Contemporary Surgical Trends in the Management of Upper Tract Calculi

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Abbreviations and Acronyms

ABU = American Board of Urology

PCNL = percutaneous nephrolithotomy

SWL = shock wave lithotripsy

URS = ureteroscopy

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For another article on a related topic see page 1030.

Purpose: Upper tract nephrolithiasis is a common surgical condition that is treated with multiple surgical techniques, including shock wave lithotripsy, ureteroscopy and percutaneous nephrolithotomy. We analyzed case logs submitted to the ABU by candidates for initial certification and recertification to help elucidate the trends in management of upper tract urinary calculi.

Materials and Methods: Annualized case logs from 2003 to 2012 were analyzed. We used logistic regression models to assess how surgeon specific attributes affected the way that upper tract stones were treated. Cases were identified by the CPT code of the corresponding procedure.

Results: A total of 6,620 urologists in 3 certification groups recorded case logs, including 2,275 for initial certification, 2,381 for first recertification and 1,964 for second recertification. A total of 441,162 procedures were logged, of which 54.2% were ureteroscopy, 41.3% were shock wave lithotripsy and 4.5% were percutaneous nephrolithotomy. From 2003 to 2013 there was an increase in ureteroscopy from 40.9% to 59.6% and a corresponding decrease in shock wave lithotripsy from 54% to 36.3%. For new urologists ureteroscopy increased from 47.6% to 70.9% of all stones cases logged and for senior clinicians ureteroscopy increased from 40% to 55%. Endourologists performed a significantly higher proportion of percutaneous nephrolithotomies than nonendourologists (10.6% vs 3.69%, $p < 0.0001$) and a significantly smaller proportion of shock wave lithotripsies (34.2% vs 42.2%, $p = 0.001$).

Conclusions: Junior and senior clinicians showed a dramatic adoption of endoscopic techniques. Treatment of upper tract calculi is an evolving field and provider specific attributes affect how these stones are treated.

Key Words: urolithiasis; physician's practice patterns; ureteroscopy; lithotripsy; nephrostomy, percutaneous

In the last 30 years the management of urinary tract stone disease has undergone tremendous changes prompted by the adoption of new technological and treatment advances.[1–4] In the current era open surgery has been almost entirely replaced by the minimally invasive techniques of URS, extracorporeal SWL and PCNL. As more treatment modalities become available to treat upper tract calculi, there is a corollary increase in the complexity of decision making in the management of these stones. Urologists are often faced with surgical scenarios in which several treatment modalities may be acceptable. Several studies

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have confirmed that there is considerable variation in the practice patterns of urologists today.[5–7] The advent of this increasingly complex clinical decision making led us to investigate contemporary surgical trends in upper tract stone management.

Beginning in 2003 the ABU initiated the practice of requiring detailed electronic surgical operative logs for all candidates at initial certification as well as at each subsequent recertification.[8] These case logs serve as a unique source of the documented clinical practices of American urologists. We used these ABU surgical case logs to determine the current practice patterns of upper tract calculi treatment of urologists in the United States.

MATERIALS AND METHODS

The ABU was started in 1934 to serve as a surgical specialty board to improve standards, promote competency and encourage education in the practice of urology. Urologists may be granted certification by the ABU by completing basic training, thereby demonstrating they have attained the level of knowledge and expertise required for the care of patients with urological disease. If certified before 1985, recertification is not mandatory but for all urologists certified after 1985 mandatory recertification must be performed every 10 years.

A significant portion of certification is the completion of surgical operative logs describing a consecutive 6-month period before application submission. These logs characterize patient demographics, including age and gender, and surgeon characteristics, including age, certification group and clinical practice location. In addition, surgeons report self-appointed subspecialization in 1 of 5 areas (endourology, oncology, pediatrics, andrology and female urology). Diagnoses are logged according to ICD-9 code and surgical procedures are coded using CPT codes.

We analyzed annualized case logs from 2003 to 2012 for trends and used logistic regression models to assess how surgeon specific attributes affected the treatment of upper tract stones. Cases were identified using CPT codes as the search criteria. They included SWL (50590), URS (52336—URS with removal of stone, 52337—URS with lithotripsy, 52352—cystourethroscopy with URS and/or pyeloscopy/with removal or manipulation of calculus and 52353—cystourethroscopy with URS and/or pyeloscopy, laser lithotripsy) and PCNL (50080—stone burden less than 2 cm and 50081—stone burden greater than 2 cm). The Northwestern University Feinberg School of Medicine institutional review board granted this study exempt status.

We determined trends in the surgical management of upper tract urinary calculi among urologists who submitted case logs for ABU certification. We hypothesized that younger urologists (candidates) would be more likely to manage stones endoscopically than older (recertifying) urologists. In addition, we hypothesized that surgeons who specialized in endourology would perform an increased number of PCNLs relative to nonendourologists. Finally, we assessed surgeon and practice characteristics associated with nephrolithiasis surgery. Results were considered statistically significant at 2-sided $\alpha < 0.05$. We used multivariate logistic regression when appropriate to evaluate surgeon factors and practice factors associated with nephrolithiasis surgery.

RESULTS

A total of 6,620 urologists recorded case logs during this 9-year period from 2003 to 2012. A total of 2,275 urologists with a mean age of 34 years comprised the candidate certification cohort. In the 2 recertification cohorts we identified 2,381 and 1,964 individuals with a mean age of 43 and 53 years, respectively.

A total of 441,162 total procedures for upper tract urinary calculi were performed, of which 54.2% were URS, 41.3% were SWL and 4.5% were PCNL (see table). We observed an overall increase in URS from 40.9% of all stone procedures in 2003 to 59.6% in 2012 (fig. 1). There was a corresponding decrease in SWL from 54% to 36.3%. PCNL remained stable, accounting for 4% to 5% of all surgeries during this period ($p = 0.81$, fig. 1). New urologists showed an increase in URS during this period from 47.6% to 70.9%, representing a 23% increase. More senior surgeons (those undergoing first or second recertification) similarly showed an increase in URS from 40% in 2003 to 55% in 2012, representing a 15% increase (fig. 2).

Figure 3 shows differences in treatment modality use by endourology specialists vs nonendourologists. Endourologists performed a significantly higher proportion of PCNL than nonendourologists (10.6% vs 3.69%, OR 2.87, $p < 0.0001$) and a significantly smaller proportion of SWL (34.2% vs 42.2%, OR 0.8102 $p = 0.001$).

Additional statistical analysis was done to assess differences in stone surgery based on clinical practice location as defined by state. Although the Southeast logged the highest number of total stone surgeries, there was no statistically significant difference in stone surgery type when stratified by the population of each region in the United States. Although small individual differences existed among states, a consistent trend was noted toward increased URS in each geographic region.

Procedures by cohort from 2003 to 2012

	No. SWL	No. PCNL	No. URS	Total No.
New certification	40,850	8,784	92,026	141,660
1st Recertification	76,074	6,730	84,650	167,454
2nd Recertification	66,534	3,396	62,118	132,048
Totals	183,458	18,910	238,794	441,162

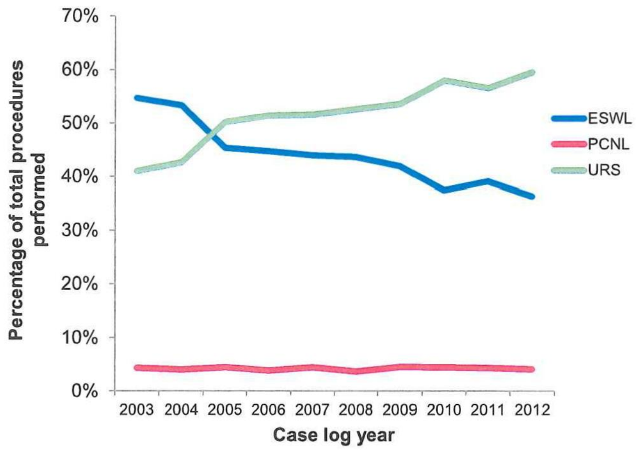

Figure 1. Change in stone treatment modality with time of all certifying urologists. *ESWL*, extracorporeal SWL.

DISCUSSION

Nephrolithiasis is a common and costly disease in the United States and its treatment remains a cornerstone of urology practice. Recent estimates demonstrate that approximately 9% of the adult American population is diagnosed with urolithiasis in a lifetime.[9] However, only a few randomized, controlled trials have been performed to determine the efficacy of the various treatment options for renal stones.[9,10] Because stone disease represents a tremendous health care burden, it is important to understand surgical practice patterns and how trends in surgical care are changing with time. Only a few studies have been done to examine the surgical trends of all 3 modalities for stone treatment.[4,11–13] Unfortunately most available studies are retrospective in nature and relied on limited national sampling databases or recall biased voluntary surveys. ABU case logs more accurately represent the practice patterns of all urologists in the United States. They avoid the referral bias of studies completed at academic institutions, which may be skewed toward more complex stone cases.[9] Since we used ABU data, our study relied on independently reviewed and approved certification case logs.

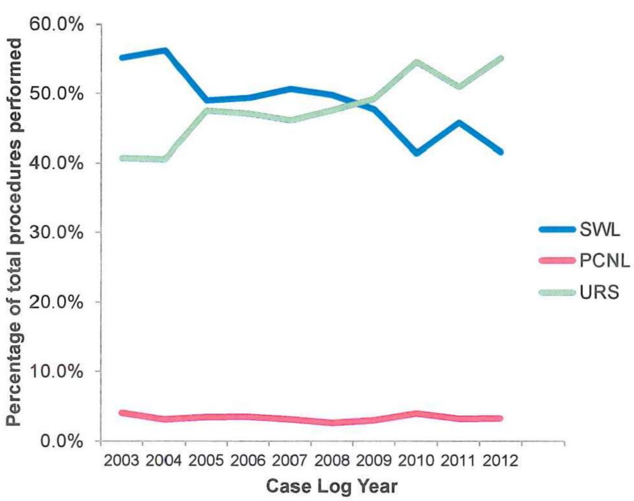

Figure 2. Change in treatment modality with time of senior urologists for first and second recertification.

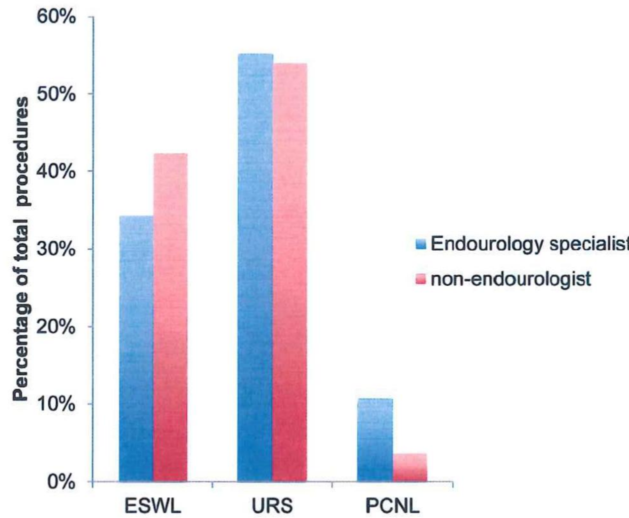

Figure 3. Treatment modality differences among specialists. Endourologists performed higher proportion of PCNL than nonendourologists (11% vs 3.7%, $p < 0.0001$). *ESWL*, extracorporeal SWL.

Our findings demonstrate that the treatment of upper tract calculi continues to evolve and provider specific attributes continue to affect stone treatment. Our study confirms the findings of previous studies showing that younger urologists have adopted endoscopic techniques at a high frequency.[14] To our knowledge this is the first study to show that senior urologists are also adopting endoscopic techniques at a rapid pace and now perform URS at a higher frequency than SWL. It is now clear that junior and senior clinicians show a dramatic increase in the adoption of these endoscopic treatment modalities for upper tract stones with a subsequent decrease in SWL. This is in contrast to a number of previous studies in which SWL was the most commonly performed procedure and URS predominated only in the junior urologist cohort.[13,14]

Modern ureteroscopic technology is the product of the last 2 decades. This development has favored urologists in the initial certification cohort who trained more recently in endoscopic techniques. Interestingly it appears that the newer technology was adopted by all cohorts in our study. There are several theories why surgeons of all generations now perform endoscopic procedures at increased frequency, including technological improvements resulting in decreased costs, and surgeon comfort and ease of use as well as improved surgical outcomes, such as stone-free and retreatment rates, compared to SWL.[15,16]

During the last 15 years there has been an increasingly widespread dispersion of technologies such as flexible URS, resulting in improved cost-effectiveness, which may account for the increased use.[17] For example, factors such as the improved durability of newer scopes[18] as well as the superior efficiency and cost-effectiveness of URS for stones up to and greater than 1 cm compared to SWL may partially account for these practice pattern changes.[19]

Furthermore, several studies confirmed higher URS surgical cure and stone-free rates compared to SWL, which might drive this change in adoption.[3–7] For example, Wu at el assessed the treatment of proximal ureteral stones and found a significantly improved stone-free rate after URS compared to SWL (92% vs 61%).[20] In addition, in a recent study Scales et al found that compared to SWL URS is associated with significantly fewer repeat treatments.[21] These findings confirm those of previous studies demonstrating that SWL has a 20% to 30% re-treatment rate and associated patient discomfort due to fragment passage.[21]

Despite the introduction of newer SWL technologies with modifications to improve SWL efficacy[22] we observed a decrease in SWL in our study. Is it possible that these newer machines have more potential problems than first generation devices, resulting in decreased use? Further research is needed to determine whether this preference for ureteroscopic techniques is due to the inferiority of SWL in completely treating the stone burden at a single session. Recent data on newer technologies, such as large focus shock wave sources, are promising since these methods may provide increased efficacy with minimal trauma.[22,23] Improved pulverization and fewer re-treatments using these newer technologies may lead to the resurgence of SWL.

PCNL use remained stable from 2003 to 2012. Although we have seen technological advances with improvements in stone fragmentation and decreased complications using PCNL,[4,24,25] it is likely that PCNL is being reserved for larger or complex stone burdens and its overall increased morbidity may limit any expanded application. Not surprisingly these cases are performed at a much higher rate by endourologists who specialize in stone surgery.

Our study is not without potential limitations. Because of the observational, prospectively collected nature of the data, we could not extrapolate causality to changes in treatment modality with time. There are numerous theories of why we see these patterns but those conclusions cannot be made from the data used in our study. Additional studies are needed to better test these hypotheses. Furthermore, because the case logs are limited to urologists who completed initial ABU certification after 1985, there is selection bias toward a younger overall population of urologists. It would be interesting to explore how the practice patterns of this older cohort differ from those of its younger counterparts. Furthermore, the ABU data set does not contain specific patient or stone data that could help elucidate possible referral biases or explain these practice patterns. Subspecialty designations are self-reported and do not reflect specific fellowship training.

As health care spending increases, it is imperative that we identify ways to improve the value of the care that we provide as urologists and understand the factors influencing treatment modality choices. We used case logs as a representation of the average work load of urologists and the ABU independently reviewed and approved the submitted logs. Although individual audits of the practice of each candidate are not feasible, the overall accuracy of the described data is strong. To date these data provide one of the most reliable representations of the work loads and practice patterns of urologists in the United States. Surgical practice patterns can be powerful data when accurately captured, and they have the potential to guide health care spending, work force estimations and clinical decision making.

CONCLUSIONS

Treatment of upper tract calculi remains an evolving field and provider specific attributes continue to affect stone treatment decisions. Our study of ABU surgical case log data provides strong evidence that URS has surpassed SWL as the primary treatment modality for upper tract stones for newly trained as well as senior urologists. PCNL continues to be performed in disproportionate numbers by those who specialize in endourology. The findings from this prospectively collected data cohort are observational in nature but provide the necessary tools to generate hypotheses. Given the current health care climate, there no doubt exists a pressing need for further illumination of the driving forces behind these trends.

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Extracorporeal Shockwave Lithotripsy Falling Out of Favor

Alicia Ault | June 04, 2015

NEW ORLEANS — Extracorporeal shockwave lithotripsy, once the gold standard for removing smaller kidney stones, has fallen out of favor, in part because it might be less effective than ureteroscopy, but does that mean it should be taken out of commission altogether?

That question was debated by four experts — two pro and two con — during a special session here at the American Urological Association 2015 Annual Meeting.

Moderator Ralph Clayman, MD, from the University of California, Irvine, opened the debate by reporting that fewer graduating urologists are doing lithotripsy, and that more urologists recertifying for the first time than for the second time are choosing the procedure for stones (29% vs 50%).

Arguing for the retention of extracorporeal shockwave lithotripsy as an option was John Denstedt, MD, from the University of Western Ontario in London, Ontario, Canada.

It has been increasingly argued that lithotripsy does not break up stones reliably, retreatment rates are higher with lithotripsy than with endoscopic procedures, and lithotripsy costs too much.

"My argument is that patient selection is the key," Dr Denstedt explained. There are strategies to enhance the efficacy of lithotripsy and it is still the least invasive therapy. "If you look closely at the literature, patient preference, cost, and morbidity all favor extracorporeal shockwave lithotripsy," he pointed out.

Patients who are obese or who have large stones are better treated with ureteroscopy, he said. In fact, with ureteroscopy, stone-free rates in the distal ureter are greater. However, with lithotripsy, stone-free rates in the proximal ureter are 80%, which is as good as or better than with ureteroscopy, he argued.

Patient selection is the key.

A Cochrane review revealed higher complication rates for ureteroscopy, even though it produced higher stone-free rates (*Cochrane Database Syst Rev*. 2012;5:CD006029). Dr Denstedt said that 2% to 6% of patients will experience perforation, evulsion, or mucosal entry, and that other studies have pointed to problems with the introduction of the urethral access sheath and the placing of stents. "We all know this is a huge problem for the patients," he said.

Low Complication Rate

The lower complication rate makes lithotripsy the preferred choice of many patients. Adding to this is the fact that clinicians skilled in ureteroscopy might be harder to find, Dr Denstedt explained.

Lithotripsy still has a place, said founding director of the International Kidney Stone Institute, James Lingeman, MD, from Indiana University in Indianapolis, who joined Dr Denstedt on the pro side of the debate.

"We don't break up stones with shockwave as we did 25 years ago," he said. "But we can maximize the effectiveness of extracorporeal shockwave lithotripsy by focusing on proper patient selection and the technique of shockwave."

To ensure effectiveness, Dr Lingeman uses what he calls a "triple D score," which takes into consideration skin-to-stone distance, stone density, and stone volume and size. "By choosing wisely, you can get very good stone clearance with shockwave lithotripsy," he explained.

Clinicians should take their time with the procedure, he said, noting that with the dry lithotripters, breaking a stone causes a cloud. If you don't wait for that cloud to dissipate, it can block the succeeding wave, he added.

New types of lithotripters — like the burst wave machine — might improve results, but in the meantime, although lithotripters are less efficient, they still work for the majority of stones, he said. "The type of lithotripter might not be as important as the shockwave technique you use," he added.

Arguing against the retention of extracorporeal shockwave lithotripsy was Olivier Traxer, MD, from University Pierre et Marie Curie in Paris.

Time to Move On

Even though lithotripters have been evolving since they were introduced in the early 1980s, "the stone-free rate in 2015 is the same" as it was 30 years ago, he said.

Over the same period of time, there have been dramatic advances in endourology, including in visualization, laser technology, and miniaturization. As a result, "in many, many centers all around the world, endourology is slowly replacing shockwave lithotripsy," Dr Traxer reported.

The European Urology Association issued new guidelines this year that recommend ureteroscopy for most stones, although lithotripsy is considered the first choice for small stones in the proximal ureter, he said.

"Shockwave lithotripsy is slowly dying," Dr Traxer said. "If shockwave lithotripsy technology doesn't improve in terms of stone treatment," he noted, "it will be completely retired very soon and replaced with endourology."

The technologic advances in endoscopic equipment have made lithotripsy practically obsolete, said Glenn Preminger, MD, from Duke University in Durham, North Carolina, adding his voice to the con side of the debate.

He cited the reasons he thinks lithotripsy should be retired. With lithotripsy, the stone-free rate depends on stone size and the procedure is reliant on renal anatomy for effective stone elimination. In contrast, endoscopy has a lower retreatment rate and is more cost-effective, and ureteroscopy no longer requires a stent for placement.

"Shockwave lithotripsy is a lot like sex; it might feel good and it might be a lot of fun, but is it right?" said Dr Preminger, who was quoting another clinician.

Dr Clayman explained that he does not view lithotripsy as an either/or proposition.

Currently, about 30% of procedures involve extracorporeal shockwave lithotripsy, down from 70%. That could decline further, he said, although that might not be the right thing.

"The future is going to be very much dependent upon the reinvention of shockwave lithotripsy and the training of our future urologists," Dr Clayman said.

Dr Clayman reports that he has an investment interest in Applied Urology, and financial relationships with Boston Scientific, Cook Urological, Greenwald Inc., and Complete Orthopedic Services. Dr Denstedt reports that he is an owner of Cook Urology and is involved in product development, and that he has a leadership and publishing position with the Endourological Society. Dr Lingeman reports that he is an owner of Beck Analytical Laboratories and is involved in product development; is a consultant or advisor to Boston Scientific Corporation and Lumenis; has an investment interest in Midstate Mobile Lithotripsy and is involved in product development; and is involved in a trial with Richard Wolf Instruments. Dr Traxer has disclosed no relevant financial relationships. Dr Preminger reports that he is a consultant or advisor to Boston Scientific and Retrophin; a meeting participant for Olympus; a leader of the Endourological Society; and is involved in health publishing with UpToDate.

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Ureteroscopy now used more than shock wave lithotripsy for treating kidney stones

Increase in hospital re-admissions, ER visits observed over 20-year period

June 01, 2012
By Wayne Kuznar

Atlanta—Ureteroscopy has overtaken extracorporeal shock wave lithotripsy (ESWL) as the treatment of choice for kidney stones, Canadian researchers recently reported.

At the same time, the need for ancillary treatments has declined but morbidity associated with kidney stone treatment has increased, said first author Michael Ordon, MD, who presented his findings at the 2012 AUA annual meeting in Atlanta.

Population-based evaluations to accurately assess trends over time in the use of different treatment modalities in the management of kidney stones have not been previously conducted. Instead, physician surveys or series from single centers have been the predominant methods used to document an increase in the use of ureteroscopy.

Studies showing high success rates, low rates of retreatment, and low rates of complications with modern ureteroscopy have largely been completed at high-volume centers with vast technical expertise.

"Accordingly, guidelines have changed to recognize ureteroscopy as a first-line treatment option along with ESWL for ureteral stones at all levels," said Dr. Ordon, fellow in endourology and minimally invasive surgery at St. Michael's Hospital, University of Toronto.

Many centers, however, may lack the up-to-date equipment and technical expertise necessary to achieve these same excellent results, said Dr. Ordon, who worked on the study with Kenneth T. Pace, MD, and colleagues.

His group sought to evaluate population-based trends in kidney stone management as well as the effects of treatment trends and technologic advances on patient morbidity in the "real world," including the need for ancillary treatment. Through the use of administrative databases, the authors designed a population-based cross-sectional time series to measure the utilization of ESWL, ureteroscopy, and percutaneous nephrolithotomy (PCNL) over the past 20 years on patients in Ontario.

All patients who underwent treatment for a kidney stone in Ontario between July 1, 1991 and Dec. 31, 2010 formed the study population. Three main data sources were used: the Ontario Health Insurance Plan's physician claims database, the Canadian Institute for Health Information-Discharge Abstract Database, and the National Ambulatory Care Reporting System.

The three principal outcomes were treatment utilization, the need for ancillary treatment (defined as a repeat or ancillary stone procedure within 90 days of the index treatment), and the proportion of treatments that required hospital readmission or emergency room (ER) visit within 7 days of hospital discharge.

The study sample included 116,115 patients who underwent 194,781 kidney stone treatments (ESWL: 96,807 treatments; ureteroscopy: 83,923 treatments; PCNL: 14,051 treatments).

The use of ESWL decreased significantly over the study period, from 68.5% of all stone procedures in 1991 to 33.7% by the end of the period ($p<.0001$). During the same time, the proportion of stones treated with ureteroscopy increased significantly, from 24.6% to 59.5% of procedures ($p=.0002$). There was no significant change over time in the proportion of kidney stones treated with PCNL (6.88% in 1991 vs. 6.85% in 2010).

The proportion of procedures that required ancillary treatments declined significantly, from 23.1% to 15.3% ($p<.0001$).

"Most of this decrease occurred after 2004," said Dr. Ordon, when ureteroscopy became the most widely used procedure for the treatment of kidney stones in Ontario.

Of the three treatment modalities, the need for ancillary treatment was lowest with ureteroscopy.

Sharp increase in hospital readmissions

Overall, the rate of hospital readmission increased significantly over the study period, from 7.27% to 10.8% ($p<.0001$), with this increase occurring mainly after 2004. Similarly, the percentage of ER visits increased significantly, from 7.11% to 10.5% ($p=.0024$). Further analysis is planned to better evaluate the increase in hospital admissions and ER visits over time. Specifically, Dr. Ordon said, "We plan to separate ER visits for non-urologic versus urologic causes to see if it changes the findings."

"Part of the influence over time [in Ontario] is that ureteroscopy became much more accessible, and so now a lot of the physicians in the community may not be offering [referral for] shock wave lithotripsy but rather offering ureteroscopy because that is something that they can provide and be reimbursed for," he said.

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Ureteroscopy and stones: Current status and future expectations

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Abstract Go to:

Urolithaisis is becoming an ever increasing urological, nephrological and primary care problem. With a lifetime prevalence approaching 10% and increasing morbidity due to stone disease, the role of ureteroscopy and stone removal is becoming more important. We discuss the current status of stone disease and review the ever increasing role that ureteroscopy has to play in its management. We discuss technological advances that have been made in stone management and give you an overview of when, how and why ureteroscopy is the most common treatment option for stone management. We touch on the role of robotic ureteroscopy and the future of ureteroscopy in the next 10 years.

Keywords: Ureteroscopy, Techniques, Ureteral stones, Calculi, Treatment, Advances

Core tip: This manuscript demonstrates the advent, technical progression and modern use of ureteroscopy for stone disease. It begins with a brief epidemiology of renal stone disease, technological advances in flexible ureteroscope, use of laser for stone disease and the different types of surgical options available. We also share the current evidence of ureteroscopy for stone treatment in obesity, pregnancy, pediatrics and patients with bleeding diathesis and large renal stones. In the end we discuss what the future holds for ureteroscopy including an insight into robotic ureteroscopy.

INTRODUCTION Go to:

With an increasingly ageing population, rising obesity, poor dietary habits and lack of adequate fluid intake we are seeing a rise in the incidence of renal and ureteric calculi[1-9]. This directly effects patient morbidity and places an ever increasing demand on healthcare resources. The concept of urinary stones is not new, indeed "cutting for the stone" was one of the classic three operations described more than 2000 years ago. It is somewhat ironic now, that endourological surgeons rarely "cut for the stone", but more "fish out" the stone with ureteroscopy (URS). Without doubt, the technological advances over the last 30 years has revolutionised our current management of urinary tract stone disease. We aim to highlight the importance of stone disease and take you through the important technological changes, discuss current concepts in stone management, explain what is new in ureteroscopy and touch on the future of ureteroscopy in the management of stone disease.

EPIDEMIOLOGY OF STONE DISEASE

Urolithiasis is a major clinical and economic burden for modern healthcare systems[10]. International epidemiological data suggest that the prevalence of stone disease is increasing[11]; with a rise in lifetime prevalence between 7%-12%. The mean age of patients with upper tract stones has remained constant at 49 years, although there has been an alarming increase of 19% in the number of children diagnosed[11]. The ever increasing prevalence of stone disease has a direct effect on healthcare resources, with the number of URS performed for stone disease increasing by 127% over the last 10 year period 2000-2010[11].

The rising prevalence of stone disease is multifactorial, but poor dietary habits and fluid intake, increasing levels of obesity and "metabolic syndrome" may further increase stone-related clinical episodes[12,13]. This emphasises the importance of education and lifestyle adaptations in attempting to prevent stone formation for at risk groups and the critical role of secondary prevention for those who have already suffered with stones.

TECHNOLOGICAL ADVANCES IN URETEROSCOPY

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The use of URS has dramatically increased over the last 30 years mainly due to the rapid speed of technological advances. Since the advent of the first recorded URS in 1912[14]; the past century has seen a continued development of the ureteroscope alongside diversification of its use. Evaluation of the urinary tract was initially explored with specula, next came urethroscopy with dilatations of the urethra using knives and wax instruments [15]. The prototype endoscope, the "Lichtleiter", was introduced back in 1806 by Phillip Bozzini, and consisted of a hollow tube transmitting candlelight *via* a mirror[15]. This enabled the first true endoscopic operation in 1853 when Desormeaux extracted a urethral papilloma through the endoscope[15]. Further modifications to the endoscope were introduced by the dermatologist Grunfield of Vienna, who developed an endoscopic loop threader and scissor forceps allowing the first endoscopic bladder papilloma excision in 1881. The step from idea to realisation of endoscopic surgery was difficult and protracted. Bozzini et al ideas from the early 1800's were well ahead of their time. They were considerably hindered by the technical capabilities of the nineteenth century engineering, which resulted in clumsy and heavy instruments. In parallel with the development of the cystoscope there was continuing advancements in the endoscopic light source. A system of mirrors and lens' were introduced alongside candlelight to transmit light through a hollow tube; this idea was superseded by fibre-optic technology utilising the principle of internal reflection permitting the "bending" of light within flexible glass[16]. These principle and understanding lead onto the development of the first rigid ureteroscope in 1980. This was developed by Perez-Castro in collaboration with Karl Storz, incorporating a separate working and optic channel. These developments allowed the art of ureteroscopy to flourish and develop over the last 35 years[17].

The development of electrohydraulic and ultrasonic lithotripsy soon followed, enabling the fragmentation of ureteric stones[17]. Flexible tip ureteroscopes were introduced in 1983[16], and the modern digital scopes soon followed. Modern digital flexible ureteroscopes consists of a fiberoptic lens, with a single cable electronically transferring the image detected at the tip of a scope to the image display on a monitor ("Chip to tip" technology). Digital and conventional (fibre-optic) flexible ureteroscopes have seen a dramatic improvement in ergonomics, with lighter scopes and improved manoeuvrability[18]. The advent of digital images has resulted in improved resolution and colour discrimination, as well as significantly reduced operative times[16,19-21]. Figure 1 demonstrates the modern flexible ureterorenoscopes that we use in clinical practice today.

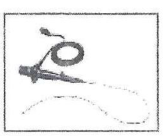

Figure 1
Flexible ureterorenoscope.

Despite improvements in scope technology, one still needs to fragment and/or remove the stone once visualised. Stones are commonly fragmented with a holmium laser (Light Amplification by Stimulated Emission of Radiation). Albert Einstein and Satyendranath Bose proposed the concept of lasers, but lasers were initially seen as a great invention with no obvious use. With time and hard work by laser pioneers, we now cannot imagine a world in which we don't use lasers. Indeed, the role of the Holmium laser in the management of renal tract stones has resulted in many stones in the urinary tract have been accessible to treatment in a minimally invasive fashion. Laser offers the surgeon a safe, effective method of stone fragmentation. One real benefit is the fact that laser can be manoeuvred around bends, enabling it to be used throughout the kidney. The lithotripter, although a useful adjuvant for ureteroscopy, has its limitations including stone retropulsion back into the kidney. The lithotripter is still commonly used for percutaneous nephrolithotomy surgery (PCNL), where larger stones can be fragmented quickly, without the need to manoeuvre around each calyx.

SURGICAL MANAGEMENT OF STONE DISEASE

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Traditionally ureteric and renal stones were managed by open surgical techniques, and it was not until the 1980s and the advent of the Dormier H3 lithotriptor that shock wave lithotripsy (SWL) became common place[16]. SWL offered a relatively minimally invasive treatment option for patients, with acceptable outcomes in terms of stone free rates (SFR)[22]. With the advent of minimally invasive surgery, particularly URS, SWL treatment numbers are falling. Recent United Kingdom, American and Australian data clearly demonstrate dramatically rising rates of ureteroscopy, which far exceed small rises in the use of SWL[1,11,23].

Current American and European Urology Association Stone guidelines summarise the current evidence based treatment for stone management based on stone size and location[24]. The size and location of the stone are the most important factors in determining which treatment options are most suitable, but individual surgeon's treatment preference is important in making treatment decisions for each treated stone.

The position of the stone in the ureter directly reflects in the success of the procedure. More distal stone have higher success rates when treated with rigid ureteroscopy, compared to the more proximal stones[24]. Indeed proximal stones can fall back into the kidney, therefore they often require a concurrent flexible ureteroscopy to achieve good stone free rates. Current guidelines recommend ureteroscopy, over other treatments including SWL, for the majority of ureteric stones[24].

In terms of stone size conservative management may be appropriate for smaller stones; 95% of stones up to 4 mm pass within 40 d[25]. Current recommendations advise the use of PCNL over URS and laser for larger more complex stones. The recommended size of stone treated by URS is increasing with each new update of stone guidelines, with the current size value of 20 mm and above favouring a percutaneous approach to treatment (PCNL)[24]. Despite this there is very good clinical evidence[26] for using URS for stones greater than 20 mm in size, with 94% deemed stone free after a mean number of 1.6 URS treatments. This data is comparable, and arguably better, than standard PCNL treatment with reduced morbidity and shorter length of hospital stay[27].

Stones greater than 2 cm often require planned two stage URS procedures to achieve complete stone clearance [28]. Although this necessitates staged procedures, it may be a worthwhile sacrifice in view of nephron preservation and the low complication rate[29]. This is not an insignificant consideration when treating an ever-increasing co-morbid patient. A comparison of the available treatment modalities, in terms of advantages, disadvantages and contraindications is summarised in Table 1.

Table 1
Advantages and disadvantages of different techniques[24]

URETEROSCOPY IN THE CURRENT ERA

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Technological advances in the design and size of the ureteroscopes has enabled easier access to the kidney and ureters *via* the urethra, removing the need for any surgical incision. With rigid and flexible URS nearly all areas in the urinary tract can be readily accessed, with stunning high quality digital optics providing very accurate assessment of stones and mucosal lesions. One of the main benefits of URS is that there are minimal contraindications for the procedure. A general anaesthetic is often required, but upper tract access with spinal or local anaesthetic can be achieved[30]. The only real contraindication would be a ureteric stricture preventing successful ureteric access and scope passage[24]. Fluoroscopy is required during URS, but radiation exposure can be reduced with careful consideration of when and how much fluoroscopy is needed. The benefits of URS are clearly evident in the literature, with low complication rates, high SFR, and short length of stay[26,28].

As with any procedure complications can happen, but the reported complication rates are relatively low[29,31]. The overall complication rate for URS is approximately 3.5%; which are mostly minor. Probably the most feared complication of ureteroscopy is ureteral avulsion, however it is rare (< 1%). Common complication include mucosal or ureteric injury (1.5%-1.7%), post-operative fever (1.8%), urosepsis, haematuria, ureteral stricture (0.1%) and persistent vesicoureteric reflux (0.1%)[29,32]. Due to its minimally invasive nature, URS can be performed as a day case procedure. This has obvious benefits for hospital finances, as well as patient satisfaction levels[11].

In recent years the role of URS has expanded, particularly with reference to an increasingly obese population, during pregnancy, bleeding diathesis and paediatric stone disease. With obesity rates at an all-time high[12,13] and the association of kidney stones in such patients, these groups can often be difficult to manage. The anaesthetic risk can be significantly increased and other treatment such as SWL or PCNL are often less successful [33]. Ureteroscopy is often ideal for such patients, as their renal tract can be readily be accessed[34]. Indeed, currently guidelines recommend URS as the most promising therapeutic option in obese patients[24].

Pregnancy offers a unique situation in terms of urinary stones disease. A cascade of metabolic changes occurs during pregnancy that may be associated with an increased likelihood of stone formation, particularly in the second and third trimester[35,36]. Whenever possible, conservative treatment of stones are encouraged. If complications do develop, URS can offer a minimally invasive treatment option for patients and hopefully avoid the need for long term urinary diversion with either a stent or nephrostomy tube[37,38]. A recent systematic review suggests that URS is a safe and effective procedure that can be used as the first line surgical management of symptomatic stones during pregnancy[36].

Patient with bleeding diathesis are at significantly increased risk of complications with treatments including SWL, PCNL, laparoscopic or open surgery[39-42]. For such patients, URS offers a safe and effective treatment modality. With ever increasing use of anticoagulation, based on risk assessment, these patients are an at-risk group and can be very difficult to manage surgically[24,43]. In term of URS and anticoagulation the literature is limited. A critical analysis of the published literature has shown good SFR with minimal complications when performing URS whilst the patient remains on anticoagulation. One worries about the rate of bleeding, but the combined data on URS reports a relatively low figure of 4% minor bleeding whilst on anticoagulation[44].

Childhood urolithiasis is becoming more prevalent, with a significant number of patients experiencing their first stone episode in childhood[24]. Such patients present diagnostic and treatment dilemmas, particularly their suitability for treatment due to their organ size. Traditionally the majority of these patients were treated with SWL, with reported SFR of approximately 80%[45]. With smaller calibre scopes and improved scope instrumentation such as smaller baskets and laser fibres, the role for URS has slowly increased. A recent systematic review has demonstrated SFR of up to 93% can be achieved with URS in a paediatric population[45].

FUTURE ADVANCES IN URETEROSCOPY

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The future of URS is one of massive technological advances. With ever decreasing scope size, better optics and new device coming to market no corner of the urinary tract is inaccessible or unsuitable for access with URS. Ever more complex patients, with a plethora of medical problem are now becoming increasingly appropriate for URS.

Robotic surgery has recently entered the field of urology, particularly with reference to prostate, bladder and renal cancer treatment. URS has also had the robotic treatment, with the introduction of robotic flexible ureteroscopy.

This "Robot" offers the surgeon the ability to control their flexible ureteroscope and laser fibre via the comfort of a robotic console. Figure 2 demonstrates this robotic device. The main robotic station holds the flexible ureteroscope whilst the surgeon controls the URS via a console and joystick devices. With only a few prototypes in clinical use and the procedure in its infancy this is a large area for future clinical development. Initial results are interesting; with the biggest benefit seeming to favour surgeon ergonomics rather than SFR[46]. Long term outcome data is awaited with anticipation.

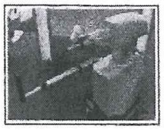

Figure 2
Robotic ureteroscopy.

Another area of future interest is the use of peptide-coated iron oxide-based microparticles[47]. These microparticles selectively adhere to calcium stone fragments enabling quicker retrieval of intraoperative stone fragments with the aid of a magnetic device, when compared to standard stone removal[47]. URS is without doubt an attractive area for technical innovation; where new advances have a huge potential to improve outcome and SFR.

CONCLUSION

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With an ever-increasing prevalence of stone disease careful consideration needs to be given to meet future demand. A large area of attention needs to be placed on primary and secondary stone prevention, with simple but effective patient education and lifestyle interventions.

In terms of URS, the future is one of great excitement. Larger stones, more complex patients, paediatric patients, pregnancy, bleeding diathesis and the obese are becoming more suitable than ever for minimally invasive URS. With the advent of future technological advances, the boundaries of what is achievable will be further expanded. Robotic is entering the playing field and is potentially the next big development in URS. The next 10 years is one of great excitement in URS and is likely to further transform of our current treatment strategies for the management of stone disease.

Footnotes

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Ureteroscopic treatment of renal calculi

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The evolution of renal calculus treatment has developed from the most invasive form of stone removal, including open nephrolithotomy, to those forms that optimize stone removal while minimizing patient morbidity. Extracorporeal shock-wave lithotripsy (ESWL) has revolutionized the treatment of renal calculi, although decreased stone-free rates are tolerated because of its minimal morbidity. ESWL is currently the most common treatment for renal stones, with average stone-free rates for solitary stones of 79.9%, 64.1%, and 53.7% for stones less than 1 cm, 1 to 2 cm, and greater than 2 cm, respectively [1]. Advances in percutaneous nephrostolithotomy (PCNL) have evolved to where stone-free rates of more than 90% can be expected, regardless of stone size or location [2]. Although the risks of PCNL are minimal compared with those in early studies, significant risks are inherent to percutaneous renal access [3]. The role of ureteroscopy (URS) in the management of renal calculi is evolving. This article reviews the indications, technique, results, and complications of using URS to treat renal calculi.

History

The evolution of URS in the treatment of renal calculi parallels advances in flexible endoscope design, development of the holmium laser for intracorporeal lithotripsy, and recognition of limitations of ESWL and PCNL. The production of flexible ureteroscopes with active deflection and small caliber was instrumental in enabling access to the entire collecting system [4–6]. Access to the entire collecting system with modern flexible ureteroscopes and techniques can be expected in up to 94% to 100% of patients [4,7].

Concomitant with the evolution of the ureteroscope, developments in intracorporeal lithotripsy and nitinol instrumentation further facilitated use of URS for renal stones. Small-caliber electrohydraulic lithotripsy (EHL) probes and flexible laser fibers optimized scope deflection, facilitating access to all calyces. The introduction of the holmium laser for intracorporeal lithotripsy was crucial to urologists' ability to ureteroscopically treat renal calculi. Unlike EHL, which destroys stones with a cavitation bubble, the holmium laser works through a photothermal mechanism [8]. Holmium laser energy is rapidly absorbed by water and has minimal tissue effects if activated with the laser fiber tip more than 2 to 3 mm away. These qualities allow extended periods of stone destruction, result in minimal tissue trauma, and maintain optimal endoscopic vision. Furthermore, unlike EHL, difficulties with endoscopic vision typically are not the result of urothelial trauma and bleeding but related to a "snow storm" effect caused by the production of tiny stone fragments.

Ureteroscopic treatment of renal calculi is also gaining popularity because of the recognition of limitations of ESWL and PCNL. Although ESWL is associated with minimal morbidity, its effectiveness is marginal in the treatment of certain stone compositions and stones in locations of the kidney, such as the lower pole. In addition, although more cost-effective than the original Dornier HM3 lithotriptor, modern-day lithotriptors are universally less effective and associated with higher retreatment rates [9]. Although renal stones are efficiently treated with PCNL, percutaneous renal access exposes patients to risks of blood transfusion, partial renal loss, and required inpatient hospital stay. URS avoids the

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risk of transrenal access and can safely be performed on an outpatient basis in more than 95% of patients [7].

Indications for ureteroscopic treatment of renal stones

Several factors influence treatment options for patients with renal stones. These factors include physician preference and experience, patient preference, patient and renal anatomy, stone characteristics, and equipment availability. These factors may preclude the use of PCNL or ESWL. Furthermore, there are specific indications favoring the ureteroscopic approach. Box 1 lists the most common indications to treat patients with renal stones ureteroscopically:

Failed extracorporeal shock-wave lithotripsy

The success of ESWL to treat renal stones ranges from 39% to 92% and varies with stone size, location, composition, and collecting system anatomy. It is now well recognized that treatment of lower pole stones is associated with a higher incidence of retained stone fragments compared to stones treated in other areas of the kidney. Lower calyceal anatomy also influences spontaneous stone passage following ESWL. Elbahnasy et al [10] demonstrated anatomic factors associated with poor stone clearance rates. Stones located in lower pole calyces with an infundibulopelvic angle less than 70°, infundibular length greater than 3 cm, and width less than 5 mm were at greater risk for retained fragments following ESWL. Retained stone fragments were especially common in patients possessing all three poor prognostic variables. Grasso and Ficazzola [11] evaluated the impact of lower calyceal anatomy on their ability to treat lower pole stones ureteroscopically. A long lower pole infundibulum (> 3 cm) and the presence of an infundibular stricture were the only statistically significant anatomic factors affecting success. Patients exhibiting anatomic factors associated with poor ESWL success may be better served with ureteroscopic stone manipulation.

Box 1. Indications for ureteroscopic treatment of renal calculi

- ESWL failure
- Lower pole stone location
- Adverse stone characteristics for ESWL
- Morbid obesity
- Musculoskeletal deformities
- Bleeding diathesis
- Calyceal diverticular stone
- Infundibular stenosis
- Horseshoe/ectopic kidney
- Ureteroscopy in conjunction with PCNL
- Patient preference

Stone characteristics

Stone fragility and radiographic visibility are also factors influencing ESWL efficacy. Cystine and calcium oxalate monohydrate stones, which are refractory to ESWL, might preferentially be treated ureteroscopically. The holmium laser is universally effective in fragmenting all stone types. In addition, radiolucent stones that may be difficult to localize for ESWL may be more definitively treated with URS.

Patient obesity

The treatment of obese patients who have an upper urinary tract stone is challenging, even in the best of circumstances. Ureteroscopic laser lithotripsy provides the best combination of an effective yet minimally procedure to treat renal stones in obese patients. Obese patients with a body mass index greater than 28 have been shown to have inferior success rates with ESWL [12]. Factors making ESWL difficult in obese patients include the following: patient weight exceeding lithotriptor table limits, the treatment distances exceeding focal lengths of lithotriptors, and difficulty imaging stones because of body habitus thickness. PCNL to remove renal calculi in obese patients is feasible but should be reserved for centers with experienced personnel who have access to specialized equipment. Pearle et al [13] showed that, with modifications in PCNL technique and by using longer nephroscopes and working sheaths, success rates and morbidity were comparable to an unselected patient population. There are few special requirements necessary to perform URS on an obese patient (Fig. 1). The limiting factors include having an anesthesiologist capable of providing anesthesia and an operating table able to sustain the weight of the patient. URS is performed with standard equipment. The size of the patient and lack of an optimal operating table often preclude use of fluoroscopy. Dash et al [14] reported an 83% success rate using URS to treat 16 morbidly obese patients who had renal stones.

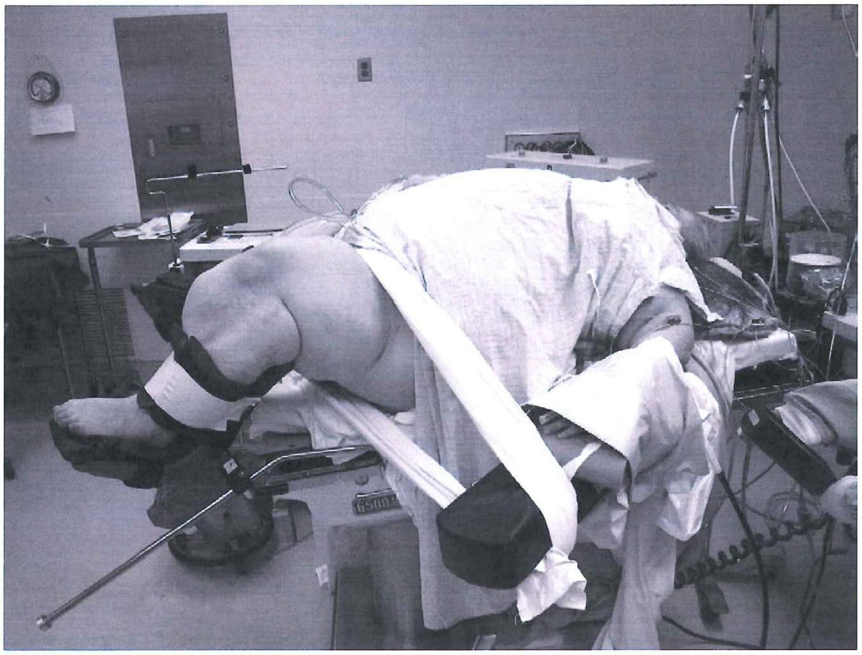

Fig. 1. A 450-lb patient positioned for ureteroscopic lithotripsy of renal stone.

Scoliosis/body deformities

Patients who have physical deformities other than obesity also may favor the ureteroscopic approach to remove kidney stones. This situation applies most commonly to patients with severe spinal deformities from spina bifida or limb contractures from spinal cord injury. Positioning difficulties caused by these abnormalities may preclude either PCNL or ESWL, making a ureteroscopic approach preferable. Fig. 2 shows an example of a patient with a body deformity that prevents stone localization by ESWL or percutaneous renal access for PCNL. She was successfully treated with ureteroscopic laser lithotripsy.

Bleeding diatheses

Ureteroscopic lithotripsy has been found to be safe in patients with uncorrected bleeding diatheses and patients who are anticoagulated [15]. Watterson et al [15] performed ureteroscopic lithotripsy in 25 patients who had bleeding diatheses or were on coumadin with a mean international normalized ratio of 2.3. Their stone-free rate was 96%, with a single complication. One patient treated with ureteroscopic EHL developed a significant retroperitoneal hemorrhage requiring transfusion. ESWL and PCNL require complete reversal of anticoagulation, which may carry a significant risk.

Associated collecting system obstruction

Patients who have renal stones associated with collecting system obstruction are also candidates for ureteroscopic treatment. This situation applies to those patients with stones contained within calyceal diverticula and calyces with stenotic infundibulae. ESWL of calyceal diverticular stones is associated with relatively poor long-term symptom-free and stone-free rates. Although percutaneous endoscopic removal of diverticular stones provides success rates greater than 80%, accessing small diverticulae in the upper pole or anterior calyces is challenging and carries significant risks [16,17]. The use of the flexible ureteroscope and holmium laser allows endoscopic incision of the obstruction followed by laser lithotripsy of the contained stone. Unlike ESWL, ureteroscopic incision offers correction of the underlying obstruction and permits ablation of the diverticulum. URS is best reserved for small stones contained in diverticula with short necks located in the upper or middle calyces (Fig. 3). Renal calculi associated with ureteropelvic junction obstruction may also be treated with URS, although alternative minimally invasive approaches are preferable.

Renal abnormalities

Stones associated with abnormally positioned renal units may represent an indication for the

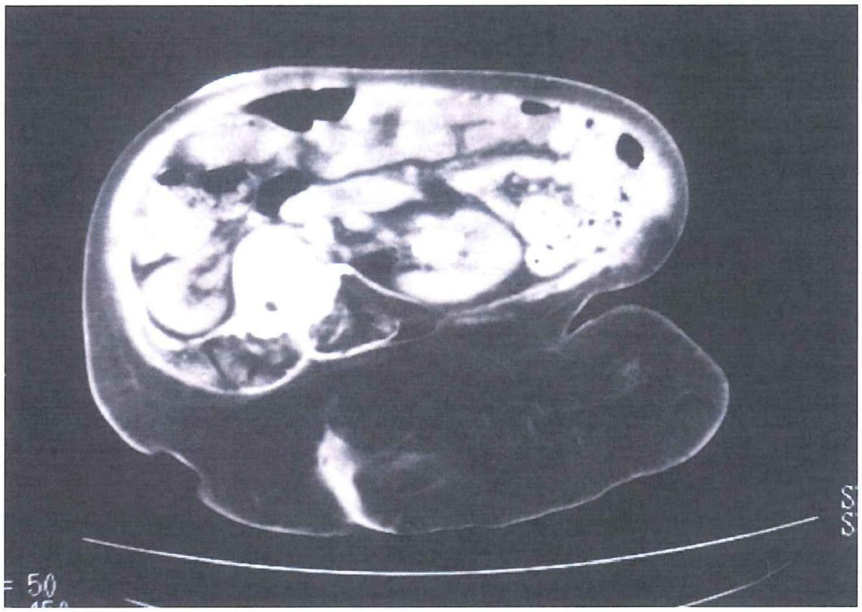

Fig. 2. CT image of patient with back abnormality precluding treatment of her renal stone with either ESWL or PCNL.

ureteroscopic approach. Horseshoe and ectopic kidneys are prone to urinary stasis and calculi formation. ESWL success rates of stones located in horseshoe and ectopic kidneys are consistently lower and retreatment rates higher than for normal kidneys [18]. Studies show only a 54% stone-free rate in patients undergoing ESWL for stones located in pelvic kidneys [19]. The poor success rate of ESWL in such situations relates to difficulties with shock-wave transmission to sites of ectopic kidneys and drainage abnormalities affecting spontaneous stone passage. Although PCNL is possible in ectopic kidneys, percutaneous renal access can be challenging because of their unpredictable vascular supply and frequently close proximity to surrounding bowel [20,21]. Although it is more invasive, good results have been demonstrated using laparoscopic-assisted percutaneous removal [22,23]. URS offers a minimally invasive treatment option for patients with small (< 2 cm) accessible stones within horseshoe or ectopic kidneys.

Conjunction with percutaneous nephrostolithotomy

The ureteroscopic manipulation of renal calculi also can serve as an adjunct to PCNL. Upper and middle calyces occasionally may be more accessible to retrograde URS than existing percutaneous nephrostomy tracts. The use of URS in combination with PCNL may obviate patients from having either ESWL or the creation of additional percutaneous tracts to remove stones inaccessible through an existing access site.

Patient preference

It is the treating physician's responsibility to outline all available options with a balanced discussion of risks, benefits, and success rates. Some patients may prefer a retrograde endoscopic approach for cosmetic reasons, to avoid the inherent risks of PCNL, or to have a more immediately definitive treatment than ESWL. Patients must understand that ureteroscopic management, although safer, is relatively inefficient compared with PCNL for fragmentation and removal of large renal stones.

Fig. 3. Retrograde pyelogram demonstrating stone contained within calyceal diverticulum.

Technique

The ureteroscopic treatment of renal calculi is best performed under general anesthesia and endotracheal intubation. Movement of the kidney caused by respiratory motion complicates intracorporeal lithotripsy in the kidney. Endotracheal intubation is preferable over a laryngeal mask because it allows the possibility for anesthesiologists to suspend respiration for short periods of time if needed.

Retrograde ureteroscopic stone manipulation is best performed with a flexible ureteroscope. The small-caliber, fully deflectable, flexible ureteroscopes allow access to stones in the entire collecting system. Ureteroscope diameters ranging from 7 to 10 F minimize ureteral trauma and decrease the need for intramural ureter dilation [24,25]. The miniaturization of ureteroscopes, however, came at a cost of endoscope durability. Afane et al [26] evaluated scope durability in the first generation of small-caliber ($\leq$9 F) ureteroscopes. They found scopes required repair after an average of 6 to 15 uses. The loss of tip deflection was the most common problem, occurring most frequently after procedures requiring access into the lower pole. Manufacturers of endoscopes aim to develop ureteroscopes with improved durability and deflection capabilities. The DUR-8 ureteroscope offered by ACMI (Southborough, Massachusetts) has a 6.75-F tip, gradually expanding to a 10-F base. In the authors' experience, this scope exhibits improved durability compared with other flexible ureteroscopes with tip diameters less than 9 F. More recently, ACMI developed the DUR-8 Elite ureteroscope (Fig. 4). This ureteroscope incorporates active secondary deflection in addition to primary tip deflection, purportedly improving access to lower pole calyces.

Small-caliber flexible ureteroscopes minimize the need for dilation of the intramural ureter before scope introduction. In a study of 155 patients undergoing URS, only 8% of patients required ureteral orifice dilation [7]. Bagley [27] evaluated dilation requirements associated with different-caliber ureteroscopes. He found that the use of a 9-F ureteroscope required dilation 33% of the time, whereas ureteroscopes with a diameter less than 8.4 F required dilation less than 5% of the time.

The use of a ureteral access sheath may further facilitate flexible URS (Fig. 5). These hydrophilic sheaths have outer diameters ranging from 12 to 14 F and are fluoroscopically positioned. The use of an access sheath reportedly reduces operative time and cost [28]. These sheaths facilitate egress of irrigant and small stone fragments through their lumens during flexible URS. The efflux of irrigation maintains endoscopic vision, especially during treatment of large renal calculi. Furthermore, this drainage decreases intrarenal pressures, thereby reducing the risk of bacteremia [29]. If an access sheath is not used, the placement of a small-caliber Foley catheter into the bladder facilitates bladder and upper tract drainage.

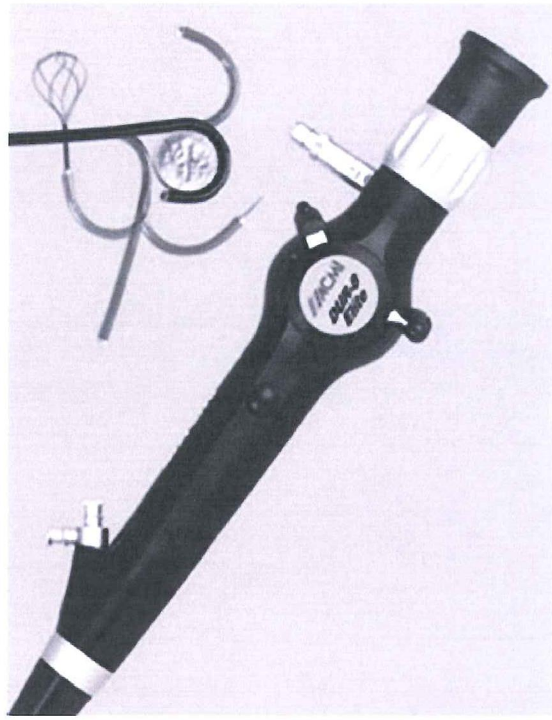

Fig. 4. The DUR-8 Elite ureteroscope incorporates active deflection of ureteroscope tip and secondary deflection mechanisms. (Courtesy of ACMI Corporation, Southborough, MA; with permission.)

Modern flexible ureteroscopes typically possess a 3.6-F working channel. Many innovative ureteroscopic instruments have been designed for intrarenal stone manipulation. The development of small-caliber intracorporeal lithotrite probes and laser fibers minimizes loss of scope deflection while maximizing irrigation capabilities. EHL probes are available in sizes as small as 1.9 F and laser fibers as small as 200 μm. The holmium laser has revolutionized endoscopic lithotripsy for renal calculi. Its ability to fragment stones of all compositions while causing minimal urothelial trauma enables urologists to treat stones of any size while maintaining optimal endoscopic vision.

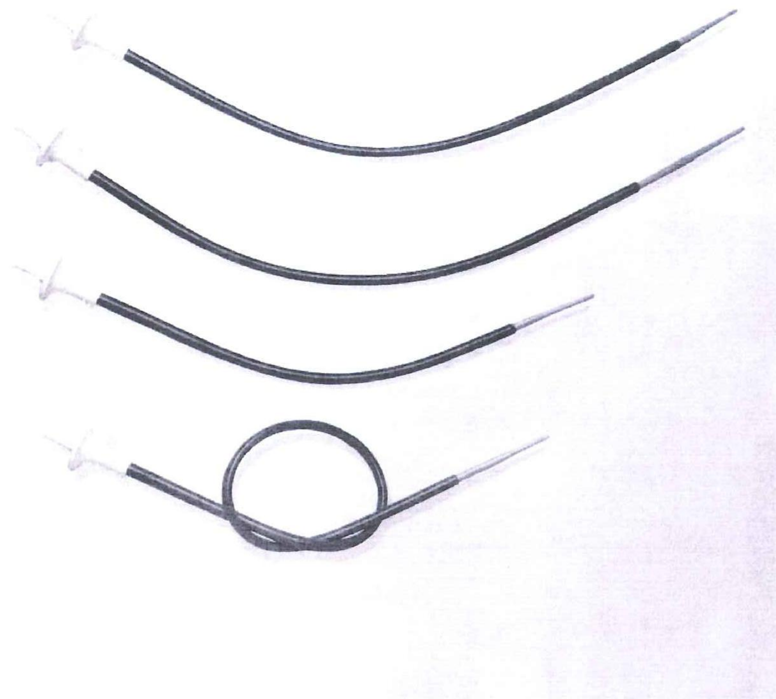

Fig. 5. The ureteral access sheath can be used to facilitate URS. (Courtesy of Applied Medical, Rancho Santa Margarita, CA; with permission.)

The development of nitinol instrument devices also has facilitated the advances of ureteroscopic stone treatment. Nitinol baskets are less traumatic and more durable than standard steel wire instruments. Nitinol's flexibility profile also minimizes loss of scope tip deflection, which is most important during treatment of lower pole stones.

The ureteroscopic treatment of lower pole stones requires knowledge of technical nuances and the availability of crucial equipment. Having access to a small-caliber flexible ureteroscope with 180° tip deflection is required. With use, all scopes progressively lose tip deflection capabilities. If endoscopic access to the desired lower calyx is not possible on full deflection of the ureteroscope tip, the scope should be advanced to make use of its passive secondary deflection mechanism (Fig. 6). As previously mentioned, ACMI recently released the Elite ureteroscope, which has both active primary and secondary deflection. Repositioning of the patient may also be useful. Patients who have stones in the lower calyx should be positioned in Trendelenberg, and manual syringe irrigation should be used to flush stone fragments to a more cephalad position. Herrell and Buchanan [30] described positioning patients in the flank position to facilitate calyceal stones falling into the renal pelvis.

If patient repositioning and irrigation are unsuccessful, lower calyceal stones can be grasped and repositioned to a more accessible cephalad calyx. Repositioning of lower pole stones enhances the ability to perform intracorporeal lithotripsy and reduces strain on endoscopes. Auge et al [31] found that use of a 2.6-F nitinol grasping device (Graspit, Boston Scientific, Natick, Massachusetts) or a 2.4-F nitinol basket resulted in less deflection loss than a 200-μm laser fiber (Fig. 7). The Dimension basket (Bard Urological, Covington, Georgia) is a nitinol basket with articulating wires to facilitate stone capture and release (Fig. 8). Landman and Clayman [32] described use of a "bare-naked" basket. Removal of the outer sleeve of a nitinol basket increases scope deflection and maximizes irrigation capabilities. Stones contained within a bare-naked basket are entrapped by pulling the

Fig. 6. Radiograph depicting use of secondary deflection to access the lower pole.

basket back against the tip of the ureteroscope. Repositioning of stones to a more cephalad calyx also allows use of larger-diameter, more-efficient laser fibers. Vassar et al [33] showed that the 365-μm holmium laser fiber was more efficient and less prone to fiber degradation than smaller fibers that are often required to treat lower pole calculi in situ. Studies on stone repositioning also demonstrated improved success rates compared with treating stones in situ [31,34]. Auge et al [31] found the 3-month stone-free rate for 36 patients treated ureteroscopically for renal stones favored stone repositioning versus in situ lithotripsy (90% versus 83% success rates, respectively).

In 1994, the American Urological Association's Nephrolithiasis Guidelines Panel provided recommendations for treatment of staghorn calculi [35]. They concluded that, under most circumstances, patients with staghorn calculi are best served by initial PCNL followed by adjunctive ESWL or PCNL as needed. Several centers have reported using ureteroscopic lithotripsy to treat patients with large renal calculi (including staghorns). The most common indications to treat these patients ureteroscopically were comorbidities that precluded PCNL. The treatment of large calculi commonly requires more than one staged procedure. The placement of ureteral catheters to irrigate stone fragments following intrarenal lithotripsy has been described. Grasso and Ficazzola [11] described a technique of positioning a 5-F Cobra catheter with its tip in the lower pole adjacent to a second 6-F ureteral catheter used for outflow. A dilute antibiotic solution was used to irrigate through the Cobra catheter at a rate of 100 cc per hour. The authors further described irrigation with alkalizing agents or tromethamine for uric acid or cystine stones, respectively. Irrigation for 36 to 48 hours is performed before a second-look procedure.

Knowledge of the previously described technical maneuvers and availability of the described equipment should facilitate ureteroscopic treatment of stones in any location of the kidney. Increasing surgeon experience along with continued improvements in endoscopic instrumentation will allow urologists to successfully treat more patients ureteroscopically who are currently being treated percutaneously.

Results

Multiple studies have evaluated the efficacy of treating renal stones ureteroscopically [11,34,36–42]. Although few differences in technique are described, studies vary significantly in definition and time interval to determination of treatment success. In general, continuing intracorporeal lithotripsy until residual stone fragments are no greater than 2 mm is the preferred method. Overall, reported treatment success rates for ureteroscopic treatment of renal stones varies from 50% to 92% (Table 1).

Three studies evaluated ureteroscopic treatment of lower pole calculi and the benefit of stone repositioning [11,34,36]. Overall stone-free rates varied from 65% to 85%. Kourambas et al [34] repositioned only stones that could not be effectively treated in situ. Stone repositioning was required in 10 of 36 patients who had lower pole stones. Stone-free rates seemed to be improved in lower pole stones that were repositioned compared with those treated in situ. Stone repositioning improved stone-free rates from 61% to 79% in the Schuster et al [36] study and from 83% to 90% in the Kourambas et al [34] study.

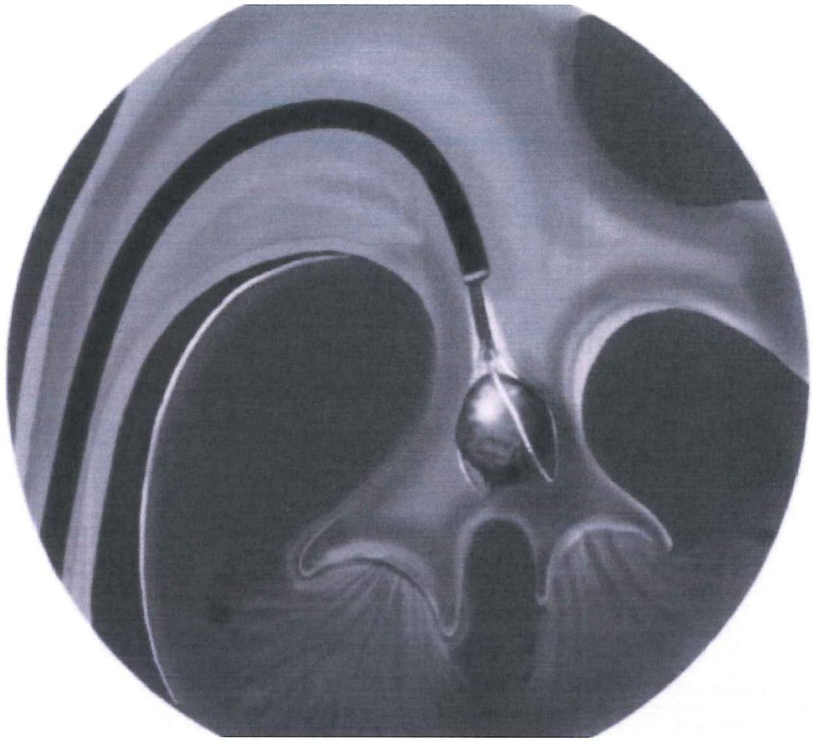

Fig. 7. The nitinol "Graspit" device used to reposition lower pole stones. (Courtesy of Microvasive, Boston Scientific Corporation, Natick, MA; with permission.)

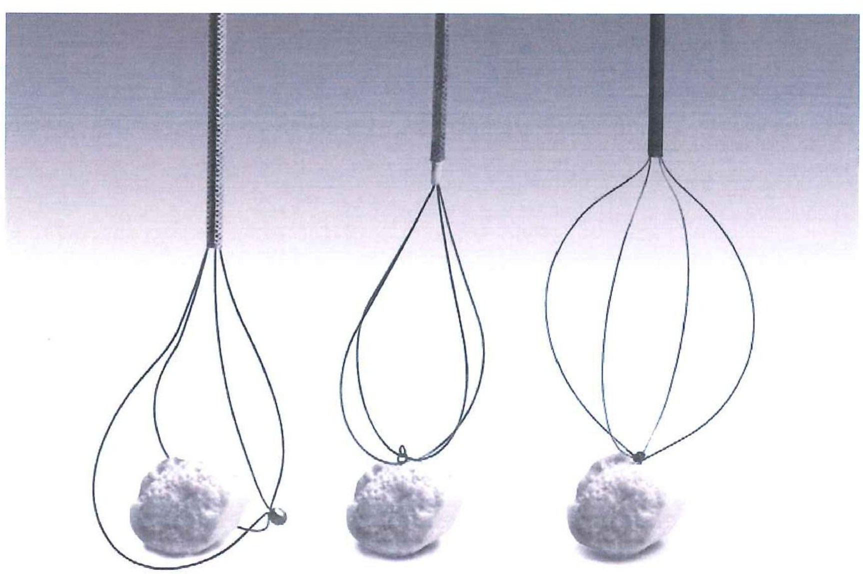

Fig. 8. The nitinol "Dimension" stone basket provides articulating basket wires to facilitate stone entrapment and release. (Courtesy of Bard Urological, Covington, GA; with permission.)

Table 1
Results from studies evaluating URS for renal stones

First author	No. patients	Success (%)	Comment
Schuster [36]	78	79[a]	LPS
Kourambas [34]	36	85[b]	LPS
Grasso [11]	90	76[b]	LPS
Sofer [38]	54	84[b]	—
Elashry [37]	45	92[b]	Ureteral/renal
Fabrizio [39]	100	77[b]	—
El-Anany [40]	35	77[b]	Stones > 2 cm
Grasso [41]	45	84[a]	Stones > 2 cm
Aso [42]	34	50[b]	Staghorn calcull

[a] Fragments < 2 mm.
[b] Stone-free.
Abbreviation: LPS, lower pole stones.

Treatment success also highly depends on the size of treated stones. Grasso et al's [11] study of 90 patients reported the following treatment success rates: 82% for stones that were 10 mm or smaller, 72% for stones 10 to 20 mm, and 65% for stones that were larger than 20 mm. Three studies examined the utility of using URS to treat large renal stones (> 2 cm) [40–42]. Overall success rates defined as either stone-free or stones smaller than 2 mm varied from 50% to 84%. Multiple procedures were often required. Sixteen of 45 patients in Grasso et al's [41] study required more than one procedure, whereas 34 patients in Aso et al's [42] study required an average of 1.6 procedures. As previously mentioned, adjunctive upper tract irrigation was performed in some patients in the study reported by Grasso et al [41].

Reported complication rates are few and typically minor. Minor complication rates range from 0% to 13% and consist primarily of pain or urinary tract infection. No major complications other than the retroperitoneal hemorrhage occurring in a patient with the uncorrected bleeding diathesis have been reported [15]. Significant complications, including ureteral stricture, have been reported to occur in 1.5% of nonspecific patients undergoing URS [43]. Longer-term follow-up periods may be required to determine the true stricture risk associated with ureteroscopic treatment of renal calculi.

Summary

Although ureteroscopic treatment of renal calculi is safe and effective, it is relatively inefficient compared with ESWL and PCNL. It should be considered primary therapy for patients with lower pole stones who have adverse ESWL characteristics and patients who are not suitable candidates for PCNL. There are also numerous clinical situations, as outlined previously, where the ureteroscopic approach is favored over other treatment modalities.

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