Urinary Diversion

Series Editor:
Bernard Fallon, MD
Professor
Department of Urology
University of Iowa
Iowa City, IA

Contributor:
Jerilyn M. Latini, MD
Fellow Associate
Reconstructive Urology and Urodynamics
Department of Urology
University of Iowa
Iowa City, IA

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INTRODUCTION

Following the description of the original surgical technique for internal urinary diversion in 1852 by Simon, numerous procedures have been devised to divert or reconstruct the urinary tract. Historically, 3 major categories of urinary diversions have been described: (1) formation of a fistulous tract between the ureters and intact bowel, (2) implantation of ureters into a partially excluded segment of the gastrointestinal tract, and (3) implantation of ureters into an artificial bladder formed from a completely excluded part of the gastrointestinal tract.1 The first 2 types of diversions include continent diversions with the anal sphincter (in which urine is eliminated by evacuation) and have declined in popularity with time. The third category has come to the forefront and continues to be expanded and modified internationally. It is subdivided into appliance-dependent urinary diversions (based on creation of a conduit), continent catheterizable reservoirs, and orthotopic bladder replacements (neobladders). Continent urinary diversions utilize 1 of 3 mechanisms for continence: the anal sphincter, an intestinal valve, or the urethral sphincter. This review considers continent urinary diversions with the anal sphincter but focuses more on appliance-dependent diversions, continent catheterizable reservoirs, and orthotopic bladder replacements.

SURGICAL CONSIDERATIONS

PATIENT SELECTION

Indications for urinary diversion are presented in Table 1. The goals of diversion include control over urine elimination, preservation of renal and intestinal function, avoidance of metabolic abnormalities, and prevention of malignancy. Patients and procedures are selected based on disease status, comorbidities, renal and hepatic function, prior surgery and/or radiation, inherent gastrointestinal disease, life expectancy, motor ability, willingness to self-catheterize and perform self-care, comprehension of the regimen required, quality of life, and type of urinary diversion or reconstruction planned.

Adequate renal function (ie, renal blood flow, glomerular filtration/permeability, tubular transport, and concentrating/diluting ability) to blunt the metabolic effects of gastrointestinal reabsorption of urinary solutes is critical for patients being considered for urinary diversion. Continent diversions require a greater degree of renal function than do conduit diversions. Generally, those with normal urine protein levels, a glomerular filtration rate (GFR) of greater than 40 mL/min, and a serum creatinine level of less than 2 mg/dL do well with urinary diversion. Patients with creatinine levels greater than 2 mg/dL should have renal function studies performed prior to diversion to demonstrate values: creatinine clearance greater than 60 mL/min, GFR greater than 35 mL/min, the ability to acidify urine to a pH of less than 5.8 after an ammonium chloride load, urine osmolality greater than 600 mOsm/kg following water deprivation, and minimal urine protein. Those with obstructive renal insufficiency or failure should undergo pre-operative upper tract decompression and then have true baseline renal function reassessed prior to urinary diversion. Reabsorption and recirculation of urinary solutes also requires normal liver function.

SURGICAL ANATOMY

Urinary diversions have been performed using all gastrointestinal segments, sometimes in combination. Each segment is associated with particular advantages that are capitalized upon and disadvantages that hinder usefulness. The type, length, function and metabolic impact of the gastrointestinal segment used is critical, with significant effects on long-term sequelae and outcomes.

Stomach

The capacity of the stomach varies with age, averaging approximately 30 mL at birth, 1000 mL at puberty, and 1500 mL in adulthood. The stomach has an extensive, interconnected vascular supply (Figure 1), and 3 of its 4 major nutrient arteries can be divided without necrosis or significant dysfunction. A pedicle of antrum/pylorus or a wedge of fundus based on the gastroepiploic arteries can be mobilized to the pelvis for

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diversion or reconstruction. The right gastroepiploic artery is preferred because its course and caliber are more reliably constant. The stomach’s thick seromuscular layer is well-suited for ureteral reimplantations and Mitrofanoff continence mechanisms.

Compared to intestinal tissue, stomach is less permeable to urinary solutes, produces less mucus, and improves urine acidification. Use of stomach tissue can help to compensate for hyperchloremic metabolic acidosis, especially in the presence of renal insufficiency or failure. Calculus formation is decreased, and owing to the acidic pH of the urine, the incidence of colonization/bacteriuria is lower (25%) as compared with ileal and colonic segments (60%–80%). Stomach is excellent for ureteral implantation and may be useful when other bowel segments are not available or advisable (eg, in the presence of exstrophy, short gut, malabsorption, extensive abdominal adhesions, or following radiation).

Complications associated with the use of stomach include increased frequency and urgency, hematuria-dysuria syndrome, and metabolic alkalosis in chronic renal failure patients. Acidic urine (pH of 5–7) may cause ulcerative peristomal skin problems.

Small Bowel

The length of the small bowel varies based on bowel activity when measured, but is estimated to be between 240 and 440 cm in adults. Average length of the duodenum is 20 cm; jejunum, 100 to 110 cm; and ileum, 150 to 160 cm. The lumen is widest in the duodenum and decreases distally (jejunum, 4 cm and ileum, 3.5 cm), with the smallest diameter being approximately 26 cm from the ileocecal valve. Ileal mesentery is thicker than jejunal mesentery. Mesenteric arteries to distal ileum arborize with a greater number of arcades, and their vessels are smaller than in jejunum (Figure 2). Jejunal mesenteric arcades are usually single, with larger diameter vessels. Mesenteric fat usually extends all the way to the bowel in ileum, unlike in jejunum. Superior mesenteric artery branches supply jejunum and ileum (Figure 3), arborizing into arcades and sending small straight vessels to the mesenteric border that anastomose within the bowel wall. Approximately 15 cm of small bowel can survive lateral to a straight vessel, but it is generally advised not to clear off more than 8 cm of bowel because of the risk of distal ischemia. The terminal ileum joins the cecum, penetrates its posteromedial wall, and forces mucosa, submucosa, and circular muscle from the terminal ileum into the cecal lumen, forming the ileocecal valve.

Jejunum is not often used in urinary diversions because of severe metabolic and electrolyte sequelae. If jejunum is the only intestinal segment available, then the most distal segment should be used to minimize subsequent electrolyte disturbances.

Ileum is one of the most familiar and frequently utilized segments in urinary diversion, the other being colon. Both ileum and colon have favorable absorptive characteristics but increased mucus production. In addition, they carry an increased risk of calculus formation, infection, and neoplasia. Similar metabolic and electrolyte abnormalities occur with ileum and colon, and with comparable frequency. Unlike colon, however, ileum is not well-suited for non-refluxing ureteral implantation. Occasionally ileal mesentery is short and fat, making mobilization into the pelvis difficult.

Large Bowel

The large bowel is approximately 1.4 to 1.7 m long. Average width of the cecum is approximately 7.5 cm; ascending colon, 6 cm; and descending/sigmoid colon, 3.5 to 4 cm. Three well-differentiated teniae merge at the cecum’s medial inferior border, marking the

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**Table 1. Indications for Urinary Diversion**

<table>
<thead>
<tr>
<th>Category</th>
<th>Indications</th>
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<tbody>
<tr>
<td>Congenital conditions</td>
<td>Posterior urethral valves</td>
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<td></td>
<td>Bladder extrophy and epispadias complex</td>
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<td></td>
<td>Functionally contracted bladder</td>
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<td></td>
<td>Neurogenic bladder dysfunction</td>
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<td>Idiopathic bladder instability</td>
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<td>Inflammatory conditions</td>
<td>Chronic cystitis</td>
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<td>Interstitial cystitis</td>
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<td>Tuberculosis</td>
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<td></td>
<td>Schistosomiasis</td>
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<td></td>
<td>Chemical cystitis</td>
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<tr>
<td>Traumatic causes</td>
<td>Traumatic causes</td>
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<td></td>
<td>Multiple surgical procedures on the diseased bladder</td>
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<td></td>
<td>Inadvertent surgical injury</td>
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<td></td>
<td>Violent trauma</td>
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<tr>
<td>Miscellaneous causes</td>
<td>Miscellaneous causes</td>
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<tr>
<td></td>
<td>Radiation therapy</td>
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<td></td>
<td>Fistulas</td>
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<td></td>
<td>Conversion from conduit diversion</td>
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<td></td>
<td>Cystectomy for malignant conditions</td>
</tr>
</tbody>
</table>

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appendix. The length of the ascending colon is approximately 15 cm; transverse colon, 50 cm; descending colon, 25 cm; sigmoid colon, 40 cm; and rectum, 12 cm.

The arterial supply of the large bowel varies, arising from the superior mesenteric, inferior mesenteric and/or internal iliac arteries and anastomosing into arcades 2 to 3 cm from the mesenteric border (ie, the marginal artery of Drummond) (Figure 3). Colon can be mobilized considerably based on this anastomotic network. Three tenuous anastomotic areas exist: the junction of the sigmoid and superior hemorrhoidal arteries (Sudek’s critical point), between the middle and right colic arteries, and between the middle and left colic arteries. Bowel anastomoses in these areas usually heal well given meticulous surgical technique; however, it is usually better to choose one side or the other, thus avoiding these areas.

The colon is relatively easily mobilized to any part of the abdomen or pelvis. Its thick wall and teniae are ideal for nonrefluxing ureterointestinal anastomoses. If the ileocecal valve is preserved, less significant nutritional issues occur with colon as compared to ileum. If the ileocecal valve is not preserved, however, malabsorption may occur when colon is used as a result of excessive ileal bacterial colonization and fluid and/or bicarbonate loss. Patients who undergo conduit or reservoir creation utilizing colon must undergo preoperative radiographic or colonoscopic examination of the entire large intestine and not just sigmoidoscopy to rule out mass lesions.

Bowel Preparation

Proper mechanical and antibiotic bowel preparation decreases the incidence of wound infection, intraperitoneal abscess, and anastomotic dehiscence.4–6 The bacterial concentration (organisms/g of feces) in jejunum is 10 to 105; in ileum, 105 to 107; in ascending colon, 106 to 108; and in descending colon, 106 to 1012. Mechanical bowel preparation reduces the amount of feces and thereby the total number of bacteria but not the bacterial concentration, whereas antibiotic preparation reduces the bacterial concentration. Appropriate antibiotic bowel preparation reduces fecal bacterial concentration to 102 organisms/g of feces.7 Systemic antibiotics must be given prior to incision to be effective, and cover anaerobes. Potential risks of antibiotic bowel preparation and systemic antibiotic use are an increased incidence of postoperative diarrhea and pseudomembranous enterocolitis.

Morbidity and Mortality

Morbidity and mortality of urinary diversion procedures are related to both the enteroenterostomy and the bowel segment placed in the urinary tract. Properly performed gastrointestinal anastomoses, whether using staples or sutures, have similar complication rates. Sutured anastomoses or nonabsorbable staples are preferable if exposed to urine due to the risk of stone formation along nonabsorbable staples. Complications following

Urinary diversions are discussed by McDougal, Benson, and Stein in their excellent, comprehensive literature reviews. The reader is referred to these discussions for further study.

**URETERAL REFLUX**

**Refluxing Versus Nonrefluxing Ureterointestinal Anastomoses**

The roles of refluxing versus nonrefluxing ureterointestinal anastomoses in urinary diversions remain somewhat controversial. Vesicoureteral reflux is dangerous when associated with infection, obstruction, or high pressures; however, the literature has not established whether reflux in the presence of normal, unobstructed ureters contributes to renal deterioration.

Antireflux mechanisms in conduits are not necessary. Most conduit patients do well despite chronic reflux because ideally, urine is never at a higher pressure than it is at the renal pelvis. Antireflux mechanisms in continent catheterizable reservoirs and continent diversions with the anal sphincter are critical and are not controversial. The need for antireflux mechanisms in orthotopic diversions is controversial. In the ideal neobladder, urine storage and voiding occur at low pressures, the urine is sterile, and the external sphincter acts as a “pop-off” valve, making an antireflux mechanism unnecessary. However, it cannot be predicted preoperatively which neobladders will maintain these ideal circumstances long-term. Some neobladders will become chronically colonized with bacteria. In addition, some neobladder patients will require intermittent catheterization to adequately empty the neobladder and maintain low pressure systems. Because of the potential for bacteriuria and high intrareservoir voiding pressures, incorporation of an antireflux mechanism is advocated by some groups.

Well-designed, prospective, randomized trials of appropriate numbers of patients do not exist that critically evaluate whether reflux prevention is necessary or indicated in all or selected urinary diversions. An in-depth literature review is presented elsewhere. An advantage of refluxing ureterointestinal anastomoses is the ability to follow the upper tracts.
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radiographically by placing radio-opaque material into the conduit or reservoir. Lack of reflux signifies stricture or obstruction. In selecting patients for nonrefluxing anastomoses, renal function must be seriously considered because postoperative retrograde loopograms have no utility. Instead, the patient must undergo intravenous urography with the inherent risk of nephrotoxicity.

Antireflux Techniques

Techniques to create effective antireflux as well as reliable continence mechanisms continue to be refined. Common antireflux techniques include the following:

1. Submucosal tunnel in colonic wall.13,14
2. Direct ileal end-to-side ureteral anastomosis to intact tubularized ileum above an intussuscepted nipple valve (Figure 4), as in the Kock pouch/hemi-Kock neobladder.15
3. Direct end-to-side ureteral anastomosis into an interposed isoperistaltic tubularized ileal limb. This Studer16 limb minimizes reflux through isoperistalsis.
4. Ureteral implantation into a submucosal ileal groove.17
5. Split-cuff technique or end-to-side ureteral anastomosis into ileum with formation of a cuff at the distal ureter.18
6. Flap valve technique (Figure 4). Adjacent bowel segments that lie side by side create a serosal trough in which a tubular structure can be laid (eg, ureter, intestine, appendix) and the mucosal edges sutured together to create a serous-lined tunnel from the trough.12,15–21
7. Flap valve T mechanism, a modification of the flap valve technique.22 A tapered ileal segment (afferent limb) is embedded into a serosal trough created by a U-shaped proximal ileal segment. Ureters are anastomosed to the afferent limb. Even grossly dilated or very short ureters can be anastomosed, fashioned to the appropriate length needed.

Complications of Ureterointestinal Anastomoses

Complications of ureterointestinal anastomoses include leakage, stricture or obstruction, and reflux into anastomoses that were created as nonrefluxing. Antireflux techniques tend to be associated with a slightly higher incidence of ureterointestinal anastomotic stricture.

Significant complications have been associated with intussuscepted nipple valves, including stone formation on exposed nonabsorbable staples securing the afferent nipple valve, afferent nipple stenosis (likely due to ischemia after mesentery is stripped from the intussuscepted limb), and extussusception (ie, prolapsed afferent limb). The interior pouch pressure that compresses the nipple valve and produces continence is unfortunately the same pressure that causes lateral displacement of the reservoir wall over time. This results in gradual effacement and prolapse of the nipple and loss of the continence mechanism. The complications associated with intussuscepted nipple valves have not been found with flap valves with intermediate follow-up.23

DETUBULARIZATION AND RECONFIGURATION OF THE BOWEL

Rationale for Pouch Construction

Continent diversions should provide adequate capacity, storage pressures of less than 40 cm H2O,24 long-term preservation of upper tract function, and voluntary reliable control of continence and evacuation.

Refashioning the bowel into a pouch rather than a conduit is based on Goodwin’s work with augmentation cystoplasty. The shortest possible length of bowel should be used to create a low-pressure, high-volume, nonrefluxing reservoir, minimizing gastrointestinal and metabolic sequelae. This is accomplished by detubularization and reconfiguration of intact bowel segments.26,27 Detubularization (incising the bowel along its antimesenteric border) and reconfiguration (folding and sewing the edges together) into spherical forms greatly increases volume and decreases pressure.

Coordinated intestinal muscle and nerve activity propels intestinal contents in the normal aboral direction.
Detubularization interrupts rhythmic intestinal peristaltic contractions. Benefits include: upper and lower tract protection from intermittent high pressures, decreased susceptibility to reflux and pyelonephritis, increased stability of intussuscepted nipple-valves, and improved continence.

Reconfiguration is also important. For a given length of bowel, reservoir volume and intraluminal pressure depends on geometric configuration.30 The goal of reconfiguration is to obtain a spherical reservoir. Spheres have the greatest volume for the smallest surface area and shortest initial length of bowel. Spherical reservoirs with larger radius have lower filling pressures (p) without coordinated wall contractions.26,28,29 According to the laws of LaPlace and Pascal, for a given wall tension (t), a larger radius results in decreased pressure. Geometric pouch capacity is determined by configuration (v = r² × h, where h is the height of the cylinder), accommodation (t = p × r²), and compliance, or viscoelastic properties of the bowel.29

With filling and emptying over time (ie, cycling), reservoir capacity increases. True capacity is obtained after approximately 6 months’ maturation of the reservoir.29 Reservoir capacity, rate of diuresis, efficacy of emptying, and urethral resistance (if present) determine the reservoir’s functional stability. If pouch emptying is incomplete or chronically delayed, reservoirs and neobladders can become overdistended or decompensated. Defunctionalized diversions lose capacity over time.30

Absorbable Stapling Techniques

Bowel detubularization and reconfiguration is arguably the most time-consuming, tedious part of reconstructive urinary diversion procedures. Absorbable staples (first reported by Bonney and Robinson31) have reduced the operative time required for bowel reconfiguration and reservoir construction, with reliable short- and long-term results. Significant developments of staplers that both staple and divide using smaller staples have furthered their use. Absorbable staples have been used for both large and small bowel pouches, but the diameter of colon may be more suited than that of small bowel segments for the staplers and staples that are currently available.

OPTIONS FOR URINARY DIVERSION

CASE PRESENTATION

A 64-year-old man is diagnosed with stage T2 high-grade transitional cell carcinoma (TCC) of the bladder following transurethral resection of a sessile bladder tumor. Random bladder biopsies rule out concomitant carcinoma in situ. Upper tract cytologic and radiologic studies are negative for multifocal disease. Treatment options are discussed and the patient chooses to undergo radical cystoprostatectomy as definitive treatment. He is referred for lower urinary tract reconstruction following radical cystoprostatectomy.

- The patient expresses a strong desire for a continent urinary diversion. What are his options?

Cystoprostatectomy

A 64-year-old man is diagnosed with stage T2 high-grade transitional cell carcinoma (TCC) of the bladder following transurethral resection of a sessile bladder tumor. Random bladder biopsies rule out concomitant carcinoma in situ. Upper tract cytologic and radiologic studies are negative for multifocal disease. Treatment options are discussed and the patient chooses to undergo radical cystoprostatectomy as definitive treatment. He is referred for lower urinary tract reconstruction following radical cystoprostatectomy.

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Absorbable Suturing Techniques

Absorbable staples have become the traditional method for internal anastomosis of ureterointestinal anastomoses. The ideal stapler for continent urinary diversions is one that is absorbable, degradable, with minimal gas production, and reliable and reproducible. Absorbable stapling techniques were introduced in 1962 by Toldt and Kock for ileal pouches.32,33 The ureters are anastomosed to the antimesenteric border of the rectosigmoid with antireflux submucosal tunnels. Ureterosigmoidostomy was the mainstay of diversion until the 1950s, when metabolic disturbances (ie, acidosis, hyperkalemia), renal deterioration, pyelonephritis, and secondary malignancies at ureterointestinal anastomoses were reported. Increased frequency and urgency and nighttime incontinence were common.34,35 and were linked to intestinal contractions with reservoir pressure elevations.

Detubularization and reconfiguration of the bowel created a low-pressure reservoir, improving continence and maintaining renal function. Kock first applied these principles to ureterosigmoidostomy by detubularizing the rectosigmoid and augmenting it with an ileal patch.36 In developing countries, where incontinent stomas are not socially acceptable and external collection devices and catheters are not available due to cost, ureterosigmoidostomy and rectal bladders became procedures of choice and these techniques were further investigated and modified. Antibiotics, alkalinization, absorbable sutures, and antireflux techniques have addressed the traditional complications associated with ureterosigmoidostomy. Close monitoring must be performed long-term to assess for secondary malignancy.
Rectal Bladder Urinary Diversions

Rectal bladder urinary diversions incorporate principles of ureterosigmoidostomy but separate the urinary and fecal streams. The ureters are transplanted to the rectal stump and the proximal sigmoid is managed by colostomy or brought to the perineum. Contraindications include an incompetent anal sphincter, pelvic radiation, sigmoid diverticulosis or polyps, creatinine level greater than 1.5 mg/dL, dilated ureters (which carry an increased chance of reflux and obstruction), and hepatic insufficiency (which may lead to ammonia intoxication). Relative contraindications include a neurogenic bladder or bowel because anal sphincter dysfunction may be present. Anal sphincter competence must be proved preoperatively by testing with a 200- to 300-mL saline enema held for more than 3 hours. Dynamic testing is useful to determine the anal sphincter profile, presence or absence of incontinence, and closure pressures at baseline and under stress maneuvers.

Other Techniques

The Mainz (mixed augmentation ileum and cecum) II ureterosigmoidostomy (sigma rectum pouch) is an acceptable option for primary diversion, revision of ureterosigmoidostomy, and conversion of a colon conduit to continent diversion. There is no significant metabolic advantage compared to ureterosigmoidostomy (both often require oral alkalinization).

Other continent diversions with the anal sphincter include the double folded rectosigmoid bladder, augmented-valved rectum/patched rectal pouch, and hemi-Kock/T-pouch procedures with valved rectum. Detailed descriptions will not be presented here.

Secondary Colonic Malignancy Following Diversions with the Anal Sphincter

The rate of secondary colonic malignancy is 3.5% to 19%, with time to development approaching 26 years (range 3–53 years). Annual pouchoscopy, specifically examining the ureterointestinal anastomoses, is indicated in all ureterosigmoidostomy/rectal bladder patients. The urine and feces should be monitored for blood, but barium enemas should not be used because if the antireflux procedure fails, refluxed barium can cause renal damage.

- The patient chooses to optimally undergo neobladder creation. What are the advantages and disadvantages of this type of continent urinary diversion?

ORTHOTOPIC BLADDER REPLACEMENTS

Orthotopic urinary diversions, or “neobladders,” are anastomosed to the urethra, relying on the intact rhabdosphincter continence mechanism. Goals of orthotopic diversions include volitional residual-free voiding through the urethra, avoidance of intermittent catheterization, and allowing the potential for sterile urine. Nocturnal incontinence is common following creation of a neobladder. The first human orthotopic diversion is credited to Lemoine (1913), but the technique was not popularized until 1979.

An absolute contraindication to neobladder creation is urethral tumor involvement. Relative contraindications are: advanced physiologic (rather than chronological) age, radiation, external sphincter dysfunction, impaired mental state, poor manual dexterity, poor mobility, and urethral stricture. Patients must understand and be willing and able to self-catheterize, should it become necessary. Obesity is not a contraindication; in fact, neobladders may be preferable in obese patients because manipulating a urostomy appliance or self-catheterizing through a thick abdominal wall may be difficult.

Under no circumstances should the cancer operation be compromised in order to facilitate creation of a neobladder. Prior to 1990, neobladders were reserved for male bladder cancer patients and were contraindicated in female patients. This is because in women, the entire urethra was routinely removed during cystectomy to achieve an adequate surgical margin. However, it has been determined that the urethra can be preserved in many female patients without oncologic compromise. Anatomic study of the female continence mechanism demonstrates that continence can be maintained, therefore neobladders may be appropriate for selected female bladder patients.

The overall risk of urethral TCC after cystectomy (occurrence of tumor in the remaining urothelium) is approximately 10% in men. Prostatic urethral involvement, specifically stromal invasion, is the strongest independent predictor of subsequent urethral TCC. In women with bladder cancer, bladder neck and anterior vaginal wall tumor involvement are significant risk factors for development of urethral TCC after cystectomy. Carcinoma-in-situ and upper tract/multifocal tumors are not independent risks for urethral TCC and should not preclude orthotopic diversion in either sex. Intraoperative frozen section of the apical prostatic/distal urethral surgical margin should be negative prior to neobladder creation in patients of either sex. Indications for urethrectomy at cystectomy in either sex are carcinoma-in-situ or urethral tumor involvement. Delayed urethrectomy should be performed in catheterizable reservoir patients with urethral tumor involvement identified on final pathologic analysis.
Urethral wash cytology is indicated to monitor the remaining native urethral urothelium in all patients.

Many neobladders and modifications have been described, including the Camey I/II, vesical ileal Padovana (VIP), Hautmann, Studer, hemi-Kock, S-, and T-pouch ileal neobladders; the Mainz and Le Bag ileocecal neobladders; and right colon and sigmoid colon neobladders. A complete review of these techniques is beyond the scope of this publication.

- If frozen-section pathologic analysis at the time of this patient’s radical cystoprostatectomy reveals extension of high-grade TCC into the prostatic urethra, creation of a neobladder would not be an option. What other continent diversions are available to this patient?

**CONTINENT CATHETERIZABLE RESERVOIRS**

**Catheterizable Continen ce Mechanisms**

Unlike either neobladders or diversions utilizing the anal sphincter, continent catheterizable reservoirs rely upon the creation of an intestinal valve in the efferent limb to provide continence. Creation of the continence mechanism is challenging and is responsible for a diversion’s ultimate success or failure. (Gastric pouches are constructed less commonly than intestinal ones, but may be useful alternatives in situations that preclude the use of intestinal segments. A 7- to 10-cm wedge from the greater curvature is fashioned into a pouch or incorporated into an ileal reservoir, creating a composite diversion.54)

**Nipple valve techniques.** Procedures utilizing a nipple valve include the Kock pouch (continent ileal reservoir), the Mainz I pouch, and the right colon (Mansson) pouch. An extension of the Kock procedure for continent ileostomy,55 the Kock pouch56 provides urinary continence with an antireflux intussuscepted ileoileal nipple valve. Although Kock pouches have largely been abandoned due to high complication and reoperation rates, creation of a Kock limb remains an important technique in repairing failed continent/antireflux mechanisms. The Kock nipple valve is reproducible and allows easy endoscopic access; however, it uses staples, is susceptible to extussusception, and has a failure rate of approximately 10% to 15% at best.

The Mainz I pouch has undergone many modifications, mostly due to problems with the nipple valve. This technique uses the ileocecal valve to stabilize the nipple valve, which may be constructed using intussuscepted terminal ileum, in-situ tunneled appendix, or ileocecum.57–59 Right colon pouches (Mansson) with intussuscepted terminal ileum/ileocecal nipple valves are variations of continent cecal reservoirs using intact cecal segments.60,61 Differences in nipple valve stabilization exist among various right colon pouch techniques.

**Flap valve techniques.** Nonintussuscepted flap valves were developed in response to the disadvantages of nipple valves.22 The Mitrofanoff principle involves creation of a flap valve that is simple and stable, whereby in situ or transposed appendix is tunneled into the cecal teniae. If appendix is not available, an ileal62 or right colon63 tube (ie, a pseudoappendix) can be used. If a short appendix cannot reach the abdominal wall or umbilicus after tunneling, greater length is gained by including intact cecum.64 The terminal ileum can be left long, reaching high into the retroperitoneum, useful with short ureters.

Monti65 described a novel continence mechanism to construct an efferent conduit based on the Mitrofanoff principle. A 2- to 3-cm terminal ileal segment is opened along one mesenteric border, reconfigured longitudinally, and closed. The width of the segment is chosen based on the desired circumference of the tube to be created. Two nearby segments can be isolated, reconfigured, and joined if a longer tube is needed. Any narrow-lumen tube can be implanted submucosally as an efferent continence mechanism (eg, appendix, fallopian tube, ureter, skin tube, umbilical vein, ileum).

The T pouch incorporates flap valve T mechanisms (described earlier) for both antireflux and continence.22 Serosal troughs create pseudotunnels that prevent reflux and provide continence.

**Plicated ileocecal valves.** Plicated ileocecal valves are dependable continence mechanisms.66 The Indiana pouch is created from a 10-cm length of terminal ileum and the entire right colon. An appendectomy is performed if the appendix will not be used as the continence mechanism. (If the appendix is left in situ, infection or abscess is a risk.) The ileocecal valve is plicated or imbricated using various techniques (eg, nonabsorbable, doubly-imbricating Lembert sutures or purse-string sutures), and the terminal ileum is tapered into a catheterizable stoma or neourethra.67–69 Metal staples are used to create the efferent limb, and absorbable staples are used for the reservoir. The Indiana valve is simple to construct and reliable; however, the technique creates fixed resistance with a long afferent limb that may be difficult to catheterize. Indiana pouches are associated with slightly higher rates of incontinence and increased difficulty with catheterization compared with Kock pouches, but remain one of the most reliable catheterizable reservoirs, with few short- or long-term complications.

**Complications of Continent Catheterizable Reservoirs**

All patients with catheterizable reservoirs have chronic bacteriuria; if asymptomatic, antibiotics are not indicated.70
“Pouchitis” is manifested by pain in the pouch area and explosive incontinence from the continent stoma. This is caused by temporary continence mechanism failure due to hypercontractility of the bowel comprising the pouch. Symptoms usually resolve with antibiotics.

Urinary retention, a true urologic emergency, occurs infrequently, most often in pouches with nipple valves. Flexible pouchoscopy or a coude-tipped catheter is useful for accomplishing catheterization. Once a catheter is placed, it should be left indwelling for more than 3 days to let the stomal edema and trauma resolve.

Intraperitoneal pouch rupture (often following mild abdominal trauma) is more common in patients with altered or decreased sensation of pouch fullness.71–73 Immediate radiological studies and pouch decompression are indicated. Surgical exploration/repair is indicated for large defects and peritonitis. Those with a nonacute abdomen or smaller pouch defect may be managed conservatively (ie, catheter drainage, antibiotics).

- In discussing the options for continent urinary diversion with the patient, which other urinary diversion techniques should be presented as back-up options, if the planned continent diversion were not possible for some reason?

APPLIANCE-DEPENDENT URINARY DIVERSIONS

Cutaneous Ureterostomy

Cutaneous ureterostomy was associated with many complications, including ureteral retraction beneath the skin, urinoma, abscess, distal ureteral sloughing, stomal stenosis, and obstructive renal failure.74 Largely abandoned except in patients with very dilated ureters, cutaneous ureterostomy is mentioned because it may be an option for selected poor-risk, debilitated, ill patients, optimally with a solitary kidney. Patients with massively dilated upper tracts or renal insufficiency with aperistaltic ureters do not do well with diversions other than cutaneous ureterostomy.

CUTANEOS URETEROSTOMY

Cutaneous ureterostomy with nephropexy can effectively correct uremia and obstructive renal failure and alleviate inappropriate urinary incontinence (eg, caused by fistula). Ureteral stents and percutaneous nephrostomy remain the conservative techniques of choice to establish ureteral drainage. However, cutaneous ureterostomy may be the only palliative solution. It is a simple procedure, requiring a single exteriorized ureteral anastomosis to the skin, and is associated with minimal anabolic healing compared with other diversions.74–77

Gastrointestinal Urinary Conduits

Many modern diversions are based on the ileal conduit, popularized by Bricker78 and Cordonnier.79 A urinary conduit is an isolated, vascularized bowel segment with ureters attached distally and an externalized stoma proximally.

Stomal location. The stoma is matured at the site that has been marked preoperatively. The standard nipple or rosebud stoma works well. For patients with higher body mass, short or thick ileal mesentery, or irradiated bowel, a loop-end ileostomy or Turnbull loop stoma may be preferable for preserving mesenteric length.80 Meticulous attention must be paid to marking the stoma site preoperatively with the patient sitting or standing. The stoma must not be placed in a skin crease, at the waistband or belt line, under the pannus, or close to abdominal scars. Stomal location is ideally in the right or left lower quadrant on a line between the umbilicus and the anterior superior iliac spine, as far lateral as possible, but such that the bowel segment comprising the stoma traverses the rectus muscle (thereby limiting para- stomal herniae). Even with modern stomal devices and techniques of stoma care, the praise or blame for their performance lies with the surgeon. The best urinary diversion works poorly if the appliance leaks.81 Placement of a continent catheterizable stoma is often at the umbilicus or in the lower abdominal quadrant through the rectus, below the “bikini line.” Additionally, an external stomal site (or sites) should always be marked preoperatively in case a planned orthotopic diversion needs to be abandoned because of unanticipated intraoperative issues.

Anastomotic technique. There are many well-described techniques for nonrefluxing ureterointestinal anastomosis: (1) ureters joined side-by-side like cupped hands, anastomosed to the side (Barzilay)82 or butt end (Wallace)83 of the conduit; (2) ureters sewn individually to the ventral side of the conduit (Bricker)78; and (3) the Lahey Clinic method,84 in which the left ureter is always placed on the proximal butt end and the right as an end-to-side to simplify future endoscopic identification. It is recommended that all conduits be retroperitonealized and ureterointestinal anastomoses stented with temporary silastic catheters.

Gastrointestinal segments. The ileal conduit (10 to 15 cm of distal ileum, 15 cm proximal to the ileocecal valve) is a simple conduit to create and is associated with the fewest intraoperative and immediate postoperative complications. Stomach conduits are rarely indicated. Externalized stomach (ie, stoma) is associated with high incidence of stomatitis, skin ulceration, and difficult stomal maintenance issues. Jejunal conduits (10 to 15 cm of jejunum, 15 to 25 cm from the ligament of Treitz) are associated with significant electrolyte abnormalities and
are only indicated in certain situations: when ileum or colon are not available owing to irradiation, intrinsic bowel disease, surgical removal, or extrophy; or for high diversions to reach ureters that have been shortened because of malignancy.

Following pelvic irradiation, transverse colon conduits are optimal. If the ureters are short, ileocecum provides a long ileal segment to replace ureteral length and the cecum for the stoma. Sigmoid colon is useful after pelvic exenteration with colostomy because a separate bowel anastomosis is not needed. Contraindications to using sigmoid colon are diverticulosis or diverticulitis, division of the hypogastric arteries leaving the rectum in situ, and following pelvic irradiation.

Adynamic dilated ureters should not be used with any conduit. Urine must first reach the conduit lumen before peristalsis of a properly functioning conduit can remove it. Large adynamic ureters allow urine to become stagnant and not effectively reach the conduit. One should consider ileal ureter, ileal sleeve, pyeloileocutaneous anastomosis, or cutaneous ureterostomy instead.

Ileal Vesicostomy

Ileal vesicostomy can be optimal for spinal cord injured patients or those with significant neurologic disease. An intact ileal segment is placed over a wide transverse cystotomy and brought out as an abdominal stoma. This decompresses the bladder. This technique is especially useful in patients with detrusor sphincter dyssynergia; however, patients with detrusor hyperreflexia are at higher risk for incontinence with this procedure. Complications include bladder and kidney stones, stomal stenosis, and incontinence (requiring bladder neck closure).

Conversion from Conduit to Continent Diversion

The primary indications for converting a functioning conduit to a continent diversion (“undiversion”) are patient preference and quality of life. Ideally, the existing conduit should be used in the conversion to minimize complications and metabolic sequelae.

SEQUELAE OF URINARY DIVERSIONS

METABOLIC COMPLICATIONS

Chronic metabolic sequelae following urinary diversions are well described\(^1\) and depend on the gastrointestinal segment used and its surface area; urine dwell time; urinary solute concentration and pH; and renal, hepatic, and intestinal function. Metabolic complications arise from either bowel contact with urine or reduced intestinal resorptive surface area (Table 2). Altered solute reabsorption across the semipermeable and metabolically active gastrointestinal segment placed within the urinary tract can cause electrolyte abnormalities, altered sensorium, abnormal drug metabolism, osteomalacia, growth retardation, persistent or recurrent infections, and renal/reservoir calculi.

When assessing urinalysis results in diversion patients, one should keep in mind that the diversion bowel mucosa is permeable to solutes and water, allowing osmolality to equilibrate. Consequently, urine osmolality does not accurately reflect renal function. Nor does urine pH reflect the kidneys’ ability to acidify urine because of acidification/alkalinization by the gastrointestinal segment.\(^5\)\(^6\)

Altered bone metabolism and osteomalacia are related to chronic acidosis (buffered by bone phosphate mobilization), excessive renal calcium loss, and vitamin D resistance. Reabsorption of urinary sulfate leads to increased renal calcium and magnesium loss.\(^8\) Symptoms of osteomalacia are lethargy, joint pain, and proximal myopathy.

Treatment is aimed at remineralization of bone and includes correction of acidosis (with bicarbonate) and calcium supplementation.\(^8\)\(^9\) Diversion-related osteomalacia that is not corrected with restoration of acid-base balance may be due to renal vitamin D resistance (independent of chronic acidosis) and is correctable with 1-alpha-hydroxycholecalciferol (a vitamin D metabolite).

Urinary diversion has detrimental effects on growth and development in children. Evidence supports decreased linear growth in human\(^9\) and animal studies.\(^1\)\(^1\) Obvious alterations in growth and development do not occur, but significant changes in linear growth are apparent after a decade or more in patients whose diversions were fashioned during childhood.

Altered sensorium can occur with magnesium deficiency (nutritional or caused by renal loss), abnormal ammonia metabolism, or drug intoxication. Patients with normal liver function can metabolize excess absorbed urinary ammonia. Liver dysfunction or bacteriuria with urea-splitting organisms can overload hepatic detoxifying ability, resulting in confusion, personality changes, unresponsiveness, seizure, and coma.

Treatment of ammoniagenic coma includes reservoir drainage using a rectal tube or Foley catheter to reduce urine dwell time, administration of neomycin to decrease the ammonia load in the gastrointestinal tract, lactulose and arginine glutamate to bind ammonia, and decreased dietary protein. Continent diversions are
<table>
<thead>
<tr>
<th>Physiologic Function</th>
<th>Electrolyte/Metabolic Abnormality</th>
<th>Management</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stomach</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secretion of Cl−, H⁺, K⁺</td>
<td>Hypochloremic, hypokalemic metabolic alkalosis</td>
<td>Saline administration, KCl replenishment, proton pump inhibitors; intractable cases may require surgical removal of the segment.</td>
<td>Maintenance doses of KCl; for severe cases, proton pump inhibitors.</td>
</tr>
<tr>
<td>Gastrin secretion</td>
<td>Hypergastrinemia may cause peptic ulcer disease, metabolic alkalosis, and dysuria-hematuria syndrome</td>
<td>As above; also avoid antral segment of the stomach for augmentation.</td>
<td>As above; in addition to sodium bicarbonate for dysuria-hematuria syndrome.</td>
</tr>
<tr>
<td>Secretion of intrinsic factor</td>
<td>Vitamin B₁₂ deficiency</td>
<td>Parenteral vitamin B₁₂ replacement</td>
<td></td>
</tr>
<tr>
<td>Jejunum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secretes Na⁺ and Cl⁻, reabsorbs K⁺ and H⁺</td>
<td>Hyponatremic, hyperkalemic, hypochloremic metabolic acidosis, and azotemia, secondary hyperaldosteronemia exacerbates the abnormality. Results in lethargy, nausea, vomiting, dehydration, muscular weakness, and elevated temperature (jejunal conduit syndrome).</td>
<td>Rehydration with sodium chloride solution, correction of acidosis with sodium bicarbonate</td>
<td>Oral sodium chloride supplements and continuous hydration. Avoid this segment if possible.</td>
</tr>
<tr>
<td>Folic acid absorption</td>
<td>Folic acid deficiency</td>
<td>Parenteral replacement of folic acid</td>
<td>Avoid this segment if possible.</td>
</tr>
<tr>
<td><strong>Ileum and colon</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net absorption of ionized ammonium and Cl⁻, inability to absorb K⁺ (especially in colon)</td>
<td>Hyperchloremic metabolic acidosis, sometimes hypokalemia as well</td>
<td>Correction of acidosis with parenteral/oral sodium bicarbonate. Alternatively, sodium citrate plus citric acid or Shohl’s solution may be used. Simultaneous potassium replacement is essential.</td>
<td>Supplements of oral bicitrates or sodium bicarbonate or Shohl’s solution. Chlorpromazine or nicotinic acid can reduce the need for alkalizing agents.</td>
</tr>
<tr>
<td>Absorption of bile salts, fat, and fat-soluble vitamins</td>
<td>Fat malabsorption, deficiency of fat-soluble vitamins</td>
<td>Replacement of fat-soluble vitamins</td>
<td></td>
</tr>
<tr>
<td>Absorption of vitamin B₁₂</td>
<td>Vitamin B₁₂ deficiency</td>
<td>Parenteral vitamin B₁₂ replacement</td>
<td>Save the distal portion of ileum.</td>
</tr>
</tbody>
</table>

contraindicated in patients with liver dysfunction.\textsuperscript{92,93}

Altered drug metabolism in urinary diversion patients can result in toxic serum levels of drugs. Drugs absorbed by the gastrointestinal tract and excreted unchanged from the kidneys (eg, methotrexate, phenytoin) are re-exposed to the intestinal diversion segment and reabsorbed. To minimize drug toxicity problems, adequate hydration and effective urine drainage must be provided.

Patients with intestinal urinary diversions have a higher incidence of bacteriuria (ie, positive urine cultures) and bacteremia. Intact intestinal tract exists symbiotically with bacteria and thus is incapable of inhibiting bacterial growth (in contrast to urothelium). Intestine placed into the urinary tract therefore is a source of ascending infection and may make urine less bacteriostatic, promoting bacterial growth. Asymptomatic patients should be observed rather than treated. Patients with symptoms should be treated based on documented cultures.

Etiologies for stone formation include chronic dehydration; metabolic abnormalities; increased absorption of calcium, phosphate, sulfate, or magnesium; enteric hyperoxaluria; hypocitraturia; urinary stasis; intestinal mucus production; presence of foreign bodies (nonabsorbable staples/sutures); and chronic bacteriuria with urea-splitting organisms.\textsuperscript{84,94} Therapy includes hydration, a low-fat diet, cholestyramine (binds bile salts), oral citrate, selective antibiotics, and routine drainage/irrigation.

Loss of significant intestinal resorptive surface area can lead to short bowel syndrome and nutritional and motility issues. Loss of 60 to 100 cm of ileum results in malabsorption of bile salts with increased gallstone formation, colonic mucosal irritation, decreased transit time, and cathartic diarrhea. Loss of more than 100 cm of ileum results in fat malabsorption with steatorrhea and resultant hyperoxaluria. Loss of the terminal ileum can result in vitamin B\textsubscript{12} deficiency, which leads to megaloblastic anemia and irreversible neurological deficits, decreased transit time, and deficiency of fat-soluble vitamins. Vitamin B\textsubscript{12} deficiency takes many years to develop and can be prevented or treated with vitamin B\textsubscript{12} injections. Retention of the distal 35 to 50 cm of terminal ileum prevents B\textsubscript{12} malabsorption and bile acid loss.

Loss of the ileocecal valve results in reflux of colonic bacteria into ileum with bacterial overgrowth, fatty acid and bile salt malabsorption, deficiency of fat-soluble vitamins and calcium, and decreased transit time. Loss of significant colonic length results in diarrhea and dehydration because of decreased fluid and electrolyte absorption. These significant sequelae can often be managed with nutritional supplementation, low fat diet, bile salt sequestrants, and bowel motility agents.

**SECONDARY MALIGNANCY**

Secondary malignancy has been reported in all bowel segments exposed to urine, whether mixed with feces or not.\textsuperscript{42,95} Case reports of adenocarcinoma, adenomatous polyps, sarcoma, and TCC have been reported in patients with ileal and colon conduits and bladder augmentations. There is generally a 10- to 20-year interval following surgery before cancer becomes clinically evident. The etiologic mechanism is not understood. The highest incidence of secondary malignancy has been reported when transitional epithelium is juxtaposed to colonic epithelium with both kinds of tissue continually exposed to the fecal stream.\textsuperscript{96,97} Adenocarcinoma may develop when urothelium is left in contact with intestinal mucosa, even if the diversion is defunctionalized (and therefore exposure to urine has ceased).\textsuperscript{98} If the urothelium is removed from the intestinal tract, adenocarcinoma does not develop, suggesting that any anastomosis between urothelium and the intestinal tract should be removed once defunctionalized and not just ligated or divided and left in situ. Whether malignancy arises from the urothelial or intestinal mucosa is unknown. Evidence suggests that malignancy can develop from urothelium itself, and not only as a result of urine’s effect on the intestinal mucosa.\textsuperscript{99}

Patients with ureterosigmoidostomies or uretero-colonic diversions require special mention. Ureters in these patients have a high incidence of dysplasia\textsuperscript{100} and malignancy at the ureterointestinal anastomosis. Therefore, patients should undergo routine colonoscopy with special inspection of the ureterointestinal anastomoses.

All patients with urinary diversions should undergo urine cytology starting approximately 10 years after diversion, whether or not the diversion was performed because of cancer. Patients developing microscopic or gross hematuria must be fully evaluated because malignancies developing earlier than 10 years have been reported.\textsuperscript{101}

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