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Review Article

Bladder Augmentation

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Abstract: This paper reviews bladder augmentation, which has been proved to be an effective way of providing a well functioning urine reservoir that protects the upper urinary tract and allows patients to have a good quality of life. Good results have been achieved with the use of all types of bowel segments. Lifetime follow-up and recognition of the complications is mandatory. Very careful patient selection is essential in order to achieve better long-term results. The principle of urothelial preservation, introduced by autoaugmentation, is very promising in the effort to create a compliant urinary reservoir without metabolic disturbance and without the risk of cancer.

Keywords: Autoaugmentation; Bladder; Complications; Enterocystoplasty; Gastrocystoplasty

Introduction

The urinary bladder as a reservoir has the ability to increase its volume during the filling phase of the micturition cycle with little or no change in intravesical pressure. Although it is an involuntary organ, an individual can initiate or inhibit contractions of the sphincteric mechanism, permitting voiding or maintaining continence under voluntary control. Its function depends on the integrity of its innervation and the sphincteric mechanism of both vesical neck and proximal urethra. The normal bladder can accommodate volumes up to 400-500 ml while sustaining an intravesical pressure of about 10 cmH_2O. A sensation of fullness leads to the active contraction of the detrusor, which increases the intravesical pressure and results in voiding. Many neurological pathways are involved in micturition, alteration of any of which may cause bladder dysfunction. A variety of pathological conditions may lead to a diseased bladder with restricted capacity or abnormal contractility. Augmentation cystoplasty is a well established procedure during which the bladder is enlarged by incorporating a variety of different patches into the native bladder. In substitution cystoplasty a large proportion of the bladder is resected and replaced by a selected gastrointestinal segment. Enterocystoplasty was first described by von Mikulicz [1], in 1899, who used a segment of ileum in order to enlarge a bladder contracture of unknown cause. In the early 1950s Couvelaire [2] persevered with the concept of augmentation and successfully augmented the bladder with tuberculous contracture in 3 patients using tubular segments of cecum. Also in the 1950s Tasker [3] and Goodwin et al. [4,5] proposed the technique of small bowel detubularization for a cut-patch cystoplasty [6]. Various segments of intestine and stomach have been used since then, but enterocystoplasty has gained wide acceptance as a surgical method in order to enable a capacious low-pressure reservoir to empty completely and at the same time protect the upper urinary tract.

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Indications

The indications for bladder augmentation include a small, contracted bladder and a dysfunctional bladder with poor compliance. In the first category the most common conditions that may cause a smaller bladder are chronic interstitial cystitis, tuberculosis, post-radiotherapy cystitis and bladder cancer [7]. Augmentation cystoplasty is appropriate in patients with a small-capacity bladder, whereas for a patient who may have symptomatic disease, excision of a significant proportion

of the bladder which is causing the symptoms and substitution cystoplasty is the best therapeutic solution. Bladder substitution could be applied in cases of solitary well differentiated transitional cell carcinomas of the bladder treated by subtotal cystectomy [8,9]. Augmentation cystoplasty is a widely accepted surgical method for refractory detrusor instability and neuropathic bladder dysfunction [10]. Detrusor instability is usually associated with increasing age, whereas stress urinary incontinence, outflow obstruction and detrusor hyperreflexia are usually seen in patients with neurological disease. Augmentation cystoplasty is an effective treatment in cases of detrusor instability and detrusor hyperreflexia when conservative treatment has failed [11]. Bladder capacity and compliance are increased after augmentation cystoplasty and there is a significant decrease in the detrusor pressure rise during the filling phase, proven urodynamically [12]. The creation of a capacious low-pressure reservoir in order to be able to empty completely can be facilitated by clean intermittent catheterization [13,14]. In cases of severe neurogenic dysfunction with marked thickening of the bladder wall substitution cystoplasty must be taken into consideration. Patients with urinary incontinence and a normal urethra may be managed synchronously with augmentation cystoplasty and an artificial urinary sphincter or periurethral bulking agent (Teflon, collagen, autologous fat) or colposuspension in females. When the urethra is damaged the augmented bladder can be drained via a continent vesicostomy by interposing a vital tube using the Mitrofanoff technique or other variations (appendix, ileal tube, preputial skin) [15,16].

In recent years the indications for augmentation cystoplasty have been expanded to include an increasing number of congenital bladder abnormalities. In bladder exstrophy augmentation cystoplasty could be used in cases with persistent decreased bladder capacity and subsequent upper tract changes [17]. Good results have been reported with the use of augmentation cystoplasty for the treatment of unstable bladders with poor compliance in young boys previously treated for posterior urethral valves [18]. Also, in young patients who may have an unstable bladder apart from untreated vesicoureteric reflux, augmentation cystoplasty may be an effective method of treatment [19]. It has also been reported as an effective surgical technique for the treatment of neuropathic bladder and bowel dysfunction [20].

Patient Selection

Each candidate for augmentation enterocystoplasty should have a thorough laboratory investigation for blood urea nitrogen level, serum creatinine and electrolytes. The surgeon should beware of patients with impaired renal function, who may develop significant metabolic acidosis in the postoperative period [21]. At least a minimum of reserve (e.g. creatinine clearance >40 ml/min) must be assured, unless renal transplantation is scheduled after the augmentation cystoplasty. Resorption of ammonia through the bowel used in cystoplasty could be crucial in patients with hepatic failure, and therefore liver function tests and arterial blood gases should also be checked preoperatively. Intravenous urography and voiding cystography should be performed to check for upper urinary tract abnormalities and possible vesicoureteral reflux, and to assess bladder size. A radionuclide scan helps define renal function. Urethrocystoscopy is also essential to check the continence mechanism and any other intravesical pathology, and to be certain that intermittent catheterization will be feasible if indicated. In patients with interstitial cystitis biopsy alone with urine cytological examination may be necessary to exclude carcinoma in situ. Finally, urodynamic evaluation of each patient with bladder dysfunction plays a major role in the preoperative investigation. The process of the primary disease, along with other possible coexisting diseases and the physical and mental status of the patient, is very important for the success of the operation. Inability of the patient to perform regular clean intermittent catheterization, if required, may lead to subsequent upper urinary tract deterioration [22]. In most cases several treatment choices can be proposed.

Augmentation Techniques

Ileocystoplasty

The ileum was the first bowel segment used for experimental augmentation cystoplasty, and ileocystoplasty has wide clinical use. Although bowel contractions cannot be completely abolished, it has become clear that detubularization of the bowel is important to prevent peristaltic waves and achieve greater volume in the reservoir. A segment of ileum, its length varying from 20 to 40 cm, close to the ileocecal valve is chosen and opened along its antimesenteric border. It is then used as a patch or is reconfigured, usually into a U and S shape, and anastomosed to the bladder, which is incised sagittally (Fig. 1) [23–26]. Recently, a star incision of the bladder as a modification of sagittal cystotomy has been described [27]. The ureters may be left intact or may be reimplanted into the bowel or the bladder, preferably by creating a submucosal tunnel, ensuring that an adequate length of the ureter is being preserved. Another surgical technique is the ileocecocystoplasty, where segments of ileum and cecum of equivalent length are used. These bowel segments are opened by incising along their antimesenteric borders and then folded and reconfigured to form a ‘cup’, which is then anastomosed to the bladder (Fig. 2). The ileocecal segment with different modifications [28–31] has also been used, especially for bladder substitution and when the supravesical continence mechanism must be preserved. The use of the appendix to form a continent urinary reservoir has become quite widely accepted by many

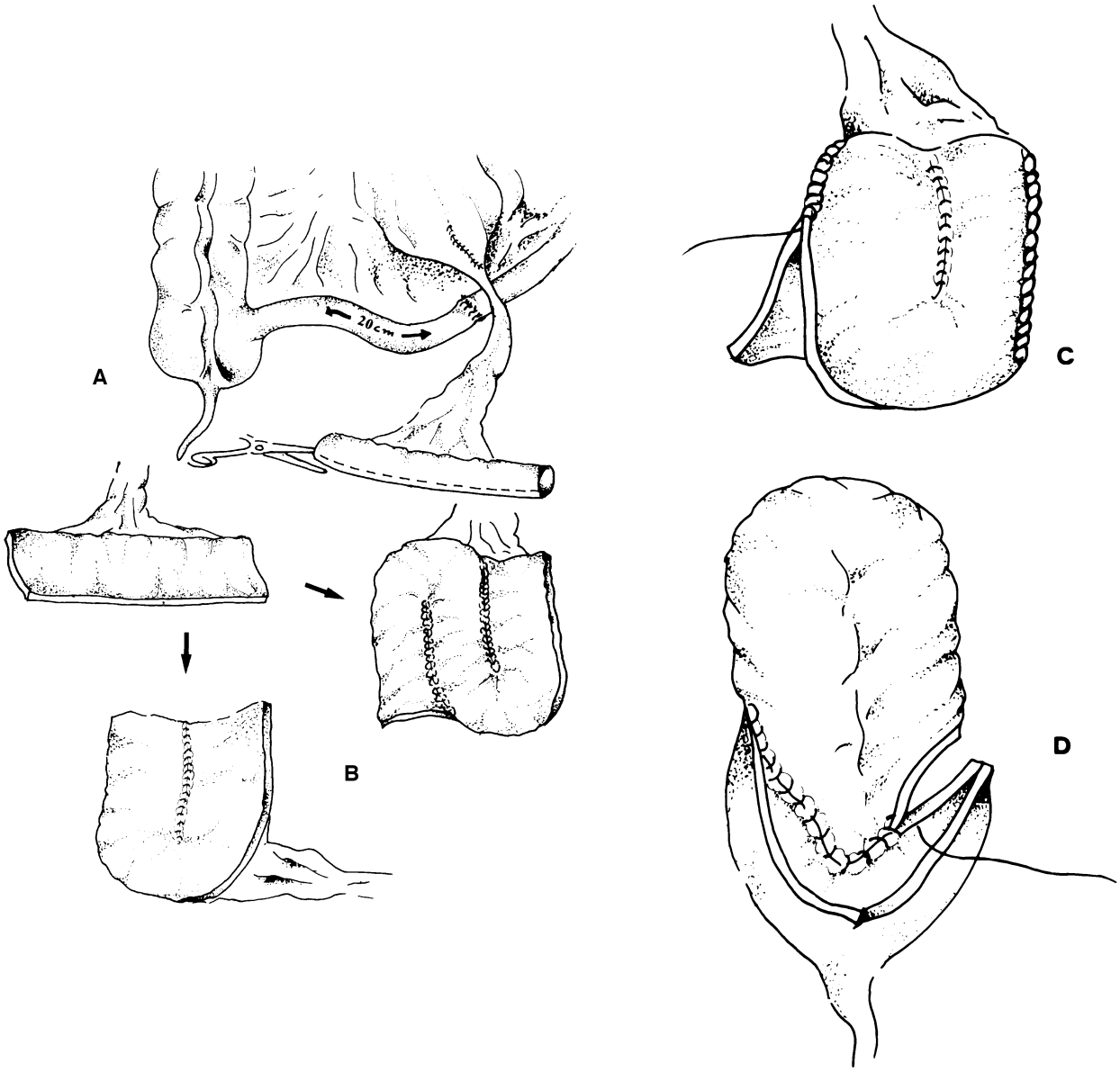

Fig. 1. A, B Ileocystoplasty: a segment of ileum, 20–40 cm long, is isolated and opened along its antimesenteric border. The opened segment is reconfigured into a U or S shape. **C, D** The reconfigured segment is anastomosed to the bladder.

surgeons. A continent mechanism is achieved by bringing the appendix to the abdominal wall, which is then readily catheterizable by self-intermittent catheterization.

Colocystoplasty

Another part of the gastrointestinal tract, which was first proposed by Couvelaire and is quite commonly used, is the large bowel. Non-detubularized cecum is not preferred for augmentation cystoplasty because of strong bowel contractions, which may cause incontinence. The sigmoid colon seems to be the best material. According to this technique an adequate length of sigmoid is selected and isolated. It is then opened along its antimesenteric border and reconfigured into a U or S shape, and anastomosed to the bladder in a similar manner as with ileocystoplasty (Fig. 3). The advantages of this technique are the large lumen size of the sigmoid colon and its proximity to the bladder [32].

Gastrocystoplasty

Gastric segment, first described by Sinaiko [33], has been used for bladder augmentation and substitution in both children and adults [34–36]. The advantages of using stomach include minimal mucus production and net chloride excretion. A segment 10–20 cm in length

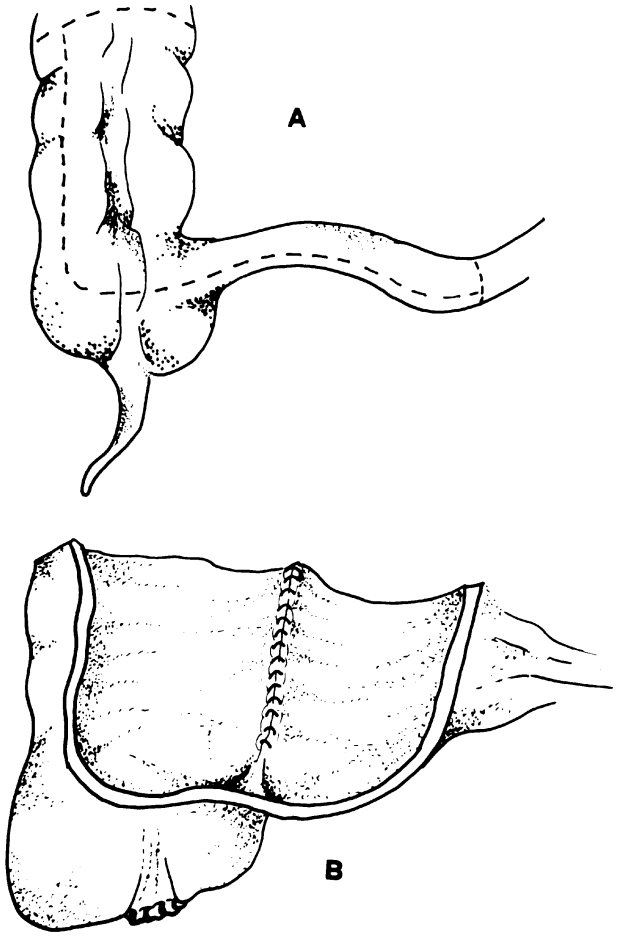

Fig. 2. A Ileocystoplasty: a segment of ileum and cecum of equivalent length is selected and incised along its antimesenteric border. **B** The opened segment is reconfigured into a 'cup' and anastomosed to the bladder.

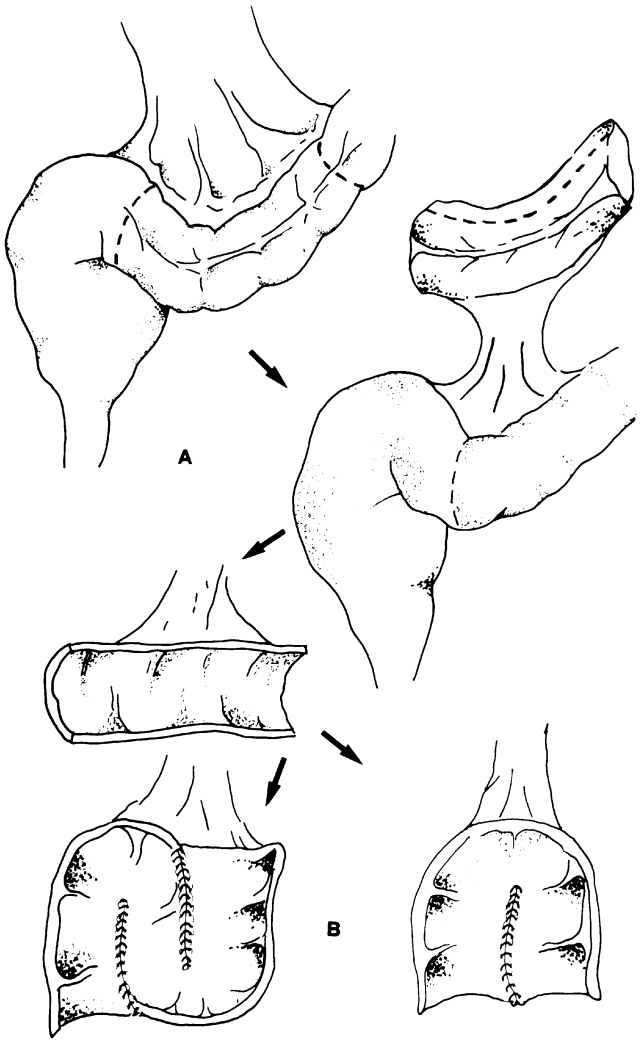

Fig. 3. A Colocystoplasty. An adequate length segment of sigmoid is selected and isolated and then opened along its antimesenteric border. **B** The opened segment is reconfigured into an S or a U shape and anastomosed to the bladder.

of the greater curvature [37] is used to augment the bladder. Its blood supply is preserved and the gastric segment is mobilized in order to approximate the bladder (Fig. 4).

Ureterocystoplasty

An alternative to gastrointestinocystoplasty is the technique of ureterocystoplasty, which is used to create a neobladder lined with transitional epithelium [38,39], thereby avoiding the complications and side effects that result from incorporating gastrointestinal segments into the urinary tract. Segments of a megaureter are used after nephrectomy in patients who may have had a non-functioning kidney draining into a megaureter. The ureter is folded upon itself and reconfigured into a U shape, similar to intestinocystoplasty, and is then anastomosed to the bladder, which is opened in the sagittal plane (Fig. 5). In a reported case the lower pole of a duplicated ureteral system was used for ureterocystoplasty [40].

Autoaugmentation

Another way to augment the bladder using native urothelial tissue is the technique of autoaugmentation. The concept is simple: a large diverticular bulge is created by stripping the detrusor with dissection at the dome of the bladder, thereby, increasing the storage capacity of the bladder and reducing storage pressure (Fig. 6) [41]. An interesting proposal is autoaugmentation done laparoscopically [42]. Although with this technique the problems of incorporating the gastrointestinal segment in the urinary tract are avoided, the resulting bladder capacity and compliance are not preserved because of possible late fibrosis. To eliminate

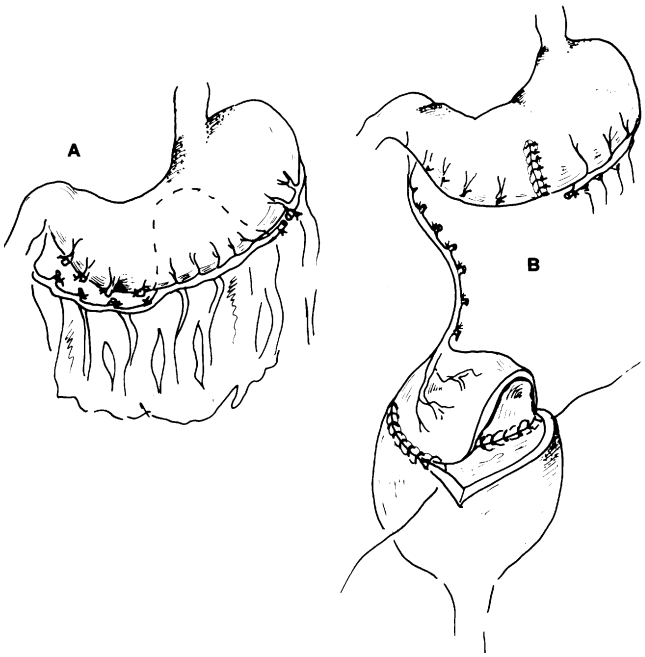

Fig. 4. A Gastrocystoplasty. A segment 10–20 cm in length of the greater curvature of the stomach is excised. **B** The gastric segment is mobilized and anastomosed to the bladder.

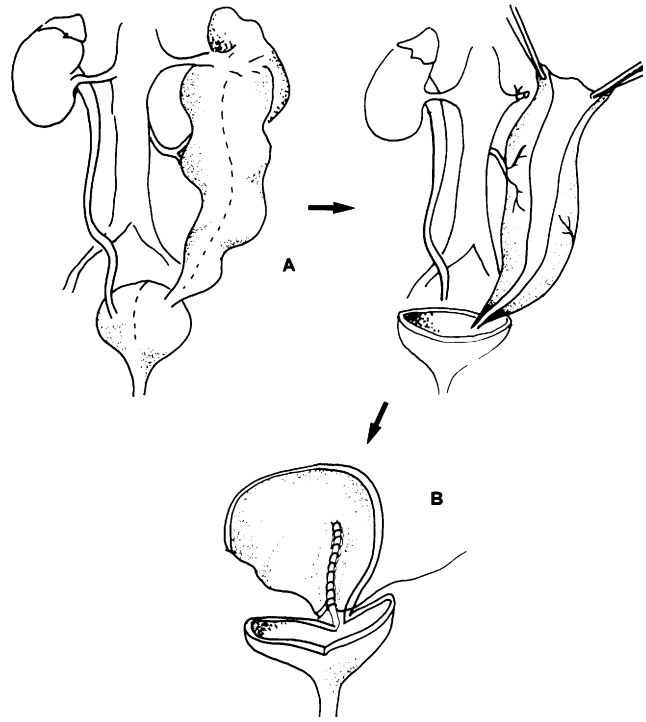

Fig. 5. A Ureterocystoplasty. After nephrectomy the megaureter is opened along its length, preserving its blood supply. **B** The ureter is folded upon itself and reconfigured into a U shape and anastomosed to the bladder in a similar way as in ileocystoplasty.

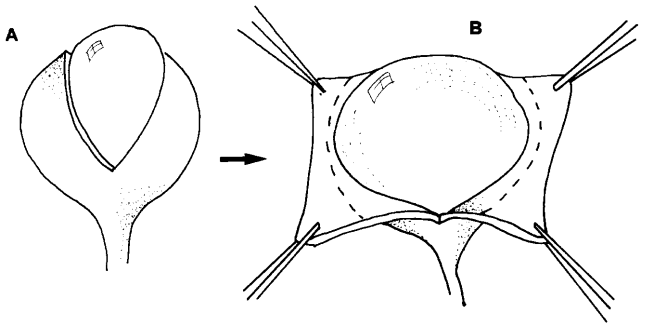

Fig. 6. Autoaugmentation. **A** Incision of the detrusor and bulging of the bladder mucosa. **B** The detrusor is stripped and excised from the bladder mucosa.

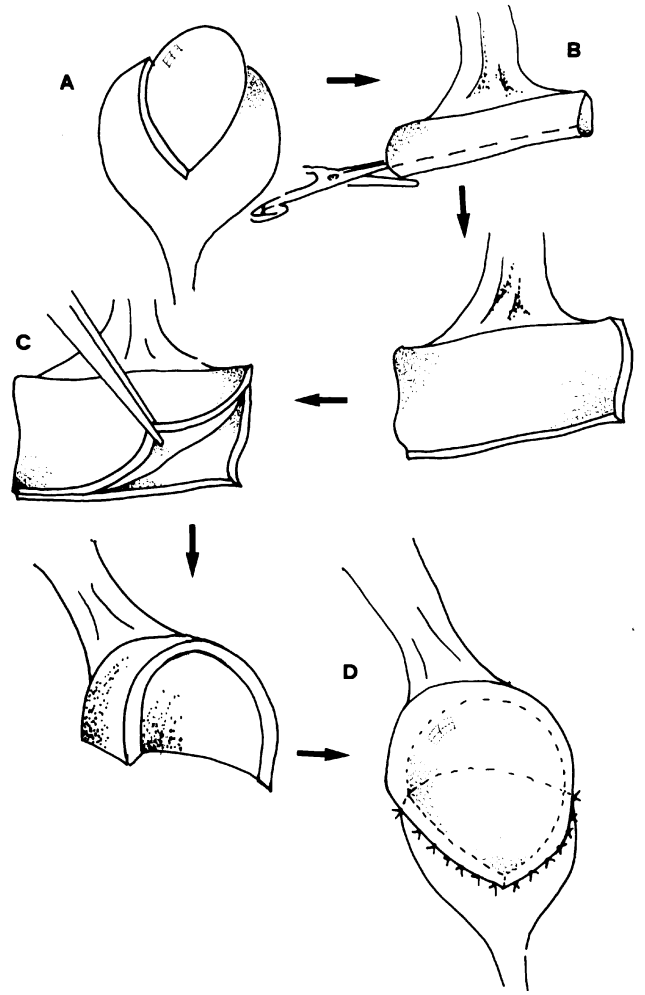

Fig. 7. Autoaugmentation with de-epithelialized segment of small intestine. **A** Incision of the detrusor. **B** Incision of a small intestine segment along its antimesenteric border. **C** De-epithelialization of the enteric segment. **D** Covering the urothelial bladder diverticulum with the de-epithelialized segment of small intestine.

this complication, the urethrothelial bulge was covered with demucosalized segments of stomach to provide a muscular backing for the diverticulum. The technique was applied in sheep and humans, resulting in a good effect [43–45]. The same technique of combining autoaugmentation and demucosalized sigmoid was also used in canines and humans [46]. In the clinical application of this technique there was an increase in

bladder compliance and the follow-up period remained free of metabolic complications. Recent experimental studies done in rabbits presented good results in improving bladder compliance with the use of isolated de-epithelialized segments of small intestine covering the bladder mucosa diverticulum [47].

Other Techniques

To avoid exposing the intestinal mucosa to urine, alternative augmentation enterocystoplasty techniques have been performed using demucosalized reversed seromuscular flaps [48]. Experience with this procedure using ileum, colon and stomach in canine and sheep models has been reported [49–51]. Although good re-epithelialization of the serosal surface of the bowel occurred, there was contraction of the patch due to the trauma of the mucosal stripping. However, initial clinical experience with this procedure, named seromuscular colocystoplasty lined with urothelium (SCLU), showed satisfactory results [52]. Pedicled rectus and gracilis muscle flaps have been used in dogs as patches for bladder reconstruction [53], but once again the bladder capacity was not preserved because of contraction, fibrosis and ossification of the flaps.

Complications and Side Effects

Complications and side effects with augmentation cystoplasty are significantly infrequent compared with neobladder formation. Small bowel obstruction and wound infection with abscess formation are seen as early complications, more often with the use of colon. Also, ureteral leakage may become a problem, especially when an adequate length of the reimplanted ureter is not preserved.

Resorption of chloride and ammonium, resulting in a decrease in arterial pH, has been noted in patients who had their bladder augmented with intestinal segments. This is related to the secretory and absorptive capabilities of the bowel segment used, but hyperchloremic metabolic acidosis rarely poses a major clinical problem in these patients [54]. Bowel dysfunction may be present after cystoplasty owing to disruption of the enterohepatic bile circulation, which can be managed with anion exchange resins [55]. The loss of the ileocecal valve may result in diarrhea [56] and vitamin B_{12} deficiency, which is due to the decreased absorption of the distal ileum, and it may result in megaloblastic anemia. Mucus production, which is slightly increased with colonic segments, is not clinically significant but may occasionally impair bladder emptying. Bacteriuria may also be present after enterocystoplasty, which, when it is combined with mucus production, may lead to stone formation, something that has been reported in 52% of a pediatric population who have had augmentation cystoplasty [57]. A rich daily fluid intake, eradication of the infection and routine irrigation of the augmented bladder, especially in patients who are voiding without the need for self-catheterization, should be advised. Incontinence, especially nocturnal, may become a problem in a number of patients, who may require reoperation. Follow-up by ultrasound estimation of residual urine is adequate and intermittent self-catheterization is indicated when residual volumes are greater than 100 ml.

One of the most troublesome complications of enterocystoplasty is the spontaneous perforation that has been reported with increasing incidence (3%–6%) over recent years. This complication may occur with any gastrointestinal segment used in cystoplasty, and its possible cause is the ischemia of the bowel wall secondary to overdistension or trauma during self-catheterization. In most cases surgical exploration is needed [58].

The complications and side effects of enterocystoplasty, such as metabolic abnormalities, bacteriuria, mucus production and lithiasis, are eliminated with the use of stomach in bladder augmentation. On the other hand, hematuria–dysuria syndrome due to gastric acid secretions, and hypokalemic, hypochloremic metabolic alkalosis due to hypersecretion of gastrin, are known side effects of gastrocystoplasty [59,60]. Lifelong oral omeprazole may be required after gastrocystoplasty. Uninhibited rhythmic contractions have been noted and urodynamically proved in a significantly large number of patients with gastrocystoplasty, resulting in incontinence and reflux and in some cases requiring secondary enterocystoplasty [61].

The potential risk of tumor development has been identified with bladder enterocystoplasty, and malignancy may arise many years after augmentation [62]. However, no reliable data on the incidence of malignant transformation in patients with enterocystoplasty are available. An experimental study has shown that hyperplastic changes were observed in all gastrointestinal patches, with fewer incidences in ileocystoplasty [63,64]. Thus, urine cytology and cystoscopy must definitely be included in the follow-up of augmentation cystoplasty.

Comments

The reconstruction of urinary organs is a reality nowadays, and urologists seek new methods to improve their surgical techniques and provide a better quality of life to their patients. The initial indications for bladder augmentation in adult patients with tuberculosis, interstitial cystitis and other forms of small bladder are extended in adult and pediatric populations to cases with unstable bladder and poor bladder compliance, and congenital anomalies. With regard to surgical techniques, enterocystoplasty has been the most widely accepted way to augment the bladder. Although some surgeons have claimed that the use of ileum (‘clam’ enterocystoplasty) has a better augmenting effect as far as compliance is concerned, good results have been

achieved with the use of all bowel segments. No matter which intestinal segment is chosen, the surgeon should be familiar with the advantages and disadvantages of each method and be able to properly select the appropriate technique. The complications of enterocystoplasty that can arise from the immediate contact of urine with the intestinal tract are well known. The use of gastric segment provides a different material for bladder augmentation, avoiding some of the complications caused by the use of bowel, but it may still result in postoperative syndromes which can be very irritating to the patient. The indications for this more complicated type of operation should be taken into consideration, limiting its use to patients with short bowel syndrome or impaired renal function.

Bladder augmentation using the ureter is a reasonable choice in patients with megaureter and poorly or nonfunctioning kidneys. The autoaugmentation technique avoids all complications that may arise with the use of gastroenterocystoplasty techniques, but more follow-up data are needed for it to be widely applicable. The proposed modifications of autoaugmentation are very promising, but they are still in the research field.

Conclusively, bladder augmentation is one of the most useful tools in urology in the treatment of an increasing number of lower and upper urinary tract problems. It seems to have great benefit for detrusor instability and poor bladder compliance and, combined with incorporation of an artificial sphincter or another technique of reconstruction of the continence mechanism or clean intermittent self-catheterization, may provide a well functioning urine reservoir, allowing patients to have a good quality of life. Lifetime follow-up and recognition of the complications is mandatory. Very careful patient selection is essential in order to achieve better long-term results. The principle of urothelial preservation, introduced by autoaugmentation, is very promising in the effort to create a compliant urine reservoir without metabolic disturbances and without the risk of cancer.

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