table 1.[6,12-18] Another concern with pediatric Ho: YAG laser cystolithotripsy is the potential risk of intraoperative urethral injury and subsequent stricture formation. In the present study evidence of urethral stricture formation was not noted in any of the children, as assessed by the symptoms and uroflow measurements. The diameter of the male child's urethra remains relatively constant throughout most of childhood and is approximately 12F to 14F,[23] we routinely used an 8F endoscope that facilitated an easy and atraumatic passage through the pediatric urethra. Although prolonged operative time is a well recognized factor that may be hazardous to the delicate urethra in children,[24] it was not considered significant in our study as the mean operative time (38 minutes) compared favorably with those of other endoscopic studies in which the mean operative times ranged from 42-72 minutes.[25,26] We surmise that in our group of children, the use of a miniature endoscope and the effective and rapid pulverization of the calculus by holmium laser energy averted intraoperative urethral trauma and subsequent urethral stricture formation in the long term.

The optimal treatment of vesical calculi in children remains a matter of opinion. In addition to transurethral Ho: YAG laser cystolithotripsy, the other treatment modalities include open surgery, percutaneous suprapubic cystolithotomy, transurethral pneumatic cystolithotripsy and SWL.[5,10,11] Traditionally, vesical calculi in children have been managed by open cystolithotomy. In certain clinical situations such as large stone burdens and multiple calculi, open surgery is preferred. However, open cystolithotomy is an invasive procedure and prone to increased morbidity and convalescence.[5] Percutaneous suprapubic cystolithotomy is a minimally invasive technique that has been recently described.[10] This procedure is arguably advantageous in infants and very young children, who are potentially more vulnerable to urethral damage from instrumentation. Though this technique provides excellent stone-free rates, it is technically more demanding and requires a longer learning curve. Furthermore, the procedure is occasionally accompanied by complications such as paralytic ileus and peritoneal extravasation.[10] Another treatment option that has been described in children is the transurethral pneumatic cystolithotripsy.[5,24,27] Although safe and effective, the ballistic nature of the energy source tends to cause stone displacement increasing the operative time, and besides, the stone fragments tend to be larger than the sand-like particles produced by Ho: YAG lasertripsy.[5,24] Recently, SWL has also been employed to treat childhood vesical calculi.[5] Although its noninvasiveness makes it an attractive therapeutic option in children, the success rates with SWL are distinctly inferior as compared to the other techniques.[5] Thus, when one compares the efficacy, safety and invasiveness of the various procedures, transurethral Ho: YAG laser cystolithotripsy seems to be a more favorable treatment option.

Conclusions

Our study shows that Ho: YAG laser cystolithotripsy is an effective, safe and minimally invasive modality for the management of bladder calculi in children. From our experience we believe it holds great promise and is worthy of further long-term studies. □

References

1. Denstedt JD, Eberwein PM, Singh RR. The Swiss Lithoclast: A new device for intracorporeal lithotripsy. *J Urol* 1992; 148:1088-1090.
2. Razvi HA, Song TV, Denstedt JD. Management of vesical calculi: Comparison of lithotripsy devices. *J Endourol* 1996;10:559-563.
3. Johnson DE, Cromeens DJ, Price RE. Use of the Holmium: YAG laser in urology. *Laser Surg Med* 1992;12:353-363.
4. Devarajan R, Ashraf M, Beck RO, Lemberger RJ, Taylor MC. Holmium: YAG lasertripsy for ureteric calculi: an experience of 300 procedures. *Br J Urol* 1998;82:342-347.

5. Rizvi SAH, Naqvi SAA, Hussain Z, Hashmi A, Hussain M, Zafar MN, Sultan S, Mehdi H. Management of pediatric urolithiasis in Pakistan: experience with 1,440 children. *J Urol* 2003;169:634-637.
6. Grasso M. Experience with the holmium laser as an endoscopic lithotrite. *Urology* 1996;48(2):199-206.
7. Bower WF, Kwok B, Yeung CK. Variability in normative urine flow rates. *J Urol* 2004;171:2657-2659.
8. Vanwaeyenbergh J, Vergauwe D, Verbeeck RM. Infrared spectrometric analysis of endemic bladder stones in Niger. *Eur Urol* 1995;27:154-159.
9. Al Shammary EJ, Taka AS, Rifat UN. Mineralogy and chemistry of urinary stones in pediatric age group in Iraq – A study in medical geochemistry. *Arab J Urol* 2005;3:24-30.
10. Salah MA, Holman E, Toth C. Percutaneous suprapubic cystolithotripsy for pediatric bladder stones in a developing country. *Eur Urol* 2001;39:466-470.
11. Holman E, Khan AM, Flasko T, Toth C, Salah MA. Endoscopic management of pediatric urolithiasis in a developing country. *Urology* 2004;63:159-162.
12. McIver BD, Griffin KP, Harris JM, Teichman JMH. Cystoscopic holmium lithotripsy of large bladder calculi. *Techn Urol* 1996;2:65-67.
13. Reddy PP, Barrieras DJ, Bagli DJ, McLorie GA, Khoury AE, Merguerian PA. Initial experience with endoscopic holmium laser lithotripsy for pediatric urolithiasis. *J Urol* 1999;162(5):1714-1716.
14. Lipke M, Schulsinger D, Sheynkin Y, Frischer Z, Waltzer W. Endoscopic treatment of bladder calculi in post-renal transplant patients: a 10-year experience. *J Endourol* 2004;18(8):787-790.
15. Costello AJ, Westcott MJ, Peters JS. Experience with the holmium laser as an endoscopic lithotrite. *Aust NZJ Surg* 2000;70(5):348-350.
16. Cain MP, Casale AJ, Kaefer M, Yerkes E, Rink RC. Percutaneous cystolithotomy in the pediatric augmented bladder. *J Urol* 2002;168(4 Pt 2):1881-1882.
17. Teichman JMH, Rogenes VJ, McIver BJ, Harris JM. Holmium: yttrium-aluminum-garnet laser cystolithotripsy of large bladder calculi. *Urology* 1997;13:739-744.
18. Gould DL. Holmium: YAG laser and its use in the treatment of urolithiasis: our first 160 cases. *J Endourol* 1998;12:23-26.
19. Teichman JMH, Vassar GJ, Glickman RD. Holmium: YAG lithotripsy efficiency varies with stone composition. *Urology* 1998;52:393-397.
20. Teichman JMH, Vassar GJ, Bishoff JT, Bellman GC. Holmium: YAG lithotripsy yields smaller fragments than lithoclast, pulsed dye laser or electrohydraulic lithotripsy. *J Urol* 1998;159:17-23.
21. Vassar GJ, Teichman JMH, Glickman RD, Weintraub SE, Chan KF, Pfefer TJ, Welch AJ. Holmium: YAG lithotripsy: photothermal mechanism. *J Endourol* 1999;13:181-184.
22. Desai M. Endoscopic management of stones in children. *Curr Opin Urol* 2005;15(2):107-112.
23. Jordan GH, Robey EL. Editorial comment. *J Endourol* 1994;8:159.
24. Shokeir AA. Transurethral cystolitholapaxy in children. *J Endourol* 1994;8:157-160.
25. Shroff S, Watson GM. Experience with ureteroscopy in children. *Br J Urol* 1995;75:395-400.
26. Al-Busaidy SS, Prem AR, Medhat M, Al-Bulushi YHK. Ureteric calculi in children: preliminary experience with Holmium: YAG laser lithotripsy. *BJU Intl* 2004;93:1318-1323.
27. Fraser M, Joyce AD, Thomas DFM, Eardley I, Clark PB. Minimally invasive treatment of urinary tract calculi in children. *BJU Intl* 1999;84:339-342.