Published in final edited form as:

J Urol. 2015 April ; 193(4): 1270–1274. doi:10.1016/j.juro.2014.09.095.

Complications of Surgical Management of Upper Tract Calculi in Spina Bifida Patients: Analysis of Nationwide Data

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Abstract

Purpose—The management of upper urinary tract stones in patients with spina bifida is challenging but poorly described in the literature. We compared urolithiasis interventions and related complications in patients with spina bifida to those in other stone formers using a national database.

Materials and Methods—We retrospectively reviewed the NIS to identify hospital admissions for renal and ureteral stones from 1998 to 2011. We used ICD-9-CM codes to identify urological interventions, including shock wave lithotripsy, ureteroscopy, percutaneous nephrolithotomy and ureteral stent placement. NSQIP data were used to identify postoperative complications.

Results—We identified 4,287,529 weighted stone hospital admissions, including 12,315 (0.3%) of patients with spina bifida. Compared to those without spina bifida the patients with spina bifida who had urolithiasis were significantly younger (mean age 34 vs 53 years), more likely to have public insurance (72% vs 44%) and renal vs ureteral calculi (81% vs 58%), and undergo percutaneous nephrolithotomy (27% vs 8%). After adjusting for age, insurance, comorbidity, treatment year, surgery type, stone location and hospital factors patients with spina bifida were more likely to have urinary tract infections (OR 2.5), urinary complications (OR 3.1), acute renal failure (OR 1.9), respiratory complications (OR 2.0), pneumonia (OR 1.5), respiratory insufficiency (OR 3.2), prolonged mechanical ventilation (OR 3.2), sepsis (OR 2.7), pulmonary embolism (OR 3.0), cardiac complications (OR 2.4) and bleeding (OR 1.6).

Conclusions—Compared to those without spina bifida the patients with spina bifida who were hospitalized for urolithiasis were younger, and more likely to have renal stones and undergo percutaneous nephrolithotomy. Urolithiasis procedures in patients with spina bifida were associated with a significantly higher risk of in-hospital postoperative complications.

Keywords

urolithiasis; postoperative complications; lithotripsy; ureteroscopy; spina dysraphism

Spina bifida is the most common permanently disabling multisystem birth defect in the United States.^{1,2} Urological complications of SB may include neurogenic bladder, urinary

incontinence, recurrent UTIs, vesicoureteral reflux and urolithiasis. Patients with SB are at well documented increased risk for lower urinary tract stones.^{3,4} However, SB is also associated with an increased risk of upper tract urolithiasis with potentially etiological factors such as urinary stasis, frequent instrumentation, bacteriuria and recurrent UTIs.

Upper tract urolithiasis can be potentially more harmful to patients with SB than to others. Because patients with SB may have neurosensory defects and be at increased risk for bacteriuria, urolithiasis may present later with urosepsis rather than with earlier symptoms such as flank/abdominal pain.⁵⁻⁷ Anecdotally we have noted that managing upper tract calculi is often challenging. Surgical procedures in patients with SB have the potential to be technically difficult since they are often complicated by an abnormal body habitus, skeletal malformation, obesity and aberrant genitourinary anatomy. We hypothesized that treatment related complications are more common in patients with SB but to our knowledge this risk has not been analyzed in any study. Therefore, we compared treatments and related complications of urolithiasis interventions in patients with SB to those in other stone formers using a national database of all ages.

Materials and Methods

Data Source

The NIS is an all-payer database managed at HCUP (Healthcare Cost and Utilization Project) and sponsored by the AHRQ (Agency for Healthcare Research and Quality). NIS data are obtained from a 20% stratified probability sample of American hospitals based on 5 hospital characteristics, including ownership status, number of beds, teaching status, urban/rural location and geographic region. The NIS includes post-stratification discharge weights that may be used to calculate national estimates.⁸

Selection

Patients and covariates—We identified all inpatient hospital encounters between 1998 and 2011 for patients with an ICD-9-CM diagnosis code for upper tract urolithiasis (592.0 and 592.1). Patients with SB were identified based on an ICD-9-CM diagnostic code (741 and 756.17).

Predictor variables were a priori selected based on biological plausibility and/or demonstrated associations in the literature. Covariates included basic patient demographics such as age, gender, race, insurance payer (public vs private), median household income quartiles by ZIP Code™, the Elixhauser comorbidity index,⁹ treatment year, treatment modalities such as SWL (ICD-9-CM 98.51), URS (ICD-9-CM 56.31), PCNL (ICD-9-CM 55.03, 55.04) and ureteral stent placement (ICD-9-CM 59.8), and stone location. We also used hospital level factors such as hospital teaching status (metropolitan nonteaching, metropolitan teaching and nonmetropolitan), geographic region (Northeast, South, Midwest and West) and size.

Outcomes—The primary outcome was immediate postoperative complications during the same admission. Complications were identified by the ICD-9-CM code that most closely corresponded to the complications described by the NSQIP (supplementary Appendix,

<http://jurology.com/>).^{10,11} As the main outcomes we included superficial and deep surgical site infections, peritoneal abscess, ARF, UTI, postoperative urinary complications, postoperative respiratory complications, pneumonia, postoperative respiratory insufficiency, adult respiratory distress syndrome, systemic sepsis, pulmonary embolism, greater than 96-hour mechanical ventilation, cerebrovascular accident, postoperative cardiac complications, acute myocardial infarction, cardiac arrest, bleeding and deep vein thrombus. We also examined in-hospital deaths, LOS and total hospital costs for the admission.

Statistical Analysis

Bivariate analysis was done to compare patient demographics and hospital level characteristics in patients with and without SB who had urolithiasis. We used the Rao-Scott chi-square test, t-test or Wilcoxon rank sum test as appropriate based on data characteristics and distribution. All analyses were weighted using NIS specific estimated weights and covariance matrices. NIS cost-to-charge files were used to convert hospital charges to cost. Due to file availability cost was only estimated from 2001 to 2011.¹² Multivariate logistic regression for NSQIP postoperative complications and in-hospital deaths, and negative binomial regression for LOS and cost were fitted to examine factors, specifically SB, that predicted the outcomes. Generalized estimating equations were used to account for the NIS complex survey design in addition to hospital clustering effects. An α of 0.05 and 95% CIs served as criteria for statistical significance. Analysis was done with SAS® 9.2.

Results

Demographics

We identified a total of 4,287,529 weighted upper tract stone admissions, including 12,315 (0.3%) weighted in patients with SB (table 1). Mean $\pm$ SD patient age was 52.6 ± 0.1 years. Males were 49.5% of the overall cohort.

Compared with those without SB the patients with SB who had urolithiasis were significantly younger (mean age 34.3 ± 0.5 vs 52.6 ± 0.1 years, $p < 0.001$). They were also more likely to have public insurance (71.5% vs 43.5%) and renal calculi (67.7% vs 40.0%), undergo PCNL (26.5% vs 6.0%), be treated at a teaching hospital (67.7% vs 40.0%) and have increased LOS (mean $\pm$ SD 3.7 ± 5.1 vs 1.9 ± 2.0 days, each $p < 0.001$). Mean overall LOS was 1.9 ± 2.0 days.

Postoperative Complications

On bivariate analysis compared to patients without SB who had urolithiasis patients with SB who underwent surgical intervention were more likely to experience postoperative UTIs (OR 2.1), urinary complications (OR 4.7), respiratory complications (OR 2.0), respiratory insufficiency (OR 3.1), sepsis (OR 2.0), prolonged (greater than 96 hours) mechanical ventilation (OR 2.9) and bleeding (OR 2.3, each $p < 0.001$, table 1). There were too few postoperative superficial and deep surgical site infections, peritoneal abscesses and cerebrovascular accident events to perform a thorough analysis.

After adjusting for age, insurance, year, comorbidity, surgery type, stone location, teaching status, hospital region and hospital size patients with SB who underwent urolithiasis procedures were more likely to experience postoperative UTIs (OR 2.5), urinary complications (OR 3.1), ARF (OR 1.9), respiratory complications (OR 2.0), respiratory insufficiency (OR 3.2), sepsis (OR 2.7, each $p < 0.001$), pneumonia (OR 1.5, $p = 0.02$), pulmonary embolism (OR 3.0, $p = 0.03$), prolonged (greater than 96 hours) mechanical ventilation (OR 2.1, $p = 0.002$), cardiac complications (OR 2.4, $p = 0.03$), bleeding (OR 1.6, $p = 0.009$) and increased LOS (RR 1.7, $p < 0.001$, table 2).

SB Economic Impact on Upper Tract Calculi Median LOS in surgical patients with SB was significantly increased compared to that in surgical patients without SB (3.7 vs 1.9 days, $p < 0.001$). This trend was notable even after adjusting for age, insurance, year, comorbidity, stone location, teaching status, hospital region, surgery type and hospital size (RR 1.8, $p < 0.001$).

Compared to patients without SB with stones the patients with SB also had significantly higher median overall inpatient costs per admission (\$9,081 vs \$5,900, $p < 0.001$) and surgical inpatient costs per admission (\$11,396 vs \$7,093, $p < 0.001$). After adjusting for age, insurance, year, comorbidity, stone location, surgery type, LOS, hospital teaching status, hospital region and hospital size SB remained significantly associated with increased hospital cost (RR 1.1, $p < 0.001$).

Discussion

In our analysis patients with SB were at significantly increased risk for complications after urolithiasis compared to patients without SB. As perhaps might be expected, this was particularly true for the genitourinary system (UTI, ARF and urinary complications) and the respiratory system (respiratory complications, respiratory insufficiency, pulmonary embolism and prolonged mechanical ventilation). Other significant postoperative complications included sepsis, bleeding and cardiac complications.

Patients with SB often present with significant bacteriuria, positioning and access challenges, and anatomical abnormalities, which not only make them more susceptible to stone formation but also increase the complexity of and complications related to surgical management.^{7,13} As a result, comprehensive preoperative evaluation, and risk assessment and mitigation should be carefully planned. Specifically patients with SB should be carefully evaluated for respiratory function with a detailed discussion with patients about the higher risk of complications and prolonged mechanical ventilation. The surgical team should also stay alert for any early sign of infection/sepsis with precautionary methods such as more aggressive antibiotic prophylaxis. This recommendation is similar to that in previous studies of patients with spinal cord injury, who were also reported to have an increased complication rate after SWL, URS and PCNL.^{14–17} Since patients with SB and patients with spinal cord injury have many common characteristics, these similar results are not surprising.

Patients with SB and upper tract urolithiasis were significantly younger, and more likely to have renal instead of ureteral calculi, be treated at a teaching hospital and undergo PCNL. Although using these data we could not identify the exact explanation for these associations, we speculate that larger renal stones may develop in patients with SB and they may be treated with PCNL primarily due to infection and/or an abnormal body habitus. Due to complexity and the fact that many if not most patients with SB are routinely treated at multidisciplinary SB clinics, it is not surprising that these surgeries are frequently performed at teaching hospitals.

SB stone admissions were associated with increased LOS and costs compared to nonSB admissions. We hypothesize that a much higher incidence of postoperative complications contributed the most to the longer LOS and higher charge per admission. Ramachandra et al reviewed the upper tract stone population with vs without SB from 2004 to 2011 in the PHIS (Pediatric Health Information Systems) database.⁶ They similarly found that patients with SB who had upper tract stones showed twice the median cost per admission and were at twice the risk for repeat stone procedures.

These findings must be interpreted in the context of study limitations. The NIS represents a 20% stratified sample of American hospital admissions. As such, our reported results may not be generalizable to encounters not in the sample pool. However, the NIS provides meticulous tracking of discharge and hospital weights to minimize the risk of sampling bias. Additionally, the NIS is a large retrospective administrative database that might be affected by miscoding bias. Our analysis relied on the accuracy of the diagnostic and procedure codes in the NIS. While the NIS accuracy level is high for an administrative database, it is possible that at least some portion of our cohort may have been incorrectly coded. For instance, upper tract calculi ICD-9 codes provide an unfair representation of ureteral calculi due to under reporting and, therefore, an overestimation of renal calculi.¹⁸ Furthermore, the NSQIP complications that we identified may represent associated or preoperative conditions and not true postoperative complications because the NIS does not provide temporal relationships among diagnosis codes. For example, patients with SB may be overly categorized with UTI preoperatively with frequent bacteruria due to colonization. Despite these limitations, as noted the NIS database is rigorously monitored and audited for coding accuracy. Therefore, it represents a reasonably reliable panorama of the characteristics of an inpatient urolithiasis cohort.

Because the NIS provides admission based rather than patient based data, it is impossible to track a given patient with time. We could not assess longer term outcomes or whether individuals had multiple admissions. The retrospective nature of the NIS also limits the available data and possible analyses. For example, we had no data on the patient stone burden or on treatment success. We also had no data to enable us to consider relevant surgical history such as lower urinary tract reconstruction with bowel segments. Therefore, we cannot comment on whether clinicians should have a high or a low threshold for definitive stone treatment in patients with SB or whether certain treatment modalities are superior in this population. Further studies are warranted to investigate proper indications for SB urolithiasis procedures that balance the benefit while minimizing the risk of associated complications.

Conclusions

Compared to those without SB the patients with SB who were hospitalized for upper tract urolithiasis were younger, at higher risk for renal than ureteral stones, and more likely to undergo PCNL and be treated at a teaching hospital. They also had a longer LOS and higher costs per admission. Urolithiasis procedures in patients with SB were associated with a significantly higher risk of multiple in-hospital postoperative complications affecting multiple organ systems. Preoperative risk assessments and postoperative care pathways should be comprehensively implemented in patients with SB who undergo urolithiasis treatment.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Supported by National Institute of Diabetes and Digestive and Kidney Diseases Grant K12-DK100024 (JCR).

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Abbreviations and Acronyms

ARF	acute renal failure
LOS	length of stay
NIS	Nationwide Inpatient Sample
NSQIP	National Surgical Quality Improvement Program
PCNL	percutaneous nephrolithotomy
SB	spina bifida
SWL	shock wave lithotripsy
URS	ureteroscopy
UTI	urinary tract infection

Table 1
Characteristics, postoperative complications and outcomes in patients with and without SB treated with urolithiasis surgery

	Total No. (%)	No. SB (%)	No. No SB (%)	p Value
Overall	4,287,529	12,315	4,275,214	
Male	2,120,656	5,521 (44.8)	2,115,135 (49.5)	<0.001
Female	2,161,587	6,819 (55.4)	2,154,768 (50.4)	
Insurance:				<0.001
Public	1,867,188	8,806 (71.5)	1,858,383 (43.5)	
Private	1,942,226	2,895 (23.5)	1,939,332 (45.4)	
Other	465,507	615 (5.0)	464,892 (10.9)	
Treatment yr:				<0.001
1998–2004	1,866,453	4,599 (37.3)	1,861,854 (43.5)	
2005–2011	2,421,076	7,741 (62.9)	2,413,335 (56.4)	
Surgery type:				<0.001
SWL	125,192	477 (3.9)	124,715 (2.9)	
URS	255,638	585 (4.8)	255,054 (6.0)	
PCNL	261,299	3,267 (26.5)	258,032 (6.0)	
Stent	1,399,131	2,766 (22.5)	1,396,365 (32.7)	
Stone location:				<0.001
Kidney	1,717,716	8,332 (67.7)	1,709,384 (40.0)	
Ureter	2,552,526	3,918 (31.8)	2,548,607 (59.6)	
Postop outcome:	2,041,261	7,095	2,034,166	
UTI	256,059	1,525 (12.38)	254,534 (5.95)	<0.001
Urinary complications	10,969	161 (1.31)	10,808 (0.25)	<0.001
ARF	159,687	528 (4.29)	159,160 (3.72)	0.92
Respiratory complications	28,010	183 (1.49)	27,827 (0.65)	<0.001
Pneumonia	37,391	147 (1.19)	37,245 (0.87)	0.30
Respiratory insufficiency	7,393	73 (0.59)	7,320 (0.17)	<0.001
Acute respiratory distress syndrome	1,954	15 (0.12)	1,938 (0.05)	0.23
Systemic sepsis	145,666	876 (7.11)	144,790 (3.39)	<0.001
Pulmonary embolism	2,998	20 (0.16)	2,978 (0.07)	0.15
Greater than 96-hr ventilation	8,799	83 (0.67)	8,716 (0.20)	<0.001
Cardiac complications	6,427	33 (0.27)	6,394 (0.15)	0.22
Cardiac arrest	1,369	14 (0.11)	1,355 (0.03)	0.05
Bleeding	22,145	166 (1.35)	21,978 (0.51)	<0.001
In-hospital death	7,089	20 (0.16)	7,069 (0.17)	0.77

Table 2
Bivariate and multivariate analysis of SB associations with postoperative complications

NSQIP Complications	OR (95% CI)		p Value*
	Unadjusted	Adjusted*	
UTI	2.1 (1.9–2.5)	2.5 (2.1–2.9)	<0.001
Urinary complications	4.7 (3.3–6.5)	3.1 (2.1–4.4)	<0.001
ARF	1.0 (0.8–1.3)	1.9 (1.5–2.4)	<0.001
Respiratory complications	2.0 (1.5–2.8)	2.0 (1.4–2.8)	<0.001
Pneumonia	1.2 (0.8–1.7)	1.5 (1.1–2.2)	0.02
Respiratory insufficiency	3.1 (1.8–5.2)	3.2 (1.9–5.3)	<0.001
Acute respiratory distress syndrome	2.4 (0.6–10.6)	2.2 (0.5–9.4)	0.27
Systemic sepsis	2.0 (1.7–2.4)	2.7 (2.2–3.2)	<0.001
Pulmonary embolism	2.1 (0.8–5.4)	3.0 (1.1–8.2)	0.03
Greater than 96-hr ventilation	2.9 (1.8–4.7)	2.1 (1.3–3.3)	0.002
Cardiac complications	1.6 (0.8–3.4)	2.4 (1.1–5.2)	0.03
Myocardial infarction	0.1 (0.02–1.0)	0.5 (0.1–3.3)	0.44
Cardiac arrest	3.2 (1.0–10.0)	3.1 (0.9–10.4)	0.06
Bleeding	2.3 (1.7–3.3)	1.6 (1.1–2.3)	0.009
Deep vein thrombosis	1.0 (0.1–7.3)	1.4 (0.2–10.9)	0.74
In-hospital death	0.7 (0.3–2.3)	2.0 (0.7–5.5)	0.16

* Adjusted for age, insurance, year, comorbidity, surgery type, stone location, teaching status, and hospital region and bed size.