Received: 18 September 2023 | Accepted: 26 November 2023

DOI: 10.1002/nau.25350

INVITED REVIEW

Neurourology Urodynamics | SUFU Society of Urodynamics, Female Pelvic Medicine & Urogenital Reconstruction | WILEY

Continent catheterizable urinary channels: Lessons for lifelong urological care from a comparative analysis of very long-term complications and revision-free survival of three different types

Pepijn D. Polm | **Coen H. H. Christiaans** | **Pieter Dik** | **Michel I. A. Wyndaele** | **Laetitia M. O. de Kort**

Department of Urology, UMC Utrecht, Utrecht, The Netherlands

Correspondence
Pepijn D. Polm, Department of Urology, UMC Utrecht, Heidelberglaan 100, 3584 CX Utrecht, The Netherlands.
Email: p.d.polm@umcutrecht.nl

Abstract

Introduction: Continent catheterizable channels (CCC) provide an alternative route to the bladder in both pediatric and adult patients. This study compared very long-term complications and revision-free survival of three different CCC techniques: appendicovesicostomy (AVS), ileum (Monti), and tubularized bladder flap (TBF).

Materials and Methods: A retrospective cohort study was performed. Data from adult patients with CCC under surveillance at our academic tertiary referral urological center in 2020 and 2021 were collected. Both patients who acquired the CCC as a child and as an adult were included. The primary outcome was revision-free survival of the three CCC types. The secondary outcome was the prevalence of complications requiring surgical revision. Revisions were categorized as major (open subfascial or complete revisions) and minor (open suprafascial or endoscopic).

Results: We included 173 CCCs (AVS 90, Monti 51, TBF 32). Median follow-up was 12.4 years (4.8–18). Mean revision-free survival was 162 ± 13 months, with no significant difference between the three types. Ninety-two individual CCCs (53%) required surgical revision and a total of 157 surgical revisions were performed. Seventy CCCs (40%) required major surgical revision: AVS (27/90%–30%), Monti (31/51%–61%), TBF (12/32%–38%).

Conclusion: Complications of CCCs are common; in this study with very long-term follow-up, more than half of CCCs required surgical revision. Revisions were more common in Monti channels compared with AVS and TBF. The mean revision-free survival of >13 years illustrates the sustained long-term durability of CCCs which is important in the lifelong urological care of this population with high life expectancy.

KEYWORDS
continent catherizable channel, long-term complications, neurogenic bladder

1 | INTRODUCTION

Lower urinary tract dysfunction (LUTD) is a significant clinical challenge with the primary goal of achieving continence and preventing renal function deterioration. While timely, complete, and independent bladder emptying is critical, spontaneous voiding is often hindered by the inherent nature of LUTD, which includes acquired and congenital conditions such as neurogenic LUT dysfunction (NLUTD), bladder exstrophy, and posterior urethral valves. As a result, clean intermittent catheterization (CIC) is often required.[1,2]

Transurethral CIC is generally feasible in mobile male patients with adequate manual dexterity and a patent urethra. However, in patients involving urethral pathology, increased urethral sensitivity, or wheelchair-bound female patients, conventional CIC may prove challenging or impossible. To overcome these challenges and optimize bladder management, a continent catheterizable channel (CCC) offers an alternative route to the bladder in both pediatric and adult patients.

The origins of the CCC can be traced back to the work of Mitrofanoff in 1980, when he first described an appendicovesicostomy (AVS). He described the use of the appendix with its preserved mesenteric blood supply, creating a submucosal tunnel within the bladder for stomal continence, and anastomosing the channel to the skin at the umbilicus, an approach now known as the "Mitrofanoff principle."[3] In case the appendix is unavailable or unusable due to a narrow lumen or insufficient length, an alternative CCC can be constructed from retubularized ileum (Monti) as first described by Yang and Monti.[4,5] For patients requiring a longer channel, spiral retubularization (Casale procedure) or the use of a double ileal segment can be used.[6]

Another option, in case of sufficient bladder capacity, is a tubularized bladder flap (TBF). This technique has several advantages: less invasive procedure with no intraperitoneal involvement, no need for bowel anastomosis (ileum) or closure (appendix).[7,8]

Complications associated with CCCs are common and have been extensively documented in retrospective cohorts with varying parameters and length of follow-up. Notably, the majority of published cohorts focus on CCCs performed in a pediatric population. Some of these studies evaluate differences in revision rates between the different CCC techniques, with some cohorts showing a slightly higher revision rate of Monti channels compared with AVS.[9–12]

The prevalence of complications is related to the duration of follow-up. This necessitates long-term studies, as CCCs are often constructed in young patients with lifelong LUTD and with a considerable life expectancy and subject to several transitions. However, the previously reported literature is limited by a median follow-up of 6–7 years in larger cohorts. This is likely the consequence of loss to follow-up during the transition from child to adult care (adolescence). Longer follow-up, beyond adolescence, is essential to understand the longitudinal behavior of CCCs over time.

Another important gap in the existing literature is the lack of comparative studies of the three CCC techniques in the adult population. Although a single study has been conducted to compare the three techniques in children,[11] a notable lack of research on the comparison of these three techniques in adult patients and through transition (s) remains.

This study aims to analyze the very long-term complications and revision-free survival of three different types of CCC (AVS, Monti, TBF). The results of this study will provide valuable insights into the long-term outcomes of CCCs, facilitating improved clinical management and informed shared decision-making for healthcare professionals and patients subject to lifelong urological care.

2 | MATERIALS AND METHODS

In this retrospective cross-sectional cohort study, we included all adult patients with a CCC attending annual surveillance at our academic tertiary referral urology center in 2020 and 2021. Specifically, we considered three different types of CCC: AVS, Monti, and TBF. CCCs derived from alternative tissues using different techniques were excluded from the analysis. Patients with less than 1 year follow-up were also excluded.

The choice of technique (AVS, Monti, or TBF) was determined perioperatively by the pediatric or reconstructive adult urologist, considering factors such as bladder capacity, appendix availability and viability, and the potential need for concomitant bladder augmentation or antegrade colonic enema channel. As a guiding principle, the least invasive procedure was preferred and bowel anastomosis was avoided if possible.

At our institution, patients with CCCs are invited to annual standardized outpatient follow-up visits. We run an adolescent clinic to facilitate the transition from

pediatric to adult urological care. Follow-up includes a comprehensive medical interview with special emphasis on assessing CCC-related function and quality of life and identifying potential problems such as catheterization frequency and volume, catheterization difficulties, channel leakage, and other CCC-related concerns.

Relevant data were retrospectively collected from patients' medical records, including medical history, indication for CCC creation, age at CCC creation, gender, concomitant or previous bladder surgery, and preoperative bladder capacity. Preoperative bladder capacity was obtained from the most recent preoperative urodynamic study, if available, or from operative reports (peroperative assessment of capacity before CCC construction).

The primary endpoint of this study was surgical revision-free survival, defined as the time between CCC creation and the first surgical revision. Surgical revisions were further categorized into major (including subfascial, open surgical corrections, and complete revision) and minor (including endoscopic or open suprafascial corrections). When an entirely new CCC was required, it was classified as a major revision, but also considered separately as a complete revision. The new CCC was subsequently considered as a new case.

The secondary objective was the prevalence of long-term complications requiring surgery for each type of CCC, categorized in stomal incontinence, channel/stomal stenosis, and false route. All outcomes were compared among the three different types of CCC.

Stomal stenosis was defined as the inability to catheterize the CCC due to stenosis at any level (skin, bladder, or tract) and requiring surgical revision. Notably, cases in which outpatient dilatation or temporary use of an indwelling catheter resolved catheterization difficulties were not considered surgical revisions.

Continence status was assessed retrospectively at two defined time points: 1 year after surgery and at the end of the follow-up period. Urodynamic filling cystometry was performed in patients with bothersome urinary incontinence to differentiate between bladder storage problems and inadequate stomal closure pressure. Parameters such as bladder capacity, detrusor overactivity, bladder compliance, final filling pressure, and detrusor leak point pressure (DLPP) were determined when appropriate. A DLPP greater than 20 cmH2O was found to be significant in predicting upper urinary tract dilatation in a recent study of urodynamic parameters in 158 children.[13] A DLPP of less than 20 cmH2O was therefore considered as inadequate stomal closure pressure and a potential reason for surgical stoma correction. Conversely, a DLPP greater than 20 cmH2O suggested that stomal incontinence was unrelated to inadequate stomal closure.

The data collected were comparatively analyzed using the Freeman–Halton extension of the Fisher exact probability test. Stoma survival was evaluated using Kaplan–Meier survival curves with Mantel–Cox comparisons. Statistical analyses were performed using IBM SPSS Statistics 27 with a critical significance level of $p < 0.05$. This study was conducted with the approval of the local ethics review board.

3 | RESULTS

Inclusion criteria were met by 153 patients. The total number of included CCCs was 173: 90 AVS, 51 Monti, and 32 TBF. Median age at operation was 14.4 years (Interquartile range [IQR]: 9.1–28.9). Median follow-up was 12.4 years (IQR: 4.8–18). There were no significant differences in underlying pathology and baseline characteristics per CCC type as shown in Table 1.

In total, 79 revision surgeries in AVS (37 major), 56 in Monti (48 major), and 22 in TBF (14 major) were performed. The indications for surgical revision per technique are presented in Table 2. The percentage of CCCs requiring revision was significantly higher in the Monti group compared with other techniques. In addition, the Monti group had a higher percentage of major revisions. There were no significant differences between AVS and TBF. There were no significant differences in the indications for revision between the groups.

Subgroup analysis was performed for age at CCC creation (age <18 and age >18 years). The results are shown in Table 3. In the adult group, a lower representation of TBF's and comparatively shorter follow-up periods were observed. The adult cohort had a lower percentage of CCCs requiring revision (43% vs. 63%).

Survival analysis was used to evaluate the revision-free survival of the different CCC techniques. There was no significant difference in revision-free survival (Mantel-Cox comparison; $p = 0.09$). When the entire cohort was analyzed, the mean revision-free survival was 162 ± 13 months. The Kaplan–Meier survival curve illustrating CCC revision-free survival per technique is shown in Figure 1. The estimated 1-year prevalences of surgical revision for AVS, Monti, and TBF were 19%, 25%, and 13%, respectively. For 2 years these were 27%, 42%, and 28%, and for 5 years 40%, 53%, and 36%. For 10- and 15 years these were 48%, 61%, and 36%, and 54%, 69%, and 50%, respectively.

TABLE 1 Baseline characteristics.

	AVS $n = 90$	Monti $n = 51$	TBF $n = 32$	Total $n = 173$
Median age at operation in years (IQR)	12.05 (7.7–26.0)	18.9 (11.6–41.2)	14.4 (11.2–16.8)	14.4 (9.1–28.9)
Age <18 years at operation (%)	57 (63)	24 (47)	25 (78)	106 (62)
Gender, male (%)	34 (38)	16 (31)	12 (38)	62 (36)
Median follow-up in years (IQR)	15.2 (6.75–19.4)	8.0 (3.2–16.4)	9.6 (4.5–16.5)	12.4 (4.8–18)
Median pre/peroperative bladder capacity in mL (IQR)	265 (150–480)	355 (250–550)	450 (355–625)	350 (203–544)
Bladder surgery in history[a] (%)	33 (37)	30 (59)	9 (28)	72 (42)
CCC in history (%)	2 (1)	15 (29)	3 (9)	20 (12)
Concomitant bladder surgery[a] (%)	76 (84)	35 (69)	17 (53)	128 (74)
Underlying pathology				
Neurogenic lower urinary tract dysfunction (%)	56 (62)	38 (75)	24 (75)	118 (68)
Exstrophia vesicae (%)	16 (18)	1 (2)	0	17 (10)
Detrusor underactivity (%)	1 (1)	3 (6)	1 (3)	5 (3)
Urethral pathology (%)	4 (4)	1 (2)	0	5 (3)
Urinary incontinence (%)	4 (4)	4 (8)	1 (3)	9 (5)
Other (%)	9 (10)	4 (8)	6 (19)	19 (11)

Abbreviations: AVS, appendicovesicostomy; CCC, continent catherizable channel; IQR, interquartile range; TBF, tubularized bladder flap.

[a]Bladder augmentation, detrusorectomy, sling procedure, closure of the bladder neck.

TABLE 2 Surgical revision per technique.

	AVS, $n = 90$	Monti, $n = 51$	TBF, $n = 32$	Total, $n = 173$	p Value
CCCs with revision (%)	42 (47)	35 (67)	15 (47)	92 (53)	0.03
CCCs with major revisions (%)	27 (30)	31 (61)	12 (38)	70 (40)	0.02
CCCs with complete revision (%)	10 (11)	6 (11)	4 (13)	20 (12)	NS
Prevalence of indications for surgical revision					
Stomal stenosis (%)	28 (31)	16 (31)	12 (38)	56 (32)	NS
False route (%)	3 (3)	1 (2)	3 (9)	7 (4)	NS
Urinary incontinence (%)	17 (19)	18 (35)	3 (9)	38 (22)	NS
Urinary incontinence with detrusor leak point pressure <20 cmH2O (%)	7 (8)	7 (14)	2 (6)	16 (9)	NS

Abbreviations: AVS, appendicovesicostomy; CCC, continent catherizable channel; NS, nonsignificant, meaning no significant difference was observed between CCC techniques ($p > 0.05$); TBF, tubularized bladder flap.

TABLE 3 Subgroup analysis for age at time of continent catheterizable channel creation.

		AVS, $n = 90$	Monti, $n = 51$	TBF, $n = 32$	Total, $n = 173$
CCCs in subgroup	<18 years	57	24	25	106
	>18 years	33	27	7	67
Median follow up in months (IQR)	<18 years	199.7 (176.0– 257.7)	192.4 (93.6–253.2)	130.8 (88.7– 201.3)	190 (123–243)
	>18 years	96.6 (50.0– 143.8)	94 (39.2–133.1)	49.2 (33.4–76.0)	89.6 (39.6–154.0)
CCCs with revision (%)	<18 years	31 (54)	20 (83)	12 (38)	63 (59)
	>18 years	11 (33)	15 (56)	3 (43)	29 (43)
CCCs with major revisions (%)	<18 years	18 (32)	12 (50)	11 (44)	41 (39)
	>18 years	9 (27)	19 (70)	1 (14)	29 (43)

Abbreviations: AVS, appendicovesicostomy; CCC, continent catherizable channel; IQR, interquartile range; TBF, tubularized bladder flap.

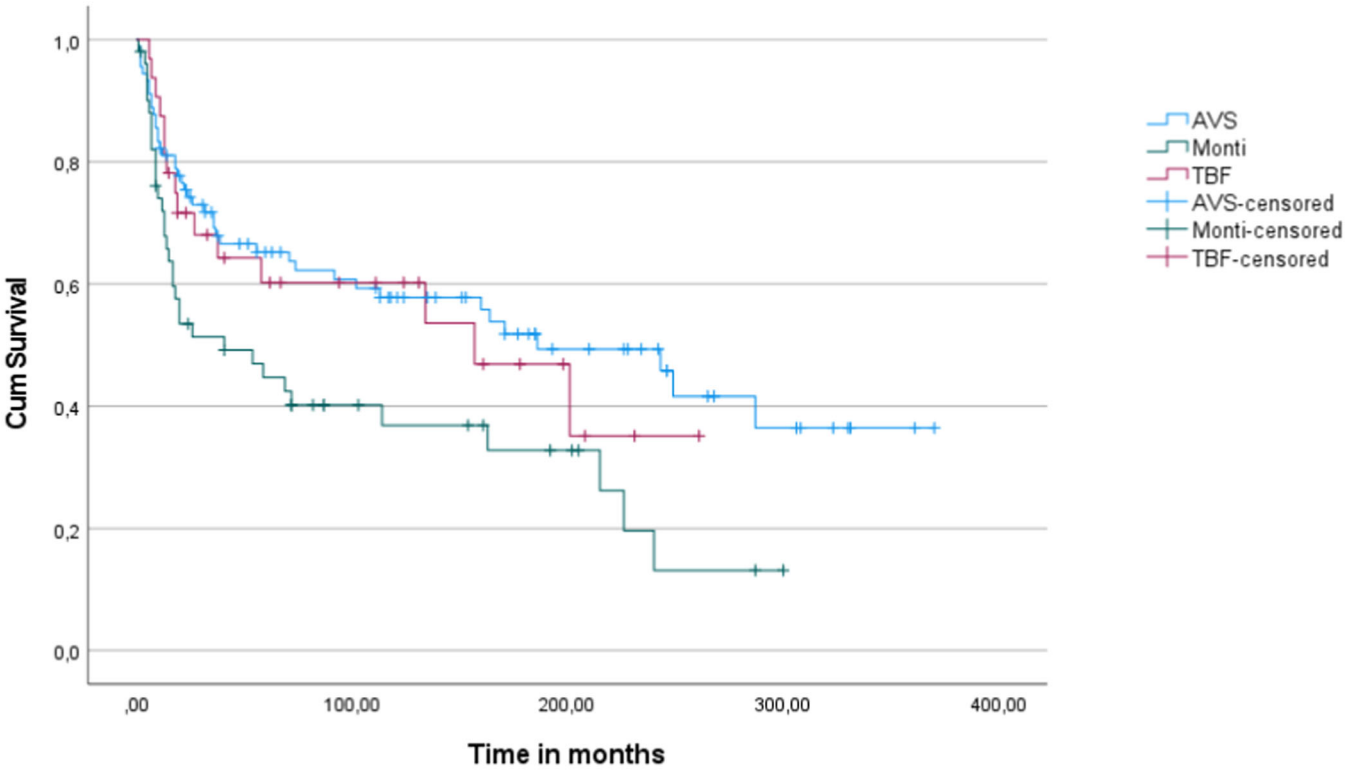

FIGURE 1 Kaplan–Meier Curve of revision-free survival/time of continent catheterizable channel to first surgical revision per technique.

4 | DISCUSSION

In this study 173 CCCs were included with a median follow-up of 12.4 years. When analyzing surgical revision rates by CCC type, a significant difference was observed between Monti on one hand (2/3 requiring revision), and AVS and TBF on the other hand (almost half requiring revision). There was also a significant difference in major revisions, with the percentage in Monti channels almost twice as high. Noteworthy, Monti procedures were more often performed in patients with a history of prior bladder surgery and as a secondary CCC. There were no significant differences in the prevalence of specific indications for revision between the CCCs.

The prevalence of complications requiring surgical revision in CCCs is highly influenced by several factors, including the duration of patient follow-up, the intensity of follow-up, the criteria used to define complications, and the selection of patients. Therefore, comparative analyses of surgical revision data with previously published cohorts must be performed with caution, taking into account the inherent heterogeneity of

patients and the differences in follow-up between and with previous studies.

Szymanski et al. have made a significant contribution to the existing literature with their study of 510 CCCs. This is the largest described cohort and includes 214 AVSs followed for a median of 5.7 years and 296 Monti's followed for a median of 7.7 years. Total revisions, stomal stenosis, and incontinence showed similar incidence rates between AVS and Monti. Subfascial revisions were significantly more common with Monti (17%) than with AVS (7%).[9] In our study, there was an overall higher frequency of major revisions (AVS 30%, Monti 61%, TBF 38%). This may partially be attributed to the longer duration and higher intensity of follow-up. The significant difference in major complications between the AVS and Monti techniques is a consistent observation.

Based on their findings, Szymanski et al. conclude that the appendix is the preferred choice for CCC above the restructured small bowel. Other factors such as concomitant surgery, gender, age, and date of surgery did not emerge as significant predictors of subfascial revisions with either technique.[9]

Our findings support the preference for AVS over Monti. This preference is not only due to the avoidance of bowel anastomosis but also due to the shown increased durability. The characteristics of the AVS (such as the absence of longitudinal suture lines and use of a natural lumen) potentially provide advantages in reducing susceptibility to ischemia, stenosis, and trauma.

In addition to comparing AVS to Monti, our study includes a head-to-head comparison with a third technique, TBF. Originally introduced in 2002 for pediatric patients by Cain et al., this approach encountered challenges, with the initial series documenting a prevalence of stomal stenosis of 60%. As a result, the authors found that while TBF emerged as a viable alternative, and despite its advantages of being a less invasive (extraperitoneal) procedure with no bowel closure or reanastomosis, it was not preferred over well-established techniques such as AVS or Monti.[7]

A previous study from our institution on CCCs in pediatric patients is the only other study directly comparing TBF to other CCCs. It showed no significant differences between TBF and other types of CCC with a median follow-up of 85 months.[10] In our current study, which also includes adults and has longer follow-up, a direct comparison of AVS and TBF showed a comparable need for surgical revision in both techniques in half of patients. The prevalence of major surgical revision was not significantly different: approximately 1/3 of patients. It is important to note that the AVS group had a longer median follow-up than the TBF group (15.2 years vs. 9.6 years). However, a time-to-event survival analysis showed a remarkably similar trajectory for AVS and TBF surgical revision-free survival.

Our results indicate that the adult cohort (aged >18 years at construction) has a relatively lower revision rate. This may be influenced by the shorter duration of follow-up. Whether transition periods influence the rate of complications requiring surgical revision cannot be determined from our data and study design, but warrants further investigation as it may be another reason for the higher complication rates at higher age after CCC construction in childhood. Changes in constitution and proportions could induce CCC problems during or after transition, as it is a created channel that may develop differently compared with its environment.

In the context of the timing of complications, the study by Leslie et al. suggests an initial peak in complications during the early phases of follow-up. This is followed by a period of relative stability characterized by a decreased need for surgical revision. However, there is a subsequent phase characterized by an increased incidence of complications, which is attributed to the cumulative effects of sustained CCC use leading to "wear and tear."[10] The survival analysis in our present study confirms this proposed hypothesis. We also found that approximately 1/3 of CCCs required their first surgical revision within the first 2 years. These trends are consistent with this hypothesis by Leslie et al.

The design of this study has several limitations. The cross-sectional and retrospective nature inherently limits the ability to establish causal relationships. Our study has a median follow-up of 12.4 years, which represents a remarkable extension beyond the follow-up periods reported in any other described cohort. The very long follow-up may potentially introduce selection bias among the included patients. The present study provides a cross-sectional perspective, including patients currently under surveillance at our tertiary center. The higher prevalence of complications requiring surgical revision may be due to the fact that patients with more complex CCCs remained under surveillance at our center, while patients with less problematic CCCs may have transferred to a nonacademic hospital closer to their homes, especially after the coronavirus disease 2019 (COVID-19) pandemic.

We took a pragmatic approach by assessing only complications requiring surgical correction to minimize missing data. While providing valuable insights, these limitations underscore the importance of interpreting findings with caution and acknowledging potential design and follow-up biases. Non-CCC complications and complications not requiring surgical revision were not analyzed in this study, but insight into their prevalence may also be helpful in counseling patients. To adequately investigate this, a prospective study is needed.

Looking ahead, future research in the field of CCCs should focus on the quality of life aspect for patients.

While existing studies have primarily focused on surgical outcomes and complications, there is a growing need to address the broader impact of CCCs on patients' overall well-being. Prospectively exploring parameters such as psychosocial adjustment, functional outcomes, and patient satisfaction will provide a better understanding of the real-world implications of creating a CCC.

Furthermore, future research and development should prioritize refinement of techniques that yield comparably reliable CCCs while reducing the invasiveness of the procedure. We believe that in cases where bladder volume is sufficient, TBF should be the preferred option, although larger cohorts within the adult population warrant further investigation. For patients requiring an AVS or Monti, robotic-assisted methods emerge as a promising innovation. Recent studies have demonstrated equivalent functional outcomes and complication rates while limiting hospital stay and postoperative discomfort.[14]

5 | CONCLUSION

CCCs are an elegant solution for individuals who require CIC but are unable to use the urethra. In patients undergoing CCC procedures, 53% had surgical revision over an extended median follow-up period of 12.4 years. Major revisions were needed in 40% and were significantly more common in Monti CCCs compared with AVS and TBF. While complications requiring surgery were frequent, the mean revision-free survival of 162 months underlines the sustained long-term durability of CCCs, but also stresses the importance of frequent long-term (lifelong) follow-up. In patients with adequate bladder volume, we advocate TBF as the primary choice due to its minimally invasive nature, avoiding intraperitoneal involvement and bowel anastomosis.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This research protocol was approved by our institutions Medical Research Ethics Committee (research protocol number 22/1050).

ORCID

Pepijn D. Polm http://orcid.org/0000-0002-8403-5977

REFERENCES

1. Dik P, Klijn AJ, van Gool JD, de Jong-de Vos van Steenwijk CCE, de Jong TPVM. Early start to therapy preserves kidney function in spina bifida patients. *Eur Urol*. 2006;49(5):908-913.
2. Lapides J, Diokno AC, Silber SJ, Lowe BS. Clean, intermittent self-catheterization in the treatment of urinary tract disease. *J Urol*. 1972;107:458-461.
3. Mitrofanoff P. [Trans-appendicular continent cystostomy in the management of the neurogenic bladder]. *Chir Pediatr*. 1980;21:297-305.
4. Yang WH. Yang needle tunneling technique in creating antireflux and continent mechanisms. *J Urol*. 1993;150:830-834.
5. Monti PR, Lara RC, Dutra MA, De Carvalho JR. New techniques for construction of efferent conduits based on the mitrofanoff principle. *Urology*. 1997;49:112-115.
6. Casale AJ. A long continent ileovesicostomy using a single piece of bowel. *J Urol*. 1999;162:1743-1745.
7. Cain MP, Rink RC, Yerkes EB, Kaefer M, Casale AJ. Long-term followup and outcome of continent catheterizable vesicostomy using the rink modification. *J Urol*. 2002;168(6):2583-2585. doi:10.1016/S0022-5347(05)64221-8
8. Baumgart E, Stoffel JT. The Boari bladder flap: an effective continent stoma for the high-compliance neurogenic bladder. *BJU Int*. 2010;105:1291-1294.
9. Szymanski KM, Whittam B, Misseri R, et al. Long-term outcomes of catheterizable continent urinary channels: what do you use, where you put it, and does it matter? *J Pediatr Urol*. 2015;11:210.e1-210.e7.
10. Leslie B, Lorenzo AJ, Moore K, Farhat WA, Bägli DJ, Pippi Salle JL. Long-term followup and time to event outcome analysis of continent catheterizable channels. *J Urol*. 2011;185:2298-2302.
11. Polm PD, de Kort LMO, de Jong TPVM, Dik P. Techniques used to create continent catheterizable channels: a comparison of long-term results in children. *Urology*. 2017;110:192-195.
12. O'Connor EM, Foley C, Taylor C, et al. Appendix or ileum—which is the best material for mitrofanoff channel formation in adults? *J Urol*. 2019;202(4):757-762.
13. Lyu L, Yao YX, Liu EP, et al. A study of urodynamic parameters at different bladder filling stages for predicting upper urinary tract dilatation. *Int Neurourol J*. 2022;26(1):52-59.
14. Galansky L, Andolfi C, Adamic B, Gundeti MS. Continent cutaneous catheterizable channels in pediatric patients: a decade of experience with open and robotic approaches in a single center. *Eur Urol*. 2021;79(6):866-878.

How to cite this article: Polm PD, Christiaans CHH, Dik P, Wyndaele MIA, de Kort LMO. Continent catheterizable urinary channels: lessons for lifelong urological care from a comparative analysis of very long-term complications and revision-free survival of three different types. *Neurourol Urodyn*. 2024;43:1083-1089. doi:10.1002/nau.25350