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Economic Outcomes of Treatment for Ureteral and Renal Stones: A Systematic Literature Review

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Abstract

Purpose—We evaluated the cost-effectiveness of ureteral/renal stone treatment by comparing ureteroscopy, extracorporeal shock wave lithotripsy and percutaneous nephrolithotomy.

Materials and Methods—We performed a systematic literature search to identify studies of treatment for adults with ureteral and renal stones that were published between 1995 and 2010. For inclusion in analysis studies had to provide the stone-free rate and the cost of at least 2 therapies.

Results—Ten studies were identified, including 8 with an observational design and 2 that synthesized data using decision modeling techniques. Five of 6 studies, including 1 of 2 from the United States, compared ureteroscopy vs shock wave lithotripsy for proximal stones and showed a higher stone-free rate and lower cost for ureteroscopy. Four of the 5 studies, including the only American study, compared ureteroscopy vs shock wave lithotripsy for distal ureteral stones and also showed such an economically dominant result. Studies of shock wave lithotripsy vs percutaneous nephrolithotomy and ureteroscopy vs percutaneous nephrolithotomy for renal stones demonstrated higher cost and a higher stone-free rate for percutaneous nephrolithotomy.

Conclusions—Despite the great heterogeneity and limited quality of available cost-effectiveness evaluations most studies demonstrated that ureteroscopy was more favorable than shock wave lithotripsy for ureteral stones in stone-free rate and cost.

Keywords

kidney calculi; ureteral calculi; cost-benefit analysis; lithotripsy; ureteroscopy

KIDNEY Stones affect approximately 10% of the American population with significant increases in disease prevalence for men and women.¹ Most patients who present to the emergency department with a symptomatic kidney stone ultimately pass the stone spontaneously and do not require surgical intervention. However, a significant proportion of patients with stone disease require some form of surgical treatment.² Since in many cases the superiority of one

surgical approach over another is an unresolved issue, there are often multiple accepted treatment options for a single stone scenario.

In recent years the medical community has become increasingly aware of the economic implications of these treatment decisions. Cost-effectiveness evaluations are a way to evaluate clinical effects and costs when comparing multiple treatment options. A cost-effectiveness evaluation assesses differences in costs between 2 or more competing interventions relative to the difference in outcomes. When a therapy is clinically superior and less costly, it is clear that this is the optimal therapy and it is termed dominant. However, in many cases a therapy may have a better clinical outcome but also be more costly or vice versa. In this case decision makers, eg health care payers, clinicians or patients, must decide what is cost-effective or a reasonable ratio of cost per increase in health outcomes.

Cost-effectiveness evaluations can guide policy and optimize the use of health care resources. Costs in a cost-effectiveness analysis can be limited to direct medical costs or they can also include indirect costs, eg those related to productivity loss. The types of costs included depend on the perspective of the evaluation, eg health care payer, societal or patient. Which therapy is cost-effective may differ depending on the perspective.

As health care spending becomes further constrained and entities such as accountable care organizations become widespread, studies of cost-effectiveness will become increasingly important. Thus, we performed a systematic literature review of the cost-effectiveness literature published in the last 15 years to compare the most common surgical options for adults with ureteral and renal stones, including URS, SWL and PNL.

METHODS

Study Identification and Selection

The criteria used to consider published studies for review were population (adults who required intervention for the primary treatment of ureteral and renal stones), interventions (URS, PNL or SWL with a second, third or fourth generation HM3 [Dornier Medtech, Kennesaw, Georgia], excluding comparisons of interventions of interest with open surgery), outcomes (cost and SFR), study design (any comparative design, eg randomized, controlled trials and retrospective and prospective studies), decision analytic modeling studies (decision trees synthesizing any of the mentioned study types and the medical literature to assess the costs and clinical outcomes during the entire intervention period), publication date (1995 to 2010), all perspectives and any country.

The MEDLINE®, Embase® and Cochrane databases were searched with a predefined search strategy using terms related to renal and ureteral stones, URS, SWL and PNL. For each identified citation it was determined whether the study met the predefined selection criteria based on title and abstract. For studies that met the criteria or for which they were unclear full text reports were obtained and evaluated. If SFR or costs were not reported, the study was excluded from analysis.

Data Extraction

Study design, patient characteristics, total costs per patient and SFR were extracted from the included studies. In contrast to modeling studies, for observational studies the corresponding 95% CIs were calculated based on the reported SD and on sample size, if reported. The assumption underlying calculation of the 95% CI was that the sample size was sufficiently large relative to the skewness of the cost data in the study sample that the sampling

distribution of the mean cost estimate could be approximated with a normal distribution. Accordingly the 95% CI could be calculated based on the reported SD and sample size.

Differences in costs between the compared interventions of each study and differences in SFR served as the basis for interpreting the relative cost-effectiveness of the compared interventions in each study. All costs were converted to 2008 U.S. dollars using country specific consumer price indexes, 2008 exchange rates and the health care Consumer Price Index.

The validated QHES instrument was used to assess the quality of included studies.^{3,4} QHES contains 16 items relating to appropriate methods, validity and transparency results, and comprehensive reporting. Each item carries a weighted point value and has a minimum and maximum score of 0 and 100 points, respectively. The results of the validity assessment served to determine the quality of the evidence base when interpreting the results.

RESULTS

Study Identification and Selection

Figure 1 shows the results of the literature search. The abstract review excluded 137 of 172 studies (80%). The full text review of the 35 remaining studies excluded 25 (71%), primarily since they did not report the required outcomes.

Study and Patient Characteristics

The table lists the study and patient characteristics of the 10 included cost-effectiveness series. Studies were identified from various countries with various designs, perspectives and stone sites. The average stone burden was generally comparable across ureteral stone and across renal stone studies.

Eight cost-effectiveness studies evaluating all parts of the ureter were identified and all compared SWL with URS. Five groups evaluated distal ureteral stones (Bierkens,⁵ Chang,⁶ Huang,⁷ Lotan⁸ and Wolf⁹ et al), representing American, European and Asian studies. Three groups evaluated mid ureteral stones (Bierkens,⁵ Huang⁷ and Lotan⁸ et al), representing American, European and Asian studies. Five groups evaluated proximal ureteral stones (Huang,⁷ Lotan,⁸ Izamin,¹⁰ Parker¹¹ and Wu¹² et al), representing the U.S. and Asia. All except 2 ureteral stone studies used an observational design, that is Lotan⁸ and Wolf⁹ et al used decision analytic models.

The cost-effectiveness studies by Hyams¹³ and May¹⁴ et al that evaluated renal stones were U.S. based and from a payer perspective. May et al compared SWL with PNL using an observational study design supplemented with external efficacy evidence. Hyams et al compared URS with PNL in an observational setting.¹³

Study quality ranged from 43 to 85 points on the QHES scale^{3,4} with an average $\pm$ SD score of 57 ± 16.6 points. Four of the 10 studies scored below 50 points, indicating poor quality.^{5,6,11,13} Four studies scored between 50 and 74 points, indicating fair quality.^{7,9,12,14} Two studies were of high quality, including that of Izamin et al with a score of 82 (a Malaysian observational study of proximal ureteral stones with a societal perspective)¹⁰ and that of Lotan et al⁸ with a score of 85 (an American decision analytic model of distal, mid and proximal ureteral stones with a payer perspective).⁸ The 2 renal stone studies scored below 60 points.^{13,14} For all studies the most common, important limitations were non-transparent descriptions of methods and analysis, lack of an explicit rationale for the perspective, no randomized, controlled trial evidence and no discussion of limitations and potential biases.

Cost-Effectiveness

The table shows the cost, SFR, and difference in costs and SFRs for all studies evaluated. Figure 2 shows the results of ureteral stone studies from the U.S.

Stones

Distal ureter—Four of the 5 studies comparing URS vs SWL for distal ureteral stones showed higher SFR and lower costs for URS.^{6–9} Economically dominant results were obtained in the U.S. by Wolf⁹ and Lotan⁸ et al, and in Asia by Chang⁶ and Huang⁷ et al. The results of the 2 American studies were consistent since each showed a URS saving of approximately \$2,000 in 2008 U.S. dollars compared to SWL. The 2 studies from Taiwan showed cost savings for URS but the amounts differed.^{6,7} Since Huang et al used a hospital perspective⁷ and Chang et al used a payer perspective,⁶ it is not surprising that there were differences in cost. In contrast, the study by Bierkens et al from The Netherlands indicated that URS had a greater SFR but also higher costs than SWL.⁵ The additional cost for URS was \$12,813 per additional successfully treated patient compared to SWL. However, in this study all URS procedures were done on an inpatient basis and all SWLs were done on an outpatient basis.

Mid ureter—Similar to the results of distal stone studies, of the mid ureteral studies those from the U.S. and Asia indicated higher SFRs and lower costs for URS than for SWL. The European study showed greater SFR for URS but also higher costs.⁵ The cost-effectiveness ratio of URS for the study by Bierkens et al relative to SWL was \$17,318 per successfully treated patient.⁵ The study by Huang et al from Taiwan indicated similar costs savings for URS compared to SWL as it did for distal stones but a much greater benefit for mid ureteral stones with respect to SFR.⁷ The American study by Lotan et al provided results for the HM3 and for newer SWL generations.⁸ It indicated increased costs and SFR compared to URS for each SWL type but a much greater SFR for URS compared to newer SWLs than for HM3s.

Proximal ureter—Four of the 5 studies of proximal ureteral stones comparing URS vs SWL showed higher SFR and lower costs for URS.^{7,8,10–12} While all 3 Asian studies demonstrated that URS was the dominant technology, they had widely varying cost differences, which is not surprising since they used different perspectives (hospital, societal and patient) and were from different countries with different health care systems (Taiwan and Malaysia).^{7,10,12} The American studies had different outcomes. Each study showed lower costs for URS but Parker et al found that URS was associated with greater SFR and lower costs than SWL.¹¹ In contrast, Lotan et al found a higher SFR for HM3 and nonHM3 SWL relative to that of URS.⁸ In that series the cost-effectiveness ratio for HM3 and nonHM3 SWL relative to URS was \$65,500 and \$47,975, respectively, per additional successfully treated patient.

Kidney—The American study by May et al showed higher costs with PNL relative to SWL for lower renal calculi.¹⁴ The cost per successfully treated patient was \$92,556 for PNL relative to SWL. The study by Hyams et al evaluating PNL and URS for 2 to 3 cm renal stones indicated a higher clearance rate and costs for PNL, resulting in a cost-effectiveness ratio of \$31,357 per successfully treated patient for PNL vs URS.¹³

DISCUSSION

SWL, URS and PNL are safe, accepted treatments for upper urinary tract calculi. These interventions have been the subject of direct comparisons and meta-analyses, which in some cases showed no evidence to support differences in clinical effectiveness. However, our

series revealed readily apparent differences in costs for these interventions. For ureteral stones our analysis showed that URS was associated with a greater SFR and lower costs than SWL. The highest quality studies by Lotan⁸ and Izamin¹⁰ et al demonstrated that under most circumstances URS dominated economically. In contrast, the study by Bierkens et al, who found higher costs for URS, had one of the lowest quality scores and much of the cost difference may be attributable to inpatient URS and outpatient SWL.⁵ For renal calculi PNL was associated with greater stone clearance than alternative modalities. However, PNL costs were significantly greater than the costs of SWL and URS.

There are some limitations of this analysis. While the literature indicates that URS is less costly and better clinically, due to the wide variety of health care systems represented we could not evaluate the magnitude of the benefit for URS with respect to cost. Also, since most studies were from a third-party payer perspective, our series does not include societal costs, such as lost work wages. However, the medical costs of URS and SWL likely dwarf any costs incurred by patient and societal level costs.

Our findings are consistent with those of other groups who reviewed the cost of surgical stone management. More than a decade ago Chandhoke investigated the clinical effectiveness and cost-effectiveness of surgical treatments for stone disease.¹⁵ At that time URS was superior to SWL in each metric. In a 2007 review of the economics of stone management Lotan and Pearle found that most cost based studies of URS and SWL showed higher costs for SWL than for URS.¹⁶ However, although they addressed the issue of cost, the scope of the review did not include health outcomes. In the current era of cost containment when an understanding of the comparative effectiveness among treatment interventions is becoming ever more important, our analysis advances these prior series and better quantifies the cost-effectiveness of stone treatments. In this way our study may best inform decision making, such that stone treatment costs might be controlled without affecting overall health quality.

Although we identified a modest body of literature (10 studies) on the cost-effectiveness of surgical treatments for upper tract calculi, the quality of the evidence was often limited. Our metric to define the quality of our source studies was the QHES assessment. Ultimately this instrument classified a third of the studies reviewed as poor quality with a score of less than 50 of a possible 100 points. We take away several common themes in our QHES assessments, which can be constructively applied to future study designs. Among the most common flaws that limited the quality of these studies was opaque study methodology, which limited the interpretation of findings. Other less severe but still important flaws were a lack of examination and discussion of study limitations and biases, which also could affect the ultimate interpretation of the study.

Going forward, there is a need for high quality cost-effectiveness studies of the surgical management of kidney stone disease. We found a relative dearth of studies of the cost-effectiveness of surgical stone treatment and those that we found were often not well done. Properly designed economic evaluations allow comparisons of costs and consequences of surgical interventions, and can expose inefficiency among these interventions. The limited quantity and poor quality of the current body of stone disease cost-effectiveness literature suggests that as future studies are designed, urologists may be well served to partner with health economists.

CONCLUSIONS

Based on our analysis URS appears to save costs and have a higher success rate than SWL for ureteral stones. However, few studies were well designed and adhered to recognized

quality metrics. Since the incidence of kidney stone disease is increasing and will likely to be an ever greater contributor to health care costs, urologists should continue to evaluate the economic impact of stone treatment with the goal of maximizing clinical and economic outcomes. These issues are complex and future studies to maximize the quality of economic evaluation will assist in guiding the optimal strategy for renal and ureteral stone management.

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Abbreviations and Acronyms

PNL	percutaneous nephrolithotomy
QHES	Quality of Health Economic Studies
SFR	stone-free rate
SWL	shock wave lithotripsy
URS	ureteroscopy
U.S.	United States

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Figure 1.
Literature search

Figure 2.

American ureteral study cost-effectiveness results shown as cost difference vs SFR difference for URS vs SWL

Study and patient characteristics, and cost-effectiveness results by study

References	Design	Country	Perspective	Overall QHES Score		Stone Site	Intervention	No. Pts	Mean Stone Size	Mean 2008 \$ Cost (95% CI)		Mean % Stone Free (95% CI)	
										Total/Pt	Rate		
Chang et al ⁶	Observational	Taiwan	3rd-Party payer	43		Distal ureter	SWL (nonHM3), URS	524, 430	29.8, 29.0 mm ²	1,165, 1,081	–84	87 (84.1–89.9), 96 (94.1–97.9)	9 (5.6–12.4)
Wolf et al ⁹	Decision analytic model	U.S.	3rd-Party payer	72		Distal ureter	SWL, URS	Not available	—	11,138, 9,173	–1,965	84.5 (78.5–90.5), 92.1 (89.1–95.1)	7.6 (0.9–14.3)
Bierkens et al ⁵	Observational	Netherlands	Societal	43		Distal + mid ureter	SWL (nonHM3), URS	63, 105	46.0 mm ² Distal + 63.0 mid, 47.0 distal + 50.0 mid	2,023 Distal + 3,190 mid, 4,329 distal + 4,229 mid	2,306 Distal + 1,039 mid	81 (69.4–92.6) Distal + 90 (76.5–100) mid, 99 (96.8–100) distal + 96 (88.3–100) mid	18 (6.2–29.8) Distal + 6 (–9.5–21.5) mid
Huang et al ⁷	Observational	Taiwan	Hospital	52		Distal, mid + proximal ureter	SWL (nonHM3), URS	360, 88	11 + 11.2 mm	650 (621.4–678.6) Distal, 695.6 (636.8–754.3) mid + 904.1 (877.2–931.1) proximal, 623 (559.9–686.0) distal, 670 (599.1–740.7) mid + 766 (713.6–817.9) * proximal	–27 (–96–42) Distal, –26 (–118–66) mid + –138 (–197–80) proximal *	88.1 (83.2–93) Distal, 70.8 (57.9–83.7) mid + 52.8 (47.6–58) proximal, 94.4 (86.9–101.9) distal, 87.5 (74.3–100.7) mid + 85.7 (72.7–98.7) proximal	6.3 (–2.7–15.3) Distal, 16.7 (–1.8–35.2) mid + 32.9 (18.9–46.9) proximal
Lotan et al ⁸	Decision analytic model	U.S.	3rd-Party payer	85		Distal, mid + proximal ureter	SWL (HM3), SWL (nonHM3), URS	Not available	Not reported	6,039 Distal, 6,055 mid + 6,421 proximal, 6,301 distal, 6,482 mid + 6,374 proximal, 3,711 distal, 3,834 mid + 4,455 proximal	vs SWL (HM3) distal, –2,221 mid + –1,965 proximal, vs SWL (nonHM3) –2,590 distal, –2,647 mid + –1,919 proximal	89.0 Distal, 89.0 mid + 83.0 proximal, vs SWL (nonHM3) proximal, 82.0 distal, 78.0 mid + 84.0 proximal,	vs SWL (HM3) 6.0 distal, 3.0 mid + –3.0 proximal, vs SWL (nonHM3) 13.0 distal, 14.0 mid + –4.0 proximal

References	Design	Country	Perspective	Overall QHES Score	Stone Site	Intervention	No. Pts	Mean Stone Size	Mean 2008 \$ Cost (95% CI)		Mean % Stone Free (95% CI)	
									Total/Pt	Rate	Rate	Rate
Izamin et al ¹⁰	Observational	Malaysia	Societal	82	Proximal ureter	SWL, URS	30, 37	14.2, 9.5 mm	295 (287–302), 197 (181–213) [‡]	–98 (–115–80) [‡]	53.3 (35.5–71.2), 67.6 (52.5–82.7)	14.2 (–9.1–37.6)
Parker et al ¹¹	Observational	U.S.	3rd-Party payer	43	Proximal ureter	SWL, URS	111, 109	Not reported	20,762 (19,388–22,136), 12,495 (11,558–13,431)	–8,267 (–9,930–6,604)	55 (45.7–64.3), 90.8 (85.4–96.2)	35.8 (25.1–46.5)
Wu et al ¹²	Observational	Taiwan	Pt	52	Proximal ureter	SWL (nonHM3), URS	119, 101	57.9, 108.3 mm ²	1,495 (1,404–1,586), 1,174 (1,098–1,249)	–322 (–440–v203)	63.8 (55.2–72.5), 83.2 (75.9–90.5)	19.3 (8–30.6)
May et al ¹⁴	Observational/model analysis	U.S.	3rd-Party payer	57	Kidney	SWL (HM3), PNL	114, 10	Less than 10 mm in 63 pts, 11–20 in 45 + greater than 20 in 6, not reported	12,638, 40,965	28,327	64.7, 95.3	30.6
Hyams et al ¹³	Observational	U.S.	3rd-Party payer	43	Kidney	URS, PNL	19, 20	24.0, 24.0 mm	6,675, 19,845	13,170	47 (24.6–69.4), 89 (75.3–100)	42 (15.7–68.3)

^{*} Exchange rate \$1 = 30.30 NT\$ as of June 30, 2008.

[‡] Exchange rate \$1 = 3.27 MYR as of June 30, 2008.