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Is the Economic Impact and Utilization of Imaging Studies for Pediatric Urolithiasis across the United States Increasing?

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Abstract

Objective—To identify longitudinal trends of economic impact and resource utilization for management of pediatric urolithiasis using national databases.

Methods—We analyzed the 2006-2012 Nationwide Emergency Department Sample and Nationwide Inpatient Sample. We used ICD-9 codes to identify patients (< 18 y) diagnosed with urolithiasis. Diagnostic imaging and surgeries were identified using ICD-9 and CPT codes. We abstracted demographic, imaging, procedure, and charge data. Weighted descriptive statistics were calculated to describe the population's demographics and economic expenditures by clinical setting and year.

Results—In total, 45,333 inpatient admissions (68% females) and 234,559 ED encounters (63% females) were identified. Most patients (84%) were teenagers and the southern region of the United States was the most common geographic region for all encounters (44%). There was no significant trend in number of urolithiasis encounters over the period studied. Utilization of all imaging techniques increased; in particular, CT was used in 23% of encounters in 2006 and 40% in 2012 ($p<0.0001$). The mean charge per ED visit increased by 60% from \$3,645 in 2006 to \$5,827 in 2012 ($p<0.0001$). The mean charge increased for inpatient admissions by 102%, from \$16,399 in 2006 to \$33,205 in 2012 ($p<0.0001$). Total charges increased 72% over the study period from \$230 million in 2006 to \$395 million in 2012 ($p<0.0001$), outpacing medical inflation over the same period.

Conclusions—Charges for pediatric urolithiasis management increased by 65% from 2006-2012 despite stable frequency of patient encounters. The utilization of CT in pediatric urolithiasis increased as well.

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Keywords

urolithiasis; diagnostic imaging; costs; pediatrics

INTRODUCTION

A large body of evidence demonstrates that urolithiasis is increasing in the United States among children and adolescents.¹⁻³ Similar trends in adults have been associated with increased annual healthcare expenditures, amounting to \$2 billion in 2000.⁴ We recently estimated the 2009 combined emergency department (ED) and inpatient charges for pediatric urolithiasis to be \$375 million.⁵ However, data regarding longitudinal economic trends are currently lacking.

Concurrently, the management of pediatric stone disease continues to evolve. In 2007, the American Urological Association and European Association of Urology (EAU) published their joint guidelines for treating children with stone disease. Their consensus was that ureteroscopy (URS) and shock wave lithotripsy (SWL) were both viable options in children, and that the treatment modality must be individualized for the child and stone characteristics.⁶ Similar recommendations occur in the 2016 EAU/European Society for Pediatric Urology Guidelines, which also recommended ultrasound as the first-line imaging modality among children with suspected stone disease.⁷ While URS has often been limited by endoscope size, technological improvements and development of smaller scopes should continue to make this an appealing option. A recent systematic review by Ishii *et al* found an initial URS procedure failed to reach completion in only 2.2% of children.⁸ Meanwhile medical expulsive therapy has gained traction as well.⁹

Our objective was thus to examine nationally representative databases to identify economic and resource utilization trends in urolithiasis among children in the United States. We hypothesized an increase in charges and encounters related to urolithiasis over time.

METHODS

Data Sources

To capture ED and inpatient encounters we used 2 database sources for this study. To identify patients who were evaluated in the ED, we analyzed the Nationwide Emergency Department Sample (NEDS) from years 2006-2012. NEDS is an all-payer database managed by the Healthcare Cost and Utilization Project (HCUP) and sponsored by AHRQ (Agency for Healthcare Research and Quality). Data in NEDS are drawn from a 20% stratified probability sample of hospital based EDs in the United States based on 5 hospital characteristics, including ownership profit status, trauma center designation, teaching status, urban/rural location and hospital region. NEDS contains ED encounters that do not result in hospital admission as well as data on patients seen in the ED who are subsequently admitted to the same hospital. NEDS captures patient demographics, clinical features such as acute and chronic diagnostic codes and procedures performed in the ED, as well as subsequent admission, ED disposition and charge data. HCUP has defined post-stratification discharge

weights that may be used to calculate national estimates. Using these weights NEDS represents 135 million ED visits per year.¹⁰

To capture patients directly admitted to a hospital we analyzed the National Inpatient Sample (NIS) over the same time period. Like NEDS, NIS is also managed by HCUP. Data in NIS are from a 20% stratified probability sample of United States hospitals, including pediatric and general hospitals, based on 5 hospital characteristics, including ownership status, number of beds, teaching status, urban/rural location and geographic region. NIS includes post-stratification discharge weights to estimate 35 million hospital admissions per year.¹¹

Patient Selection

We identified patient encounters in NEDS and NIS using ICD-9 codes for urolithiasis (592.0 or 592.1). We included only patients who were 18 years or younger at the time of their encounter. Using both CPT and ICD-9 procedural codes (**Supplementary Table 1**), we identified encounters involving no surgical intervention, placement of ureteral stent, SWL, URS, or a percutaneous nephrolithotomy (PCNL) procedure. Similarly, CPT and ICD-9 codes (**Supplementary Table 2**) were used to identify diagnostic imaging performed including ultrasound (US) and computerized tomography (CT). Patients were categorized as having no documented imaging study, US, CT, or both US and CT.

Statistical Analysis

Weighted descriptive statistics were calculated as per HCUP recommendations for patient demographics, procedures performed, imaging utilized, hospital charges by setting (ED vs. Inpatient), and year. Wald Chi square and analysis of variance (ANOVA) tests were used where appropriate. We used a linear regression model adjusting for the correlation structure of the data in order to determine whether there was a trend of charges over time. Our outcome of interest was the total charges for each pediatric urolithiasis encounter.

On our initial analysis, charge data was missing in 12% of encounters. In order to avoid under-estimating the charges from these missing encounters, we elected to proceed using imputed values. However, there were differences noted between the group with complete charge data and the group with missing charges in several areas. The step-wise progression of this analysis is provided in **Supplementary Table 3**.

We first imputed 1 data set for the missing charges to compare to encounters with complete data; when imputing missing charges we used Proc MI to impute missing charges based on the HCUP weight (multiplied by 1000 to create an integer value), care setting, year, and hospital region. We then performed multiple imputation using 20 iterations of these imputed data sets to estimate the total charges for missing cases. Using Proc MIAnalyze, we estimated the weighted mean and median for total charges between care settings and year. We calculated confidence intervals for these values when variation existed across imputed data sets. We did not calculate confidence intervals when there was no variation across imputed data sets, *e.g.* when the added imputed values did not shift the overall median charge or when the number of missing values was small for a given group.

As a secondary analysis we computed Mean charge by care setting, year, and procedure from our imputed data sets. When the weighted count for a procedure was less than or equal to 15 we excluded the mean charge from the analysis as per HCUP requirements. We estimated the weighted sum by care setting and year by multiplying the weighted means by their respective weighted counts.

A two-sided alpha of 0.05 was used as criteria for statistical significance. All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC).

RESULTS

Demographics

We identified 279,932 weighted encounters related to urolithiasis over the study period, approximately 84% of which were ED visits. 84% of encounters were for ages 12-18 years, 64% were female, and 44% occurred in hospitals in the south (**Table 1**). There was no significant change in the number of stone diagnoses during inpatient or ED encounters over the study period ($p=0.3240$).

Economic Impact

Table 2 lists the per-encounter economic impact of urolithiasis management by year and clinical setting for all patients. There was a statistically significant increase in both the ED and inpatient charges over the years queried ($p<0.0001$ for trend). As expected, the charges for patients who underwent operative management were significantly higher than for patients discharged without intervention. For example, in 2011 the mean charge for an ED encounter from which the patient was discharged without intervention was \$4,976. In that same year, ED encounters involving stent placement had a mean charge of more than \$15,400, those involving URS had a median charge of \$14,936, and SWL had a mean charge of \$14,921. The total annual sum of ED and inpatient charges increased significantly over the period studied from \$230 million in 2006 to \$395 million in 2012 (**Figure 1**, $p<0.0001$).

Imaging Studies

Table 3 lists the imaging procedures performed. Both CT and US imaging increased in use over the years studied. In 2006, 23% of all urolithiasis encounters involved the use of CT while only 2% utilized US. By 2012, CT use increased to 40% of all encounters while US remained below 10% ($p<0.0001$). Although the percentage of patients imaged with multiple modalities remained low (3% in 2012), this also occurred more frequently as the years progressed.

Operative Intervention

Over the seven years queried, only 2% of ED encounters involved urological procedures compared to 32% of inpatient encounters (**Supplementary Table 4**). The most common procedure performed in both settings was ureteral stent placement (59% of all ED surgeries and 67% of inpatient surgeries). There was no significant temporal change in overall procedure utilization.

DISCUSSION

To our knowledge, this study represents the most comprehensive longitudinal hospital based assessment of the economic impact of pediatric urolithiasis in the United States to date. From 2006 to 2012, the annual charges related to a diagnosis of pediatric urolithiasis in the inpatient and ED settings increased by 72% to \$395 million. In comparison, the total hospital based expenditures in the US over the same time period increased by 48%.¹²

Our findings suggest two driving forces for the increase in charges; price inflation and increased use of CT imaging. The role inflation played can be estimated using the Consumer Price Index published by the United States Department of Labor, Bureau of Labor Statistics. Based on medical care inflation, the charges of \$230 million in 2006 would be expected to increase to \$284 million by 2012; this remains \$111 million less than our estimates, indicating that forces beyond just inflation are playing a role in this increased cost.¹³ The databases lack the level of granularity required to determine precisely how much the charge increase can be attributed to CT use, but all other variables we queried remained stable over the study period; this includes rates of procedures and incidence of encounters. This is consistent with national trends in overall healthcare costs; the drivers of health care spending in the United States are multifactorial and in many disease processes prevalence is not one of them.¹⁴

Our study demonstrates a concerning trend in utilization of ionizing radiation in pediatric patients. We found the use of CT nearly doubled over the years studied. This finding is in keeping with previous studies demonstrating similar increases in CT scan use in children over similar time periods.^{15, 16} While CT is more sensitive for the detection of stones, the benefits must be carefully weighed against the risks in children. There is a relatively small estimated risk of malignancy in children undergoing imaging; that increased risk is directly correlated with increased ionizing radiation dose.¹⁷ Further, in treatment of stone disease, the operative management often requires additional radiation beyond that used in the diagnostic work-up.¹⁸ Smith-Bindman *et al* compared the effectiveness of CT vs. US by randomizing 2,759 adults seen in the ED with suspected nephrolithiasis to US and CT. They found no difference in rates of complications, return visits, or hospitalizations between the groups while 6-month cumulative radiation was significantly lower in patients receiving US.¹⁹ Similarly, Passerotti *et al* found that use of CT rarely had a significant impact on clinical and surgical decision-making by pediatric urologists.²⁰ Recent work by Ziembra *et al* found pediatric EDs implementing a care pathway using US for suspected urolithiasis to be protective; children evaluated in a pathway were 71% less likely to receive CT.²¹

Stent placement was the most common procedure performed in ED and inpatient encounters. This may be due to the acuity of the visit and need for prompt drainage of the collecting system without further manipulation due to infection. We did not find a significant change in the rate at which individual definitive stone procedures are being performed in these settings. This may be explained by shifts in the setting where surgical management occurs; recent data show a 4-fold increase in ambulatory surgery visits,⁴ and care provided in ambulatory surgery centers would not be captured by either database.

Interestingly, our study found a stable incidence of stone encounters in the years studied. This is in contrast to previous studies demonstrating an increased incidence among U.S. children.¹⁻³ These studies primarily focus on years preceding our cohort, but data from freestanding pediatric hospitals showed a plateau of encounters from 2006 to 2008;² our data may represent a continuation of this plateau or, more likely, a shift to outpatient management. Of note, data from the National Health and Nutrition Examination Survey from 2003 to 2012 found a stable prevalence of obesity among U.S. youth.²² Meanwhile, concurrent survey data suggests that efforts to improve diet among adolescents have been successful.²³ Thus, our findings of stable stone prevalence in the inpatient setting mirrors stabilization of external contributors to urolithiasis.

Our findings must be interpreted in the context of the study limitations. First, no nationwide data source provides all-payer economic data on outpatient visits, ambulatory surgery encounters pharmaceuticals, laboratory tests, or outpatient imaging. Thus, procedures commonly performed in an ambulatory setting such as SWL and URS are not represented in our analysis. Furthermore, the indirect costs of stone disease, such as parental missed time at work, are likely to be substantial. However, these data are not available in the sources analyzed for this study nor are they readily estimable based on the available literature. Therefore, these values are likely a significant underestimate of the total economic burden of pediatric stone disease. In 2006 and 2007, the outpatient management of stone disease was estimated to increase total costs by at least 20% in adults.²⁴ No similar estimates for children are available; however, anecdotally we have noted that children seem to be managed in an outpatient manner at least as often as adults. Additionally, NEDS captures charge data but not cost data. Because hospital charges and collections may vary due to regional or local marketplace influence, our findings may represent an inflated estimate from the true cost. Clearly, if the cost-to-charge ratio was available, a more representative estimate would have been calculated.

NIS and NEDS are derived from stratified sampled data. Although HCUP has included more hospitals and states with time (44 at present), these data sets are not wholly representative of all hospitals and regions in the United States. As such, our reported results may not be generalizable to encounters not in the sample pool. Further, NIS and NEDS are large, retrospective administrative databases that may be affected by inaccurate or incomplete coding. Our analysis relies on the accuracy of the diagnostic and procedure codes in the databases and it is possible that at least some portion of our cohort may have been incorrectly coded. However, HCUP rigorously monitors and audits these data for coding accuracy to minimize bias.

It is worth noting for the years 2006-2011 NIS included all discharges from a sample of hospitals participating in HCUP. Beginning in 2012, the NIS was redesigned to include a 20% sample of discharges from all hospitals in HCUP. We believe this redesign does not significantly alter our findings. According to the HCUP redesign report, the modifications were compared to the 2011 database and found to change the charge data by 0.7%.²⁵

Lastly, because NIS and NEDS represent encounter-based data rather than patient-based data, it is impossible to track a given patient across time. We could not assess any accrued

charge estimation beyond each encounter or whether patients may have been accounted for multiple times. However, this lack of continuity should not have a significant impact on our conclusions and total estimates. Whether a hospital bill or imaging utilized was accrued by a single patient admitted twice or by two patients who were each admitted once would not change the total charges nor procedures and imaging performed.

CONCLUSION

From 2006 to 2012, the overall economic impact of inpatient and ED pediatric urolithiasis encounters increased by 72% while the frequency of encounters remained stable. A significant driver of this increase appears to be greater reliance on CT imaging in the pediatric population. Despite evidence that non-irradiating imaging such as US may be comparable (and arguably are preferable) to CT in acute stone episodes, the use of CT continues to increase.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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ABBREVIATIONS

AHRQ	Agency for Healthcare Research and Quality
CPT	Current Procedural Terminology
CT	Computerized Tomography
EAU	European Association of Urology
ED	Emergency department
HCUP	Healthcare Cost and Utilization Project
ICD-9	International Classification of Diseases, 9 th Edition
NEDS	Nationwide Emergency Department Sample
NIS	Nationwide Inpatient Sample
PCNL	Percutaneous nephrolithotomy
SWL	Shock wave lithotripsy
URS	Ureteroscopy
US	Ultrasound

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Figure 1.
Total Annual Charges

Table 1

Patient demographics

	Inpatient (%) (n=45,333)	ED (%) (n=234,559)	Total (n=279,932)	p value
Age category (yrs)				<0.0001
Infant (<1)	1,455 (3.2%)	1,384 (0.6%)	2,840	
Toddlers (1-2)	871 (1.9%)	1,051 (0.4%)	1,920	
Preschool (3-5)	1,569 (3.5%)	2,835 (1.2%)	4,405	
School age (6-12)	8,383 (18.5%)	26,682 (11.4%)	35,065	
Adolescent (13-18)	33,057 (72.9%)	202,649 (86.4%)	235,705	
Gender				<0.0001
Female	30,673 (68.0%)	148,364 (63.3%)	179,035	
Male	14,461 (32.0%)	86,195 (36.7%)	100,655	
Race/Ethnicity				<0.0001
White	26,288 (57.9%)	*		
Black	2,188 (4.8%)	*		
Hispanic	6,347 (14%)	*		
Asian/Pacific Islander	468 (1.0%)	*		
Native American	216 (0.5%)	*		
Other	1,597 (3.5%)	*		
Unknown	8,829 (18.3%)	*		
Insurance				<0.0001
Public	16,949 (37.5%)	70,951 (30.3%)	87,900	
Private	26,250 (58.0%)	152,278 (65.1%)	178,525	
Other	2,053 (4.5%)	10,636 (4.5%)	12,690	
Discharge quarter				0.0002
January–March	11,323 (25.0%)	55,015 (23.5%)	66,335	
April–June	11,151 (24.6%)	55,415 (23.6%)	66,565	
July–September	11,719 (25.9%)	64,983 (27.7%)	76,700	
October–December	11,110 (24.5%)	59,154 (25.2%)	70,265	
Median ZIP Code				0.0371
Income				
Q1	12,833 (28.9%)	59,970 (26.0%)	72,800	
Q2	11,538 (26.0%)	63,238 (27.2%)	74,775	
Q3	10,720 (24.2%)	57,632 (25.0%)	68,350	
Q4	9,288 (20.9%)	49,963 (21.6%)	59,250	
Hospital region				0.1580
Northeast	8,191 (18.1%)	35,108 (15.0%)	43,295	

	Inpatient (%) (n=45,333)	ED (%) (n=234,559)	Total (n=279,932)	p value
Midwest	10,857 (23.9%)	56,727 (24.2%)	67,585	
South	18,588 (41.0%)	104,115 (44.4%)	122,700	
West	7,699 (17.0%)	38,651 (16.5%)	46,350	

* Denotes data elements not available in NEDS

Table 2

Yearly mean charge per encounter (95% CI) by setting

	ED	Inpatient
2006	\$3,645 (\$3,458 - \$3,832)	\$16,399 (\$12,996 - \$19,802)
2007	\$4,252 (\$4,029 - \$4,475)	\$21,154 (\$16,654 - \$25,654)
2008	\$4,737 (\$4,494 - \$4,980)	\$22,264 (\$19,223 - \$25,305)
2009	\$5,182 (\$4,938 - \$5,426)	\$32,135 (\$24,101 - \$40,169)
2010	\$5,379 (\$5,122 - \$5,637)	\$26,791 (\$22,588 - \$30,993)
2011	\$5,125 (\$4,886 - \$5,365)	\$26,241 (\$22,614 - \$29,869)
2012	\$5,827 (\$5,535 - \$6,119)	\$33,205 (\$28,688 - \$37,721)

Table 3

Imaging utilization by year (p<0.0001)

	Total Encounters	US (%)	CT (%)	US+CT (%)
2006	38,345	649 (1.7%)	8,706 (22.7%)	298 (0.8%)
2007	39,360	521 (1.3%)	8,892 (22.6%)	293 (0.7%)
2008	40,300	836 (2.1%)	12,036 (29.9%)	393 (1%)
2009	40,120	1,226 (3.1%)	12,686 (31.6%)	371 (0.9%)
2010	41,330	1,587 (3.8%)	13,690 (33.1%)	558 (1.3%)
2011	40,665	2,220 (5.5%)	13,838 (34%)	796 (2%)
2012	39,810	2,505 (6.3%)	14,762 (37.1%)	1,023 (2.6%)