The Use of Bowel in Urologic Reconstructive Surgery

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KEYWORDS
- Urinary diversion • Bladder substitution • Neobladder • Ileal ureter
- Bladder augmentation • Appendicovesicostomy • Metabolic changes

KEY POINTS
- Urologists routinely use intestinal segments for reconstructive procedures and surgeons often encounter such reconstructions of the urinary tract.
- Surgeons should have a clear understanding of the most common urinary reconstructions using intestinal segments.
- Urinary tract reconstructions using intestinal segments can result in a variety of metabolic and electrolyte abnormalities.

Intestinal surgery involves an operative space shared by both general surgeons and urologists and is a border region where these 2 surgical disciplines often intersect. Urologists routinely use both small and large bowel for reconstructive procedures and surgeons often encounter such reconstructions of the urinary tract. It is therefore essential for surgeons to have a clear understanding of the urologic indications for using intestinal segments for reconstructive procedures, the variety of such reconstructions, the anatomic landmarks and potential pitfalls that should be considered when intraoperatively encountering such reconstructions, and the potential metabolic consequences associated with the incorporation of bowel segments into the urinary collecting system.

URINARY DIVERSION

Urinary diversion involves the separation of the ureters from the bladder and the development of an alternate route of urinary evacuation. The goal of urinary diversion is to provide a convenient and reliable drainage system when the native bladder is
no longer able to serve this function. Common indications for urinary diversion include:

- Bladder or other pelvic malignancies requiring removal of the bladder
- Congenital anomalies of bladder development
- Intractable urinary incontinence
- Intractable bladder hemorrhage

Although a full description of all variants of urinary reconstruction involving intestinal segments is beyond the scope of this article, it is informative to understand the historical evolution of these procedures, the anatomic principles fundamental to each procedure, and the most common variations that surgeons can expect to encounter.

**URETEROSIGMOIDOSTOMY**

In 1852, Simon described the first urinary diversion after performing a ureterosigmoidostomy on a patient with congenital bladder exstrophy. Ureterosigmoidostomy involves the implantation of the ureters into the tenia of the sigmoid colon, resulting in a combined evacuation of urine and feces per rectum. This procedure remained the most common form of urinary diversion for nearly a century. However, with longer-term follow-up it became clear that ureterosigmoidostomy often led to significant complications, to include:

- Chronic diarrhea and consequent electrolyte abnormalities
- Upper urinary tract obstruction
- Chronic pyelonephritis, renal scarring, and renal insufficiency
- Secondary malignant neoplasms occurring at the ureterocolonic implantation site

This realization led to further investigations in which the ureters were implanted into a variety of other bowel segments that were separated from the fecal stream.

**CONDUIT URINARY DIVERSIONS**

In 1950, Bricker ushered in a new era in urinary diversion with his description of the intestinal conduit urinary diversion with cutaneous drainage. Although conduit urinary diversion had conceptually been described earlier by Zaayer in 1911, it was Bricker’s simple and straightforward description of the ileal conduit diversion that popularized this procedure.

**ILEAL CONDUIT**

The ileal conduit remains the most common form of urinary diversion in the world and it is therefore often encountered by surgeons. It is generally constructed from a ~20-cm segment of ileum with its distal end ~20 cm proximal to the ileocecal junction (Fig. 1). In general, when urologists harvest a segment of small bowel for reconstructive purposes the remaining bowel is brought cephalad to it and continuity is reestablished. Ileal conduits are most often placed in the right lower quadrant of the abdomen rather than the left because of limitations of the length of the distal ileal mesentery. The ureteropenile anastomosis may be performed in the following 2 ways:

- The Bricker technique, in which the ureters are reimplanted individually in an end-to-side fashion to the proximal end of the ileal conduit (Fig. 2).
The Wallace technique, in which the ureters are spatulated and then joined together in an end-to-end fashion (Fig. 3).

The proximal end of the ileal conduit is usually fixed to the posterior peritoneum to prevent volvulus of the conduit. The lateral aspect of the ureter may also be fixed to the lateral edge of the peritoneum to prevent intestinal herniation of bowel lateral to the

Fig. 1. Ileal conduit urinary diversion. (From Parekh DJ, Donat SM. Urinary diversion: options, patient selection, and outcomes. Semin Oncol 2007;34(2):98–109; with permission.)

Fig. 2. Bricker technique for ureteroileal anastomosis. (From Manoharan M, Tunuguntla HS. Standard reconstruction techniques: techniques of ureteroneocystostomy during urinary diversion. Surg Oncol Clin N Am 2005;14(2):367–79; with permission.)
conduit. The distal end of the conduit is brought through the rectus abdominis muscle, anchored to the fascia, and everted and matured into a cutaneous stoma.

**JEJUNAL CONDUIT**

Conduit urinary diversions using jejunum are only used if no other bowel segment is available. Although construction of a jejunal conduit is technically identical to the construction of an ileal conduit, the use of jejunum results in significant electrolyte abnormalities, which limits its usefulness in reconstructive urologic procedures.

**COLON CONDUITS**

Although urologists primarily use small bowel segments for urinary reconstruction there are multiple scenarios in which small bowel is not available, or has been previously irradiated, or when large bowel is anatomically preferable. Colon conduits using either transverse or sigmoid colon are therefore an important alternative option for urinary diversion.
TRANSVERSE COLON CONDUIT

A transverse colon conduit is an excellent option for patients who have previously undergone extensive pelvic irradiation limiting the use of small bowel. In addition, when there is limited ureteral length the proximity of the transverse colon to the upper ureters allows even short ureteral segments to be implanted to form a transverse colon conduit. Transverse colon conduit stomas are generally placed high on either side of the patient’s abdomen.

Note that, unlike other small and large bowel conduits, after harvesting a segment of transverse colon for reconstructive purposes the remaining bowel is usually brought caudad to it and continuity reestablished.

SIGMOID COLON CONDUIT

The sigmoid colon is generally the intestinal segment used for a urinary conduit if the ileum is not available. It is also a good choice in patients undergoing pelvic exenteration with colostomy placement, because no bowel anastomosis needs to be made. Although a double-barreled stoma may be performed, the fecal and urinary stoma sites are generally separated (Fig. 4). The sigmoid colon conduit is placed in the left lower quadrant of the abdomen lateral to the reapproximated sigmoid colon. The ureters are separately reimplanted end to side into the tenia of the colon, and the proximal end of the colon conduit fixed to the posterior peritoneum.

For sigmoid conduits, note that surgeons can generally follow the course of the tenia to identify the location of the ureteroileal anastomoses.

CONTINENT URINARY DIVERSION

In 1982, Koch and colleagues first reported on an ileal reservoir urinary diversion with a cutaneous catheterizable stoma. This report generated great interest and encouraged the development of a variety of continent urinary diversions based on both small

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Fig. 4. Double-barreled wet colostomy with inferiorly placed sigmoid colon conduit. (From Chokshi RJ, Kuhrt MP, Schmidt C, et al. Single institution experience comparing double-barreled wet colostomy to ileal conduit for urinary and fecal diversion. Urology 2011;78(4):856–62; with permission.)
and large bowel urinary reservoirs. Although there is no single ideal continent urinary diversion, they all share in common the following 2 elements:

- A reservoir pouch constructed of a detubularized bowel segment. Detubularization is intended to reduce peristaltic high-pressure contractions, which in turn can lead to chronically increased intrarenal pressures, renal insufficiency, as well as stomal incontinence.
- An efferent continent limb that is brought to the skin surface and through which clean intermittent catheterization can be performed.

Although a large variety of continent urinary diversions have been described, the most common continent urinary diversions are based on the right-sided ascending colon and terminal ileum, and are commonly referred to as an Indiana pouch. The cecum and ascending colon are detubularized and then folded over in a clam-shell fashion to create a spherical reservoir (Fig. 5). The ureters are separately reimplanted end to side into the tenia of the colon. The right-colon pouch is secured to the right anterior abdominal wall and the distal ileum is tapered and brought to the skin in the right lower quadrant of the abdomen as a cutaneous catheterizable stoma. Urinary continence is based on the ileocecal valve, although it may also be reinforced by imbricating sutures placed at the ileocecal junction.

Surgical considerations when operating on patients with conduits or urinary diversions:

- In patients with a conduit or continent diversion stoma the contralateral ureter is brought under the sigmoid colon mesentery in the avascular plane above the sacrum.
- The proximal end of an intestinal conduit, which is generally the location of the ureteroileal anastomosis, is often fixed to the posterior peritoneum and adherent to the region of the common iliac vessels. This point can serve as a landmark, but can also make dissection in this region more difficult.
- For inadvertent injuries to a conduit or continent urinary diversion, urologic consultation is recommended. If a urologist is not available, the injury should be repaired in a running fashion with absorbable suture (eg, 2-0 polyglactin) in 2 layers. The repair should be tested by gentle normal saline irrigation via the stoma. A catheter should be placed via the stoma (eg, 16 Fr) and left in place to provide maximal low-pressure drainage. A closed suction pelvic drain should also be placed. The drain may be removed once output is minimal, and if the drain fluid creatinine level is equivalent to the serum creatinine level (ie, consistent with serous fluid rather than urine).

Although continent urinary diversion with a catheterizable stoma is an excellent option for a patient who does not wish to have a conduit diversion, the popularity of the procedure has dramatically decreased over the past several decades with the emergence of orthotopic bladder substitution.

BLADDER SUBSTITUTION (COMMONLY REFERRED TO AS A NEOBLADDER)

In 1979, Camey and LeDuc first described the technique of bladder substitution in which the ureters were anastomosed to one end of a segment of ileum, and the other end was directly anastomosed to the urethra. Further modifications have included folding detubularized segments of ileum into J-shaped or W-shaped reservoirs. In general, 40 to 60 cm of distal ileum are harvested for the bladder
substitution, with ~20 cm of terminal ileum left in place. For a J-pouch the ileal segment is detubularized except for a proximal 5-cm to 10-cm chimney segment to which the ureters are anastomosed (Fig. 6). For a W-pouch the ileal segment is either completely detubularized and the ureters are reimplanted into the posterior wall of the reservoir, or the proximal segment of ileum is not detubularized and the ureters are anastomosed to a chimney segment as in a J-pouch (Fig. 7). In either case the ileal bladder substitution is directly anastomosed to the urethra. Bladder substitutions lie predominantly in the midline, and most often extend toward the right side, but sometimes lie toward the left depending on the orientation of the small bowel mesentery. Continence is provided by the patients’ native continence mechanism, thereby allowing patients to either void per urethra, or to perform clean intermittent catheterization per urethra.

Fig. 5. Indiana pouch continent urinary diversion. (From Parekh DJ, Donat SM. Urinary diversion: options, patient selection, and outcomes. Semin Oncol 2007;34(2):98–109; with permission.)
Surgical considerations when operating on patients with bladder substitutions:

- Before making an abdominal incision a urethral catheter should be placed in a sterile fashion in order to decompress the bladder substitution. This technique also allows for intraoperative filling of the bladder substitution to facilitate anatomic dissection as well as identification of inadvertent injuries to it.
- Intestinal bladder substitutions may produce significant mucus, which can cause mucous plugging of catheters, poor drainage, and over distention. For this reason, large-caliber catheters (eg, 20–22 Fr) should ideally be placed. Note that anastomotic scarring at the ileal-urethral junction may only allow placement of a smaller-caliber catheter. If the catheter is to remain in place postoperatively, it should be gently irrigated with ~ 30 mL of sterile water or saline 4 times daily, and as needed, to prevent mucous plugging. Note that perforation of a bladder substitution is an intraperitoneal perforation, and is a potentially fatal complication.
- Intestinal bladder substitutions generally lie low in the midline abdomen and pelvis, and are often encountered when performing a low midline abdominal incision.
- Although ileal bladder substitutions predominantly lie in the midline, if a proximal chimney has been preserved the ureteroileal anastomosis most often extends toward the right side and is often adherent to the region of the common iliac vessels.
- For pelvic trauma that has disrupted the urethra, a large-caliber suprapubic tube (eg, 20–22 Fr) may be directly placed into the anterior bladder substitution. This catheter should also be routinely irrigated to prevent mucous plugging.
For inadvertent injuries to a bladder substitution, urologic consultation is recommended. If a urologist is not available, the injury to the bladder substitution should be repaired in a running fashion with absorbable suture (eg, 2-0 polyglactin) in 2 layers. The repair should be tested by irrigating the previously placed catheter. The catheter should be left in place to provide maximal low-pressure drainage. A closed suction pelvic drain should also be placed. The drain may be removed once output is minimal, and if the drain fluid creatinine level is equivalent to the serum creatinine level (ie, consistent with serous fluid rather than urine.)

**BLADDER AUGMENTATION/CYSTOPLASTY**

Bladder augmentation (addition), or cystoplasty, is performed in patients with small-capacity, high-pressure bladders. This procedure is most often done in children, especially those with spina bifida or other spinal dysraphism. The terminal ileum was the first bowel segment described for cystoplasty, and is the most commonly used bowel

![Fig. 7. W-pouch ileal bladder substitution. End-to-side ureteroileal anastomosis through posterior wall of W-pouch. (A) Ileal neobladder is constructed by removed 68 cm. long ileal segment and orientating it into W shape with 4, 15 cm limbs. (B) Most proimal 8 to 12 cm of ileal segment are not detubularized and remaining 60 cm of bowel are opened along anti-mesenteric border. (C) Posterior plate of W is sewn together. (D) Pouch is closed. (E) Ileal urethral anastomosis. (From Hollowell CM, Christiano AP, Steinberg GD. Technique of Hautmann ileal neobladder with chimney modification: interim results in 50 patients. J Urol 2000;163(1):47–50. [discussion: 50–1]; with permission.)](image-url)
segment\textsuperscript{14} (Fig. 8). The cecum, sigmoid colon, and stomach (gastrocystoplasty) can also be used (Fig. 9). In essence, a segment of detubularized bowel is used to increase the capacity of the bladder. The bladder is opened, and the segment of intestine is sutured to the bladder.

Short-term complications of bladder augmentation include anastomotic leak, most of which heals with conservative management. Occasionally, prolonged catheter drainage and bilateral nephrostomy tubes are necessary to allow the leak to heal. Long-term complications include:

- Recurrent urinary tract infections
- Bladder stones (10\%–50\%)
- Bladder perforation, carcinoma
- Metabolic disorders

The bowel segments used in cystoplasty continue to make mucus, which may require occasional bladder irrigation. As with a perforated bladder substitution, perforation of an augmented bladder is a potentially fatal complication. Acute abdominal pain is the most common presenting symptom; other symptoms include nausea, vomiting, oliguria, and fever. In addition, patients with neurogenic bladders often have impaired sensation, which may delay the diagnosis. A high index of suspicion should be maintained in these patients. For patients who present with a suspected perforation of an augmented bladder, computed tomography cystogram is the study of choice. Treatment of bladder perforation includes immediate catheter drainage and operative repair of the perforation. Urologic consultation should be obtained. If a urologist is not available, the bladder should be repaired in 2 layers with absorbable suture. The bladder repair should be tested to make sure it is watertight.\textsuperscript{15}

APPENDICOVESICOSTOMY

Patients with neurogenic bladder dysfunction often have physical limitations that prevent easy access to the urethra, particularly if they are wheelchair bound. In addition,
for patients (and especially children) with normal urethral sensation, compliance with a routine catheterization schedule may be difficult to maintain. For this reason, continent catheterizable stomas are often used.

The most common type of catheterizable stoma in children is an appendicovesicostomy. The appendix is ideal for this purpose, because it is a natural tubular structure that can safely be removed from the gastrointestinal tract without significant morbidity. Typically, the distal end of the appendix is tunneled into a posterolateral position within the bladder, and the base of the appendix is brought up to the abdominal wall (Fig. 10).

Note that, most commonly, the base of the appendix is hidden within the umbilicus. The appendix and bladder wall are often secured to the peritoneum beneath the fascia to reduce the problem of conduit kinking with bladder filling.

Stomal stenosis is a common complication, generally occurring in 10% to 20% of patients with appendicovesicostomy. Appendiceal perforation can also occur, but should heal with catheter placement (eg, 12–16 Fr) into the appendicovesicostomy.
ILEAL URETERAL SUBSTITUTION

In cases of pan-ureteral stricture or other cause of ureteral loss, a segment of ileum can be used to bridge the gap. The ileal ureter was first described by Shoemaker in 1909. After the diseased portion of ureter is either removed or excluded, an appropriate length of ileum is used to connect either the renal pelvis or proximal ureter to the bladder (Fig. 11). In general, the mesentery for an ileal ureter has to be divided more extensively than for an ileal conduit in order to achieve maximal length and mobility.

Note that, in general, after bowel continuity has been reestablished, the ileal ureter is brought through the colonic mesentery laterally. Alternatively, on the right side, the cecum and ascending colon can be reflected superiorly to avoid the mesenteric window.

Ileal ureters are usually not performed in patients with a serum creatinine level of greater than 2 mg/dL, or if the patients have bladder dysfunction/outlet obstruction, inflammatory bowel disease, or radiation enteritis. Potential complications of an ileal ureter include:

- Urinary leak or fistula
- Mucous plugging of the ileal segment
- Bowel obstruction
- Kinking of the ileal segment
- Ischemic necrosis of the ileal segment is a rare complication but should be considered in cases of an acute abdomen

Fig. 10. Appendicovesicostomy. (From Wille MA, Zagaja GP, Shalhav AL, et al. Continence outcomes in patients undergoing robotic assisted laparoscopic Mitrofanoff appendicovesicostomy. J Urol 2011;185(4):1438–43; with permission.)

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Interposition of bowel into the urinary tract may lead to acute or chronic metabolic complications. In general, these complications can be divided into the following categories:

- Electrolyte abnormalities
- Nutritional disturbances
- Abnormal drug metabolism
- Bone disease

This article focuses here on the pathophysiology, clinical presentation, and treatment of these metabolic complications.

**Electrolyte Abnormalities**

**Stomach**

A hypochloremic, hypokalemic, metabolic alkalosis may develop if the stomach is incorporated into the urinary tract because of the gastric mucosa’s secretion of hydrogen, chloride, and potassium ions into the urine. This complication is rarely clinically significant in well-hydrated patients with normal renal function; however, a severe metabolic alkalosis may develop in patients who become acutely dehydrated or develop impaired renal function. Clinically, patients present with lethargy, respiratory insufficiency, and ventricular arrhythmias. Alkalosis is generally managed successfully with intravenous hydration, repletion of potassium, and H2 blockers to suppress the loss of acid into the urine. If H2 blockers fail, then a proton pump inhibitor may be used. Response rates to medical therapies are high; however, an intractable life-threatening metabolic alkalosis may require removal of the gastric segment.

![Fig. 11. Ileal ureteral substitution. (From Nakada SY, Best SL. Management of upper urinary tract obstruction. In: Wein AJ, editor. Campbell-Walsh urology. 11th edition. Elsevier: Philadelphia; 2016. p. 49, 1104-47.e7; with permission.)](image)
**Jejunum**

All efforts should be made to avoid or minimize the use of the jejunum for intestinal urinary reconstruction. Interposition of this segment often leads to severe and intractable electrolyte abnormalities. The jejunum’s secretion of sodium and chloride, coupled with the resorption of potassium and hydrogen, produces a hyponatremic, hyperkalemic, metabolic acidosis. Of particular concern with hyponatremia is the development of hypovolemia. In response to hypovolemia, the kidneys secrete renin. Activation of the renin-angiotensin-aldosterone system causes the kidney to resorb sodium and secrete potassium in the urine. When this low-sodium, high-potassium urine comes into contact with the jejunum, the jejunum secretes more sodium and resorbs more potassium, thereby creating a self-perpetuating cycle and worsening the metabolic derangement. When severe, these patients present with lethargy, nausea, vomiting, dehydration, weakness, and fever. Treatment consists of saline administration to correct dehydration and hyponatremia, and administration of sodium bicarbonate to correct the acidosis. Note that hyperalimentation solutions should be avoided because they can exacerbate the metabolic derangement. Preventive measures consist of oral sodium chloride supplementation and adequate hydration.

**Ileum and colon**

A hyperchloremic metabolic acidosis may develop if ileum or colon is used for urinary tract reconstruction because of absorption of ammonium chloride and secretion of carbonic acid by the ileum or colon. Concomitant hypokalemia may also occur and is more pronounced when the colon is used because of its limited ability to absorb potassium. If there is evidence of a hyperchloremic metabolic acidosis, even if mild, it should be treated with oral sodium bicarbonate or bicitrates. If severe, acute treatment consists of correction of the acidosis with administration of sodium bicarbonate and simultaneous potassium repletion. Concomitant potassium repletion is critical during correction of the metabolic acidosis to avoid severe hypokalemia.

**Nutritional Disturbances**

A variety of nutritional disturbances may occur with intestinal urinary diversion because of the loss of absorptive tissue following a bowel segment removal. When the stomach or terminal ileum is removed from the gastrointestinal tract, B12 deficiency may develop. This deficiency is caused by loss of the production of intrinsic factor, a cofactor necessary for B12 absorption within the terminal ileum. The body contains large stores of B12; therefore, a clinically significant deficiency may not develop for 3 to 5 years. B12 deficiency primarily manifests as megaloblastic anemia and sensory neuropathy. Diagnosis is based on low B12 levels but also increased levels of methylmalonic acid and homocysteine. Treatment consists of B12 injections.

If the ileum or ileocecal valve is removed, persistent diarrhea may develop because of abnormal bile salt metabolism. Bile salt is normally absorbed by the ileum and has a secretory effect on the colon that leads to chronic diarrhea. Cholestyramine, which acts to bind the bile salt, can be used to treat chronic diarrhea. Loss of the ileocecal valve also allows bacteria from the colon to reflux into the small bowel, resulting in bacteria overgrowth, fat malabsorption, and fat-soluble vitamin deficiency. Treatment consists of dietary modification with a low-fat diet and supplementation of fat-soluble vitamins if indicated.

**Infection**

Intestinal urinary diversion increases the risk for recurrent urinary tract infections, bacteremia, and sepsis. Although the mechanism is not fully understood, the high
incidence of bacterial urinary colonization is thought to lead to bacteria dissemination into the blood stream.20 Up to 75% of asymptomatic patients have positive urine cultures20; therefore, patients should not be treated without clinical signs of infection except for proteus and pseudomonas infections. These species are particularly virulent in the urinary system and mandate treatment even if the patient fails to manifest clinical symptoms. Systemically ill patients present with fever, chill, flank pain, malaise, and leukocytosis. A urine sample should be obtained via straight catheterization using sterile technique to confirm the diagnosis to minimize contamination from colonization. Urine samples obtained from a urostomy bag have an exceedingly high rate of bacterial contamination and should not be used. Treatment generally consists of intravenous fluid resuscitation, correction of electrolyte abnormalities, and antibiotic therapy based on culture sensitivity.

**Abnormal Drug Metabolism**

Intestinal urinary diversion increases the risk for abnormal drug metabolism leading to drug toxicity in the body. Medications normally absorbed by the gastrointestinal tract and excreted unchanged by the kidneys are most likely to become problematic.20 Commonly problematic medications include phenytoin, lithium, β-lactam and aminoglycoside antibiotics, methotrexate, and cisplatin. Drug levels should be carefully and regularly monitored to prevent toxicity. Continuous drainage with placement of a Foley catheter should be considered if a patient requires chemotherapy treatment.

**Bone Disease**

Intestinal urinary diversion often leads to the development of osteomalacia and altered bone mineralization caused by chronic metabolic acidosis, vitamin D resistance, and persistent loss of calcium via the kidneys. The bones act to buffer the acidosis with the release of calcium, leading to demineralization over time. Correction of metabolic acidosis is critical to prevent bone loss and facilitate remineralization.22 Treatment consists of correcting the metabolic acidosis and calcium supplementation. If bone density fails to improve, the active metabolite of vitamin D, 1-alpha-hydroxycholecalciferol, should be administered.

**REFERENCES**