Appendix or Ileum—Which is the Best Material for Mitrofanoff Channel Formation in Adults?

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**Purpose:** We report long-term data on a large cohort of adults who underwent formation of a continent catheterizable channel for various indications. We examined outcomes according to the tissue used for channel formation.

**Materials and Methods:** We retrospectively reviewed the case notes of 176 consecutive adult patients in whom a continent catheterizable channel was created using the Mitrofanoff principle for a broad range of indications a median of 142 months (range 54 to 386) previously. We evaluated outcomes in terms of continued use and continence for each type of material used for channel formation.

**Results:** At the time of this review 165 of the 173 patients (95.4%) included in this study were alive. We included 114 women (65.9%) and 59 men (34.1%) who underwent surgery at a median age of 42 years (range 18 to 73) with a mean followup of 78.6 months (median 60, range 2 to 365). The rate of revision for all causes was higher in the ileal group than in the group with an appendiceal channel (channel stenosis rate 22.7% vs 17.2%, p = 0.39, and channel incontinence rate 36.0% vs 19.5%, p = 0.03). Although 38.7% of patients underwent major surgical revision of the channel at some point, 75.9% of channels continued to be used, of which 90.2% were continent.

**Conclusions:** This study provides a pragmatic overview of the outcome of these challenging cases. Mitrofanoff channel formation represents a durable technique. Appendix and ileum are each a viable choice for tissue use. Tissue selection depends on availability and individual patient factors.

**Key Words:** urinary bladder, urinary diversion, appendix, ileum, urinary incontinence

First described in pediatrics, the formation of a continent catheterizable channel using the Mitrofanoff principle has been used for the last few decades in adult populations.1–7 Adult populations in which this procedure is done represent a diverse cohort, encompassing patients with congenital conditions who may have undergone numerous procedures in childhood (eg those with bladder extrophy and/or epispadias) and those with acquired conditions which may only present later in life such as cancer, end stage urinary incontinence or an inflammatory bladder condition. Adult patients treated with urological reconstruction have often already undergone numerous previous surgeries so that tissue available for reconstruction may be limited.8 The main longer term clinical challenges in
the formation of such channels in adults include channel incontinence and difficult catheterization with the formation of a successful Mitrofanoff channel often achieved at the expense of a high revision rate.8–11

In this study we examined a large adult cohort in which formation of a continent catheterizable stoma was done for various indications. We compare different tissues used for channel formation and quantify the risk of stenosis and incontinence.

METHODS

We retrospectively reviewed the records of consecutive patients older than 18 years old in whom a continent catheterizable channel was created using the Mitrofanoff principle at our institution between 1985 and 2013. In this single center, multisurgeon series 9 consultant surgeons with a subspecialist interest in reconstructive urology performed Mitrofanoff channel formation during this study period sequentially and in parallel.

The tissue type for channel formation was recorded. If available, the appendix was used for catheterizable channel formation. When the appendix was not available due to prior use, removal, or inadequate length or caliber, small bowel was used in the form of a single or double Monti channel. When a continent channel was reconstructed from a previous ileal conduit, a detubularized portion of the ileum was sometimes used. A portion of ureter was considered in cases of prior or concomitant transureteroureterostomy in which the distal ureteral segment was detached and used as the catheterizable channel. Bladder or large bowel, which was occasionally used if it appeared more accessible than other tissues, was categorized as other.

Demographic information was collected, including patient age at surgery, gender and followup. Patients were categorized by the etiology of underlying incontinence into 5 distinct subgroups, including neurological, end stage urinary incontinence, congenital, malignancy and bladder pain syndrome.

Details of the original surgical procedure were recorded. Specifically data were recorded on Mitrofanoff channel type and location, and details of concomitant bladder augmentation or other surgical procedures. Complications and the need for subsequent endoscopic or open procedures were recorded. Only continent and channel related complications were recorded in this analysis as we believed that complications such as stone formation were unrelated to the type of channel used.

Time to first major revision, if required, was recorded. This was defined as subfascial distal channel revision or total channel replacement. All revision events were counted during the study period such that if a patient required revision for channel incontinence and a subsequent revision for channel stenosis, these events were counted separately. Skin level revision of the channel included suprafascial revision for channel stomal stenosis, granulation tissue at the channel stoma or channel stomal prolapse repair. Intraluminal bulking agents were considered for mild channel incontinence. They were typically inserted in a 4-quadrant manner using a 0-degree cystoscope to achieve adequate tissue coaptation in the submucosal portion of the channel. Regardless of the number of surgical revisions, channel status was assessed at the last followup.

Only patients who underwent the initial Mitrofanoff channel formation surgery more than 5 years ago were included in this study to ensure that adequate followup data were available. Patients with less than 12 months of followup data available were considered lost to followup.

Patients were generally discharged home 5 to 10 days postoperatively with a 12Fr to 16Fr catheter in the channel. A 16Fr catheter was used when possible, often in addition to a urethral or suprapubic catheter, for 6 weeks until the anastomosis healed. Patients then returned to activate the channel by instigating clean intermittent self-catheterization via the continent channel. Patients were typically followed 6 months later with renal ultrasound and blood work. Notwithstanding any issues, patients were generally followed annually thereafter with blood results and an alternating regimen of renal ultrasound and mercaptoacetyltri glycine renogram imaging.

All statistical analysis was performed with Prism® 7. The chi-square test was used to assess differences between groups according to whether the channel was created from appendix or ileum (single and double Monti or tapered ileum). Ethics committee approval was not required as this type of outcomes review is considered a service evaluation at our institution. All work was done at University College London Hospital.

RESULTS

Population Characteristics

We identified 176 consecutive patients, of whom 3 were subsequently excluded from final analysis due to a lack of adequate followup data. The table outlines demographic details. Overall 13 patients (7.5%) were lost to followup, including 7 with an appendiceal channel and 6 with an ileal channel (p = 0.99).

External Stoma Location and Reservoir Type

The external stoma was located at the umbilicus in 114 patients (65.9%), in the right lower quadrant in 49 (28.3%) and on the left side of the abdomen in 6 (3.5%). Of the patients 137 (77.5%) also underwent augmentation cystoplasty or neobladder formation before or at the time of Mitrofanoff channel creation.

Channel Complications

The supplementary table (https://www.jurology.com) outlines the rate of channel related complications and the channel revision rate. Overall 95 patients (55.0%) experienced some difficult catheterization with or without channel narrowing. This was nonsignificantly higher in the appendiceal channel group vs the ileal channel group (57.5% vs 53.3%, p = 0.6). Those with a channel created of tapered ileum and ureter...
### Patient characteristics by continent catheterizable channel type, bladder neck management and current channel status

#### Ileum

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Single, Double + Tapered</th>
<th>Single Monti</th>
<th>Double Monti</th>
<th>Tapered Previous Conduit</th>
<th>Ureter</th>
<th>Other</th>
<th>Overall</th>
</tr>
</thead>
</table>
| No. pts (%) | 87 (50.3) | 75 (43.4) | 30 (17.3) | 37 (21.4) | 8 (4.6) | 8 (4.6) | 3 (1.7) | 173 (

| No. alive (%) | 81 (50.0) | 70 (43.2) | 27 (16.7) | 35 (21.6) | 8 (4.9) | 8 (4.9) | 3 (1.9) | 162 (1

| Median age at surgery (range) | 36 (18–73) | 45 (18–71) | 45.5 (18–71) | 43 (22–68) | 44.5 (25–56) | 37.5 (19–60) | 38 (23–49) | 42 (18–73) | 162 (1

| No. female (%) | 50 (58.1) | 56 (74.7) | 22 (73.3) | 26 (70.3) | 8 (100) | 5 (62.5) | 3 (100) | 114 (64.8) | 162 (1

| No. surgery in 2008 or after (%) | 35 (40.2) | 17 (22.7) | 3 (10.0) | 14 (37.8) | 0 (0) | 1 (12.5) | 0 (0) | 93 (57.0) | 162 (1

| Median mos followup (range) | 57 (2–365) | 68 (2–294) | 68 (2–294) | 61 (2–229) | 207 (14–229) | 97 (57–111) | 60 (2–365) | 162 (1

#### Bladder neck management

| No. currently used channels/total No. (%): | 63/81 (77.8) | 50/70 (71.4) | 18/27 (66.7) | 25/35 (71.4) | 7/8 (87.5) | 8/8 (100.0) | 23/123 (18.7) | 123/162 (75.9) | 162 (1

| Patient | 27/63 | 20/50 | 5/18 | 15/25 | 0/7 | 2/8 | 1/3 | 50/123 | 123/162 (75.9) | 162 (1

| Closed before catheterizable channel formation | 6/63 | 13/50 | 4/18 | 3/25 | 6/7 | 5/8 | 1/3 | 50/123 | 123/162 (75.9) | 162 (1

| Closed at catheterizable channel formation | 23/63 | 17/50 | 5/18 | 6/25 | 1/7 | 1/8 | 0/3 | 50/123 | 123/162 (75.9) | 162 (1

| Closed after catheterizable channel formation | 7/63 | 5/50 | 4/18 | 1/25 | 0/7 | 0/8 | 0/3 | 50/123 | 123/162 (75.9) | 162 (1

| No. unused channel/total No.: | 18/81 | 20/70 | 8/27 | 10/35 | 1/8 | 0/8 | 1/3 | 50/123 | 123/162 (75.9) | 162 (1

| Patient | 9/18 | 8/20 | 2/9 | 6/10 | 0/1 | 0/8 | 0/3 | 17/39 | 123/162 (75.9) | 162 (1

| Closed before catheterizable channel formation | 1/18 | 3/20 | 1/9 | 1/10 | 0/1 | 0/8 | 0/3 | 4/39 | 123/162 (75.9) | 162 (1

| Closed at catheterizable channel formation | 2/18 | 2/20 | 2/9 | 0/10 | 0/1 | 0/8 | 0/3 | 5/39 | 123/162 (75.9) | 162 (1

| Closed after catheterizable channel formation | 6/18 | 7/20 | 4/9 | 3/10 | 0/1 | 0/8 | 0/3 | 13/39 | 123/162 (75.9) | 162 (1

#### Current channel status

| No. currently used channels/total No. (%): | 63/81 (77.8) | 50/70 (71.4) | 18/27 (66.7) | 25/35 (71.4) | 7/8 (87.5) | 8/8 (100.0) | 23/123 (18.7) | 123/162 (75.9) | 162 (1

| Original conduit | 49 (60.5) | 27 (38.6) | 8 (29.6) | 15 (42.9) | 4 (50.0) | 7 (87.5) | 1 (33.3) | 84 (51.9) | 162 (1

| Revised new conduit | 14 (17.3) | 23 (32.9) | 10 (37.0) | 10 (28.6) | 3 (37.5) | 1 (12.5) | 1 (33.3) | 39 (24.1) | 162 (1

| No. reason catheterizable channel not used/total No. (%): | 24/87 (27.6) | 25 (33.3) | 12 (40.0) | 12 (32.4) | 1 (12.5) | 0 | 0 | 50 (28.9) | 162 (1

| Conversion to ileal conduit | 7 (8.0) | 12 (16.0) | 6 (20.0) | 5 (13.5) | 1 (12.5) | 1 (33.3) | 19 (11.0) | 162 (1

| Other* | 11 (12.6) | 8 (10.7) | 3 (10.0) | 5 (13.5) | 0 | 0 | 20 (11.6) | 162 (1

| Pt death | 6 (6.9) | 5 (6.7) | 3 (10.0) | 2 (5.4) | 0 | 1 (33.3) | 11 (6.4) | 162 (1

| No. conduit status: | 63 | 50 | 18 | 25 | 7 | 8 | 2 | 123 | 162 (1

| Catheterizable | 63 | 50 | 18 | 25 | 7 | 8 | 2 | 123 | 162 (1

| Continent | 60 | 42 | 16 | 22 | 4 | 8 | 1 | 111 | 162 (1

* Indwelling catheter, clean intermittent self-catheterization or no further requirement for channel.
had the lowest difficult catheterization rate with only 3 (37.5%) and 2 patients (25.0%) in each group, respectively, experiencing it. These findings are in direct contrast to findings of channel incontinence with the highest rate in patients with a channel created of tapered ileum (7 or 87.5%). Overall 72 patients (41.6%) experienced some degree of channel incontinence. The channel incontinence rate was significantly higher in the 45 patients (60.0%) with an ileal channel compared to the 25 (28.7%) with an appendiceal channel (p < 0.001).

Overall, 71 patients (41%) required skin level revision of the channel due to difficult catheterization related to skin level stenosis of the external channel stoma and/or a distal channel stricture. This superficial revision rate was again nonsignificantly higher in the appendiceal vs the ileal group (43.7% vs 37.3%, p = 0.41). Overall 67 patients (38.7%) required complete channel revision at some point due to difficult catheterization and/or incontinence. Patients were significantly more likely to undergo major channel revision if the channel was constructed from ileum than from appendix (50.7% vs 29.9%, p = 0.003).

In the study 34 patients (19.7%) ultimately underwent full revision of the channel due to difficult catheterization mainly related to channel stenosis, while 45 (26.0%) underwent full revision due to incontinence. Of the latter 45 patients 13 (7.5%) underwent major revision for difficult catheterization as well as channel incontinence. The revision rate due to all causes was higher in the ileal group than in the appendiceal group (channel stenosis 22.7% vs 17.2%, p = 0.39, and incontinence 36.0% vs 19.5%, p = 0.03).

Mean time to major revision in all patients was 30.8 months (median 18 months, range 1 to 182). There was no overall difference in median time to revision at 18 months between the appendiceal and ileal groups (median 19 months, range 1 to 182 vs 18 months, range 4 to 153).

**Bladder Neck Management**

The table lists urethral patency rates and the timing of bladder outlet closure, if performed. In the appendiceal group 8 patients (9.9%) required surgery for urethral incontinence, including an artificial urinary sphincter, bladder neck closure and/or completion cystectomy/urethrectomy, compared with 9 (12.9%) in the ileal group. Only 2 patients with an appendiceal channel and 2 with an ileal channel reported persistent urethral leakage despite bladder outlet surgery. One patient in the appendiceal group ultimately underwent ileal conduit formation due to urethral leakage. However, the remaining 3 patients with persistent mild urethral incontinence have managed the condition with conservative measures.

**Current Channel Status**

The table outlines the status of current channels. During the study period 11 patients (6.4%) died. A total of 19 patients (11%) elected to have the catheterizable channel converted to an ileal conduit. A further 20 patients (11.6%) no longer used the channel. They performed clean intermittent self-catheterization via the urethra, had an indwelling catheter in the urethra or channel, or were lost to followup.

Of the 162 patients who were alive at the last assessment 123 (75.9%) still used the Mitrofanoff channel. It was the original conduit in 84 patients (68.3%) and a revised new conduit in 39 (31.7%). All 123 patients (100%) who were alive with the channel in use reported that the channel was catheterizable and 111 (90.2%) reported being continent. The continence rate was significantly higher in the appendiceal group than in the ileal channel group (60 of 63 cases or 95.2% vs 42 of 50 or 84.0%, p = 0.045). All 8 patients with a Mitrofanoff type channel created of ureter continued to use the channel and were continent.

**DISCUSSION**

In our large series with a mean followup of 78.6 months we provide insights into a challenging patient cohort spanning 3 decades of urological reconstruction. Despite the high revision rate 75.9% of patients who were alive at the last assessment used the catheterizable channel, of whom 90.2% were continent.

Conversion to an ileal conduit accounted for some patients who did not use the channel at the last review. However, 20 patients (11.6%) did not use the channel for alternative reasons, such as failing health or worsening hand dexterity. Occasionally patients who are unable to catheterize via the urethra prior to Mitrofanoff formation due to pain or technical difficulties may overcome these barriers.

Channel incontinence and urethral incontinence are bothersome issues which can be difficult to treat. In our cohort 72 patients (41.6%) reported some degree of channel incontinence. Because this was defined as any channel leakage, it may have overestimated the degree of bothersome channel incontinence and its impact on quality of life. The subjective rates of channel incontinence in our series are comparable to those in other adult Mitrofanoff cohorts. Pagliara et al reported a 40% channel incontinence rate in a study of 51 adults while Redshaw et al noted channel incontinence in 43.3% of 30 adults.

The channel stomal stenosis rates were comparable to those in other series. We observed a 55%
channel stomal stenosis rate. Of the patients 41.0% underwent skin level revision at some point and 19.7% required full revision of the channel for stenosis. These revision rates are somewhat higher than in pediatric series since the incidence of channel stenosis in pediatric cohorts was reported to range from 7.4% to 31%.3,7,13–16 While rates of stenosis and channel revision similar to ours have been reported in most adult series,12,17 lower rates exist in the literature. Van der Aa et al reported that only 6 of 34 patients (17%) required full revision of the channel at a mean followup of 60 months (range 6 to 117).18 However, overall 29% of patients required channel revision for catheterization problems.

There remains a lack of consensus on the optimal tissue to form the continent catheterizable channel.19–21 Many existing adult series did not have sufficient numbers to directly compare the type of material used.22,23 Wiesner et al reported on the largest adult cohort of 977 patients who underwent continent catheterizable channel formation using appendix or an intussuscepted ileal nipple valve.24 Those investigators identified a higher channel stenosis rate but a lower incontinence rate for the appendiceal channel. However, we could not compare the usefulness of appendix vs ileum for channel formation since the intussuscepted ileal nipple valve is not constructed using the Mitrofanoff principle and it has fallen out of use because of significant problems with leakage and a high revision rate.6,24

In our series we postulated that appendiceal channels had a lower rate of stomal incontinence as it is often technically easier to create a submucosal tunnel with appendiceal channels than with those created from ileum.8 The appendix was used in the first instance if available, and if it had sufficient length. Thus, there may have been a bias toward these patients being slimmer and/or having undergone fewer previous surgeries, resulting in fewer revisions and greater continence. Ileal channels often resulted in larger caliber channels (greater than 16Fr) and we postulate that this may have contributed to easier catheterization but resulted in a greater risk of incontinence.

It is worth noting that ureter appears to provide a robust channel when used. While there were few ureteral channels in our series, only 1 of the 8 patients with a ureteral channel required revision during a median followup of 207 months (range 14 to 339). While we would not want to compromise the integrity of the renal unit, it may be worth considering this tissue modality in experienced hands when it is being dissected as a component of overall reconstruction. Favorable results of ureteral channels have also been demonstrated in a pediatric cohort.25

Important limitations to this study should be acknowledged. We were inherently limited by the retrospective nature of this review. We acknowledge that the various surgical techniques and the underlying etiologies of bladder and urethral dysfunction made it difficult to draw meaningful comparisons between the groups. However, we elected to include all consecutive patients and not exclude any patient group with the hope that this would provide a more pragmatic description of the versatility required when dealing with these complex cases.

This study represents work performed at a large tertiary referral center. We acknowledge that this study describes the work of a relatively large number of surgeons with varying practices. This has homogenized during the years with only 4 of the 36 urological surgeons at our tertiary referral center now performing this procedure.

Despite these limitations, to our knowledge this is the largest adult series in the literature of the long-term functional outcomes of continent catheterizable channel formation using the Mitrofanoff principle. Although 38.7% of patients underwent major surgical revision of the channel at some point, 75.9% were using the conduit and 90.2% were continent.

CONCLUSIONS
This study provides a pragmatic overview of the outcome of these challenging cases. Mitrofanoff channel formation represents a durable technique. Appendix and ileum are viable choices for tissue use and tissue selection depends on availability and individual patient factors.

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REFERENCES


13. McAndrew HF and Malone PS: Continent catheterizable conduits: which stoma, which conduit and which reservoir? BJU Int 2002; 89: 86.


EDITORIAL COMMENT

Catheterizable channel formation by the Mitrofanoff principle is a suitable reconstructive technique in patients with neurogenic bladder and other forms of lower urinary tract dysfunction. The authors present their long-term data (median followup 78.6 months) showing that 75.9% of conduits are still in use while 90.2% of them are still continent. The incidence of revision for stenosis and incontinence was similar or higher in the ileal group compared to the appendiceal group (stenosis 22.7% vs 17.2%, p = 0.39, and incontinence 36.0% vs 19.5%, p = 0.03) with 38.7% of patients overall requiring revision.

The authors report the benefits and the difficulties of performing these deceptively complex reconstructions in a challenging patient population. This study represents one of the largest series of its kind with a long followup. The reported 41.6% rate of incontinence is in keeping with that in other large series (references 8 and 12 in article). Interestingly more than 50% of the patients in each group experienced difficulty when catheterizing (appendiceal vs ileal 57.5% vs 53.3%, p = 0.6), pointing to the added challenges that patients may face. The study did not reach a definitive conclusion about which material would be superior when forming a Mitrofanoff channel. Also, the number of ureters used was too small to provide a useful comparison.

Ultimately appendix and ileum were found to be effective and either may be used depending on specific needs and availability. These results provide essential data regarding Mitrofanoff channels which will help surgeons choose appropriately and counsel patients more effectively.

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