Bladder Replacement and Urinary Diversion After Radical Cystectomy

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Advancements in bladder replacement construction and continent urinary diversion have reduced treatment morbidity for patients facing cystectomy.

Background: The optimal mode of urinary tract reconstruction following cystectomy continues to challenge the urologic surgeon. Disadvantages with bowel conduits have prompted the search for better techniques to improve patient outcomes.

Methods: The development of urinary tract reconstruction is reviewed, and results from several forms of continent urinary diversion and bladder replacement construction are presented. The authors report on their experience in creating continent reservoirs or neobladders in over 400 patients.

Results: Several surgical approaches are now available for continent urinary diversion. Metabolic and nutritional abnormalities, stone formation, infection, and cancer formation are potential complications.

Conclusions: Advances in surgical techniques, an understanding of the physiology of isolated bowel segments, and improvements in pre- and post-operative care have altered the field of urinary reconstruction after cystectomy for bladder cancer. Most patients can expect minimal morbidity and mortality.

Introduction

Determining the optimal mode of urinary tract reconstruction following cystectomy is a challenge for the urologic surgeon. Until recently, bowel conduits were considered the gold standard and represented the most popular form of urinary tract restoration.[1-5] However, the negative body image associated with an external ostomy appliance, as well as the risk of renal damage, led to the development of continent urinary diversion and bladder replacement reconstruction to improve outcomes for patients who undergo cystectomy.[6-13] A better understanding of isolated bowel segment physiology, improvements in surgical technique, and the acceptance of intermittent catheterization have promoted the widespread popularity of these forms of reconstruction.[7] Cancer eradication, preservation of renal function, and optimal quality of life are the ultimate goals of surgery for bladder cancer.[14]

Historical Review

The quest for an ideal technique for urinary tract reconstruction following cystectomy dates back to 1852 when Simon[15] first reported diversion of urine to a segment of bowel by creating fistulas between the ureters and the rectum in a patient with bladder exstrophy. Initially, efforts were aimed at either bringing the ureters to the skin or diverting the urine to the sigmoid colon to benefit from continence provided by the anal sphincter.[16,17] Prior to the 1950s, the use of the anal sphincter for continence established ureterosigmoidostomy as the urinary diversion of choice. During this era, techniques of nonrefluxing ureteral anastomoses were improved.[18-22] However, the risk of long-term complications with ureterosigmoidostomy was significant (hydronephrosis: 32%; pyelonephritis: 57%; metabolic derangements: 47%).[23] In 1950, Bricker[2] popularized the use of the ileum as a urinary conduit, which constituted the gold standard for patients who underwent urinary diversion until the 1980s. The need for improvements in the quality of life of patients led to the era of continent urinary diversion and bladder replacement. By applying the concepts of a cutaneous catheterizable ileocecal reservoir developed in 1950, several investigators reported encouraging initial results with colonic reservoirs in the mid 1980s.[7,8,12] and Kock et al[6] concurrently developed a catheterizable ileal pouch. Camey and LeDuc[24] reintroduced the concept of the neobladder in 1979, and other investigators improved the technique by applying the experiences of the early continent urinary diversion.[11]

Selection of Type of Urinary Diversion

The goal of surgery in the management of infiltrating bladder cancer is either curative or palliative. If the intent is palliative, then the simplest and most expeditious type of urinary diversion is best. If the goal is curative, then the patient is apprised of reconstruction options for the urinary tract and undergoes preoperative evaluation. Although the psychologic impact of surgery and diversion is significant, any type of urinary reconstruction should be acceptable with good preoperative assessment and education. Enterostomal therapists and urology nurses play pivotal roles in improving patients' coping abilities, both preoperatively and postoperatively.[25,26]

Factors that affect the choice of urinary diversion include patient age, manual dexterity, body habitus, physical and mental status, renal function, prognosis of the primary disease, existing bowel pathology, prior radiation or chemotherapy, the presence of urethral disease, the expectations, preferences, and fears of the patient, the experience and preference of the surgeon, and cost.[27] Since there is no unanimous choice for the best method of urinary diversion, all options should be considered.

[28]
Indications for an external collecting device diversion (bowel conduit) are either absolute or relative. Absolute indications include impaired renal function, impaired physical ability to perform self-catheterization, and inability to understand the significance and possible complications of a continent diversion. Relative indications include advanced age, need for postoperative chemotherapy, previous pelvic irradiation, bowel disease (Crohn's disease, colitis, cancer), body habitus, diseased urethra, and impaired functional status.[29,30] Patient choice also is a key factor in selection.

Options in Continent Urinary Diversion

**Continent Cutaneous Urinary Reservoir**

In 1986, Kock et al.[6] described a technique for construction of an internal ileal reservoir that consists of a 80-cm segment of terminal ileum isolated on its mesentery at approximately 50 cm proximal to the ileocecal valve. Proximal and distal 17-cm segments are excised to form the afferent and efferent limbs to the pouch, and two medial 23-cm segments are detubularized, approximated, and remodeled to form the reservoir. Afferent and efferent continent nipple valves are then created by entussuscepting sections of bowel 5- to 6-cm in length with strips of Marlex or polyglycolic acid mesh around the bases of the intussusceptions. The ureters are anastomosed to the afferent limb using a mucosa-to-mucosa anastomosis, the pouch is closed, and the efferent limb is brought through the abdominal wall and fixed to the rectus fascia using a Dexon collar to form a stoma through which urine can pass.

In 1992, Fisch et al.[31] described a form of continent urinary diversion termed the Mainz pouch, which utilized cecum and ileum. To create the reservoir, 10 to 15 cm of cecum and ascending colon, as well as terminal ileal segments of equal length, are isolated and detubularized. The posterior wall of the pouch is completed by anastomosis of the ascending colon with the ileal loop, starting at the inferior aspect. The latter is then anastomosed with the next proximal ileal segment. The ureters are implanted in an antirefluxing manner in an open-end technique through a submucosal tunnel of 4 cm to 5 cm in length. To create the continence mechanism, an additional 8 to 12 cm of ileum is isolated to form an ileal intussuscepted valve by invaginating and fixing 6 cm of this latter segment with metal staples. Alternatively, continent can be achieved by submucosal embedding of the appendix.

In 1985, Rowland et al.[32] described the cecoileal continent urinary reservoir, in which approximately 8 to 10 cm of terminal ileum and 25 to 30 cm of cecum and ascending colon are isolated.[33] The colonic segment is detubularized either by incising along its antimesenteric surface with scissors or cautery or by placing a 60- to 75-mm gastrointestinal anastomosis (GIA) stapler between the two more lateral tenia. The continence mechanism is then created by tapering the efferent limb (terminal ileum) over a 12F red rubber catheter resting against the antimesenteric surface of the ileum. A 60-mm GIA metal staple is applied to excise the redundant antimesenteric portion of the ileum and to create a smooth tube for catheterization using 16F to 18F catheters. The ureters are tunneled into the tenia of the colonic segment through an inverted "T" incision. A mucosal incision is then made for the orifice, the ureter is cut either obliquely or spatulated, and a ureter-to-mucosa anastomosis is performed over a 5F to 8F stent using interrupted 5-0 absorbable, synthetic, monofilament sutures. The cephalad end of the pouch is folded to the cecal end, and the reservoir is closed with a single layer of running 3-0 braided synthetic absorbable suture.

In 1986, Light et al.[34] described Le Bag, in which 20 cm of cecum and ascending colon are isolated with a corresponding length of terminal ileum. Following detubularization, the free ileal and colonic borders are sutured together, and the pouch is closed as described in the Kock procedure. The ureters are reimplanted on the colonic portion of the pouch according to the preference of the surgeon. After tapering and reinforcing the ileocecal valve, the ileal tail is brought through the abdominal wall as the continent segment.

In 1986, we described a different form of continent urinary diversion utilizing an extended colon segment.[35] Creation of the reservoir begins with wide mobilization of the right colon and terminal ileum. The mid-transverse colon and distal ileum are transected using automatic staplers. The last 10 cm to 15 cm of ileum is preserved, depending on the abdominal wall thickness. Using standard stapling techniques, an ileocolonic anastomosis is performed to restore bowel continuity. The colonic segment is turned into itself in the form of a "U" and is detubularized, either by opening the bowel along its antimesenteric border or by using an absorbable automated surgical stapler. The medial edge is then closed with running 3-0 absorbable suture, and the ureters are brought through the posterior wall of the colon where they are anastomosed directly, mucosa to mucosa. To create the continence mechanism, the redundant antimesenteric portion of the distal ileum is excised with surgical staplers. The reservoir is then closed with a running, locking 3-0 absorbable suture (Figs 1-5).[36]

Orthotopic Bladder

Camey and LeDuc.[24] Hautmann et al.[11] and Studer and Turner[37] described the creation of a bladder from different bowel segments as an alternative for handling continuity of the urinary tract after cystectomy.

Complications Relating to Techniques

Complications from earlier techniques affect 2% of patients with continent urinary diversion and 4.5% of patients with neoplasms. Complications include infection, wound dehiscence, urinary fistulas, prolonged ileus (longer than seven days), small bowel obstruction, respiratory distress (atelectasis, pneumonia, pulmonary embolus),
myocardial infarction, deep venous thrombosis, and bleeding.

**Metabolic and Nutritional Effects**

Possible metabolic and nutritional consequences associated with small and large intestinal segments for continent diversion of the urinary tract include disturbances of electrolyte metabolism, abnormal drug metabolism, calculus formation, altered hepatic metabolism, nutritional disturbances, osteomalacia, impaired sensorium, growth retardation, infection, and cancer development.[38,39]

**Electrolyte Abnormalities**

Hypercarnitonic metabolic acidosis develops as a result of sodium secretion (in exchange for hydrogen) and bicarbonate (in exchange of chloride), as well as reabsorption of ammonia, ammonium, hydrogen ions, and chloride when these segments are exposed to urine. The mechanism that appears to be most responsible for hypercarnitonic metabolic acidosis is excess absorption of chloride and ammonia, which maintains a chronic endogenous acid load.[40] Since chloride seems to be more readily absorbed from colonic than from ileal reservoirs and since electrolytic derangements predominate when longer colonic segments are used for reservoir construction, the use of an ileal segment may be preferable in patients with impaired renal function.[41]

Hypokalemia and total body depletion of potassium may occur in patients with urinary intestinal diversion. Potassium depletion is probably the result of renal potassium wasting as a consequence of renal damage, osmotic diuresis, and gut loss through intestinal secretion.[40]

Hypocalcemia is a consequence of depleted body calcium stores and excessive renal wasting.[40] The chronic acidosis is buffered by carbonate from the bone with subsequent release of calcium into the circulation, which is then cleared by the kidney and results in a gradual decrease in body calcium stores. An impairment of renal tubular calcium reabsorption also occurs. Normal bone mineral metabolism requires the interaction of calcium, magnesium, and phosphate, which are influenced by parathyroid hormone, calcitonin, and vitamin D. Osteomalacia in adults and rickets in children -- essentially the same condition -- are characterized by chronic loss of bone and calcium and lead to hypercalcemia and bone demineralization. Mineral losses are eventually replaced by osteoid with a resultant decrease in bone strength. Alterations in bone mineral content occur in most patients who have had a urinary intestinal diversion for extended periods of time.[42]

**Calculation Formation**

The incidence of renal stone formation increases in patients with intestinal urinary reconstruction. The increases range between 16.7% and 26.5% with the Kock pouch, 5.4% with the Indiana pouch, and 9.8% with the Mainz pouch.[43,44] In our series, at a mean follow-up of 6.3 years, we found a 15% incidence of stone formation.[45] With a shorter follow-up, the incidence of urinary calculi in neobladders ranges between 2.1% and 2.7% (herm-Kock neobladder and Hautmann ileal neobladder, respectively).[46] Generally, the stones are comprised of struvite, calcium oxalate, calcium phosphate, or uric acid, and mixtures of these minerals often are present in the same stone. Most stones reported to be infectious are comprised of struvite and/or carbonate apatite and are related to foreign materials and infection. A small but significant portion of stones are metabolic and consist of calcium phosphate and/or calcium oxalate secondary to hypercarnitonic metabolic acidosis.[47] Common risk factors for urolithiasis are chronic colonization of the reservoir with bacteria secondary to urine alkalinity.[45] Renal infection with urease-producing bacteria, the presence of foreign materials (eg, sutures, metallic staples, nonabsorbable collars) in the reservoir, retained intestinal mucous, and increased urinary excretion of phosphate, sulfate, and magnesium, and hypocitraturia.[47]

**Nutritional Disturbances**

The liver synthesizes and conjugates bile salts that are necessary for proper fat digestion and for the uptake of vitamins A and D. After fat stimulates their release into the duodenum, bile salts are actively reabsorbed by the distal ileum and returned to the liver by the enterohepatic circulation to be used again. After ileal resection, length-dependent alterations in bile metabolism can lead to a multitude of intestinal events that may result in diarrhea. Even though considerable amounts of bile salts are lost in the colon, the liver can synthesize and maintain the salt pool after resection of up to 100 cm of ileum. If ileal resection is greater than 100 cm, hepatic bile salt synthesis cannot match the losses. In this case, micelle formation in the jejunum decreases, and fat malabsorption leads to steatorrhea (fecal fat of more than 20 g per day) and diarrhea. Hydroxylated fatty acids directly decrease colonic absorptive capacity, cause active secretion of electrolytes and water, and form soaps, which are cathartic.[48]

Vitamin B12 is excreted exclusively into the bile. It is highly conserved by active uptake at the terminal ileum and returned to the liver by the enterohepatic circulation. Body stores of vitamin B12 may last three to six years in complete malabsorption and six to 30 years in partial malabsorption.[48] Loss of the distal ileum can impair vitamin B12 absorption. A loss of 50 cm of terminal ileum appears to be the critical margin for sufficient vitamin B12 absorption. Substitution of vitamin B12 should be prescribed to patients who lose more than 50 cm of terminal ileum beginning several years after surgery.

Following removal of the ileocecal valve, the absorptive processes in some patients may be affected due to the development of high concentrations of bacteria in the ileum. Severe diarrhea may occur as a result of fat malabsorption or irritation of unreabsorbed bile salts on the colonic mucosa.[38] Diarrhea also may occur when major portions of the large bowel are removed. In this case, a significant amount bicarbonate can be found in the fecal fluid, since alkaline ileal contents drain into a shortened large bowel segment, which may result in acidosis and dehydration.[38]

**Infection**

Approximately 80% of patients with continent intestinal diversion are bacteriuriac with diverse bacterial flora. In the first year of reconstruction, the incidence of septic episodes varies from 5% to 20%. The frequency of bacteriuria, pyelonephritis, and sepsis is higher in patients with continent intestinal diversion than in those with an intact bladder that is subjected to daily instrumentation by intermittent catheterization.[40]

**Carcinogenesis**

The incidence of malignancy in intestinal segments used for urinary reconstruction is currently unknown. If cancer develops, the most common site is the ureterointestinal anastomosis. The most common types of tumor are adenocarcinoma (85%) and transitional cell carcinoma (10%), with the remaining 5% consisting of signet ring cell carcinoma, adenomatous polyps, sarcoma, and undifferentiated carcinoma.[49] A possible mechanism is an increase in exposure to carcinogens such as N-nitroso compounds, which are highly mutagenic and induce tumors in many animal species. Nitrate is normally excreted by the kidney into the urine, and many species of Gram-negative bacteria (Escherichia coli, Proteus, Klebsiella, Pseudomonas) can reduce nitrate and catalyze the conversion of nitrite and secondary amines present in the urine into N-nitroso compounds. Fecal bacteria are presumably responsible for the formation of these substances, although the admixture of urine and feces is not considered an absolute requirement for this production. Long-term surveillance is mandatory for patients who have undergone urinary reconstruction with intestinal segments.
Complications Related to the Reconstructed System

Obstruction

Ureterointestinal anastomosis obstruction is a serious complication, and surgical intervention is usually required to preserve the upper urinary tract. Common factors predisposing to anastomotic structure formation are inadequate ureteral length, poor vascular supply, poor surgical technique with ureteral twisting, and possibly an increased angulation with chronic reservoir distension.[45] The mean incidence for this complication is 7.5% with continent reservoirs; with neobladders, the incidence is higher.[46] When the ureters are reimplemented, the incidence of obstruction is even higher (28%).[47] Ureterointestinal anastomosis obstruction may be managed either by balloon dilatation and stenting or by an open surgical procedure through a transreservoir approach.

The incidence of acute pyelonephritis ranges up to 5.8% with continent diversions and up to 8.0% with neobladders. In most cases, its onset is related to obstruction of the ureterointestinal anastomosis.[45]

Reflex

The estimated incidence of intestinoureteral reflex is 2.6% with continent reservoirs and 0.4% with neobladders.[45,46] Despite the controversy regarding the optimal type of ureterointestinal reimplantation (tunneled vs nontunneled), the incidence of reflex is low regardless of which reimplantation technique is used.

Reservoir Complications

Hypertonicity of the bowel reservoir with associated episodes of urine leakage has been noted in 5.6% of pouches and in 4.2% of neobladders.[46] Whether the bowel is detubularized or left in its original tubular form, bowel motility resumes in some segments across anastomotic lines. Pressure spikes may be noticed in both detubularized and tubularized segments of bowel.[40]

Spontaneous perforation of the urinary reservoir is a rare complication. The incidence with continent reservoirs is 4.8%, and no cases have been reported with neobladders.

Efferent Limb Complications

Dysfunction of the continence segment occurs in 6% of patients with continent reservoirs, and dysfunction of the intestinourethral anastomosis with neobladders occurs in 2.75% of patients.[46] Dysfunction of the continence segment (ileocecal valve) may be due to intrinsic factors (eg, a dysfunctional plicated bowel limb) or extrinsic factors (eg, a parastomal hernia).[50] Multiple abdominal wall scars, weight gain, and a chronic increase in intra-abdominal pressure due to constipation or chronic obstructive pulmonary disease may favor hernia development.[45] Difficulty with emptying the reservoir is encountered in 7% of patients with continent cutaneous reservoirs and in 12% of those with neobladders.[46] In the former, the difficulty may be related to a long and tortuous efferent limb, the creation of a false passage, or the development of a stricture along the efferent limb. For patients with neobladders, the main causes of difficulty are intestinourethral strictures (6.26%) and urethral cancer recurrence (3% to 18%).[48,51]

Protrusion of a ventral hernia through the incision line developed in one (1.7%) of our 60 patients. Other series report an incidence rate of ventral hernia that ranges from 4.4% to 14%.[27,30] Meticulous closure of the abdominal wall with appropriate suture materials is the cornerstone in preventing this complication.

Conclusions

Significant advances in surgical techniques, a better understanding of isolated bowel segment physiology, and improvements in preoperative and postoperative care have revolutionized the field of urinary reconstruction after cystectomy for bladder cancer. The majority of patients who undergo this procedure can expect minimal morbidity and mortality and an enhanced quality of life. The stride still continues to refine the surgical techniques for urinary tract reconstruction.

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