

Shock Wave Lithotripsy vs Ureteroscopy: Variation in Surgical Management of Kidney Stones at Freestanding Children's Hospitals

Hsin-Hsiao Scott Wang, Lin Huang, Jonathan C. Routh and Caleb P. Nelson*

From the Department of Urology, Children's Hospital Boston, Boston, Massachusetts

Abbreviations and Acronyms

PHIS = Pediatric Health Information System

SWL = shock wave lithotripsy

URS = ureteroscopy

Submitted for publication August 29, 2011.

* Correspondence: Department of Urology, Children's Hospital Boston, 300 Longwood Ave., HU-359, Boston, Massachusetts 02115 (telephone: 617-355-3338; FAX: 617-730-0474; e-mail: caleb.nelson@childrens.harvard.edu).

Purpose: Although shock wave lithotripsy has long been considered the gold standard for treatment of kidney stones in children, ureteroscopy has become increasingly common. The factors determining procedure choice at individual centers are unclear. We sought to identify patient and hospital factors associated with the choice between shock wave lithotripsy and ureteroscopy.

Materials and Methods: We searched the Pediatric Health Information System hospital database to identify patients with renal calculi who underwent inpatient or outpatient shock wave lithotripsy or ureteroscopy between 2000 and 2008. We used multivariate regression to evaluate whether procedure type was associated with hospital level factors, including treating hospital, region, size and teaching status, or patient level factors, including age, race, gender and insurance type.

Results: We identified 3,377 children with renal stones, of whom 538 (16%) underwent surgery (shock wave lithotripsy in 48%, ureteroscopy in 52%). Procedures in 445 patients at hospitals performing both procedures were included. The relative proportion of ureteroscopy increased during the study period (24% from 2000 to 2002 vs 50% from 2006 to 2008, $p = 0.0001$). Procedure choice was not significantly associated with patient age ($p = 0.2$), gender ($p = 0.1$), race ($p = 0.07$), insurance ($p = 0.9$), hospital size ($p = 0.6$) or teaching status ($p = 0.99$). Procedure choice varied significantly by geographical region ($p = 0.05$), regional population ($p = 0.002$) and stone location ($p < 0.0001$). On multivariable analysis controlling for stone location, gender and treatment year the treating hospital was still highly associated with procedure choice.

Conclusions: There is wide variation in procedure choice for children with kidney stones at freestanding children's hospitals in the United States. Treatment choice depends significantly on the hospital at which a patient undergoes treatment.

Key Words: lithotripsy, pediatrics, ureteroscopy, urolithiasis

SHOCK wave lithotripsy has long been considered the gold standard for surgical treatment of kidney stones in children. The major benefits include low apparent morbidity and rare serious complications. However, reported efficacy has varied with stone-free rates ranging from 58% to 90%.¹⁻³ High repeat treatment rates have also been reported.⁴

In the last decade there has been increasing interest in the role of URS in children with stones. Remarkable technical advances in endoscopic equipment—small diameter, flexible ureteroscopes with improved optical capability, increased range of motion and multichannel function, as well as increased availability and lower cost of holmium:YAG laser—

have meant that ureteroscopic treatment of urolithiasis is a viable option even in young patients.⁵ As a result, many urologists now consider URS to be first-line treatment for children with stones requiring surgical intervention.^{6,7} However, other experts have cited the potential for complications, as well as technical challenges (particularly in children with a history of congenital anomalies or reconstructive surgery),⁸ as reasons to favor SWL. Although the relative risks and benefits of these 2 treatment approaches are not clearly defined, most clinicians tend to favor one treatment over the other. However, the factors determining the choice between SWL and URS are uncertain. We sought to identify patient and hospital factors associated with the choice between SWL and URS for children undergoing surgery for kidney stones.

METHODS

Data Source

We used the Pediatric Health Information System, a national database of administrative and billing data from 42 freestanding children's hospitals affiliated with the Child Health Corporation of America (Shawnee Mission, Kansas). The PHIS database is composed of more than 125 discrete data points drawn from more than 1,000,000 pediatric patient encounters, including data from inpatient admissions, ambulatory medical and/or surgical short stay areas, and emergency department visits. PHIS data are screened for accuracy on a quarterly basis through the joint efforts of the Child Health Corporation of America, an independent data manager (Thomson Reuters Corp., New York, New York) and each participating hospital. Data are accepted into PHIS only when classified errors occur in less than 2% of hospital quarterly data. We only included data from hospitals that contributed data on all inpatient, emergency and short stay visits for a given year. Hospitals that contributed partial data (eg inpatient admissions only) were excluded from the analysis.

Patient Population

We identified all hospital encounters occurring between January 2000 and December 2008 for patients younger than 18 years with an ICD-9-CM diagnosis code for renal stones (592.0). We identified patients who underwent either SWL or URS for stone disease within 6 months of initial PHIS presentation, using CPT procedure codes for ureteroscopy (52325, 52344, 52345, 52346, 52351, 52352, 52353, 52354, 52355) and SWL (50590). To allow us to analyze specific patient and hospital level factors associated with procedure choice, the analysis was further limited to hospitals performing both procedures during the study period.

Variable Selection

Treatment classification was defined a priori as SWL or URS within 6 months of initial appearance of urolithiasis diagnostic codes in the PHIS database for a given patient. The 6-month window serves to minimize inclusion of patients with long-standing disease undergoing multiple

subsequent procedures. Predictor variables included patient level factors such as age, gender, race/ethnicity, insurance type (private vs public) and procedure year, and hospital level factors such as teaching status, bed count, United States census region, metropolitan area population and individual hospital at which a patient was treated. Presence of ureteral stone (in addition to renal stone) was assessed through additional presence of ICD-9 code 592.1.

Statistical Methods

Bivariate associations between the procedure choice (defined as SWL or URS) and predictor variables were assessed. Wilcoxon rank sum tests were used for continuous variables, and chi-square tests, Mantel-Haenszel trend test or Fisher exact test was performed for categorical variables.

We developed a logistic regression model to assess the relationships between predictor variables and procedure choice for patients who were treated at hospitals that performed SWL and URS. For the multivariable analysis the hospital at which a patient was treated was used as a fixed effect. We chose a priori to examine the relationship between procedure choice and key predictor variables (patient age, patient insurance status, ureteral stone and individual hospital) as well as any other patient level covariates with a p value of 0.2 or less on initial bivariate analysis. The reference hospital for the model was the hospital with the most balanced distribution of SWL vs URS. The odds of SWL for a given patient for each other hospital were compared to this reference hospital. Model diagnostics revealed no significant violations of regression assumptions.

The predicted probability of a procedure being used at a particular hospital was determined by back transforming data from the logistic model. All analyses were performed using SAS®, version 9.2. All tests were 2-sided with significance defined as a p value of 0.05 or less. The study was exempt from formal review by the institutional review board, and administrative approval was obtained from PHIS before data extraction and analysis.

RESULTS

We initially identified 3,377 children with urolithiasis, of whom 538 (16%) underwent surgery (SWL in 48%, URS in 52%) at a PHIS hospital during the study period. One hospital performed only SWL, 10 hospitals performed only URS and 16 hospitals performed both procedures during the study period. Thus, our study cohort was limited to patients treated at those 16 hospitals performing both procedures during the study period. Procedures in 445 patients (URS in 42%, SWL in 58%) were included for comparison of factors. Table 1 presents patient and procedure characteristics. Mean patient age was 11.5 years. Most patients were white and carried private insurance. Several patients had a code for a ureteral stone in addition to the renal stone. The majority of procedures were performed at teaching hospitals, reflective of the PHIS hospitals themselves. The total number of both procedures increased during the study period, with more than half

Table 1. Comparison of patient characteristics at hospitals performing SWL and URS, by procedure type

	All Pts		SWL		Ureteroscopy		p Value
No. pts (%)	445	(100)	256	(58)	189	(42)	—
Mean \pm SD age (yrs)	11.5 \pm 4.4		11.3 \pm 4.5		11.8 \pm 4.3		0.2*
No. yrs age (%):							0.4†
0–1	5	(1)	3	(1)	2	(1)	
1–3	14	(3)	8	(3)	6	(3)	
3–6	43	(10)	31	(12)	12	(6)	
6–12	156	(35)	88	(34)	68	(36)	
12–18	227	(51)	126	(50)	101	(53)	
No. gender (%)							0.1‡
M	194	(44)	120	(47)	74	(39)	
F	251	(56)	136	(53)	115	(61)	
No. race/ethnicity (%)							0.07‡
White	344	(77)	190	(74)	154	(82)	
Black	12	(3)	8	(3)	4	(2)	
Hispanic	36	(8)	28	(11)	8	(4)	
Other	53	(12)	30	(12)	23	(12)	
No. insurance type (%)							0.9‡
Public	109	(24)	62	(24)	47	(25)	
Private	334	(76)	192	(76)	142	(75)	
No. study period (%)							0.0001†
2000–2002	50	(11)	38	(15)	12	(6)	
2003–2005	137	(31)	88	(34)	49	(26)	
2006–2008	258	(58)	130	(51)	128	(68)	
Median (IQR) metro area population in millions	2.4 (2.4–3.0)		2.6 (2.4–3.4)		2.4 (2.4–3.0)		0.002§
Mean \pm SD hospital bed count	262 \pm 46		261 \pm 51		263 \pm 39		0.6*
No. teaching hospital (%)							0.99‡
Yes	431	(97)	248	(97)	183	(97)	
No	12	(3)	7	(3)	5	(3)	
No. census region (%)							0.05‡
Northeast	139	(31)	71	(28)	68	(36)	
Midwest	134	(30)	73	(29)	61	(32)	
South	96	(22)	60	(24)	36	(19)	
West	74	(17)	51	(20)	23	(12)	
No. ureteral stone (%)							<0.0001‡
Yes	60	(13)	8	(3)	52	(28)	
No	385	(87)	248	(97)	137	(72)	

* t test.

† Mantel-Haenszel chi-square trend test.

‡ Fisher exact test.

§ Wilcoxon rank sum test.

of both procedure types being performed during the final 3 years of the study period, reflecting partly the increase in the number of participating PHIS hospitals during this period.

The results of the bivariate analyses of factors associated with procedure choice are shown in table 1. As a proportion of all stone procedures, URS cases (vs SWL) increased steadily during the study period from 24% of all procedures during 2000 to 2002 to 36% during 2003 to 2005 to 50% during 2006 to 2008 ($p = 0.0001$). Not surprisingly, the presence of a ureteral stone code in addition to the renal stone code was strongly associated with procedure choice, with 87% of affected patients undergoing URS.

Procedure choice was not significantly associated with patient age or insurance, but there was a trend toward male gender ($p = 0.1$) and nonwhite race ($p = 0.07$) being more likely treated with SWL (table 1). On the hospital level URS was more commonly per-

formed at hospitals in the Northeast and the Midwest, while SWL predominated in the South and West ($p = 0.05$). SWL was also more common in larger metropolitan areas ($p = 0.002$). Hospital bed count and teaching hospital status were not associated with procedure choice.

After adjusting for these covariates in the multivariate model, procedure choice was associated with gender, study period, ureteral stone and treating hospital, with male gender, renal stone only and earlier study period more likely treated with SWL (table 2). When nonsignificant covariates were removed from the model, the regression findings for the remaining 4 significant variables were unchanged.

Using this multivariate model, we calculated the predicted probability of SWL use at each study hospital for a standard patient, who was a teenage white female with private insurance. The figure illustrates the range of predicted probabilities for this

Table 2. Association of patient and hospital factors with procedure choice based on multivariate logistic regression analysis

	Adjusted OR (95% CI)*	p Value
Age (yrs):		
0–1 (referent)	— (—)	—
1–3	1.4 (0.1–22.1)	0.8
3–6	4.8 (0.3–65.3)	0.2
6–12	2.7 (0.2–32.2)	0.4
12–18	1.6 (0.1–18.8)	0.7
Gender:		
M (referent)	— (—)	—
F	0.5 (0.3–0.9)	0.01
Race:		
White (referent)	— (—)	—
Black	1.7 (0.3–8.6)	0.5
Hispanic	1.3 (0.4–4.1)	0.7
Other	0.7 (0.3–1.6)	0.4
Insurance:		
Private (referent)	— (—)	—
Public	0.7 (0.4–1.4)	0.3
Study period:		
2000–2002 (referent)	— (—)	—
2003–2005	0.2 (0.1–0.4)	<0.0001
2006–2008	0.1 (0.03–0.2)	0.0005
Hospital:†		
R (referent)	— (—)	—
A	0.1 (0.03–0.4)	0.0002
W	13.0 (2.2–76.5)	0.0047
Ureteral stone:		
No (referent)	— (—)	—
Yes	0.1 (0.03–0.2)	<0.0001

Odds ratio is odds of SWL (vs URS) for variable category, compared to odds of SWL of reference category.

* Adjusted for age, gender, race, insurance, procedure year, ureteral stone and individual hospitals.

† Hospitals A, R and W are letter codes for 3 of 16 hospitals included in analysis. Hospital R was referent, while hospital A had lowest and hospital W had highest odds ratio.

standard patient to undergo SWL at each hospital. The predicted probability of SWL ranged from 7% (95% CI 2–23) to 93% (95% CI 71–98), depending on the treating hospital.

DISCUSSION

The surgical management of pediatric stone disease has evolved dramatically in the last few decades. SWL largely supplanted open stone surgery in children by the late 1980s and has maintained a key role to this day. However, steady improvement in endoscopic technology has propelled the increasing popularity of ureteroscopic treatment to the point where it is considered first-line management by many clinicians. Unfortunately the lack of any large randomized controlled trials directly comparing these 2 treatment modalities in children means that the optimal roles of SWL and URS for pediatric urolithiasis remain controversial.

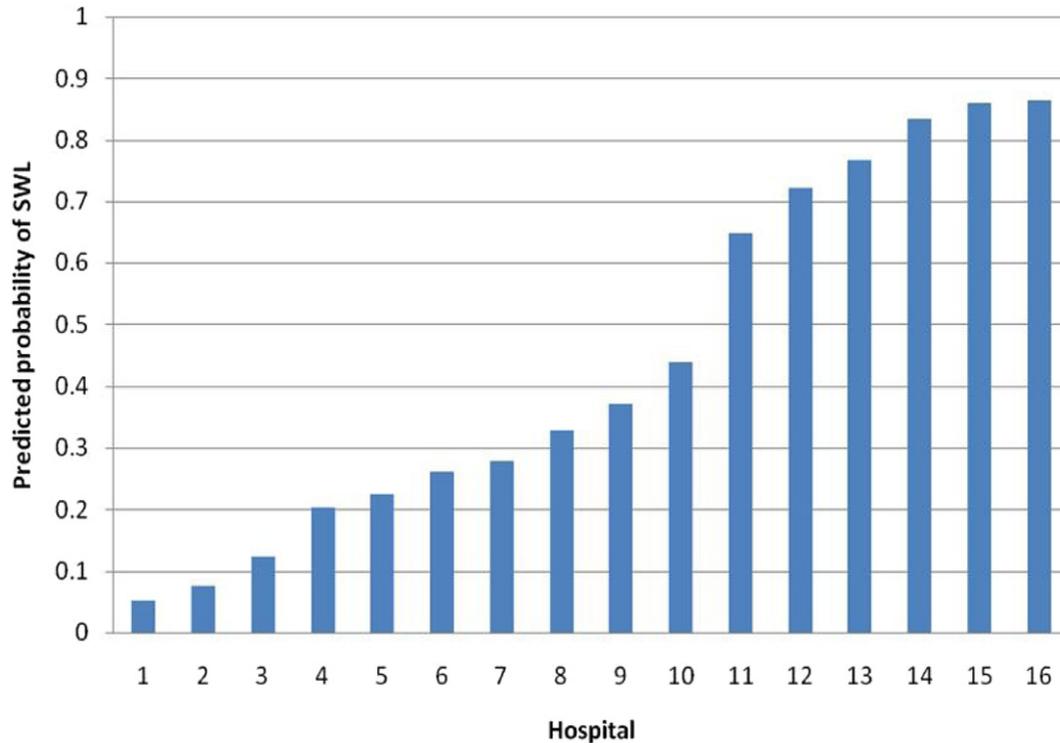
In this study rather than providing an argument for choosing one modality over the other, we exam-

ined the factors that are associated with variation in stone management at pediatric hospitals around the country. We found that the hospital at which a child underwent treatment was the single most important identifiable factor driving the choice between SWL and URS. Strikingly there was a tremendous variability in the relative use of each modality at PHIS hospitals, even at hospitals where both treatments were available and were used. The probability that a given child would undergo SWL, while holding all other factors stable, varied from 7% to 93%, depending solely on the individual hospital at which the child was treated.

Such a high degree of variability in treatment is surprising and potentially concerning. While it is clear that either SWL or URS may be a better choice for an individual child, it is unknown whether SWL or URS is the superior treatment for children with stones in general. However, it is reasonable to assume that the characteristics of such patients are roughly equivalent across PHIS hospitals, all of which are tertiary care, freestanding children's hospitals. Thus, the treatment variability that we describe is unlikely to be a reflection of inherent variability in the patient population but more likely a result of the preferences, biases and experience of the physicians making these treatment decisions. Financial factors such as regional variations in reimbursement rates and physician ownership of lithotripsy equipment may influence surgical decision making. Even in the absence of clear data indicating the superiority of one treatment over another the degree of variability among the PHIS hospitals, which persisted even after adjusting for demographic, socioeconomic and clinical factors, would seem inherently undesirable.

Such variation has been observed in other areas of medicine in situations where consensus is lacking on the most appropriate management choice.^{9–11} Unwarranted variation is a reality within the medical care system and has been documented repeatedly using a wide range of data sources. Care pattern variation has also been demonstrated, in certain circumstances, to be associated with poorer clinical outcomes.^{10–14} Previous literature has suggested that establishment of evidence-based guidelines may decrease these variations and improve health outcomes.^{13,14} In examples such as the current study, where strong evidence indicating the optimal treatment choice is lacking, these findings indicate the need for further prospective clinical research into pediatric stone management.

The findings of this study should be interpreted in light of its limitations. The PHIS database is derived from tertiary care, freestanding pediatric hospitals, and our patient population may not be typical of patients or treatment patterns at other hospital types. Similarly PHIS does not capture data from ambulatory medical or surgical clinics, or for treat-



Adjusted probability of patient undergoing SWL according to treating hospital. Displayed is adjusted predicted probability of SWL for standard study patient (white teenage female with private insurance). Predicted probability of SWL ranged from 5% (95% CI 1–17) at hospital 1 to 86% (95% CI 47–98) at hospital 16.

ment rendered before patient referral to a PHIS hospital. However, PHIS does capture data from PHIS hospital satellite and ambulatory surgical centers, which may better represent nonhospital based ambulatory settings.

To improve further the generalizability of these findings, we limited our analysis to PHIS hospitals that contribute data on all of their surgical procedures, inpatient and outpatient. Thus, the analysis is not biased by overrepresentation by surgical patients treated as inpatients, since these patients are not likely to be representative of typical patients with urolithiasis, most of whom are treated as outpatients. Furthermore, we only looked at centers that performed both procedures at least some of the time. This approach meant that our comparison of SWL and URS choice was less likely to be biased by structural factors that would be essentially determinative of procedure choice (eg access to a lithotripter or availability of ureteroscopic equipment). All sites in the analysis could and did perform each procedure type, even if their relative proportions varied greatly from one center to the next.

Our diagnostic and procedural classifications rely on the ICD-9-CM and CPT coding systems, and represent secondary data extracted from the original medical record. The potential for inaccurate data transfer or improper coding cannot be excluded and

must be considered when evaluating these data. However, as previously stated, the PHIS database is rigorously monitored and audited for coding accuracy and, therefore, represents a reasonably reliable panorama of the characteristics of its patients.

Furthermore, there may be unmeasured confounders influencing our results. No formal sensitivity analyses were performed to estimate the influence of specific confounders, either measured or unmeasured. However, we are reassured by the lack of dramatic changes in the effect estimates in the model after adjusting for other associated variables. This finding implies that although residual confounding may yet be present, it is unlikely to have a substantial effect on the reported results.

The database does not allow us to assess preoperative stone burden or location, factors that are clearly associated with the choice of surgical procedure. However, it is unlikely that variations in stone presentation have a major role in the observed hospital level treatment variation, since there is no evidence that there are significant geographical or regional variations in such stone presentation parameters. This assumption, in turn, implies that the distribution of such parameters should be relatively constant across hospitals, in which case the treatment variation is unlikely to be due to such differences. Presumably the urology service at each PHIS hospital

manages stone cases in ways consistent with physician training, experience and comfort level. In the absence of clear-cut evidence in favor of a certain treatment modality such factors are perfectly reasonable bases for making treatment decisions. Nonetheless, the degree of variability observed among a large number of pediatric, tertiary care facilities suggests that further research, with a goal of increased standardization of management, would be desirable.

CONCLUSIONS

The choice between SWL and URS for management of pediatric kidney stones varies widely at freestanding children's hospitals in the United States. Although the clinical features that drive procedure choice should be similar at facilities that offer both modalities, the final treatment rendered appears to depend primarily on the hospital at which the patient undergoes treatment.

REFERENCES

- Muslumanoglu AY, Tefekli AH, Altunrende F et al: Efficacy of extracorporeal shock wave lithotripsy for ureteric stones in children. *Int Urol Nephrol* 2006; **38**: 225.
- Nelson CP, Diamond DA, Cendron M et al: Extracorporeal shock wave lithotripsy in pediatric patients using a late generation portable lithotripter: experience at Children's Hospital Boston. *J Urol, suppl.*, 2008; **180**: 1865.
- Landau EH, Shenfeld OZ, Pode D et al: Extracorporeal shock wave lithotripsy in prepubertal children: 22-year experience at a single institution with a single lithotripter. *J Urol, suppl.*, 2009; **182**: 1835.
- Wadhwa P, Aron M, Seth A et al: Pediatric shockwave lithotripsy: size matters! *J Endourol* 2007; **21**: 141.
- Vanlangendonck R and Landman J: Ureteral access strategies: pro-access sheath. *Urol Clin North Am* 2004; **31**: 71.
- Kim SS, Kolon TF, Canter D et al: Pediatric flexible ureteroscopic lithotripsy: the Children's Hospital of Philadelphia experience. *J Urol* 2008; **180**: 2616.
- Smaldone MC, Cannon GM Jr, Wu HY et al: Is ureteroscopy first line treatment for pediatric stone disease? *J Urol* 2007; **178**: 2128.
- Krambeck AE, Gettman MT, BaniHani AH et al: Management of nephrolithiasis after Cohen cross-trigonal and Glenn-Anderson advancement ureteroneocystostomy. *J Urol* 2007; **177**: 174.
- Kleinman LC, Kosecoff J, Dubois RW et al: The medical appropriateness of tympanostomy tubes proposed for children younger than 16 years in the United States. *JAMA* 1994; **271**: 1250.
- Lieu TA, Lozano P, Finkelstein JA et al: Racial/ethnic variation in asthma status and management practices among children in managed Medicaid. *Pediatrics* 2002; **109**: 857.
- Perrin JM, Homer CJ, Berwick DM et al: Variations in rates of hospitalization of children in three urban communities. *N Engl J Med* 1989; **320**: 1183.
- Conway PH and Keren R: Factors associated with variability in outcomes for children hospitalized with urinary tract infection. *J Pediatr* 2009; **154**: 789.
- Landrigan CP, Conway PH, Stucky ER et al: Variation in pediatric hospitalists' use of proven and unproven therapies: a study from the Pediatric Research in Inpatient Settings (PRIS) network. *J Hosp Med* 2008; **3**: 292.
- Arriaga AF, Lancaster RT, Berry WR et al: The better colectomy project: association of evidence-based best-practice adherence rates to outcomes in colorectal surgery. *Ann Surg* 2009; **250**: 507.

EDITORIAL COMMENT

The authors present an interesting study using PHIS data to characterize surgical practice patterns (URS vs SWL) for pediatric nephrolithiasis from 2000 to 2008. They report that URS use significantly increased during the study period and that treatment rendered was most strongly associated with the individual treating hospital when controlling for available demographic and hospital characteristics.

The PHIS, while robust, does not include treatment outcomes, which challenges the evaluation of procedure efficacy. In addition, the final patient sample (445) was selected from only 16 freestanding children's hospitals, which does not accurately reflect national practice patterns and limits study generalizability. Eloquently acknowledging these limitations, the authors appropriately frame their

findings to conclude that the observed variation in procedure use is undesirable and reflects a lack of evidence-based guidelines.¹ These observations support the notion that further prospective evaluation is necessary to optimize clinical outcomes, standardize management and reduce health expenditures.²

Marc C. Smaldone

*Division of Urologic Oncology
Fox Chase Cancer Center
Philadelphia
and*

Michael C. Ost

*Division of Pediatric Urology
Children's Hospital of Pittsburgh
Pittsburgh, Pennsylvania*

REFERENCES

- Wennberg DE: Variation in the delivery of health care: the stakes are high. *Ann Intern Med* 1998; **128**: 866.
- Shelton JB and Saigal CS: The crossroads of evidence-based medicine and health policy: implications for urology. *World J Urol* 2011; **29**: 283.