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Cumulative incidence of outcomes and urologic procedures after augmentation cystoplasty

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Abstract

Objective—Augmentation cystoplasty (AC) is a major surgery that can be associated with long-term morbidity. This study aimed to describe the cumulative incidence of outcomes and urologic procedures in a large cohort of children who underwent AC, identify significant sources of morbidity, and to evaluate baseline factors associated with outcomes of interest.

Methods—Children ≤18 years who underwent AC in the Pediatric Health Information System from 1999 to 2010 were included. All follow-up encounters up to June 2012 were included. Cumulative incidences for 15 outcomes and urologic procedures were calculated using non-informative censoring. Sensitivity analyses were performed to determine effect of censoring assumptions and including hospitals without complete datasets. As an exploratory analysis, baseline patient factors were evaluated for associations with outcomes and urologic procedures of interest using multivariable Cox proportional hazards models adjusted for clustering by hospital.

Results—2831 AC patients were identified. Based on cumulative incidence calculations and sensitivity analyses; the cumulative incidence ranges of outcomes and procedures at 1, 3, 5, and 10 years were calculated. Examples of 10-year cumulative incidence ranges are given for the following outcomes and procedures: bladder rupture (2.9–6.4%), small bowel obstruction (5.2–10.3%), bladder stones (13.3–36.0%), pyelonephritis (16.1–37.1%), cystolithopaxy (13.3–35.1%), and reaugmentation (5.2–13.4%). The development of chronic kidney disease was strongly associated with a diagnosis of lower urinary tract obstruction (HR 13.7; 95% CI 9.4–19.9). Bladder neck surgery and stoma creation at time of AC were associated with an increased hazard of bladder rupture (HR 1.9; 95% CI 1.1–3.3) and bladder stones (HR 1.4; 95% CI 1.1–1.8) respectively.

Conclusions—Outcomes of interest and urologic procedures after AC are common. Results from this large cohort can be used to counsel patients and families about expectations after AC. Pyelonephritis, chronic kidney disease, further reconstructive surgery, and calculus disease appear

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Conflict of interest
None.

to cause significant morbidity. Collaborative efforts are needed to further reduce morbidity in this patient population.

Keywords

Augmentation cystoplasty; Bladder augmentation; Neurogenic bladder; Spina bifida; Bladder exstrophy

Introduction

Augmentation cystoplasty (AC) is a major reconstructive surgery performed in children. Indications include neurogenic and non-neurogenic bladder dysfunction when conservative therapies such as anticholinergic medications and clean intermittent catheterization (CIC) have failed to achieve acceptable urinary continence and/or bladder pressures low enough to avoid renal damage.

Long term outcomes following AC have been reported in single center series [1–4]. The incidence of outcomes can range widely between studies. For example, the incidence of bladder calculi has been reported between 10% and 52% [2,5–7]. A limited number of studies have reported on the risk of spontaneous bladder perforation and chronic kidney disease (CKD) [3,8–10]. In addition, there have been studies that have raised concern about increased risk of malignancy following AC [11,12]. Because of the risk of complications and potential increased risk of malignancy, some groups have suggested utilizing AC more conservatively [13,14]. Recent studies have reported that use of AC has been decreasing in the UK and the USA [13,15]. The cause for decline is unknown but is likely multifactorial with potential reasons including declining incidence of congenital abnormalities such as spina bifida, increased availability and earlier use of anticholinergics and clean intermittent catheterization, more conservative use of AC, and others [13,15].

In the adult urological literature, complications and outcomes after surgery as reported by single center series are often different (usually lower) from those of administrative datasets [16,17]. For guiding informed decision making, it is important to provide patients and families with realistic expectations and administrative data can be useful for this purpose. The goals of our study include to determine the cumulative incidence of outcomes and subsequent urologic procedures after AC in a large administrative dataset; to identify potential outcomes or procedures that are a significant source of morbidity and could potentially be targets for intervention and/or prevention; and to perform an exploratory analysis for patient factors associated with risk of subsequent outcomes or procedures of interest.

Methods

Dataset

Following institutional review board approval, data were accessed with the Children′s Health Corporation of America (CHCA; Shawnee Mission, KS) Pediatric Health Information System (PHIS). The PHIS is an administrative and billing dataset from 43 free standing children′s hospitals in the USA that contains information from inpatient

admissions, ambulatory medical and surgical short stay areas, and emergency department visits. PHIS data are assessed for accuracy through joint efforts of the CHCA, an independent data manager (Thomson Healthcare, Durham, NC), and participating hospitals and has been described previously [18]. A patient will have a unique identifier at a single institution and can be followed longitudinally.

Patient identification and diagnosis

Patients who underwent AC between January 1999 and December 2010 were identified by ICD-9 procedure code (57.87). Patients were considered to have a primary diagnosis of bladder exstrophy epispadias complex (BEEC) if listed (753.2, 752.62) in any encounter. A primary diagnosis of spina bifida (SB) was assigned if listed (741 .0×, 741.9×, 756.17) in any encounter and BEEC was not. A primary diagnosis of congenital lower urinary tract obstruction (LUTO) was assigned if listed (753.6, 596.0) in any encounter and BEEC and SB were not. A primary diagnosis of cloacal or anal malformation (CAM) was assigned if listed (751.5, 751.2) in any encounter and BEEC, SB, and LUTO were not. A primary diagnosis of neurogenic bladder unspecified (NB) (596.5×, 344.61) was assigned if listed in any encounter and BEEC, SB, LUTO, and CAM were not. A primary diagnosis of “other” was assigned if the above five diagnoses were not listed in any encounter.

Identification of outcomes and procedures

All subsequent encounters (inpatient admissions, ambulatory medical and surgical short stays, and emergency department visits) up to June 2012 were included. Outcomes and procedures were identified by ICD-9 diagnosis or procedure code search. ICD-9 procedure codes were used over CPT codes because ICD-9 codes are available in all years of the PHIS. For chronic kidney disease (CKD), all patient encounters prior to AC were evaluated to ensure it was not present before AC. Appendix A shows the list of ICD-9 codes used to identify outcomes and procedures.

Statistical analysis

The cumulative incidences of outcomes and procedures were calculated by utilizing the longitudinal nature of the dataset. For primary analysis, non-informative censoring was assumed.

Multivariable Cox proportional hazards models were used to look for baseline factors associated with outcomes or procedures of interest (bladder calculi, pyelonephritis, bladder rupture, CKD, reaugmentation, subsequent bladder neck surgery). A separate model was used for each outcome or procedure. Covariates were selected a priori and included: age at AC, race, diagnosis, bladder neck surgery at time of AC, and creation of stoma at time of AC. A shared frailty model was used to account for clustering by hospital. Global Schoenfeld goodness of fit tests were performed for each model and if significant, log–log plots of the significant covariates were performed and evaluated visually for clinically significant trends.

Sensitivity analyses

With non-informative censoring, because outpatient clinic visits are not in the PHIS dataset, a patient would not contribute person-time to the cumulative incidence calculation if they did not have any PHIS encounters but were still following up as an outpatient. Therefore, non-informative censoring is expected to overestimate the cumulative incidence. Not all hospitals in the PHIS dataset contribute ER visit data or outpatient surgery data, and including those hospitals in the calculations would potentially lead to underestimation of the cumulative incidence.

The first sensitivity analysis evaluated the effect of non-informative censoring assumptions. In this analysis, all patients were assumed to have outpatient clinic follow-up until June 30, 2012. The cumulative incidence with this method is expected to be underestimated, as some patients would have had outcomes at other hospitals not in the PHIS dataset. The second sensitivity analysis evaluated the effect of including hospitals with incomplete PHIS datasets. In this analysis, we excluded patients from hospitals that did not have data for inpatient admissions, ER visits, and outpatient procedures.

Results

Table 1 shows AC patient characteristics. There were 2831 patients identified and 2074 (73%) had follow-up encounters. Of the patients with follow-up encounters, the median length of follow-up time was 3.3 years. The most common diagnosis was SB (55%). At time of AC, 16.8% of patients had a bladder outlet procedure code (57.87, 59.5, 58.93, 59.4) and 39.0% of patients had a procedure code (47.99, 47.9, 47.91, 57.88) consistent with stoma creation.

Cumulative incidence of outcomes and urologic procedures

Table 2 shows the 1-, 3-, 5-, and 10-year cumulative incidence of outcomes and urologic procedures assuming non-informative censoring. Outcomes with the highest cumulative incidence included pyelonephritis, bladder calculi, and chronic kidney disease (CKD). Procedures with the highest cumulative incidence included cystolithotomy, percutaneous nephrolithotomy (PCNL), and re-augmentation. No patients with a diagnosis of bladder cancer were identified.

Sensitivity analysis

Table 3 shows the results from the two sensitivity analyses performed. Assuming all patients had outpatient clinic follow-up until June 30, 2012 resulted in lower cumulative incidences. Excluding hospitals that did not have data for inpatient admissions, ER visits, and outpatient surgeries did not have a substantial impact on the cumulative incidence with the majority of the 10-year cumulative incidences within ±1% of our primary analysis.

Baseline factors associated with outcomes and procedures

Table 4 shows results of the multivariable Cox proportional hazards models for selected outcomes and procedures. Diagnoses of LUTO, CAM, and NB were associated with increased hazard of CKD diagnosis. Diagnoses of BEEC, LUTO, and CAM were associated

with increased hazard of pyelonephritis. Having a bladder neck surgery at time of AC was associated with an increased hazard of subsequent bladder rupture (HR1.9,95% CI 1.1 –3.3) and undergoing an additional bladder neck surgery (HR1.8,95%CI 1.2–2.7).Having a stoma created at time of AC was associated with increased hazard of subsequent bladder calculi (HR 1.4, 95% CI 1.1–1.8).

Discussion

The results demonstrate outcomes of interest and urologic procedures are common following AC. The observed cumulative incidence ranges were comparable with prior reports from single center studies [1–8,10,19,20]. Bladder calculi, pyelonephritis admissions, and additional reconstructive surgeries appear to be outcomes that cause significant morbidity and we recommend further research to decrease morbidity.

In our exploratory analysis, baseline factors were associated with an increased risk of certain outcomes and subsequent procedures. The principal diagnosis was strongly associated with risk of CKD. A diagnosis of LUTO, which would include posterior urethral valves, was strongly associated with subsequent CKD diagnosis (HR 13.7, 95% CI 9.7–19.9). Developing CKD is likely related to primary pathology (LUTO) and not caused by AC itself. In some patients, AC is performed to prevent development or progression of CKD. A bladder neck surgery at time of AC was associated with almost twice the hazard of subsequent bladder rupture, which supports an observation from a single center series [3]. Bladder neck surgery at time of AC was associated with 1.8 times the hazard of subsequent bladder neck surgery which likely reflects the less than 100% success rates of bladder neck surgery in patients who need them. Having a stoma created at time of AC was associated with an increased hazard of bladder stones, as has been reported in single center series and hypothesized to be from incomplete bladder emptying [2,4,21].

Our sensitivity analysis demonstrates that cumulative incidence calculations using the PHIS dataset are highly dependent upon censoring assumptions. This demonstrates an important weakness of the PHIS dataset in determining the true cumulative incidence because of lack of outpatient follow-up visits. The true cumulative incidence is expected to be somewhere between results that assumed non-informative censoring and the sensitivity analysis that assumed all patients had outpatient follow-up to June 30, 2012. For example, the true 10-year cumulative incidence for lower tract stones would be expected to be in the range of 13–36% and for small bowel obstruction in the range of 5–10%. Although there is uncertainty in the true cumulative incidence of the outcomes, this does not mean that the results are not useful. We derived a range of cumulative incidences for several outcomes and urologic procedures in which the true cumulative incidence for this large cohort is likely to be. This can be helpful in counseling for expectations after AC as ranges are often used to describe the risk of subsequent outcomes in clinical practice.

Given the morbidity seen after AC in this cohort, a patient who undergoes AC should be seen as in a pathological state with morbidities that should be minimized. Known effective prevention strategies should be utilized. Regarding bladder calculi, studies have suggested that irrigation regimens decrease the risk significantly [22]. Regarding upper urinary tract

issues, there appears to be an increased incidence of upper tract stones and upper tract surgeries (PCNL and URS) in this population compared with the general population. Perhaps more focus on kidney stone prevention methods such as increasing urine volume and decreasing salt intake should be emphasized in these patients. A 10-year re-augmentation cumulative incidence between 5.2% and 13.4% is similar to prior published series but more study may be needed to decrease this incidence [4]. The risk of pyelonephritis and subsequent CKD is high in this population and certain diagnoses are at increased risk. Working to prevent or minimize morbidity for these patients is important.

The results point out the need to identify methods to minimize AC morbidity. Why do different centers have different reported rates of outcomes [1–3,10,23,24]? Are they managing patients differently or do they have different surgical techniques? Does a dedicated spina bifida clinic or provider affect outcomes? The PHIS dataset does not permit identification of hospitals or contain information to answer these questions. However, results from a deidentified survey sent to participating PHIS hospitals regarding AC patient management coupled with patient outcome results from PHIS dataset may identify practices associated with decreased morbidity. We recommend participation in this type of patient outcomes research as has been performed in other fields [25].

We hoped to demonstrate a method of using the longitudinal information in the PHIS dataset to study outcomes. Although there are limitations of administrative datasets, the PHIS dataset does give the opportunity to analyze outcomes in a cohort much larger than single center series. Given that the PHIS dataset has longitudinal follow-up, use of person-time for reporting cumulative incidence is a more accurate and complete description of outcomes than only reporting the proportion of patients having the outcome. Because of incomplete follow-up data in the PHIS as a result of lack of outpatient visits, we recommend performing sensitivity analyses for the cumulative incidence calculations as we have done. Accounting for clustering by hospital is preferred in multivariable models using hierarchical datasets.

Study limitations

There are limitations with calculating the cumulative incidence with PHIS. The main limitation is that outpatient visits are not included. Therefore, a patient doing well after AC without any PHIS encounters would not contribute any person-time to the cumulative incidence calculation. Assuming non-informative censoring, as we did in our primary analysis, would overestimate the cumulative incidence. Alternatively, assuming that all patients had follow-up until the end of the study unless they died would underestimate the true cumulative incidence because some patients do have outcomes or procedures at non-PHIS hospitals. Presenting both cumulative incidence calculations is more informative than presenting just one, even though both methods have limitations. It is possible that some outcomes such as pyelonephritis were managed in the outpatient setting and the PHIS data would only be able to capture the incidence of admissions and ER visits for pyelonephritis. A patient may have an outcome at another hospital and then, subsequently, follow-up back at the PHIS hospital and that outcome would not be captured and would affect calculations. In addition, patient migration and inability to determine disease severity limit the applicability of the results.

Utilizing ICD-9 diagnosis and procedure codes for identifying patient diagnosis and subsequent outcomes and procedures is only as reliable and as detailed as the coding. For example, we are unable to tell if patients had an ileal or gastric augmentation and the neurogenic bladder unspecified group is likely a heterogeneous group. In addition, the ICD-9 procedure codes for bladder neck repair are likely not included for every patient who underwent a bladder neck repair and the codes for stoma creation at time of AC would not correlate exactly with how many patients had a catheterizable channel created at time of AC.

For many outcomes and procedures studied, it is not possible to state that AC was the cause or if it is even associated because there was no control group in this study. In fact, some outcomes (e.g. CKD) are part of the natural history of underlying diagnosis and AC may be performed to prevent progression.

Conclusions

Outcomes of interest and urologic procedures after AC are common. Results from this large cohort can be used to counsel patients and families about expectations after AC. Given the incidence of pyelonephritis admissions, CKD, further reconstructive surgery, and calculus disease; collaborative efforts to reduce these costly and potentially morbid outcomes are needed.

Abbreviations

AC	augmentation cystoplasty
CKD	chronic kidney disease
PHIS	Pediatric Health Information System
LUTO	lower urinary tract obstruction
CAM	cloacal or anal malformation
NB	neurogenic bladder unspecified
BEEC	bladder exstrophy epispadias complex
SB	spina bifida

Appendix A

Appendix A

Outcome and urologic procedure ICD-9 codes and descriptions.

Outcomes	ICD-9 diagnosis codes and descriptions
Bladder rupture	596.6 Rupture of bladder, nontraumatic; 867.1 bladder and urethra injury, with open wound into cavity
Bladder stone	594 Calculus of lower urinary tract;
594.0 calculus in diverticulum of bladder;	594.1 other calculus in bladder; 594.2 calculus in urethra; 594.8 other lower urinary tract calculus; 594.9 calculus of lower urinary tract, unspecified
Upper tract stone	592 Calculus of kidney and ureter; 592.0 calculus of kidney; 592.1 calculus of ureter; 592.9 urinary calculus, unspecified

Outcomes	ICD-9 diagnosis codes and descriptions
Pyelonephritis	590 Infections of kidney; 590.0 chronic pyelonephritis; 590.1 acute pyelonephritis; 590.2 renal and perinephric abscess; 590.3pyeloureteritiscystica; 590.8 other pyelonephritis or pyeonephrosis, not specified as acute or chronic; 590.9 infection of kidney, unspecified
Small bowel obstruction	560 intestinal obstruction without mention of hernia; 560.0 intussusception; 562.0 volvulus; 560.81 intestinal or peritoneal adhesions with obstruction; 560.89 other intestinal obstruction; 560.9 unspecified intestinal obstruction
Bowel fistula	998.6 Persistent postoperative fistula; 569.81 fistula of intestine, excluding rectum and anus
CKD	585 CKD; 585.1 CKD stage 1; 585.2, CKD stage 2; 585.3, CKD stage 3; 585.4 CKD stage 4; 585.5 CKD stage 5; 585.6 end stage renal disease; 585.9 CKD, unspecified
Death	Mortality indicator in PHIS dataset
Urologic surgery	ICD-9 procedure codes and descriptions
Ureteroscopy	56.31 ureteroscopy
PCNL	55.04 percutaneous nephrostomy with fragmentation; 55.03 percutaneous nephrostomy without fragmentation
Cystolithopaxy	57.0 transurethral clearance of bladder calculus; 57.19cystolithotomy
Reaugmentation	57.87 Reconstruction of urinary bladder (Augmentation)
Stoma surgery	46.4 revision of intestinal stoma; 46.40 revision of intestinal stoma, NOS; 46.41 Revision of stoma of small intestine; 46.42 Repair of pericolostomy hernia; 46.43 Other revision of stoma of large intestine; 96.24 Dilation and manipulation of enterostomy stoma; 47.9 Other operations on appendix; 47.99 Anastomosis of appendix; 47.91 Appendicostomy, 57.88 anastomosis of bladder to intestine NOS
Bladder neck surgery	57.85 cystourethroplasty and plastic repair of bladder neck; 59.5 retropubic urethral suspension; 59.4 suprapubic sling operation; 58.93 Implantation of artificial urinary sphincter
Bladder neck injection	59.72 Injection of implant into urethra and/or bladder neck

CKD = chronic kidney disease; PCNL = percutaneous nephrolithotomy.

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Table 1

Augmentation cystoplasty patient characteristics.

Total number	2831
Number with follow-up	2074 (73%)
Median years of follow-up[a]	3.3 (1.5–6.1)
Median number of encounters[a]	5 (3–10)
Female	53.4%
Race	
White	46.8%
Black	7.8%
Hispanic	18.8%
Other/missing	26.7%
Diagnosis	
Spina bifida	55.1%
BEEC	12.6%
LUTO	2.9%
CAM	4.5%
NB	13.8%
Other	11.2%
Mean age in years (SD) at AC	9.1 (4.7)
Bladder neck surgery at AC	16.8%
Catheterizable stoma at AC	39.3%
Median LOS in days[a]	8 (6–10)

AC = augmentation cystoplasty; NB = neurogenic bladder unspecified; BEEC = bladder exstrophy epispadias complex; LUTO = lower urinary tract obstruction; CAM = cloacal or anal malformation; LOS = length of stay.

[a]Data presented as median (25–75 percentile).

Table 2

Cumulative incidence of outcomes and urologic procedures at 1, 3, 5, and 10 years assuming non-informative censoring.

	1 year *N* = 1698	3 year *N* = 1118	5 year *N* = 701	10 year *N* = 101
Outcomes				
Bladder rupture	1.1 (0.7–1.6)	3.5 (2.7–4.6)	4.1 (3.2–5.3)	6.4 (4.9–8.3)
Bladder stone	2.3 (1.7–3.1)	10.9 (9.4–12.7)	17.7(15.6–20.3)	36.0 (31.1–41.4)
Upper tract stone	0.9 (0.5–1.4)	3.4 (2.5–4.4)	6.0 (4.7–7.5)	15.5 (11.7–20.3)
Pyelonephritis	8.9 (7.7–10.3)	16.9 (15.2–18.9)	23.3 (21.1–25.7)	37.1 (32.6–41.9)
Small bowel obstruction	3.6 (2.8–4.5)	6.0 (5.0–7.2)	8.1 (6.8–9.7)	10.3 (8.4–12.6)
Bowel fistula	0.7(0.4–1.3)	2.0 (1.4–2.9)	3.0 (2.2–4.2)	5.9 (4.0–8.3)
Chronic kidney disease	3.5 (2.7–4.4)	7.0 (5.8–8.4)	9.5 (8.0–11.3)	20.3 (16.4–25.1)
Death	0.2 (0.1–0.6)	0.6 (0.3–1.2)	1.2 (0.7–2.0)	1.8 (1.1–3.1)
Procedures				
Ureteroscopy	0.4 (0.2–0.8)	0.9 (0.6–1.5)	1.5 (1.0–2.4)	2.4(1.4–4.0)
PCNL	1.1 (0.7–1.6)	2.9 (2.2–3.9)	4.2 (3.2–5.5)	8.8 (6.4–12.1)
Cystolithopaxy	3.2 (2.5–4.1)	11.3 (9.8–13.0)	17.7(15.6–20.0)	35.3 (30.4–40.7)
Reaugmentation	1.8 (1.3–2.5)	5.2 (4.2–6.4)	7.3 (5.9–8.9)	13.4(10.6–16.9)
Stoma surgery	5.6 (4.6–6.7)	13.0 (11.4–14.8)	16.9 (15.0–19.0)	27.1 (23.4–31.3)
Bladder neck surgery	2.9 (2.2–3.8)	7.1 (6.0–8.5)	9.6 (8.1–11.3)	12.6 (10.5–15.2)
Bladder neck injection	4.5 (3.7–5.6)	8.8 (7.5–10.3)	11.5 (9.9–13.4)	17.2 (14.6–20.2)

Results presented as cumulative incidence, % (95% CI).

PCNL = percutaneous nephrolithotomy.

Table 3

Sensitivity analysis for cumulative incidence calculations.

Sensitivity analysis 1: assumed all had follow-up until June 30, 2012				
	1 year ***N*** **= 2800**	**3 year** ***N*** **= 2424**	**5 year** ***N*** **= 1977**	**10 year** ***N*** **= 800**
Outcomes				
Bladder rupture	0.7(0.5–1.1)	2.0 (1.5–2.6)	2.2 (1.7–2.9)	2.9 (2.3–3.7)
Bladder stone	1.5 (1.1–2.0)	6.1 (5.2–7.0)	8.8 (7.8–10.0)	13.3 (11.8–14.8)
Upper tract stone	0.6 (0.4–0.9)	1.8 (1.4–2.4)	2.9 (2.3–3.6)	4.9 (4.0–6.0)
Pyelonephritis	5.9 (5.1–6.9)	10.2 (9.2–11.4)	12.9 (11.8–14.3)	16.1 (14.6–17.7)
Small bowel obstruction	2.5 (2.0–3.1)	3.8 (3.1–4.6)	4.6 (3.9–5.5)	5.2 (4.4–6.2)
Bowel fistula	0.5 (0.3–0.8)	1.2 (0.9–1.7)	1.6 (1.2–2.2)	2.3 (1.7–3.0)
Chronic kidney disease	5.3 (4.5–6.2)	7.7 (6.8–8.8)	9.0 (8.0–10.1)	11.5 (10.3–12.9)
Death	0.1 (0.0–0.4)	0.3 (0.2–0.7)	0.6 (0.3–0.9)	0.7(0.5–1.2)
Procedures				
Ureteroscopy	0.3 (0.1–0.5)	0.5 (0.3–0.9)	0.8 (0.5–1.2)	1.0 (0.6–1.5)
PCNL	0.7(0.5–1.1)	1.7 (1.3–2.2)	2.2 (1.7–2.8)	3.2 (2.5–4.0)
Cystolithopaxy	2.1 (1.6–2.6)	6.3 (5.5–7.3)	9.0 (7.9–10.1)	13.2 (11.7–14.7)
Reaugmentation	1.1 (0.8–1.6)	2.9 (2.4–3.6)	3.8 (3.1–4.6)	5.2 (4.4–6.3)
Stoma surgery	3.6 (3.0–4.4)	7.6 (6.7–8.7)	9.2 (8.2–10.4)	11.7(10.5–13.2)
Bladder neck surgery	1.9 (1.4–2.5)	4.2 (3.5–5.0)	5.2 (4.4–6.1)	6.0 (5.0–7.0)
Bladder neck injection	2.9 (2.3–3.6)	5.1 (4.3–6.0)	6.2 (5.4–7.2)	7.8 (6.7–8.9)
Sensitivity analysis 2: excluded hospitals without complete datasets				
	1 year ***N*** = 1503	3 year ***N*** = 996	5 year ***N*** = 633	10 year ***N*** = 93
Outcomes				
Bladder rupture	1.0 (0.7–1.6)	3.5 (2.7–4.7)	3.9 (3.0–5.1)	5.8 (4.4–7.8)
Bladder stone	2.3 (1.8–3.3)	11.5 (10.0–13.4)	18.6 (16.3–21.1)	37.6 (32.5–43.2)
Upper tract stone	0.8 (0.5–1.4)	3.2 (2.3–4.3)	5.5 (4.3–7.2)	15.1 (11.3–20.0)
Pyelonephritis	8.8 (7.5–10.3)	16.8 (14.9–18.8)	22.9 (20.5–25.4)	35.9 (31.1–41.0)
Small bowel obstruction	3.3 (2.5–4.2)	5.5 (4.5–6.8)	7.4(6.1–9.0)	9.4(7.4–11.7)
Bowel fistula	0.8 (0.5–1.3)	2.2 (1.5–3.1)	3.1 (2.3–4.3)	5.8 (3.9–8.6)
Chronic kidney disease	3.5 (2.7–4.6)	7.0 (5.7–8.5)	9.7(8.1–11.6)	19.6 (15.7–24.5)
Death	0.2 (0.1–0.6)	0.6 (0.3–1.2)	1.1 (0.6–2.0)	1.8 (1.0–3.2)
Procedures				
Ureteroscopy	0.4 (0.2–0.9)	0.9 (0.5–1.5)	1.5 (0.9–2.5)	2.5 (1.4–4.2)
PCNL	1.1 (0.7–1.7)	2.7 (2.0–3.7)	3.7 (2.8–5.0)	8.5 (6.0–12.1)
Cystolithopaxy	3.4 (2.6–4.4)	11.8 (10.2–13.7)	18.3 (16.0–20.8)	35.5 (30.6–41.0)
Reaugmentation	1.6 (1.1–2.3)	4.6 (3.6–5.8)	6.7 (5.4–8.4)	12.9 (10.0–16.5)
Stoma surgery	5.1 (4.1–6.3)	10.4 (8.8–12.1)	13.3 (11.5–15.3)	21.8 (18.2–25.9)
Bladder neck surgery	2.8 (2.0–3.6)	6.6 (5.4–8.0)	8.8 (7.3–10.6)	10.9 (8.9–13.2)
Bladder neck injection	5.2 (4.2–6.4)	9.6 (8.1–11.3)	12.6 (10.8–14.6)	18.7(15.9–22.0)

Results presented as cumulative incidence, % (95% CI).

PCNL = percutaneous nephrolithotomy.

Table 4

Baseline factors associated with outcomes or procedures of interest.[a]

	Outcome or procedure					
Baseline factors	Bladder rupture	Bladder stone	Pyelonephritis	CKD	Reaugment after AC	BNR after AC
Diagnosis						
Spina bifida	[reference]	[reference]	[reference]	[reference]	[reference]	[reference]
BEEC	0.7 (0.3–1.6)	1.7(1.2–2.3)	1.4(1.1–1.9)	1.5 (0.9–2.2)	1.7(1.02–2.7)	1.9 (1.2–2.9)
LUTO	1.8 (0.6–5.4)	0.7(0.3–1.6)	2.6 (1.7–4.0)	13.7 (9.4–19.9)	1.6 (0.7–3.9)	0.2 (0.03–1.6)
CAM	_[b]	0.9 (0.5–1.6)	2.7(1.9–3.9)	4.6 (3.0–7.0)	1.2 (0.6–2.8)	1.3 (0.6–2.7)
NB	0.8 (0.3–1.7)	0.8 (0.5–1.2)	1.3 (0.9–1.8)	3.5 (2.5–4.9)	1.3 (0.7–2.3)	0.3 (0.2–0.8)
Other	_[b]	0.2 (0.04–0.7)	1.4(0.9–2.2)	2.9 (1.8–4.7)	0.9 (0.4–2.2)	0.2 (0.1–0.9)
Race						
Caucasian	[reference]	[reference]	[reference]	[reference]	[reference]	[reference]
Black	0.9 (0.4–2.1)	0.9 (0.6–1.3)	1.0 (0.7–1.5)	0.9 (0.6–1.5)	0.7(0.3–1.6)	1.2 (0.6–2.3)
Hispanic	0.5 (0.2–1.1)	0.8 (0.6–1.1)	1.7(1.4–2.2)	1.9 (1.4–2.6)	0.6 (0.4–1.1)	0.8 (0.5–1.3)
Other/unknown	1.3 (0.7–2.4)	1.1 (0.8–1.5)	1.5 (1.2–2.0)	1.7(1.3–2.4)	1.1 (0.7–1.8)	1.2 (0.7–1.8)
BNS at AC	1.9 (1.1–3.3)	1.2 (0.9–1.6)	0.8 (0.6–1.07)	0.4 (0.3–0.7)	1.1 (0.7–1.8)	1.8 (1.2–2.7)
Stoma at AC[c]	1.1 (0.6–1.8)	1.4(1.1–1.8)	0.7 (0.6–0.9)	0.8 (0.5–1.1)	1.3 (0.8–1.9)	1.5 (1.1–2.3)
Age at AC	1.02 (0.97–1.09)	1.06 (1.03–1.09)	1.02 (0.99–1.04)	1.04 (1.01–1.07)	0.95 (0.90–0.99)	0.95 (0.91–1.00)

Data presented as hazard ratio (95% CI).

NB = neurogenic bladder unspecified; BEEC = bladder exstrophy epispadias complex; LUTO = congenital lower urinary tract obstruction; CAM = cloacal or anal malformation; BNS = bladder neck surgery; AC = augmentation cystoplasty.

[a] Multivariate Cox proportional hazard analysis performed for each outcome or procedure and adjusted for all factors (i.e. diagnosis, race, BNS at AC, Stoma at AC, and Age at AC) listed in table.

[b] No observations in this group.

[c] Stoma at AC refers to ICD-9 codes consistent with antegrade continence enema stoma or bladder catheterizable stoma.