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Contemporary multicenter outcomes of continent cutaneous ileocecocystoplasty in the adult population over a 10-year period: A Neurogenic Bladder Research Group study

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Abstract

Aims: Evidence is sparse on the long-term outcomes of continent cutaneous ileocecocystoplasty (CCIC). We hypothesized that obesity, laparoscopic/robotic approach, and concomitant surgeries would affect morbidity after CCIC and aimed to evaluate the outcomes of CCIC in adults in a multicenter contemporary study.

Methods: We retrospectively reviewed the charts of adult patients from sites in the Neurogenic Bladder Research Group undergoing CCIC (2007-2017) who had at least 6 months of follow-up. We evaluated patient demographics, surgical details, 90-day complications, and follow-up surgeries. the Mann-Whitney U test was used to compare continuous variables and χ^2 and Fisher's Exact tests were used to compare categorical variables.

Results: We included 114 patients with a median age of 41 years. The median postoperative length of stay was 8 days. At 3 months postoperatively, major complications occurred in 18 (15.8%), and 24 patients (21.1%) were readmitted. During a median follow-up of 40 months, 48 patients (42.1%) underwent 80 additional related surgeries. Twenty-three patients (20.2%) underwent at least one channel revision, most often due to obstruction (15, 13.2%) or incontinence (4, 3.5%). Of the channel revisions, 10 (8.8%) were major and 14 (12.3%) were minor. Eleven patients (9.6%) abandoned the catheterizable channel during the follow-up period. Obesity and laparoscopic/robotic surgical approach did not affect outcomes, though concomitant surgery was associated with a higher rate of follow-up surgeries.

Conclusions: In this contemporary multicenter series evaluating CCIC, we found that the short-term major complication rate was low, but many patients require follow-up surgeries, mostly related to the catheterizable channel.

KEYWORDS

augmentation cystoplasty, bladder, enterocystoplasty, neurogenic bladder

1 | INTRODUCTION

Patients with bladder dysfunction due to underlying neurologic conditions such as spinal cord injury (SCI), multiple sclerosis (MS), or spina bifida often have high-pressure storage of urine and/or inability to efficiently empty the bladder. As a result, those with neurogenic bladder (NGB) are often dependent on anticholinergic medications or bladder botulinum toxin injection to improve bladder storage, and clean intermittent catheterization (CIC) or an indwelling catheter to empty the bladder.[1-3]

When patients with NGB have persistent symptoms of incontinence or show signs of upper tract deterioration refractory to conservative therapies, surgical management with augmentation cystoplasty is a potential treatment.[4] Augmentation cystoplasty is a reconstructive surgery in which the bladder is opened and a patch of the bowel is sutured to the bladder to increase the bladder volume and decrease bladder pressure and spasticity.[5] Different segments of the gastrointestinal tract have been used for augmentation, such as the stomach, small bowel, cecum, and colon.[4,6-8] In addition to augmentation cystoplasty, some patients also undergo concomitant catheterizable channel creation to facilitate ease of CIC. In cases on concomitant catheterizable stoma creation, the continent cutaneous ileocecocystoplasty (CCIC) is a technique that uses a continuous segment of the bowel: the bladder is augmented with the detubularized cecum and right colon while the terminal ileum is tapered and used for the catheterizable channel with the ileocecal valve functioning as a natural continence mechanism.[6] One particular advantage to CCIC is in obese individuals, where the parallel mesentery to the terminal ileum arising from the right colic artery allows for the creation of a relatively long and straight channel that can reach the umbilicus in most individuals regardless of body mass index (BMI).

There are very few studies looking at outcomes and complications of augmentation cystoplasty with a catheterizable channel in the adult population with most being single-site, small cohort studies spanning long time periods where management of NGB has changed substantially. We chose to evaluate the complications of CCIC bladder augmentation in the adult population in a multicenter study with a secondary objective to compare outcomes between different subgroups of CCIC patients (obese vs nonobese; those undergoing concomitant surgeries compared to those undergoing CCIC alone; and laparoscopic/robotic-assisted vs open approach). While these subgroups have been the focus of studies of other urologic patient populations (ie, bladder cancer), most studies evaluating augmentation cystoplasty patients with NGB have not specifically examined the effect of these variables on outcomes. We hypothesized that patients who were obese or underwent concomitant surgeries had more complications and required more follow-up surgeries.

2 | METHODS

2.1 | Surgical technique

The CCIC technique was first described by Sarosdy in 1992 as a way to augment the native bladder while creating a catheterizable channel using only one bowel segment.[6] Approximately 10 to 15 cm of the cecum and ascending colon and 10 cm of terminal ileum are harvested en bloc. The ileal segment is tapered via staple reduction over a 12Fr to 14Fr catheter to create the catheterizable channel and the ileocecal valve is reinforced with imbricating sutures to create the continence mechanism. This portion of the surgery is identical to creation of an Indiana or right colon pouch.[9] The cecum and ascending colon are then detubularized and anastomosed to the bivalved bladder with the channel brought through the abdominal wall, often at the umbilicus. The surgery can be performed through an open or laparoscopic/robotic approach. Open surgery is through a full laparotomy midline incision. Laparoscopic/robotic cases are typically performed using hand-assist or robotic assistance for mobilization of the right colon, with the remainder of the surgery performed open through a lower midline or Pfannenstiel incision.

2.2 | Data collection

After institutional review board approval, we retrospectively reviewed the charts of 131 patients from seven

sites in the Neurogenic Bladder Research Group (NBRG) who underwent CCIC between January 2007 and October 2017. Data were collected in a centralized database using the Research Electronic Data Capture (REDCap) platform. We included all patients aged 18 years or older at the time of surgery who had at least 6 months of postoperative follow-up and who had not previously undergone augmentation cystoplasty or catheterizable channel creation. We excluded any centers that had fewer than four patients that met the inclusion criteria. Twenty-two patients (five from the Houston Methodist Hospital and 17 from the University of Utah) in this study have had previous outcomes reported for CCIC, while 92 patients were new.[10,11]

2.3 | Patient characteristics

Patient demographic information was collected and included: age at surgery, gender, BMI, age-adjusted Charlson Comorbidity Index, etiology of disease, bladder management before CCIC, and history of bladder botulinum toxin injection.

2.4 | Perioperative variables

Details of the surgery were collected and included: operative time, modality (open vs laparoscopic/robotic with mostly a limited supplemental pelvic Pfannenstiel incision), concomitant surgeries, and operative times.

2.5 | Outcomes

The *primary outcome* was 90-day major complications (defined as Clavien-Dindo[12] complications grade III-V), including death and readmissions. The *secondary outcome* was surgery in the total follow-up period. We defined follow-up surgeries related to CCIC as all urologic surgeries, incisional or parastomal hernia repair, and surgeries related to bowel obstruction, such as lysis of adhesions. We also included colostomy, since colostomy could be related to changes in bowel function. We then compared outcomes between different subgroups of CCIC patients to examine if obesity (defined as BMI $\geq 30\,kg/m^2$), concomitant surgical procedures at the time of CCIC, or surgical approach (laparoscopic/robotic assistance) led to an increase in major complications, readmissions, or follow-up surgeries. Lastly, a subanalysis was performed comparing patients who had 90-day major complications vs those who did not to see if there were any variables associated with complications.

Procedures per person-year of follow-up was calculated by taking the total number of follow-up surgeries—including surgeries that were performed more than once in a particular patient—and dividing it by the cumulative follow-up time in years for all of the patients.

2.6 | Statistical analysis

All statistical analyses were conducted using STATA 15 (Stata Corp, College Station, TX) with a two-sided significance level set at $P < .05$. Medians and interquartile ranges (IQRs) were reported for continuous variables, as appropriate. the Mann-Whitney U test was used to compare continuous variables. The χ^2 and Fisher's Exact tests were used to compare proportions of categorical variables.

3 | RESULTS

3.1 | Patient characteristics

A total of 114 patients from six sites were included; one center was excluded since it only had one patient that met the inclusion criteria. An additional 16 patients were excluded for the following reasons: follow-up less than 6 months (n = 12), previous augmentation cystoplasty (n = 2), and previous catheterizable channel (n = 2). Patients in this cohort underwent CCIC augmentation cystoplasty due to poor bladder compliance or refractory detrusor overactivity. Most patients in the study had a diagnosis of the neurogenic bladder (98, 86%) with SCI, MS, and spina bifida being the most common etiologies (Table 1).

3.2 | Perioperative variables

The median operative time was 313 minutes (IQR 258-382). The hospital length of stay ranged from 3 to 105 days and the median length of stay was eight days (IQR 7-12). Almost half of the cohort (45%) had a concomitant surgery at the time of CCIC creation (Table 1).

3.3 | Outcomes

In our cohort, 18 patients (15.8%) had a 90-day major complication (Clavien-Dindo grade III-V) with 10 patients readmitted due to the major complication and the other eight patients experiencing the major complication during the initial postoperative admission. A total of 24 patients (21.1%) were readmitted within 90-days of

TABLE 1 Patient characteristics, type of surgery, and postoperative outcomes

Age, y, median (IQR)	41.1	30.0-53.7
Male, n (%)	36	31.6
Body mass index, kg/m^2, median (IQR)	27.5	23.1-32.8
Age-adjusted Charlson Comorbidity Index,		
0-1	43	37.7
2-3	59	51.8
4+	12	10.5
Etiology of disease, n (%)		
Spinal cord injury	52	45.6
Spina bifida	8	7.0
Multiple sclerosis	14	12.3
Other neurologic	24	21.1
Non-neurologic	16	14.0
History of bladder botulinum toxin injection, n (%)	31	27.2
Bladder management before augmentation, n (%)[a]		
Indwelling urethral catheter	27	23.7
Indwelling suprapubic tube	28	24.6
Clean intermittent catheterization	39	34.2
Voiding/leaking/condom catheter	25	21.9
Modality, n (%)		
Open	87	76.3
Laparoscopic/robotic	27	23.7
Patients who had a concomitant surgery, n (%)	51	44.7
Operative time, min, median (IQR)	313	258-382
Hospital length of stay, d, median (IQR)	8	7-12
90-d major complication (Clavien-Dindo grade III-V), n (%)	18	15.8
90-d readmission, n (%)	24	21.1
90-d mortality, n (%)	0	0
Bladder management after augmentation, n (%)		
Indwelling catheter (urethra or channel)	7	6.1
Indwelling suprapubic tube	2	1.8
Clean intermittent catheterization	103	90.3
Other [b]	2	1.8
Postoperative follow-up, m, median (IQR)	39.6	22.6-60.8
Patients with follow-up surgeries, n (%)	48	42.1

[a]Five patients had more than one.
[b]Perineal urethrostomy; cystectomy and urinary diversion.

surgery; for 14 patients, readmission was due to minor complications. There were no patients who died within 90-days of surgery. Of the 18 patients who had major complications within 90 days of surgery, intraabdominal abscess (4, 3.5%) and bowel leak (4, 3.5%) were the most common reasons. Other 90-day complications can be found in Table 2.

During a median follow-up period of 39.6 months (IQR 22.6-60.8), 48 patients (42.1%) underwent 80 surgeries. The number of procedures per person-year of follow-up was 0.20 (80 procedures/399.01 person-years). Twenty-three patients (20.2%) underwent at least one catheterizable channel revision, including minor channel revision (replacement or revision above the abdominal fascia, injection of a bulking agent, or stomal dilation) and major channel revision (replacement or revision below abdominal fascia). One of those patients underwent injection of a bulking agent and a channel revision below the fascia. Fifteen patients (13.2%) required revisions due to obstruction of the channel while four patients (3.5%) had revisions due to channel incontinence. Eleven patients (9.6%) had abandonment of the channel (ie, did not perform CIC through the channel). Four of these patients had previously undergone channel revisions (one minor revision and three major revisions). Some reasons for the abandonment of the channel included the inability to catheterize, noncompliance, and channel complications. The most common non-channel related surgery was the treatment of bladder stones (11 patients, 9.6%). Table 3 lists all of the follow-up surgeries and channel revision outcomes.

3.4 | Subgroup analysis

3.4.1 | Body mass index

We compared 69 nonobese patients (60.5%) with 45 obese patients (39.5%). Surgical outcomes in the two groups were not significantly different (Table 5).

3.4.2 | Concomitant surgeries

A total of 51 patients (44.7%) underwent a total of 74 concomitant surgeries at the time of CCIC, while 63 patients (55.3%) underwent CCIC alone. Table 4 lists all of the concomitant surgeries. The most common concomitant surgeries were pubovaginal sling (23 patients, 20.2%) and omental flap (23 patients, 20.2%). Patients who had concomitant surgeries more commonly underwent an open surgery (44, 86.2% vs 43, 68.2%, P = .03) with significantly longer operative times (368 minutes vs 273 minutes, P < .001). The concomitant surgery group had significantly more follow-up surgeries (27, 52.9% vs 21, 33.3%, P = .04) (Table 5).

TABLE 2 The 90-d major complications by grade

Grade	Total (%)	Complication
IIIa	7 (6.1)	Intraabdominal abscess requiring drain (3)
		Bowel leak requiring drain (1)
		Urine leak requiring drain (1)
		Prolonged ileus requiring esophagogastroduodenoscopy (1)
		Pleural effusion requiring chest tube (1)
IIIb	9 (7.9)	Bowel leak requiring exploratory laparotomy (3)
		Urine leak/fistula requiring exploratory laparotomy (2)
		Intraabdominal abscess requiring exploratory laparotomy (1)
		Small bowel obstruction requiring gastrostomy tube (1)
		Small bowel obstruction requiring exploratory laparotomy (1)
		Pyelonephritis with stent migration requiring stent change (1)
IV	2 (1.8)	Respiratory distress requiring ICU admission (1)
		Altered mental status requiring ICU admission (1)

3.4.3 | Surgical modality

In the cohort, open surgery was the most common approach to CCIC creation (n = 87, 76.3%) while 27 patients (23.7%) had a laparoscopic or Da Vinci robot-assisted surgery. When comparing those undergoing open surgery compared to a laparoscopic/robotic approach, the open group had significantly more concomitant surgeries than the laparoscopic/robotic group (44, 50.6% vs 7, 25.9%, P = .03). No other differences in terms of 90-day readmission, 90-day complications, or long-term surgical revisions were seen between groups, though the laparoscopic/robotic group did have significantly shorter follow-up time compared to the open group (24.4 months vs 50.8 months, P < .001) (Table 5).

3.4.4 | Major complications

A final subgroup analysis was performed comparing the 18 patients (15.8%) who had 90-day major complications (Clavian-Dindo grade III-V) with those who did not have complications (96, 84.2%). There were no baseline patient characteristics or perioperative variables associated with major complications. Patients who had major complications had a longer hospital length of stay (11 days vs 8 days), but this difference was not statistically significant (P = .07). Expectedly, patients who had major complications were also more likely to have a 90-day readmission (10, 55.6% vs 14, 14.6%, P < .001).

4 | DISCUSSION

We found that given the procedural complexity of CCIC, postoperative morbidity, readmission, and mortality were low. Long-term, however, a significant number of patients needed future operations with the majority of these operations (23 patients, 20.2%) involving revision of the catheterizable channel.

Patients in the study, had a 90-day major complication rate of 15.8%. We did not evaluate minor complications since they were not reliably or consistently documented across the different institutions given the retrospective nature of the study. In a review of 20 studies on the outcomes of augmentation cystoplasty in adults, eight studies reported postoperative major complication rates ranging from 1.7% to 12.5%, though the postoperative period was not specified and the review only looked at studies of augmentation cystoplasty without catheterizable channels.[13] In a previous study of 31 patients who underwent CCIC, we reported an overall 30-day complication rate of 51.6% and a 30-day major complication rate of 16.1%, which is comparable to our 90-day complication rate in this expanded cohort.[11] Khavari et al[10] evaluated 34 CCIC patients and had a short-term complication rate of 17.6%, which were all minor complications that occurred during the immediate postoperative hospital stay.

In addition to complications and readmissions within 90 days of surgery, another risk following CCIC is the need for longer term follow-up surgeries and revisions. In our cohort, 42.1% of patients required further surgery during a median follow-up of 39.6 months.

TABLE 3 Follow-up surgeries and channel revisions

Patients with follow-up surgeries, n (%)	48 (42.1)
Total number of surgeries[a]	80
Bladder stone, n (%)	11 (9.6)
Ureteral or kidney stone, n (%)	3 (2.6)
Bladder neck closure, n (%)	4 (3.5)
Artificial urinary sphincter, n (%)	2 (1.8)
Suprapubic tube, n (%)	3 (2.6)
Perineal urethrostomy, n (%)	1 (0.9)
Cystectomy, urinary diversion, n (%)	1 (0.9)
Ventral hernia repair, n (%)	6 (5.3)
Parastomal hernia, n (%)	7 (6.1)
Colostomy, n (%)	3 (2.6)
Other abdominal surgery, n (%)[b]	5 (4.4)
Catheterizable channel revision, n (%)	23 (20.2)
Injection of bulking agent	2 (1.8)
Dilation of channel	3 (2.6)
Superficial revision (above fascia)	9 (7.9)
Deep revision (below fascia)	9 (7.9)
Full replacement	1 (0.9)
Reason for channel intervention, n (%)	
Obstruction	15 (13.2)
Leakage	4 (3.5)
Other[c]	4 (3.5)
Abandonment of channel, n (%)	11 (9.6)

Notes: One patient underwent two different types of channel revision; Eight patients underwent multiple surgeries of the same type.

[a]Sixteen patients underwent more than one type of surgery.

[b]Exploratory laparotomy; excision of fistula tract; three unknown.

[c]Complex wound infection; bowel leak; facilitate ventral hernia.

TABLE 4 Concomitant surgeries

Patients who had a concomitant surgery, n (%)	51 (44.7)
Total number of surgeries	74
Pubovaginal sling, n (%)	23 (20.2)
Mesh urethral sling, n (%)	3 (2.6)
Bladder neck closure, n (%)	6 (5.3)
Bladder neck reconstruction, n (%)	2 (1.8)
Omental flap, n (%)	23 (20.2)
Muscle flap, n (%)	2 (1.8)
Umbilical hernia repair, n (%)	5 (4.4)
Ventral hernia repair, n (%)	2 (1.8)
Parastomal hernia repair, n (%)[a]	1 (0.9)
Ureteral reimplant, n (%)	1 (0.9)
Colostomy, n (%)	2 (1.8)
Antegrade continence enema, n (%)	1 (0.9)
Other, n (%) [b]	3 (2.6)

Note: Prosthesis reservoir removal.

[a]Patient with prior colostomycolostomy.

[b]Drainage of pelvic abscess; resection of pelvic mass; penile.

The number of procedures per person-year of follow-up was 0.20, which is higher than other studies where rates of 0.04 procedures per person-year in pediatric patients and 0.01 surgeries per person-year in adults was noted.[14,15] Similar to our findings, where cystolitholapaxy was a very common surgery after CCIC, bladder stone removal was the most common surgery in both of these studies.[14,15]

Although stone procedures were common in our cohort, the majority of the surgeries were revisions of the catheterizable channel (23 patients, 20.2%). A study of pediatric patients who had undergone augmentation cystoplasty with a catheterizable channel showed that complications related to the channel were dependent on the type of channel.[16] Rates of channel abandonment and revisions were highest in patients with a reconfigured ileum (Monti), lower in patients with an appendicovesicostomy (Mitrofanoff), and lowest in patients with a tapered ileum and reinforced ileocecal valve (CCIC).[16] In a similar study, O'Connor et al[17] evaluated the outcomes of different types of catheterizable channels and found that 39% of patients underwent a major channel revision during a median follow-up period of 60 months. The channel incontinence and revision rates were higher in the ileal group than in the appendiceal group, though most of the ileal group had Monti channels and none of them underwent a CCIC.[17] Two different long-term series evaluating patients that underwent ileocystoplasty with either a Mitrofanoff or Monti catheterizable channel had sustainable continent catheterizable channels with a low rate of revision surgery (1 out of 13 patients, 7.7%, median follow-up 44 months[18]; 4 out of 29 patients, 13.8%, median follow-up 66 months[19]). Of note, neither of these studies specifically listed the type of channel for patients requiring revisions. In our earlier report, we showed that CCIC has superior outcomes compared with other types of channels.[11] In fact, 50% of patients who underwent a tunneled channel creation (ie, Mitrofanoff, Monti) required a subsequent procedure related to leakage or stenosis compared to 13% of patients who underwent a CCIC during a median follow-up of 16 months.[11] The rate of channel revision in our current study was approximately 20%, but our median follow-up period was more than double at 40 months. Of note, the vast majority of revisions were due to obstruction rather than leakage, which is likely attributed to the efficacy of the reinforced ileocecal valve as a continence mechanism.

TABLE 5 Comparing patient characteristics and outcomes in different subgroups based on obesity, undergoing concomitant surgeries, surgical modalities, and having major complications

	BMI <30	BMI 30+	P value	No concomitant surgery	Concomitant surgery	P value	Open	Laparoscopic/robotic	P value	Major complications	No Major complications	P value
No. patients (%)	69 (60.5)	45 (39.5)		63 (55.3)	51 (44.7)		87 (76.3)	27 (23.7)		18 (15.8)	96 (84.2)	
Age, y, median (IQR)	39.1 (28.9-52.8)	47.4 (34.7-55.9)	.28	40.2 (30.0-53.3)	43.5 (29.1-55.9)	.85	40.0 (30.2-52.8)	50.7 (29.1-57.9)	.32	43.1 (28.8-53.3)	41.1 (31.1-53.8)	.90
Male, n (%)	28 (40.6)	8 (17.8)	.01	21 (33.3)	15 (29.4)	.20	27 (31.0)	9 (33.3)	.82	7 (38.9)	29 (30.2)	.47
Body mass index, kg/m², median (IQR)			.73	27.0 (22.0-33.3)	28.9 (23.3-32.8)	.27	27.4 (23.1-33.0)	27.4 (23.1-32.0)	.90	29.5 (23.1-31.3)	27.4 (23.2-33.0)	.97
Age-adjusted Charlson Comorbidity Index, median (IQR)	2 (1-2)	2 (1-3)	.73	2 (0-2)	2 (1-3)	.19	2 (1-3)	1 (0-3)	.20	2 (1-2)	2 (1-3)	.75
Modality, n (%)			.75			.03						.31
Open	52 (75.4)	35 (77.8)		43 (68.3)	44 (86.3)					14 (77.8)	73 (76.0)	
Laparoscopic/robotic	17 (24.6)	10 (22.2)		20 (31.7)	7 (13.7)					4 (22.2)	23 (24.0)	
Concomitant surgery, n (%)	31 (44.9)	20 (44.4)	.96				44 (50.6)	7 (25.9)	.03	9 (50.0)	42 (43.7)	.62
Operative time, min, median (IQR)[a]	308 (255-370)	336 (290-435)	.25	273 (240-321)	368 (325-428)	<.001	332 (272-382)	300 (235-420)	.10	337 (298-380)	309 (255-393)	.34
Hospital length of stay, d, median (IQR)	8 (6-12)	9 (7-11)	.31	8 (6-11)	9 (7-12)	.15	8 (7-11)	9 (6-15)	.72	11 (7-19)	8 (7-11)	.07
Postoperative follow-up, m, median (IQR)	45.7 (23.2-59.2)	36.6 (19.1-61.6)	.40	36.9 (23.0-61.6)	41.2 (14.9-59.2)	.71	50.8 (23.9-64.2)	24.4 (12.7-41.2)	<.001	42.8 (26.5-59.2)	39.3 (21.4-61.2)	.88
90-d major complication (Clavien grade III-V), n (%)	11 (15.9)	7 (15.6)	.99	9 (14.3)	9 (17.7)	.80	14 (16.1)	4 (14.8)	.57			
90-d readmission, n (%)	15 (21.7)	9 (20.0)	.99	14 (22.2)	10 (19.6)	.73	20 (23.0)	4 (14.8)	.27	10 (55.6)	14 (14.6)	<.001
Patients with follow-up surgeries, n (%)	28 (40.6)	20 (44.4)	.68	21 (33.3)	27 (52.9)	.04	38 (43.7)	10 (37.0)	.54	9 (50.0)	39 (40.6)	.46
Hernia repair (ventral or parastomal), n (%)	5 (7.3)	5 (11.1)	.51	4 (6.4)	6 (11.8)	.34	9 (10.3)	1 (3.7)	.45	2 (11.1)	8 (8.3)	.66
All channel revisions n (%)	15 (21.7)	8 (17.8)	.64	10 (15.9)	13 (25.5)	.20	18 (20.7)	5 (18.5)	.81	5 (27.8)	18 (18.8)	.36
Major channel revisions, n (%)	6 (8.7)	4 (8.9)	.99	5 (7.9)	5 (9.8)	.75	9 (10.3)	1 (3.7)	.45	3 (16.7)	7 (7.3)	.19

(Continues)

TABLE 5 (Continued)

	BMI <30	BMI 30+	P value	No concomitant surgery	Concomitant surgery	P value	Open	Laparoscopic/robotic	P value	Major complications	No Major complications	P value
Minor channel revisions, n (%)	9 (13.0)	5 (11.1)	.99	5 (7.9)	9 (17.6)	.15	10 (11.5)	4 (14.8)	.74	2 (11.1)	12 (12.5)	.99
Reason for channel intervention: obstruction, n (%)	10 (14.5)	5 (11.1)	.78	7 (11.1)	8 (15.7)	.58	11 (12.6)	4 (14.8)	.75	3 (16.7)	12 (12.5)	.70
Reason for channel intervention: leakage, n (%)	2 (2.9)	2 (4.4)	.65	2 (3.2)	2 (3.9)	.99	4 (4.6)	0 (0)	.57	0 (0)	4 (4.2)	.99
Abandonment of channel, n (%)	7 (10.1)	4 (8.9)	.99	5 (7.9)	6 (11.8)	.54	10 (11.5)	1 (3.7)	.45	2 (11.1)	9 (9.4)	.68

[a]Data missing for 17 patientspatients.

In our first subgroup analysis, we evaluated the effect of BMI in adult patients on augmentation cystoplasty. Obese patients may need CCIC or other types of augmentation cystoplasty with a catheterizable channel because of challenges with catheterizing due to their body habitus.[20] However, creation of a catheterizable channel is technically much more difficult in obese patients and may be prone to a higher channel-related complication rate. In a study of 385 patients with a history of augmentation cystoplasty during childhood, Husmann found that obese patients performing CIC through the urethra were more likely to have problems with CIC compared with obese patients performing CIC through an abdominal stoma.[20] However, studies of obese patients with stomas due to bladder cancer, neurogenic bladder, or myelodysplasia demonstrate that they are more likely to develop complications, such as parastomal hernia, stomal retraction, and stomal stenosis.[21-23] Our results did not show any effect of obesity on the outcomes of CCIC; this may be due to one of the technical advantages of CCIC, in which the bowel segment has a relatively parallel mesenteric blood supply to the terminal ileum, allowing for the creation of a lengthy straight catheterizable channel even in obese patients.

In our second subgroup analysis, we found that patients who had concomitant surgeries at the time of CCIC were significantly more likely to require follow-up surgeries. Two-thirds of the patients who had concomitant surgeries underwent a bladder outlet procedure, such as a pubovaginal sling, mesh urethral sling, or bladder neck closure. In line with our results, Welk et al[15] found that a simultaneous continence procedure at the time of augmentation cystoplasty was a significant predictor of future surgical procedures. The need for a concomitant bladder outlet procedure at the time of augmentation cystoplasty has not been well established. Among the different sites involved in this study, the manner in which the urologists decided when to perform concomitant continence procedures varied. Some urologists preferred to perform a bladder outlet surgery at a later stage only if necessary,[24] while others based their decision for a concomitant procedure on the severity of the patient's incontinence, presence or lack of trabeculation or hydronephrosis, and urodynamic findings.[10]

Our third subgroup analysis evaluated the effect of surgical modality on the outcomes of CCIC. Augmentation cystoplasty is often performed through an open midline incision. With the advent of new technology and in an attempt to reduce morbidity, minimally invasive approaches have become more common. Gill et al[25] first described a partial laparoscopic approach for augmentation cystoplasty in 2000 and Elliott et al[26] described a complete laparoscopic approach in 2002. Cohen et al[27]

compared the outcomes of open augmentation cystoplasty with robotic augmentation cystoplasty in a pediatric cohort and found that complications, hospital length of stay, blood loss, and narcotic use between the two groups were comparable, though the operative time in the robotic cohort was significantly longer. Similarly, we did not find any differences in outcomes between the open and the laparoscopic/robotic assisted approaches. The median operative times between the two groups were not significantly different. Thus, our study shows that CCIC through a minimally invasive approach is feasible and can be equally efficient in experienced hands.

There are several limitations to this study. We focused on surgical morbidity rather than functional outcomes, such as bladder capacity and degree of continence, since preoperative and postoperative urodynamics data were not available for all patients. Many studies in the literature already show that the majority of patients who undergo augmentation cystoplasty for NGB experience an improvement in bladder capacity, compliance, and continence, but what is lacking are large cohort studies that evaluate short- and long-term complications of one particular type of augmentation cystoplasty, such as CCIC.[13,19,28,29] Since we conducted a retrospective chart review study, we were unable to accurately assess certain long-term complications of augmentation cystoplasty, such as metabolic disturbances, renal failure, and symptomatic urinary tract infection. We were also unable to assess patient-reported quality-of-life measures and outcomes, such as bowel dysfunction, degree of urinary incontinence, ease of bladder management/CIC, and overall satisfaction with urinary outcomes. Although a multicenter study has the advantage of providing a larger cohort, in this particular case, it adds to the heterogeneity of surgical techniques and preoperative and postoperative management. Due to the number of sites involved in the study and differing numbers of patients per site, a subset analysis comparing outcomes between sites was not feasible. There is certainly a risk of sampling bias in this study, though all of the participating sites utilized consecutive patient selection to minimize this bias. We also had a small sample size for subgroup analyses, which could explain why there were few significant differences between subgroups. Despite these limitations, this is the largest adult series in the literature evaluating the long-term morbidity outcomes of CCIC. Since the median follow-up period for this study was a little more than 3 years, it is important to continue tracking the complications and follow-up surgeries of these patients to evaluate longer-term outcomes, as we may find that a majority of patients will need a follow-up surgery by 10 or 20 years following the original augmentation cystoplasty. A randomized controlled-trial of different augmentation cystoplasty techniques would not be logistically feasible, but a prospective study with well-defined outcomes that incorporated patient-reported outcomes would be beneficial to the field.

5 | CONCLUSIONS

In this multi-center, contemporary study of CCIC, we found that the short-term major complication rate was low, but many patients required follow-up surgeries, mostly related to the catheterizable channel.

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