History of urinary diversion:

Bowel segments have been used throughout the years for various reconstructive urologic applications. The stomach, jejunum, ileum, and colon have been successfully employed for bladder augmentation and bladder replacement. The initial clinical attempts to drain urine into the rectosigmoid were performed in the 19th century. As the indications for cystectomy increased, so did the necessity to develop an optimal technique of urinary diversion. Remarkable surgical innovation has recently made possible the development and widespread use of orthotopic neobladder techniques. Approaching the beginning of this new millennium, urologists have begun to explore minimally invasive techniques to urinary diversion. Laparoscopy has been applied in an attempt to reduce the morbidity resulting from bladder removal and substitution. To date, various techniques of urinary diversion have been performed laparoscopically, either completely intracorporeally or by laparoscopic-assisted techniques.

In this chapter, we describe the morphologic and physiologic aspects related to urinary diversion in general. Following this, the worldwide available clinical experience with laparoscopic use of various bowel segments is reviewed. Finally, experimental minimally invasive approaches related to urinary diversion are also presented briefly.

Applied anatomy of the stomach, and small and large bowel, as used for urinary diversion

Stomach

The stomach is a well-vascularized organ that receives most of its blood supply from the celiac axis. Maintaining the gastroepiploic vessels that supply the greater curvature of the stomach as a pedicle, a vascularized stomach patch consisting of the entire antrum pylori or a wedge of the fundus can be mobilized to the pelvis. Furthermore, the stomach has a thick seromuscular layer that can be separated from the mucosa, thus facilitating a submucosa ureteral reimplantation when required.

Colon

The colon requires mobilization from its fixed position to achieve the mobility necessary for the reconstructive procedures. The larger diameter of the colon when compared to the ileum may be an advantage. Preservation of an intact ileocecal valve may help to avoid diarrhea and excessive bacterial colonization of the ileum.

Ileum

The ileum is a preferred segment of bowel that has been employed in various types of urologic reconstructive procedures. It is mobile, has a constant blood supply, its shape is ideal for conduit formation, and it has enough redundancy to allow various lengths of segments to be
used without compromising the host. Occasionally, the mesentery may be short, which makes its mobilization into the deep pelvis difficult.

**Physiologic considerations**

Selection of the appropriate intestinal segment must consider the physiologic properties unique to the stomach, jejunum, ileum, and colon. In each case, the ideal bowel segment must fit the patient’s condition, the renal function status, and type of diversion required.

**Metabolic implications**

**Ileum and colon**

Reabsorption of urinary ammonia and ammonium chloride by the ileal and colonic segments produces hyperchloremic metabolic acidosis. Although such acidosis occurs in most patients, it is generally of minor degree. Fr7 Severity of hyperchloremic metabolic acidosis depends on the period of contact between the urine and the intestinal mucosa, as well as the length of bowel segment used. Severe metabolic acidosis is manifested by patient weakness, fatigue, polydipsia, and anorexia. Chronic metabolic acidosis causes mobilization of calcium carbonate from bone. The carbonate combines with hydrogen while the calcium is excreted in urine, whereas can result in osteomalacia.

**Stomach**

When the stomach is employed, the gastric mucosa acts as a barrier to chloride and acid reabsorption. However, due to the secretory nature of the gastric mucosa, hypochloremic hypokalemic metabolic alkalosis may occur. Also, in cases of gastrocyoplasty, hematuria–dysuria syndrome may occur. However, in most patients these symptoms are intermittent and mild, and do not require treatment.

**Jejunum**

The jejunum is usually not employed for reconstruction of the urinary system because it potentially can cause severe electrolyte disorders such as hyponatremia, hypochloremia, hyperkalemia, azotemia, and acidosis. Rarely, when the jejunum is the only segment available, a portion of the jejunum as distal as possible should be used to minimize problems with electrolyte imbalance.

**Mechanics of tubular and detubularized bowel**

**Volume–pressure considerations**

Configuration of the selected segment of bowel directly impacts upon the reservoir volume–pressure characteristics. Laplace’s law states (for a sphere) that the tension of its wall is proportional to the product of the radius and pressure. Thus, theoretically, for a given wall tension, the greater the radius, the smaller the generated pressure. Therefore, detubularization of the bowel segment along its antimesenteric border and creation of a spherical reservoir should be the goal, aiming to preserve the upper urinary tract and to prevent incontinence.

**Renal functional considerations**

Although urinary diversion in and of itself may compromise renal function, a certain robust baseline renal reserve is necessary to efficiently eliminate the excess of urinary solutes reabsorbed by the employed intestinal segment in order to prevent potentially serious metabolic side-effects. The level of renal function required to safely perform a urinary diversion depends on the amount of bowel used for the diversion as well as the length of time that the urine stays in contact with intestinal mucosa. Thus, a higher baseline renal reserve is necessary for continent reservoirs than for short conduits. However, as a general rule, patients with serum creatinine below 2.0 mg/dl tolerate intestinal interposition in the urinary tract well.
Patient selection for laparoscopic urinary diversion

Proper patient selection is crucial to achieve good surgical outcomes. The criteria for selection of the type of urinary diversion have been outlined above. Furthermore, the criteria for selection of a laparoscopic approach in general should be followed. Contraindications include patients with acute intraperitoneal infection process and uncorrected coagulopathy. Although previous abdominal surgery is not an absolute contraindication, significant peritoneal adhesions should be factored into the decision-making process, which should be made on a case-by-case basis. Obesity is not, in itself, a contraindication to the laparoscopic approach; however, difficulty may be encountered during instrument manipulation, bowel mobilization, and while constructing an ileal conduit through the thicker abdominal wall.

Preoperative patient assessment and preparation

The preoperative assessment for patients undergoing laparoscopic urinary diversion is similar to that for the open surgery. In brief, patients undergo a complete physical examination, routine blood tests (complete blood count, renal panel, alkaline phosphatase, liver function tests, and calcium), and radiographic testing to rule out metastatic disease. On the day prior to surgery, the bowel is prepared mechanically using 4 liters of GoLYTLEY, and chemically with neomycin and metronidazole. Broad-spectrum intravenous antibiotics and subcutaneous low-molecular-weight heparin (2500 units) are given prior to surgery.

Port placement

Laparoscopic cystectomy, discussed elsewhere in this book, precedes the urinary diversion. The same five-port transperitoneal configuration is employed for both procedures, with one additional port in the left iliac fossa for the laparoscopic bowel work (Figure 51.1). A primary 10 mm port is placed at the umbilicus for the 0° laparoscope. Four secondary ports are placed under visualization: a 12 mm port to the left of the umbilicus, lateral to the rectus muscle, and two 10 mm ports in the left and right lower quadrants, approximately 2 fingerbreadths to the ipsilateral anterior superior iliac spines. In the case of an ileal conduit, another 12 mm port is placed at the preselected stoma site in the right rectus muscle; otherwise, this 12 mm port is placed at the lateral border of the rectus muscle, approximately 2 fingerbreadths caudal to the umbilicus. Finally, a 5 mm port is placed in the midline infraumbilical location, approximately 2 fingerbreadths cephalad to the symphysis pubis.

It is important to note that during the initial bowel manipulation (ileal segment isolation, ileal–ileal anastomosis) the laparoscope is inserted through the left lateral port while the surgeon works through the midline infraumbilical and the pararectal ports. If an ileal conduit is selected, this same triangular port configuration is used for the ureterointestinal anastomosis. However, if a continent reservoir is to be performed, the laparoscope is moved back to the umbilical port upon completion of bowel detubularization.

Laparoscopic ileal conduit

Ileal conduit creation

After the cystectomy and pelvic lymphadenectomy are completed, attention is focused on the urinary diversion. When an ileal conduit is selected for urinary diversion, a 15–20 cm segment of ileum is identified 20 cm away from the ileocecal junction. All bowel manipulations are performed completely intracorporeally. In this manner,
division of the selected segment of bowel and mesentery is performed using the EndoGIA stapler. Staple heights of 3.5 mm are used for bowel and 2 mm or 2.5 mm (vascular load) for the mesentery. Two firings are used to complete the distal mesenteric division and one firing is used to complete the proximal division (Figure 51.2). As in open surgery, care is taken not to compromise the main mesenteric vessels feeding the conduit. Ileoileal continuity is re-established by creating a generous side-to-side anastomosis with two sequential firings of the Endo-GIA stapler. The open ileal ends are closed with two transverse firings of the Endo-GIA stapler. The mesenteric window is closed with 3-0 silk sutures. The distal end of the conduit is exteriorized through the preselected stoma site at the rectus muscle and an end-ileal stoma is fashioned using conventional techniques.

Ureteroileal anastomosis

Technical difficulty in performing laparoscopic freehand suturing was the main reason why the initial reports of laparoscopic ileal conduit urinary diversion employed conventional open techniques to perform the ureteroileal anastomosis. In these early 1990s reports, ureteral reimplantation was performed extracorporeally through either a minilaparotomy incision or by delivering the ends of the conduit and both ureters outside the abdomen through an enlarged port-site incision. In our view, such an extracorporeal anastomosis through a limited incision, as described, may create problems as regards tissue orientation and positional distortion. Moreover, it may be difficult or even impossible to extract the ileum and the ureters to the skin level in obese patients. One decade later, with advances in intracorporeal free-hand suturing, Gill et al reported the initial two cases of laparoscopic ileal conduit where the ureterointestinal anastomosis was performed completely intracorporeally. In this technique, a 90 cm, 7F single-J stent is grasped with a laparoscopic right-angle clamp and inserted into the conduit lumen. It is then used to tent the conduit wall at the desired site of ureteroileal anastomosis. Using an electrical J hook, a small ileotomy is created and the stent is delivered into the abdominal cavity. The ureteral rim is freshened and spatulated. A 4-0 Vicryl (RB-1 needle) stitch is placed outside-in at the apex of the ureteral spatulation and is anchored to the desired site of the ileotomy. A running suture is then performed to approximate 80% of the posterior (far) wall and the J stent is fed into the ureter up to the renal pelvis. The remainder of the posterior wall anastomosis is completed. The anterior (near) wall is sutured in a running fashion with a second 4-0 suture to complete the anastomosis. The contralateral ureteral anastomosis is performed in a similar manner (Figure 51.3).

Laparoscopic orthotopic neobladder

Following cystectomy and lymphadenectomy, a 65 cm ileal segment is selected and isolated in a similar manner as described above for the ileal conduit. Bowel segment length is precisely measured by inserting a malleable footruler into the abdomen through a 12 mm port. The proximal 10–15 cm of the excluded ileal segment is reserved for the isoperistaltic Studer limb of the neobladder. The remaining length of the ileal segment is detubularized along its antimesenteric border using endo-shears with electrocautery or the harmonic scalpel. The posterior wall of the neobladder is created by continuous intracorporeal suturing of adjacent edges of the U-shaped ileal segment using 2-0 Vicryl suture on a CT-1 needle. The segment is then brought into the pelvis, avoiding any undue tension or torsion of the mesentery. The previously confirmed most-dependent portion of the ileal segment is selected for urethroileal (neobladder) anastomosis. A running circumferential suture is performed using 2-0 Vicryl on a UR-6 needle. Prior to completing the anastomosis, a 22F silicone Foley catheter is inserted per urethra. In female patients, two 90 cm single-J stents are inserted via the external urethral meatus alongside the Foley catheter and delivered into the neobladder. In the male,
these two stents are inserted through the right lateral port into the neobladder. The anterior wall of the neobladder is folded forward and the free edges are sutured to achieve a spherical configuration. Prior to completion of the neobladder suturing, a 5 cm incision is performed in the anterior wall of the Studer limb and the stents are delivered through it. Two small ileotomies are created at the side of the Studer limb, and one ureter is pulled inside the Studer limb through each ileotomy. The ureters are then freshened and spatulated. A full-thickness anchoring stitch affixes the edge of the ureter to the apex of the ileotomy. The single-J stent is delivered up to the renal pelvis and two additional stitches are placed between the ureter and the ileum wall. Finally, the anterior wall of the Studer limb is closed with a running suture (Figure 51.4). All suturing and knot tying is performed intracorporeally using a free-hand laparoscopic technique.4,15 The neobladder is irrigated through the Foley catheter and any obvious sites of leakage are specifically repaired with figure-of-eight stitches. A suprapubic catheter is inserted into the neobladder through the midline port-site incision.

**Figure 51.3**
Ileal conduit urinary diversion. The distal end of the ileal loop is exteriorized through the preselected stoma site and is secured to the skin using the standard technique. Stented bilateral ureteroileal anastomoses are completed.

**Figure 51.4**
Orthotopic neobladder urinary diversion. After isolation of the ileal segment and detubularization of the distal portion, the posterior plate is created and urethroileal anastomosis is completed using a running suture. The anterior wall of the neobladder is folded to achieve a spherical configuration of the neobladder.

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**Laparoscopic rectal sigmoid (Mainz II) pouch**

Türk and colleagues were the first to report a laparoscopic rectal sigmoid pouch.16 This rectal sphincter-based continent type of urinary diversion was successfully performed in 5 patients completely intracorporeally. Upon completion of cystectomy, the rectosigmoid colon was incised open along its antimesenteric border with a hook electrocautery. This incision was then extended for 10 cm, respectively, proximally and distally from the rectosigmoid junction. The adjacent posterior walls of the rectum and sigmoid were anastomosed side to side with absorbable running suture, forming the posterior wall of the pouch. Subsequently, the mobilized ureters were brought into the pouch and sutured to the pouch plate in a pre-prepared 3 cm submucosal bed. Single-J 8F stents were inserted through the anus into the pouch and then passed up to the renal pelvis. A submucosal tunnel was formed by suturing the mucosa over the ureters. Finally, the anterior wall of the pouch was closed with a running suture of 3-0 Vicryl. The pouch was drained transanally with a Nelaton catheter. In the female patient the specimen was extracted intact through the vagina, while in the male patient the specimen was placed in an endoscopic bag and extracted transanally.
Laparoscopic-assisted reconstruction of pouch/enterocystoplasty

Alternatively, during laparoscopic procedures, bowel manipulation as well as construction of complex enteric pouches or enterocystoplasty can be performed extracorporeally (Figure 51.5). This technique is described in Chapter 20. Generally, a 2–5 cm incision is performed to exteriorize the preselected bowel segment. Several advantages can accrue:

- bowel mesentery can be precisely incised after ensuring good vascularity using transillumination.
- side-to-side bowel anastomosis can be performed rapidly.
- contamination of the abdominal cavity can be prevented during detubularization of the loop.
- overall this approach allows considerable savings in operative times.17

Recently, we reported a laparoscopic-assisted continent Indiana pouch urinary diversion in a patient with muscle invasive bladder cancer.4 Due to urethral involvement, orthotopic diversion was contraindicated in this case. The pouch and continent catheterizable ileal limb were created extracorporeally by standard open techniques after the selected ileocecal segment was extruded through a 2–3 cm extension of the right pararectal port incision. Subsequently, the bowel was reinserted into the abdomen, and the bilateral uretero-ileal anastomoses were created intracorporeally by freehand laparoscopic techniques.

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Figure 51.5
Construction of a rectosigmoid pouch: (A) the rectosigmoid is incised at the antimesentery border; (B) the cystectomy specimen is extracted through the rectum; (C) the posterior wall is anastomosed side to side; (D) the ureters are implanted via a submucosal posterior tunnel; (E) the ureters are stented with ureteral catheters and the pouch is drained with a 26F Nelaton catheter. The anterior wall of the pouch is closed.
Laparoscopic gastroileal neobladder

Although demanding more complex gastrointestinal resection, the combination of bowel and stomach to create a pouch may have metabolic advantages compared to the use of intestinal segments alone. The tendency to metabolic acidoses when ileum or colon is used in urinary reconstruction can be counterbalanced by the combined use of stomach, due to its tendency towards metabolic alkalosis. Thus, metabolic neutrality may be achieved in highly selected cases. These composite reservoirs may be employed judiciously in the setting of metabolic acidoses, short bowel syndrome, and renal failure. To date, no clinical reports of laparoscopic use of stomach for urinary diversion have been reported. Experimentally, Carvalhal et al described the construction of a gastroileal composite reservoir in a porcine model. Briefly, the surgical steps were:

1. gastric mobilization and right gastroepiploic pedicle dissection
2. wedge resection of the greater curvature (8–12 cm × 4 cm) with Endo-GIA stapler (Figure 51.7)
3. isolation of a 20 cm ileal segment
4. stapled restoration of ileoileal continuity
5. cystectomy and ureteral dissection
6. construction of the composite gastrointestinal plate (gastric patch and U-shaped ileum) with freehand laparoscopic suturing

Figure 51.6
During laparoscopic procedures, bowel work can be performed through an extended port-site incision.

Figure 51.7
Laparoscopic wedge resection of the greater curvature of the stomach is performed to create a composite pouch with an ileal segment.
7. urethroileal anastomosis
8. bilateral reimplantation into the gastric patch
9. closure of the composite plate in a spherical manner.

Intracorporeal laparoscopic freehand suturing was employed exclusively. The complexity of the procedure explains the long mean operative time of 7.1 hours in this experimental model.

**Laparoscopic ureterocystoplasty using balloon-expanded normal ureter**

Despite all the technical advances with minimally invasive use of intestine for urinary diversion, the problems inherent to the contact of urine with bowel mucosa have not been overcome and continue to be a source of morbidity. Perhaps the ureter, with its transitional epithelium, may be the ideal tissue for bladder augmentation or replacement. However, the use of ureteral tissue for this purpose is limited to the rare patient with a megaurerter subtending a nonfunctional kidney. The concept of ureteral tissue expansion was initially proposed by Hensle and colleagues. Recently, we have completed an experimental study wherein a balloon device was used to expand the normal ureter. This balloon (Microvasive, Natick, Massachusetts) is mounted in a dual-channel catheter: one for balloon inflation and the other for proximal nephrostomy drainage. Using a porcine model, a percutaneous renal tract was dilated, followed by the passage of the expansion balloon device. The balloon was then manipulated antegradely into the juxtavesical ureter (Figure 51.8). The ureteral balloon was gradually inflated over a 2–3 week period by instillation of dilute contrast solution. The inflation was performed without anesthesia, while the animal was eating. The mean daily inflation volume was 1.8, 5.5, 9.5, and 16.1 ml/day respectively in the first, second, third and final week. Total balloon volumes averaged 12.9, 60.3 and 171.8 ml respectively, at 1, 2, and 3 weeks. After completion of ureteral balloon expansion, laparoscopic ureterocystoplasty was performed. Over a follow-up ranging from 15 days to 3 months, a mean augmented bladder capacity of 574 ± 221.3 ml was achieved. In the future, such expanded ureteral tissue may be successfully used to augment or replace the bladder using minimally invasive techniques.

**References**

Intestinal segments for urinary diversion


