Reconstructing the lower urinary tract: The Mitrofanoff principle

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ABSTRACT

Since the original description of the trans-appendicular continent cystostomy by Mitrofanoff in 1980, a variety of techniques have been described for creating a continent catheterisable channel leading to the bladder, which avoids the native urethra. The Mitrofanoff principle involves the creation of a conduit going into a low pressure reservoir, which can emptied through clean intermittent catheterization through an easily accessible stoma. A variety of tissue segments have been used for creating the conduit, but the two popular options in current urological practice remain the appendix and Yang-Monti transverse ileal tube. The Mitrofanoff procedure has an early reoperation rate for bleeding, bowel obstruction, anastomotic leak or conduit breakdown of up to 8% and the most common long-term complication noted is stomal stenosis resulting in difficulty catheterizing the conduit. However, in both pediatric and adult setting, reports imply that the procedure is durable although it is associated with an overall re-operation rate of up to 32% in contemporary series. Initial reports of laparoscopic and robotic-assisted Mitrofanoff procedures are encouraging, but long-term outcomes are still awaited.

Key words: Appendix, Mitrofanoff, reconstruction

INTRODUCTION

The management of bladder dysfunction can be complex and patients can face numerous challenges and complications in the pursuit of continence. Long-term urethral catheterization is associated with significant widely recognized problems such as catheter blockage, peri-catheter leak, urethral trauma/strictures, and colonization by bacterial organisms.

The trans-appendicular continent cystostomy was first described by Mitrofanoff in 1980, using the appendix as a conduit between the bladder and skin. This allowed the bladder to be emptied by a route other than the urethra and was a further revolutionary step in the field of urinary incontinence management following the earlier introduction of clean intermittent self-catheterization by Lapides.

Since the original description by Mitrofanoff, numerous variations have been reported as the procedure has evolved, but the underlying principles of what has become known as a Mitrofanoff procedure are the creation of a conduit going into a low pressure reservoir, which can emptied through clean intermittent catheterization through an easily accessible stoma. The indications for this procedure include refractory neurogenic bladder (with or without myelomeningocele), refractory idiopathic bladder dysfunction, severe urethral stricture disease as an adjunct to reconstruction in congenital urogenital abnormalities (cloacal exstrophy, posterior urethral valves, epispadias, and prune belly syndrome).

Advances in surgical technique have seen the development of both laparoscopic and robotic Mitrofanoff procedures. In addition, long-term outcomes of the procedure have recently been described in the literature. The aims of this article are to revisit the surgical principles laid down by Mitrofanoff, to examine the technical modifications over the past three decades and to report the long-term outcomes.

TISSUE SEGMENTS FOR CONDUIT CONSTRUCTION

Mitrofanoff used a conduit made of appendix to give access to the bladder, but different gastrointestinal and
urothelial segments have been employed for creation of a catheterizable conduit including cecum, small bowel, stomach, ureter, and bladder.[1] Currently, the appendix remains the conduit of choice where available and the most common second option is the transverse ileal (Yang-Monti) tube.

**Appendix**

Traditionally, a lower midline or Pfannenstiel incision is performed to allow access to the bladder and ileocecal junction and appendix.[2] The appendix is identified and disconnected from the cecum whilst preserving its mesentery. After passing a 14 Fr catheter down the isolated appendix [Figure 1] to check its patency, the end going into the bladder is usually tunneled submucosally for 3-4 cm into the bladder to achieve an anti-reflux effect. The appendix is then secured with absorbable sutures to the bladder muscle and mucosa. Different techniques exist for creating the anti-reflux mechanism depending on the type of conduit used (see section below).

**Transverse ileal (Yang-Monti) tube**

The Yang submucosal needle technique was first described in 1993 to reimplant ureters and to create a catheterisable ileal conduit following cystectomy in seven patients.[6] Following on from that, Monti et al. (1997) described the transversal tubularization of small segments of ileum in the canine model to create a catheterizable conduit.[7] These descriptions have formed the basis for the ‘Yang-Monti’ tube. In essence, this involves the isolation of a 2-3 cm ileal segment, which is detubularized. This is then retubularized transversely over a 14-18Fr catheter. One end of the ‘Yang-Monti’ tube is tunneled submucosally and sutured into the bladder whilst the other is brought to the abdominal wall as a stoma. In another technique when using a single ileal tube, one end can be imbricated and sutured into the reservoir and the other end brought out to the skin as a stoma.[8] Where a longer conduit is required, a double ‘Yang-Monti’ tube can be fashioned using two adjacent ileal segments which are separately detubularized and attached to each other transversely.[1,7]

**Other gastrointestinal segments - cecum and stomach**

Some authors have reported the use of cecum where the appendix alone is too short to create a conduit.[9] This involves mobilization of the appendix and the base of the cecum. A stapling device is used to transect part of the cecum and the cecal base, along with the appendix, is detubularized to create the conduit. The cecal end is implanted into the bladder. If bowel is unavailable, a gastric segment can be harvested and tubularized as reported in a cohort of 10 adult and pediatric patients with a median follow-up of 3.5 years by Close and Mitchell.[10] Whilst good continence rates were noted, there is a higher incidence of conduit complications at the skin level due to gastric acid irritation.

**Ureter, bladder and fallopian tube segments**

The ureter remains a good catheterizable channel and was indeed used partly in Mitrofanoff’s initial report. However, complication rates are noted to be higher. In a series of 22 patients using ureter as conduit, a 40% major complication rate was noted (including urine leak and need for complete revision).[11] In a further study looking at 60 conduits made with appendix or ureter, a higher stenosis rate was noted in patients where ureter was used.[12] Tubularized bladder flaps have also been described where a flap of full-thickness detrusor muscle is created and the tubularized over a 12 Fr catheter. Cain et al. reported 31 patients undergoing continent catheterizable vesicostomy who had a high stenosis rate (60%) but an excellent continence rate (100%).[13] Owing to the high stoma complication rates, ureter and bladder catheterizable conduits are less popular nowadays but remain an option in a large capacity bladder or where a redundant megaureter is available.

Some earlier reports following Mitrofanoff’s original description suggested using fallopian tube as conduit, but this has not proved popular in contemporary practice.

![Figure 1: (a) Catheter passed through appendix to check patency, (b) Appendix stoma on skin with catheter in situ](image)
especially with concerns regarding future reproductive function and high stenosis rates.[5,14]

TECHNIQUES FOR ATTACHING THE CONDUIT TO THE RESERVOIR

Mitrofanoff underlined the importance of creating an anti-reflux submucosal tunnel where the appendix joined the bladder.[2] Depending on the tissue segment used for the conduit, a number of different techniques are available for creating the submucosal tunnel and they are generally based on the principles of ureteric re-implantation. Where ureter is used for the conduit, the technique described by Le Duc can be employed. This consists of the construction of an ileal sheet in which the ureter is implanted and introduced into the lumen of the reservoir via a transmural non-refluxing channel and left unfixed intraluminally.[8] In the modified technique, the distal ureteric end is widely spatulated, forming a ureteric plate, and directly adapted to the ileal mucosa. Another antireflux implantation technique is the nipple ureteric implantation with a split cuff described by Sagalowsky. The ureter is spatulated approximately 1 cm and folded back to form a split-cuff nipple. The corners are sewn to each other except for a small gap proximally to prevent constriction.[15] When an ileal segment is used as catheterizable conduit, the Kock nipple anti-reflux technique can be performed. This uses an ileal segment as an anti-reflux mechanism to create an intussuscepted ileal valve.[16] To fix the valve, four rows of staples affixed within the leaves of the valve and on the back wall outside the reservoir are used. A simpler form of an anti-reflux mechanism can be obtained by placing the ureter or ileal segment directly into serous-lined extramural tunnels.[17]

FASHIONING OF THE STOMA AT SKIN LEVEL

Generally speaking, the conduit is attached to the abdominal wall and a stoma is fashioned. The site should be easily accessible by the patient. The most common stoma sites described for the Mitrofanoff procedure have been the umbilicus and lower abdomen.[12] Four main techniques for stoma formation have been described in the literature including direct anastomosis, umbilical stoma, tubular skin flap (TSF) and the V-quadrilateral-Z (VQZ) flap technique. Perhaps the simplest technique for stoma formation is direct anastomosis of the intestinal conduit to the skin.[12] The main problems with this technique include an exposed conduit mucosa, increasing the chance of infection, and bleeding following catheterization. An umbilical stoma is created by detaching the umbilicus from the rectus sheath and attaching the conduit to its posterior end after spatulation.[12] In the TSF technique, a 3 cm skin flap is created in the lower abdomen and tubularized with the skin surface comprising the inner lining of the conduit. The skin conduit is tunneled though the rectus muscle and an end to end anastomosis is performed to the intestinal conduit.[18] The VQZ technique for stoma creation involves the creation of a V-flap, which is sutured to the spatulated intestinal conduit.[19] A recent study looked at the complication with the three main techniques (umbilical stoma, TSF and VQZ). This involved 40 patients undergoing Mitrofanoff procedures where umbilicus was used for 31 conduits, the VQZ was used for 8 and the TSF was used for 11. The revision or dilatation rates for stomal stenosis were 45% for TSF, 25% for umbilical and 0% for VQZ flaps.[20] In addition, the decision on placement of the abdominal wall stoma may be made difficult by previous abdominal surgery or obesity. In obese patients, the umbilicus may be a good site to externalize a catheterizable channel as the abdominal wall width is thinnest at that point. In patients with previous abdominal surgery, the stoma should be sited away from abdominal scars to reduce the risk of ischemia.[18,19]

BLADDER AND BLADDER OUTLET CONSIDERATIONS

The bladder should be a good capacity, low pressure reservoir for a successful Mitrofanoff procedure. Sometimes, concomitant augmentation cystoplasty has to be performed; for instance, where preoperative urodynamics have confirmed a small bladder volume or loss of compliance with end-filling pressures more than 40 cm H2O. Hence, situations where concomitant bladder augmentation would be required at the time of a Mitrofanoff procedure include congenital bladder anomalies (bladder extrophy, epispadias, and posterior urethral valves with small capacity bladder), small capacity/poorly compliant bladder from neurogenic disease or post radiotherapy and inflammatory bladder disorders. The site of conduit implantation into the bladder has been investigated in a number of studies. In a recent study, anterior and posterior conduit implantation were compared in a cohort of 54 patients.[21] The results showed that although the rates of stomal complications were similar between the two groups, patients with anterior conduits and an increased risk of urinary tract infection and bladder stone formation. The authors postulated that patients with anteriorly implanted conduits may have suboptimal drainage.[21] In cases of augmentation cystoplasty, the catheterizable conduit can be implanted into the native bladder or the augmented patch. Continence and revision rates appear similar although one study suggested that the best combination was an appendix conduit implanted into a colonic augmentation segment.[22] The authors in that study describe a continence rate of 88% at 24 months follow-up and a revision rate of less than 20%.

The bladder outlet needs to be addressed if continence is not reached with a large capacity and compliant bladder. Bladder outlet enhancing procedures include endoscopic injection of bulking agents, bladder neck reconstructions,
and extrinsic compression of the bladder neck/urethra using slings, the artificial urinary sphincter, and bladder neck closure. When multiple bladder neck surgeries fail, bladder neck closure is often performed as the final intervention to achieve dryness, but is an irreversible procedure requiring compliance with catheterization of a cutaneous stoma. Historically, it has been reserved for the definitive treatment of intractable incontinence after prior failed procedures.²³

**SHORT- AND LONG-TERM SURGICAL OUTCOMES**

The creation of a Mitrofanoff channel is a major abdominal procedure and there is an early re-operation rate for bleeding, bowel obstruction, anastomotic leakage or breakdown of the conduit. The most common long-term complications noted in the literature are stenosis of the conduit, incontinence, and need for the surgical revision [Table 1].¹,²⁴

**Early surgical complications**

Early re-operation rate has been reported to be between 1.2% and 8%. In one recent study of 65 adult patients having Mitrofanoff procedures, Gowda et al. reported an 8% need to return to theatre in the peri-operative period for bleeding, bowel obstruction or anastomotic leak.²⁵

**Stenosis of stoma or conduit**

As regards long-term complications, stenosis of the conduit is reported in 0-100% of Mitrofanoff procedures and the incidence generally increased with the length of follow-up.²¹,²³,²⁶ For instance, in studies where appendix or ileum had been used as conduit, stomal stenosis rates were 6% at a median follow-up of 28 months but rose to 54% at 126 months.²⁴,²⁵

In addition, higher stenosis rates and stomal complications are noted in patients with conduits fashioned out of ureter, bladder or gastric segments.¹⁰-¹² The majority of studies describe initial management of stomal or conduit stenosis by endoscopic dilatation, but some patients eventually require revision surgery. One of the longest follow-up studies of 28 patients by Sahadevan et al. reported a mean frequency of dilation of 0.4 (0.1-2.4) episodes per year but 32% of patients eventually required revision of the conduit.²⁴ One of the lowest conduit stenosis rates (2.4%) was reported by Sultan et al. who followed-up 82 pediatric patients who had appendix or ileal Mitrofanoff as part of

| Study                  | No. of patients | Technique | Conduit     | Reservoir                      | Stenosis % | Revision % | Early laparotomy for postop complications % | Incontinence % |
|-----------------------|----------------|-----------|-------------|--------------------------------|------------|------------|--------------------------------------------|----------------|
| Wille et al. BJUI, 01 2012 | 3              | Robotic   | Appendix    | Native bladder                  | 0          | 0          | 0                                          | 0              |
| Wille et al. J of Urology, 04 2011 | 11             | Robotic   | Appendix    | Augmented bladder               | 0          | 27.3       | 0                                          | 9.1            |
| Gundeti et al. BJUI, 03 2011 | 5              | Robotic   | Appendix    | Augmented bladder               | 0          | 60         | 0                                          | 0              |
| Spahn et al. Urology, 05 2010 | 17             | Open      | Appendix    | Native and augmented            | 23.5       | 17.6       | –                                          | –              |
| Kajbafzadeh et al. J of Urology, 03 2010 | 13             | Open      | Ureter      | Uretero-cystoplasty             | 0          | 0          | 0                                          | 7.7            |
| Nguyen et al. J of Urology, 10 2009 | 10             | Robotic   | Appendix    | Native bladder                  | 0          | 10         | 0                                          | 30             |
| Van der Aa et al. 2009   | 35             | Open      | Ileum       | Native and augmented            | –          | 28.6       | –                                          | –              |
| Gowda et al. BJUI, 12 2008 | 65             | Open      | Appendix Ileum Ureter | Native and augmented | 75.2       | 8          | 4.6                                        |                 |
| Sultan et al. J of Urology, 10 2008 | 82             | Open      | Appendix Ileum Ureter | Augmented bladder | 2.4        | 0          | 1.2                                        | 3.7            |
| Welk et al. J of Urology, 10 2008 | 67             | Open      | Appendix Ileum Ureter | Native and augmented | 6.0        | 9.0        | 0                                          | 9.0            |
| Sahadevan BJUI, 07 2008   | 28             | Open      | Appendix Ileum Ureter | Native and augmented | 57         | 32.1       | 0                                          | 10.7           |
| England and Subramaniam J of Urology, 12 2007 | 23             | Open      | Appendix Ileum Ureter | Native and augmented | 21.7       | 8.7        | 0                                          | 7.1            |
reconstructive surgery following congenital abnormalities (posterior urethral valves, extrophy, and neuropathic bladder). The authors here attributed these good results with the use of the VQZ reconstruction at skin level and conduits made using appendix or ileum.

Some authors have compared the stenosis rates between an appendix and Yang-Monti conduit and results have been conflicting. In one study of 122 patients, stomal stenosis was noted to be less common with the Monti conduit (29%). However, another report by Naranayanswamy et al. showed that the Monti conduit was more likely to stenose (60%). A further study of 65 patients found no difference in stenosis rates between either conduit type.

Revision rates following Mitrofanoff
In cases of stomal stenosis or incontinence following an initial Mitrofanoff procedure, revision of the conduit or reservoir (e.g., further augmentation) is required. Some patients even require urinary diversion surgery. The revision rate in the literature is between 0% and 75%, again increasing with the length of follow-up. Some of the early studies reporting no revision surgery had follow-up time of less than 15 months. In contemporary series, overall revision rates have ranged from 8.7% to 32%.

At a mean follow-up of 75 months, Gowda et al. reported that following revision surgery, 92% of patients still had a Mitrofanoff conduit, of which 97% are catheterizable and 95% are continent. In the series by Sahadevan et al., 82% of patients still had a catheterizable Mitrofanoff conduit at 126 months.

Continence rates
In pediatric series, continence rates following Mitrofanoff procedures have been reported to be between 79% and 100%. Duckett and Lotfi reported a 100% continence rate in 41 patients after a mean follow-up of 3.2 years. Liard et al. had one of the longest average follow-up time of 20 years, but a recent contemporary report by Sultan et al. reported on a lower rate of 4%. Barroso et al. also reported that there was a slightly increased incidence of calculi following Mitrofanoff procedures, but noted that there was no significant difference between those who had an augmented bladder or a native bladder. It has been postulated that a further mechanism for UTI and bladder calculi formation is that the transposed intestinal segments continue to secrete mucin.

Bladder calculi and urinary tract infection (UTI)

The incidence of UTIs has not been widely reported in many of the follow-up studies. Apart from the risk factors such as the use of clean intermittent self catheterization and intestinal augmentation, compliance has been reported to be one of the pre-disposing factors for UTI. Patients who do not empty their bladder regularly seem to have a higher incidence of UTI. Inability to completely empty the reservoir can also lead to bladder calculus formation. Liard et al. showed a 22% incidence of bladder calculi at a mean follow-up time of 20 years, but a recent contemporary report by Sultan et al. reported on a lower rate of 4%. Barroso et al. also reported that there was a slightly increased incidence of calculi following Mitrofanoff procedures, but noted that there was no significant difference between those who had an augmented bladder or a native bladder. It has been postulated that a further mechanism for UTI and bladder calculi formation is that the transposed intestinal segments continue to secrete mucin.

MINIMALLY INVASIVE SURGERY

Recent reports have confirmed the technical efficacy of laparoscopic and robotic-assisted Mitrofanoff procedures. For these studies, short term results are encouraging but longer follow-up reports are required to see if they match the previously reported outcomes.

CONCLUSION

Continent urinary diversion, based on the Mitrofanoff principle, has similar outcomes in adult urological practice to those described in published pediatric case series. There is good evidence to suggest that Mitrofanoff conduits are durable, but there is a high need for re-intervention especially for stomal stenosis. However, patients should be aware of complications and the need for long-term follow-up.

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