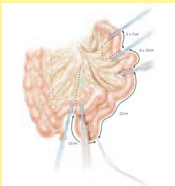

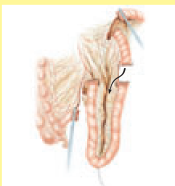

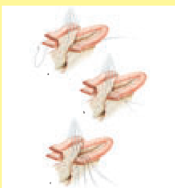

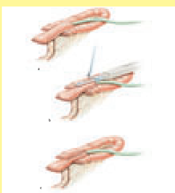

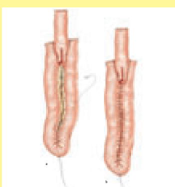

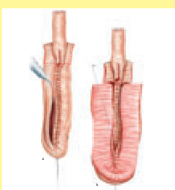

Surgical Atlas

The orthotopic T-pouch ileal neobladder

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ILLUSTRATIONS by STEPHAN SPITZER, www.spitzer-illustration.com

INTRODUCTION

Today, the goals of urinary diversion have developed from simply diverting the urine and protecting the upper urinary tracts. Contemporary objectives of urinary diversion should include a form of reconstruction which provides a safe and continent means to store and eliminate urine, with efforts to improved the quality of life of the individual [1]. Currently there are four reasonable options for lower urinary tract reconstruction: (i) an incontinent cutaneous diversion, the ileal or colon conduit; (ii) a continent cutaneous reservoir, requiring catheterization of a cutaneous stoma; (iii) a continent rectal reservoir, with storage and elimination of urine via the rectum; and (iv) the orthotopic bladder substitute, with reconstruction to the native intact urethra.

In 1950, Bricker introduced the ileal conduit, which established a technically simple and reliable form of urinary diversion [2]. This urinary diversion is common even now and is a standard to which other forms of urinary reconstruction are compared. Concurrent with Bricker's introduction of the ileal conduit, Gilchrist *et al.* [3] independently reported on the concept of a continent cutaneous form of diversion using the ileocaecal valve as the continence mechanism, and the distal ileum as a catheterizable stoma. For technical reasons, this ileocaecal reservoir garnered little support, while the simpler Bricker ileal conduit became the urinary diversion of choice for the next several decades.

The concept of a continent cutaneous urinary diversion was eventually reintroduced and popularized in the early 1980s at several large academic institutions [4–6]. This experience revolutionized urinary diversion to a continent cutaneous form of diversion. Although patients were relieved from the problems of an external collection device, catheterization of the continent abdominal stoma was required. The continent cutaneous urinary diversion was an advance and considered an improvement on the standard ileal or colon conduit, but these reservoirs are more technically challenging, take longer to construct, and are associated with a reoperation rate, particularly the efferent catheterizable limb.

A natural progression of the continent cutaneous urinary diversion was the orthotopic bladder substitute (neobladder) connected directly to the native intact urethra. The orthotopic neobladder resembles the original bladder in both location and function. Orthotopic reconstruction eliminates the need for a cutaneous stoma and a cutaneous collection device; it relies on the patients' intact rhabdosphincter continence mechanism (external striated sphincter muscle), eliminating the need for intermittent catheterization in most cases and the often difficult efferent limb of the continent cutaneous reservoir. Voiding is effectively accomplished by concomitantly increasing intra-abdominal pressure (Valsalva) with relaxation of the pelvic floor musculature.

Orthotopic reconstruction was first applied to carefully selected male patients in the mid-1980s, giving excellent clinical and functional results [7]. The positive experience in men subsequently stimulated interest in applying orthotopic reconstruction to women [8]. Based on neuroanatomical dissections [9] (which provided a better understanding of the continence mechanism in women), as well as defined pathological guidelines [10] (which allowed for proper patient selection from a cancer perspective in women), orthotopic reconstruction was successfully applied to women in the early 1990s. Most men and women currently undergoing cystectomy are appropriate candidates for orthotopic reconstruction [1].

From 1982 to 1997, the primary form of urinary diversion at the University of Southern California was the continent cutaneous ileal reservoir (Kock pouch), as described by Kock *et al.* [6–8]. The intussuscepted nipple valve provided the continence and antireflux mechanism in the Kock ileal reservoir. We have been committed to the principles of the Kock ileal reservoir and reflux prevention in patients undergoing continent urinary reconstruction. We think that the principles of the continent Kock ileal reservoir (cutaneous and orthotopic form) are sound, but complications can occur [11–13]. Most complications associated with the Kock ileal reservoir relate to the intussuscepted limb; either the antireflux (afferent limb) or the continent catheterizable (efferent limb) nipple [12,13].

A review of our experience with the Kock ileal reservoir subsequently revealed a 10% complication rate associated with the afferent intussuscepted antireflux nipple of >800 patients (including either the continent cutaneous or orthotopic Kock ileal reservoir) [12]. The three most common complications associated with the intussuscepted afferent nipple included: (i) calculi formation (associated with exposed staples that secure the afferent nipple valve) in 5%; (ii) afferent nipple stenosis (thought to be caused by ischaemic changes resulting from the mesenteric stripping required to maintain the intussuscepted limb) in 4%; and (iii) extussusception (prolapse of the afferent limb) in 1% of patients. Although most of these afferent nipple-valve complications (60%) can be easily managed with endoscopic techniques, they nonetheless can result in some morbidity. About 3% of all patients undergoing a continent Kock ileal reservoir will require an open surgical revision to repair an afferent nipple complication [12].

The need to improve upon the intussuscepted nipple valve became increasingly obvious. Based on reports from Ghoneim's group using a ureteric extra-serosal tunnel [14,15], and our experience with the Mitrofanoff appendiceal subserosal tunnel, we subsequently developed and reported our initial experience with this flap-valve T-mechanism [16]. The T-mechanism is a versatile technique that can easily be applied as an antireflux mechanism, as well as an continent mechanism in a cutaneous reservoir [17]. Since 1997, we have used the T-mechanism as an important modification to the Kock ileal reservoir [16,18].

The T-mechanism was first successfully incorporated as the afferent antireflux limb of an orthotopic reservoir (*T-pouch*) [16,18] and subsequently into an afferent antireflux and efferent continence limb of a cutaneous reservoir (*double-T-pouch*) soon after [17]. We think that the flap-valve T-mechanism has eliminated the complications associated with the intussuscepted nipple valve, while maintaining an effective antireflux or continence mechanism. The surgical technique of the orthotopic T-pouch ileal neobladder is described.

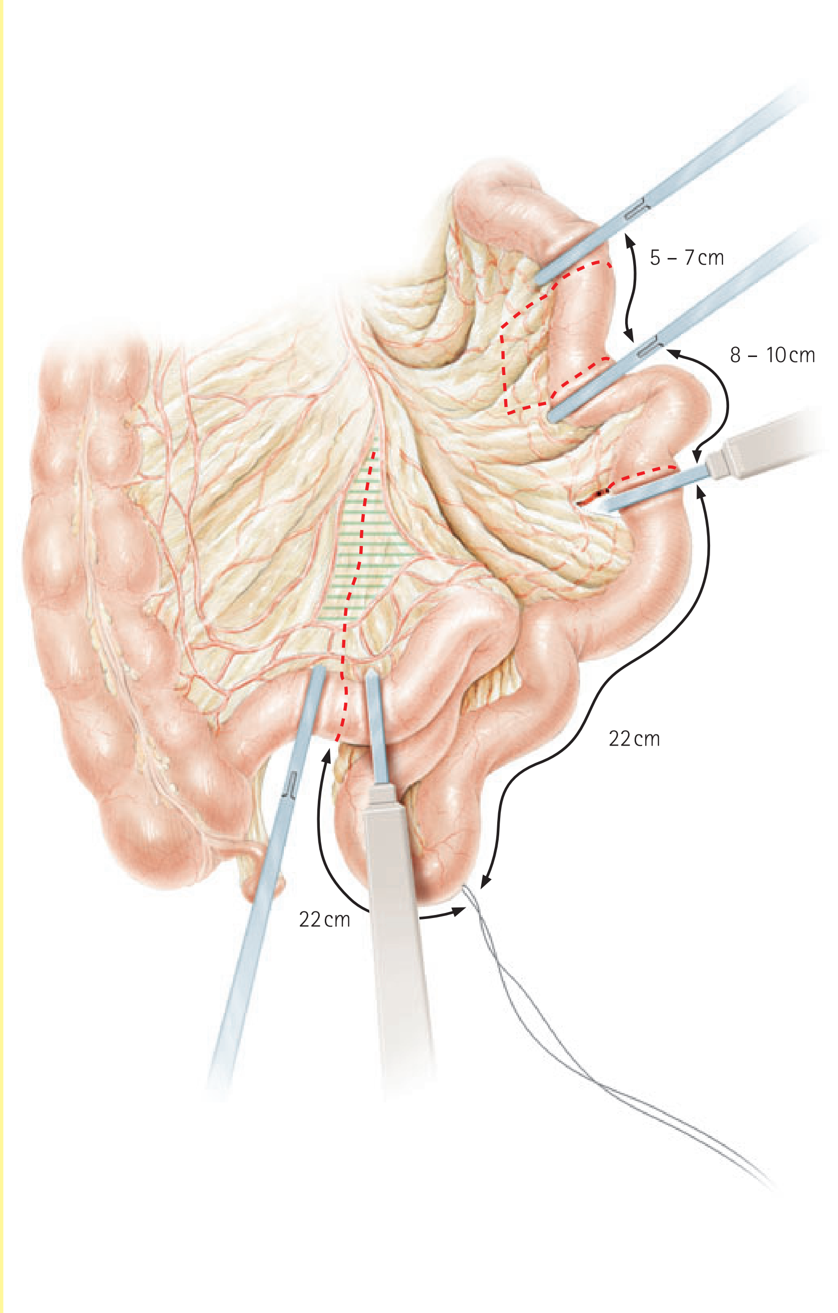


Figure 1

The terminal portion of the ileum is used to construct the orthotopic T-pouch ileal neobladder. The distal mesenteric division is best made along the avascular plane of Treves (marked green) between the ileocolic artery and terminal branches of the superior mesenteric artery. This division should extend deep into the avascular portion of the mesentery, which is essential for adequate mobility of the reservoir. However, the proximal mesenteric division is short and provides a broad vascular blood supply to the reservoir. In addition, a small window of mesentery and 5–7 cm portion of small bowel most proximal to the overall ileal segment are discarded. This helps to ensure mobility of the pouch and small bowel anastomosis.

The T-pouch reservoir is created from a 44-cm segment of distal ileum placed in a 'V' configuration. Each limb of the 'V' measures 22 cm. A proximal 8–10 cm segment of ileum (afferent limb) is used to form the afferent antireflux mechanism. Note, if the ureteric length is short or compromised, a longer afferent ileal segment (proximal ileum) can be harvested to bridge the ureteric gap.

The ileum is divided between the proximal afferent ileal segment and the 44-cm segment that will form the reservoir portion of the neobladder. The mesentery between these ileal segments is carefully incised for 2 cm, with preservation of all major vascular arcades. This mesenteric incision is directed toward the base of the mesentery and provides mobility to the afferent ileal segment which will ultimately be advanced into the serosal-lined ileal trough formed by the base of the two adjacent 22-cm segments of ileum.

The proximal end of the isolated afferent ileal segment is closed with a running Parker-Kerr suture of 3–0 chromic, and a third layer of interrupted 4–0 silk sutures. A standard small bowel anastomosis is performed to re-establish bowel continuity, and the mesenteric trap closed.

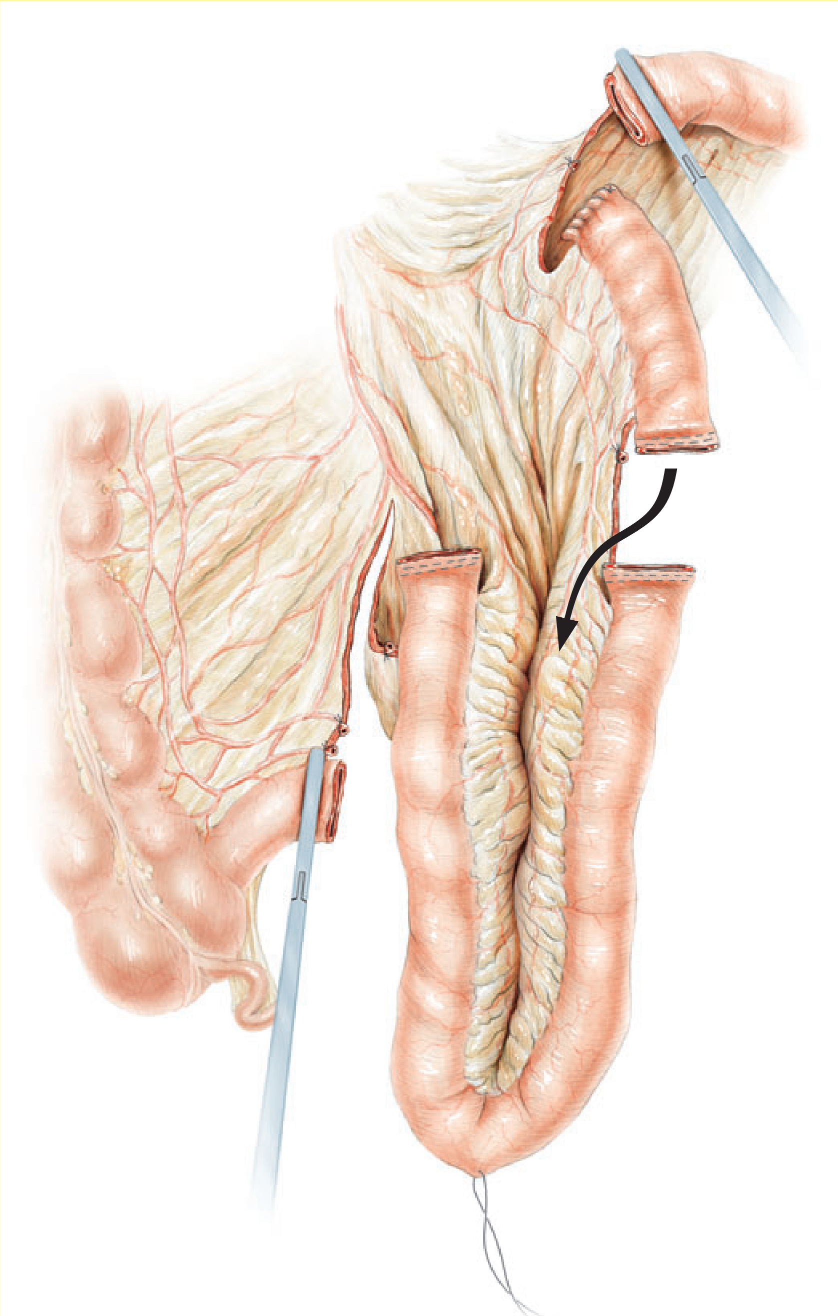


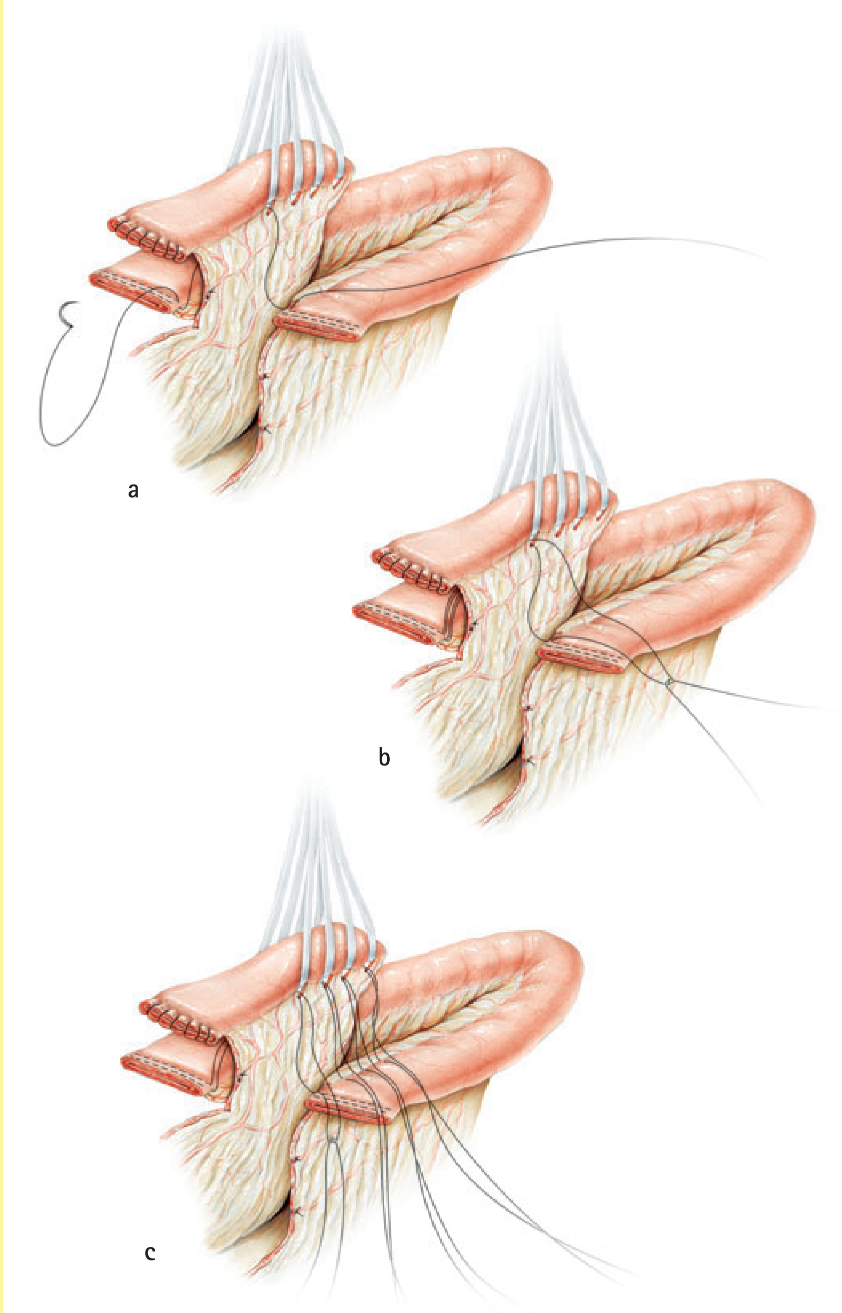
Figure 2

The isolated 44-cm ileal segment is then laid out in a 'V' configuration, the apex of the 'V' lying caudally with a suture marking a point between the 22-cm adjacent segments of ileum. The opened end (base) of the 'V' is directed in a cephalad manner. Note the serosal-lined ileal trough formed at the base of the 44-cm segment.

Figure 3

The antireflux (flap-valve) mechanism is then created by anchoring the distal 4 cm of the afferent ileal segment into the serosal-lined ileal trough formed by the two adjacent 22 cm ileal segments. First, mesenteric windows of Deaver are opened between the vascular arcades (carefully excising mesenteric fat adjacent to the serosa of the ileum, which facilitates the development of these mesenteric windows) for 4 cm proximal to the distal-most portion of the isolated afferent ileal segment. Preserving these arcades (blood vessels) maintains a well vascularized afferent limb and will allow permanent fixation of this portion of the limb into the serosal-lined ileal trough, with complete preservation of the mesentery and blood supply. Note, placing small Penrose drains through each mesenteric window helps to identify and facilitates the passage of suture through each.

A series of 3–0 silk sutures is then used to approximate the serosa of the two adjacent 22-cm ileal segments at the base of the 'V', with the sutures being passed through the previously opened windows of Deaver in the afferent ileal limb. This will then anchor the afferent limb into the serosal-lined ileal trough. Specifically, a silk suture is placed into the seromuscular portion of the bowel (adjacent to the mesentery) at the base (most cephalad portion of the 'V') of one of the 22-cm ileal segments. The suture is then passed through the most proximal window of Deaver opened in the afferent ileal limb (Fig. 3b) and placed in a corresponding seromuscular site of the bowel (next to mesentery) of the adjacent 22-cm ileal segment (Fig. 3a). The suture is brought back through the same window of Deaver and tied down (Fig. 3b). Generally, two to three silk sutures are placed within each window of Deaver to ensure that the back wall of the reservoir does not separate. This process is repeated through each window of Deaver until the distal 4 cm of the afferent segment is permanently fixed in the serosal-lined ileal trough (Fig. 3c). We have found that placing a small (5 mm) Penrose drain through each window of Deaver facilitates passage of the silk suture back and forth through the mesentery with no difficulty. The Penrose drains are systematically removed as the afferent limb is fixed within the serosal-lined ileal trough.



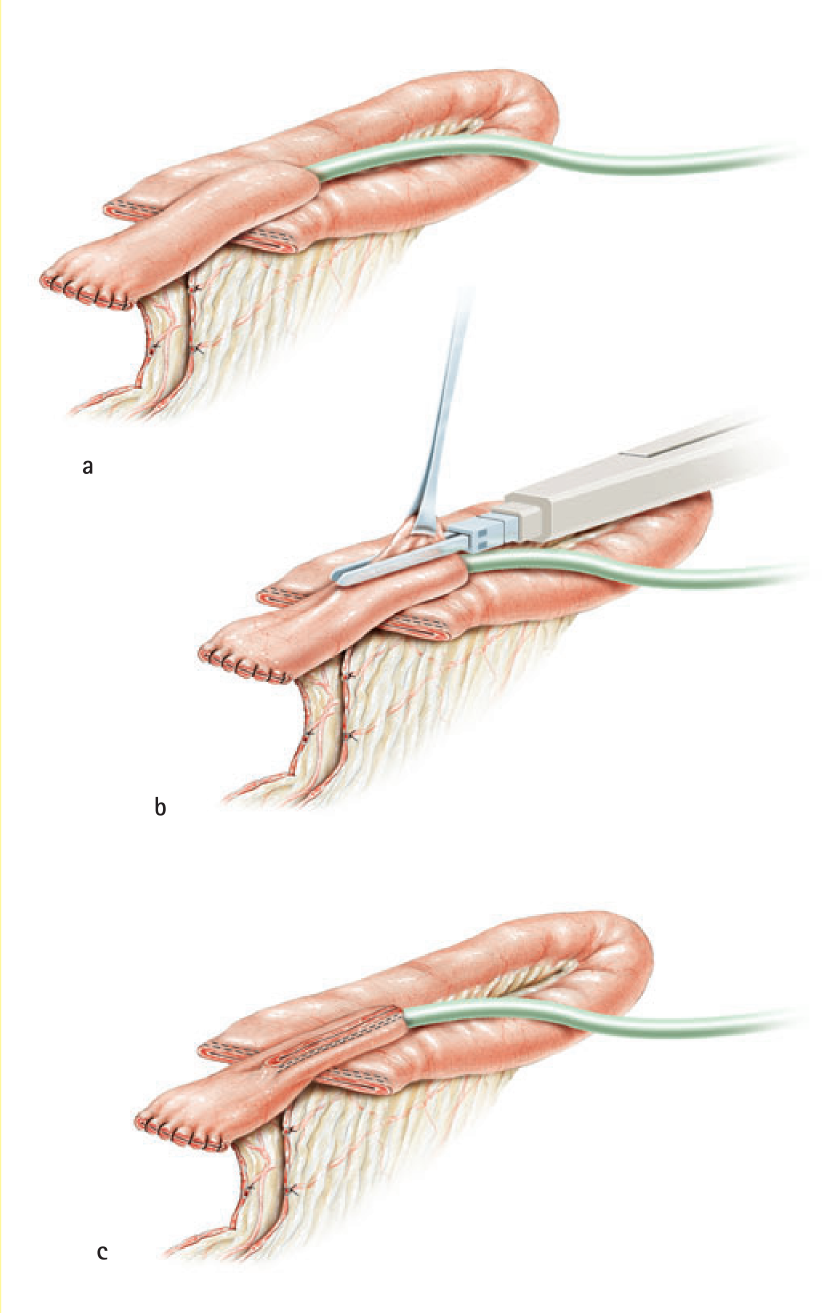
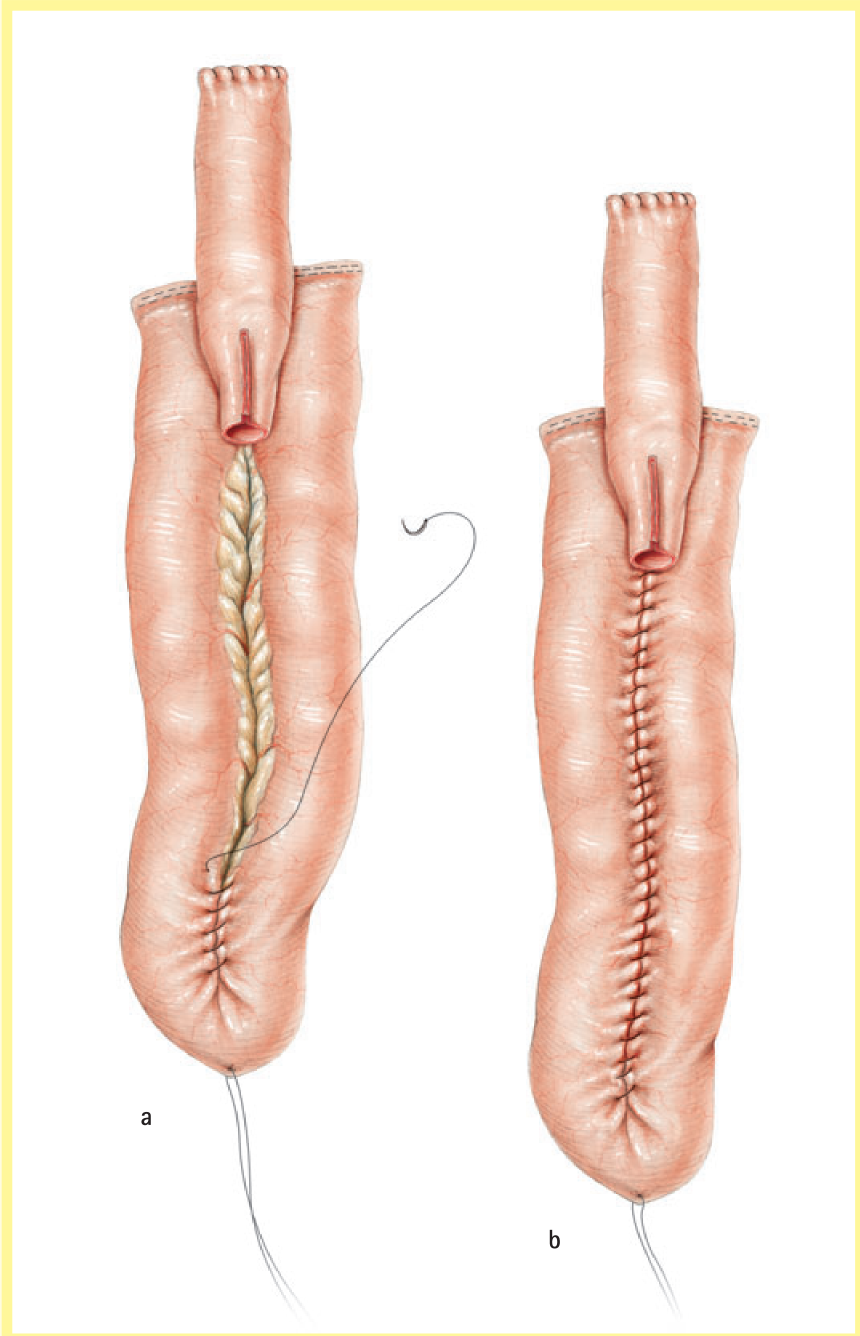


Figure 4

Next, the previously anchored portion of the afferent ileal segment (distal 4 cm) can be tapered on the antimesenteric (anterior) border over a 30 F catheter. Tapering this portion of the afferent ileal segment reduces the bulk and lumen of the afferent limb, and facilitates later coverage of the anchored afferent limb with ileal flaps. In addition, tapering of the afferent limb increases the tunnel-length to lumen diameter ratio, providing a more effective flap-valve mechanism. Since the initial description of the T-pouch, we now selectively taper the afferent limb only in cases where there is clearly a large diameter of ileum. We prefer to use a GIA-55 stapler to taper this distal 3–4 cm afferent segment (Fig. 4b). The staples will not be exposed as this staple line will be covered by ileal flaps.

Figure 5

Next, the remaining portion of the adjacent 22-cm ileal segments are approximated together with a side-to-side 3–0- polyglycolic acid suture. This suture line simply re-approximates the two ileal limbs and is placed adjacent to the mesentery, which can be with a running or interrupted suture.



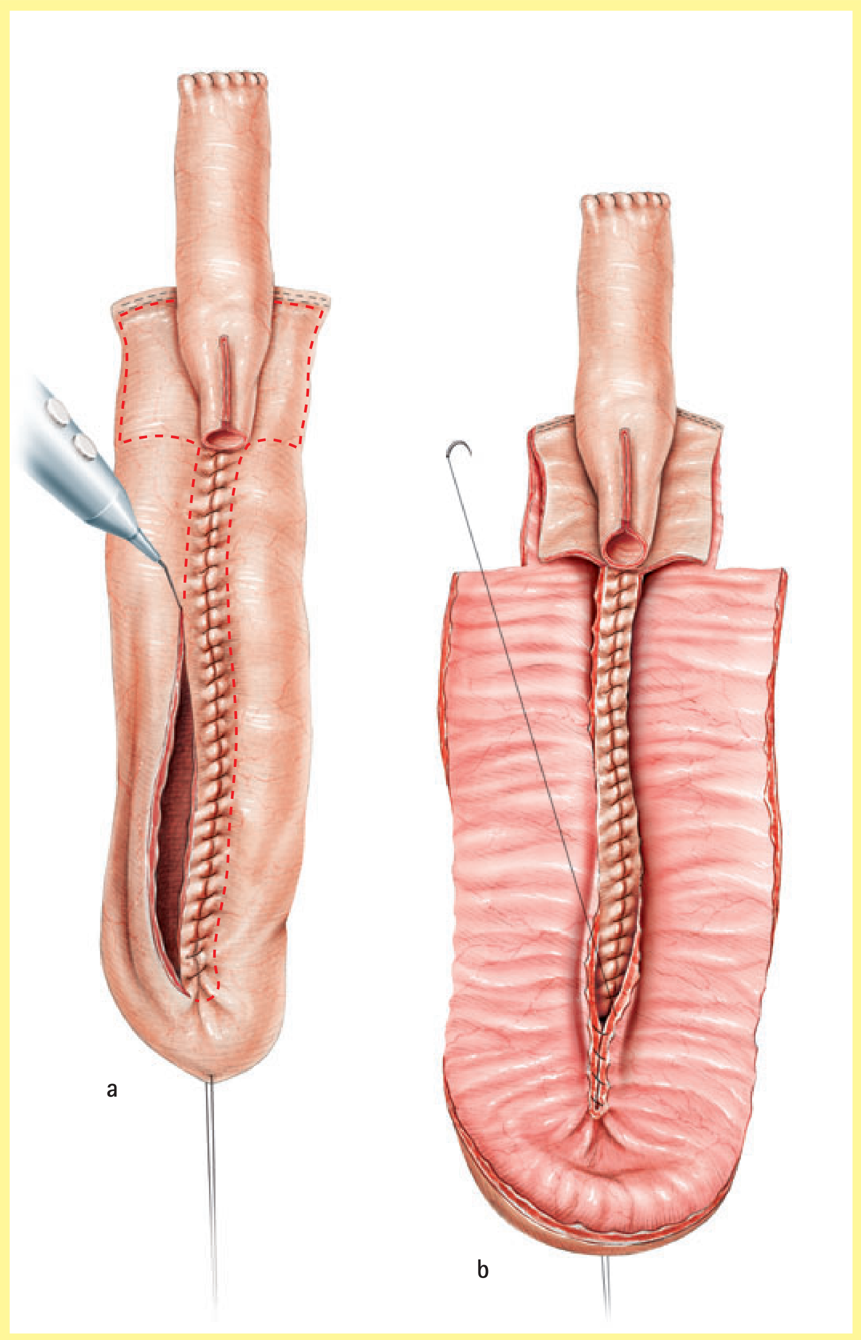


Figure 6

Starting at the apex of the 'V', the ileum is then opened immediately adjacent to the previously placed serosal suture line, using electrocautery. This incision is carried upward toward the ostium of the afferent limb where the afferent limb is anchored. Once this incision reaches the level of the afferent ostium, the incision is then extended directly lateral to the antimesenteric border of the ileum, and carried upward (cephalad) to the base of the ileal segment. An incision is made in similar fashion on the contralateral 22-cm ileal segment. Once completed, these incisions provide wide flaps of ileum that will ultimately be brought over and cover the tapered afferent ileal segment, to create the antireflux mechanism in a flap-valve technique.

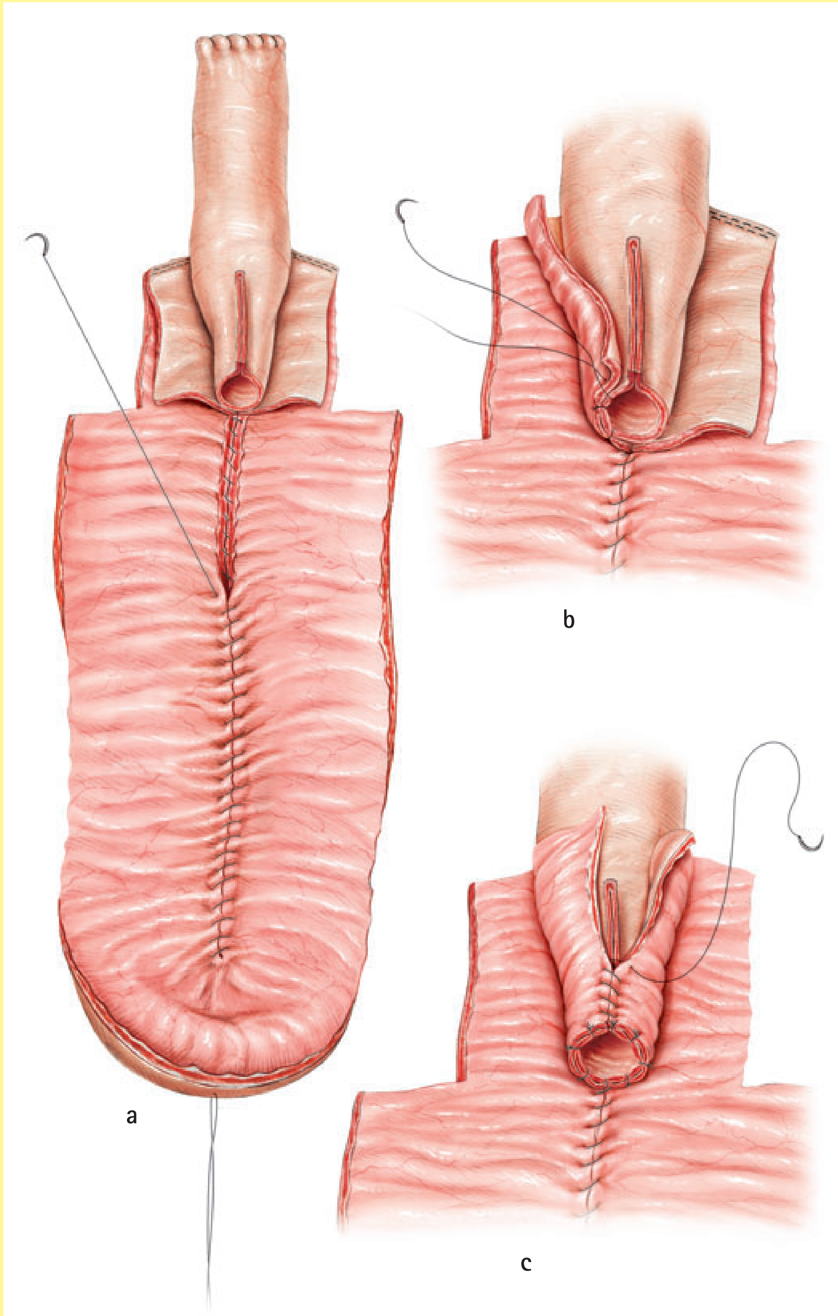


Figure 7

The previously incised ileal mucosa is then over-sutured with two layers of a running 3–0 polyglycolic acid starting at the apex and running upward toward the ostium of the afferent limb (Fig. 7a). Once the ostium of the afferent limb is reached, the running suture is tied. An interrupted mucosa-to-mucosa anastomosis is then made between the ostium of the afferent ileal limb and the incised intestinal ileal flaps, with 3–0 polyglycolic acid sutures (Fig. 7b). The mucosal edges of the ileal flaps are then approximated over the tapered portion of the afferent ileal limb (4 cm) with a running suture in two layers (Fig. 7c). This suture line completes the posterior wall of the reservoir and creates the effective flap-valve T-mechanism: the serosal-lined ileal antireflux limb.

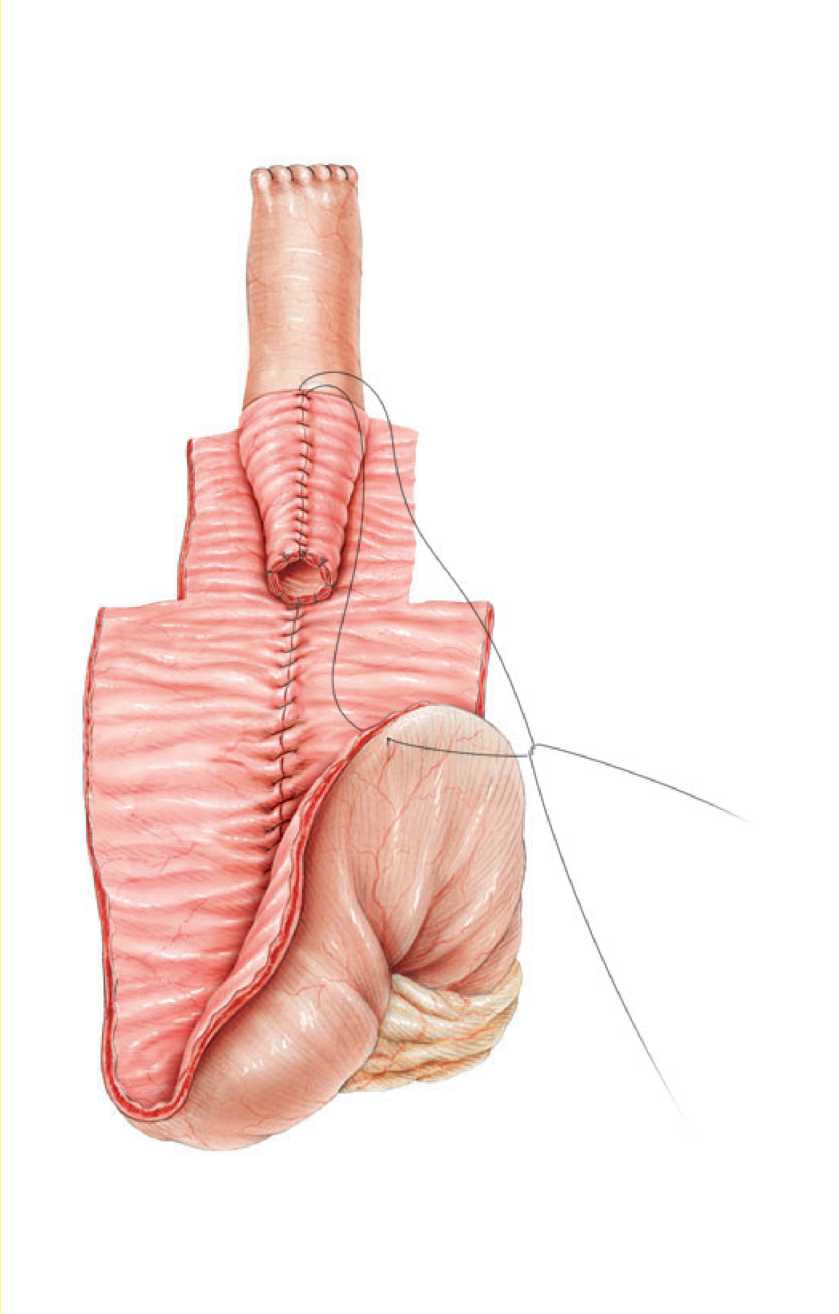


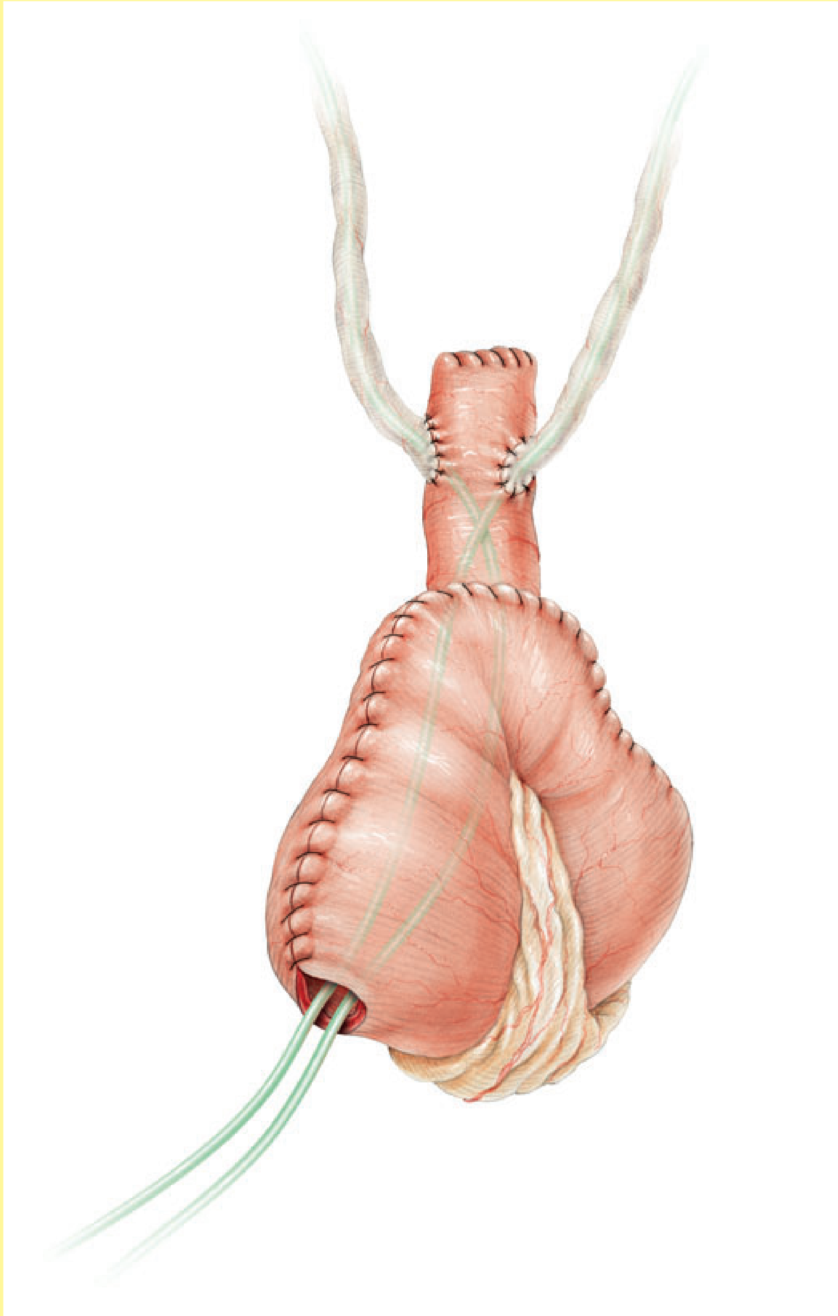
Figure 8

The reservoir is then closed by folding the ileum in half in an opposite direction to which it was opened. This effectively creates a low-pressure high-capacity urinary reservoir.

Figure 9

The anterior wall is closed with a running, two layer 3–0 polyglycolic acid suture that is watertight. This anterior suture line is stopped just before the end of the right side, to allow insertion of an index finger. This is the most mobile and dependant portion of the reservoir and will later be anastomosed to the urethra.

Once the pouch has been closed, each ureter is spatulated and a standard, bilateral end-to-side uretero-ileal anastomosis made to the proximal portion of the afferent limb using interrupted 4–0 polyglycolic acid suture. These anastomoses are stented with no. 8 infant-feeding tubes, which are directed from the ipsilateral renal pelvis (kidney), across the uretero-ileal anastomosis through the afferent limb into the reservoir and out of the neourethra. A 24 F haematuria catheter is placed urethrally to provide adequate drainage of the reservoir and the ureteric stents are secured to the end of the urethral catheter with a 3–0 nylon suture. This facilities removal of the stents at ≈3 weeks, along with the urethral catheter. A tension-free mucosa-to-mucosa urethro-ileal anastomosis is the result.



DISCUSSION

Critical components to the success of lower urinary tract reconstruction include the ability to create a large-capacity, low-pressure reservoir with an adequate continence mechanism to store urine. The landmark report in 1982 by Kock *et al.* [6] stimulated enthusiasm for a continent cutaneous form of urinary diversion, and inspired the development of a wide variety of continent cutaneous urinary reservoirs. The continent cutaneous urinary reservoir naturally developed into an orthotopic form of reconstruction, eliminating the cutaneous urostomy, stoma and the need for catheterization in most patients. Orthotopic urinary diversion has become the procedure of choice in both male and female patients requiring cystectomy during the mid and late 1980s [1].

The development of orthotopic reconstruction was a significant improvement in the development of urinary diversion. The importance of preventing the reflux of urinary constituents after orthotopic reconstruction has become a controversial subject and remains a topic of debate. We have supported, and continue to be strong proponents of, reflux prevention in all patients undergoing lower urinary tract reconstruction. We emphasize that the complications or risks associated with incorporating an antireflux mechanism (i.e. obstruction) should not outweigh the theoretical advantage of reflux prevention. To meet this end, we have been diligent in critically evaluating our antireflux techniques and continually improve upon existing ideas and methods. This evaluation has subsequently stimulated a change from the intussuscepted nipple of the Kock pouch, to the development of the flap-valve T-mechanism, incorporated as an antireflux limb in the orthotopic T-pouch ileal neobladder [16,18]. This technique provides an effective antireflux mechanism without the associated complications associated with the intussuscepted nipple. Furthermore, the T-mechanism has been applied as a catheterizable continent mechanism in cutaneous reservoirs, and is discussed elsewhere [17].

With appropriate follow-up, problems with urinary reflux became evident in patients undergoing various forms of urinary diversion, including ureterosigmoidostomy [19], and ileal conduit urinary diversion [20,21]. Richie *et al.* [22,23] showed in canine experiments that reflux of infected urine could lead to renal impairment, and suggested that antireflux techniques should be considered. The application of an antireflux mechanism was supported experimentally in colon conduits, but with longer follow-up renal deterioration also became problematic in these patients [24,25], thought to be related to high pressures, obstruction and chronically infected urine.

Currently there are many antireflux techniques [26]; the inclusion of an antireflux mechanism in the chronically infected, continent cutaneous reservoir (requiring intermittent catheterization) is important and not a source of considerable debate. With increasing popularity and further application of the low-pressure orthotopic reservoir, the issue of reflux prevention has regained attention. Studer *et al.* [27] advocate a long (20 cm), dynamic, isoperistaltic ileal segment as an afferent limb of an orthotopic neobladder reservoir. Proponents of the isoperistaltic afferent ileal limb argue that radiographic evidence of reflux in a sterile, low-pressure reservoir might not have the same importance and clinical consequence. Furthermore, the complications of late stenosis from the various antireflux techniques could potentially outweigh their theoretical advantage of protecting the upper urinary tract. However, others argue that antireflux procedures are not only theoretically inherent in humans, but are critical to preserve or maintain renal function, and important in all forms of lower urinary tract reconstruction, even orthotopic diversion. Reasons include that patients, even with an orthotopic neobladder, can have colonized bacteriuria. The unexpected patient requiring intermittent catheterization to completely empty their neobladder (which is unpredictable) will also expectedly have colonized bacteriuria with the risk of upper tract deterioration. Experimental data from dogs undergoing a low-pressure enterocystoplasty with refluxing ureteric implantation support this notion, as these dogs were found to have bacteriuria in the upper urinary tract, and pyelonephritis [28].

Reflux prevention after orthotopic diversion might become more important as the comprehensive therapy (medical and surgical) for pelvic malignancies improves, and patients' life-expectancy increases after exenteration and urinary diversion. This might then place patients at further risk of renal deterioration in the future. Subsequently, several novel antireflux mechanisms have been developed to improve on existing techniques and eliminate or reduce the complications associated with previous antireflux mechanisms, particularly obstruction [15,16,18]. A longer follow-up will be required to accurately evaluate the isoperistaltic afferent limb, and these more recent antireflux techniques, to determine if preventing reflux in patients undergoing orthotopic diversion is truly necessary.

From 1982 to 1997, we incorporated the intussuscepted nipple valve as an antireflux mechanism in all forms of continent urinary diversion, and as an efferent continence mechanism in patients undergoing a cutaneous Kock ileal reservoir [4,7,8]. The basic surgical premise and structural characteristics of the Kock ileal reservoir are sound: low-pressure, large-capacity reservoir, using an antirefluxing and continent nipple valve. However, the Achilles' heel of the Kock ileal reservoir remains the intussuscepted nipple valve. Despite several surgical modifications to improve on the construction of the intussuscepted nipple valve, there remained complications and a reoperation rate [12,13,29,30]. The need to improve on the intussuscepted nipple valve became obvious with time.

The T-mechanism is a flap-valve technique which can be applied as an antireflux and continence mechanism in lower urinary tract reconstruction [16–18]. In general, all flap-valve techniques rely on the dynamic principle that the channelled segment (appendix, ureter, intestine) is fixed and tunnelled along the inner wall of the reservoir. As the reservoir fills, the channelled segment is compressed against the wall of the pouch and continence or reflux are prevented. This technique is based on similar principles for reimplantation of the ureter into the bladder. The keys to success of the flap-valve technique include an appropriate tunnel-length to lumen-diameter ratio. Furthermore, the back wall of the reservoir must be sufficiently capable to allow compression of the tunnelled channel as the pouch fills.

The unique aspect of the T-mechanism (antireflux and continence) is the ability to create a reliable and effective flap-valve system. Maintenance of the vascular arcades (opening the windows of Deaver) provides complete preservation of the mesentery and blood supply to the entire limb, thus eliminating problems with ischaemia or stenosis of the bowel segment. Permanent fixation of the limb into the serosal-lined ileal trough should also eliminate issues associated with prolapse or extussusception of the limb. Importantly, there are no exposed metallic staples within the reservoir, which should reduce the incidence of stone formation typically associated with exposure of metallic foreign bodies to urine. Furthermore, if necessary the proximal portion of the afferent limb can be easily lengthened when there are shortened or compromised ureters. A longer proximal afferent segment can be harvested to bridge any ureteric defect to maintain a tension-free uretero-ileal anastomosis.

Several technical points on the specifics of the construction of the flap-valve T-mechanism (antireflux, continence) deserve note. An effective afferent antireflux valve can be created from 4 cm of ileum anchored within the serosal-lined ileal trough. Permanently anchoring the portion of ileum in the serosal-lined ileal trough is critical to fix the limb and prevent any valve slippage or prolapse. In addition, the silk sutures used to anchor the valve (passed through the windows of Deaver) should be placed adjacent to the mesentery, and should incorporate a generous portion of the seromuscular ileum, to prevent separation of the serosal-lined ileal trough. This trough forms the so-called 'backboard' (posterior wall to the reservoir) of the flap-valve technique, which is critical to antireflux prevention as the reservoir fills. Placing two or three sutures within each window of Deaver should prevent separation of this trough.

The antimesenteric tapering of the valve is also an important surgical/technical component when there is a large diameter ileum (>30 F), to facilitate the flap-valve T-mechanism. Tapering the afferent limb over a 30 F catheter is effective in preventing reflux of urinary constituents and protecting the upper tracts in patients undergoing an orthotopic T-pouch ileal neobladder [18]. This effectively increases the tunnel-length to lumen-diameter ratio and has provided an excellent efferent continence mechanism.

The flap-valve T-mechanism in the T-pouch provides an effective and reliable antireflux mechanism. The long-term results of the T-pouch are yet to be determined, but the initial and intermediate results have been promising [16,18]. Furthermore, we think that this technique can be easily learned, with a little experience. The T-mechanism is a very versatile flap-valve technique that can also be applied as a continent mechanism in a cutaneous reservoir (double-T-pouch). We think that reconstructive surgeons interested in lower urinary tract reconstruction should understand this concept and technique, to broaden their surgical options.

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