The earliest attempt to divert urine flow from the ureters to the intestine, was performed in 1851 by John Simon. In the absence of antibiotics, ureterosigmoidostomy and its modifications during the 19th and early 20th century have been associated with high rate of surgical and metabolic complications.

In 1910, Robert Coffey demonstrated a new method for ureterointestinal anastomosis, which renovated primary enthusiasm in ureterosigmoidostomy and it gained broad popularity during the next forty years. In 1950, Ferris and Odel reported 80% incidence of hyperchloremic metabolic acidosis following ureterosigmoidostomy. Based on further investigations by Lapides in 1951, Parsons, Powel and Pyrah in 1952, and Stamey in 1956, which clearly demonstrated that hyperchloremic metabolic acidosis is inevitable complication of ureterosigmoidostomy, this urinary diversion lost its popularity.

In 1950’s ileal conduit, popularized by Bricker, became the gold standard for the subsequent 35 years. Early attempts for continent urinary diversion occurred form 1888, by Guido Tizzoni and Alfonso Poggi, while the first reservoir-type ileal loop urinary diversion was performed by Cuneo in 1911. By better understanding of principles of detubularization, based on works of Kock and principles of clean intermittent catheterization, established by Lapides, interest in continent urinary diversion has increased. Up to date, various continent cutaneous stomal reservoirs, sigmoïdorectal pouches and orthotopic bladder substitutes have been described. Regarding encouraging improvements in biocompatible materials, alloplastic bladder replacement could be the next step for the future in bladder replacement surgery.

Key words: ureterosigmoidostomy, urinary diversion, continent urinary reservoir

INTRODUCTION

The history of urinary diversion evolved from simple cutaneous fistulae to high refined procedures creating low-pressure, high capacity, orthotopic bladder substitute. Each step was an advancement, influenced by improvements in surgical, medical and anesthetic techniques. In attempts to create an ideal intestinal bladder substitute, numerous techniques have been described and each has its advantages and disadvantages. In this article, the historical urinary diversion highlights up to date are briefly reviewed.

URETEROURETHRAL ANASTOMOSIS

Sonnenburg performed the first ureterourethral anastomosis for bladder exstrophy in 1881. He excised the bladder and made anastomosis of ureters to the urethral groove. This type of operation for bladder exstrophy was later performed by von Iterson and Eastman in 1899. Lindner in 1895 and Albarran in 1896 were performed ureterourethral anastomosis for bladder cancer.

URETEROVAGINAL ANASTOMOSIS

In 1888, Pawlick from Prague had undertaken the implantation of both ureters into the vaginal vault as a first stage before performing cystectomy for bladder papillomatosis. At the end, he anastomosed vaginal outlet to the bladder neck. A new reservoir functioned well during the next 16 years. The same procedure was successfully undertaken by TF Chavasse in 1897, for a 4 years old boy suffering from exstrophy.

Based on the work of Pawlick, ureterovaginal anastomosis was successfully used by Kossinski, Morris (1901), Bensa, Zeller (1896), Robson (1901) and Mann (1901).
CUTANEOUS URETEROSTOMY

In 1856, Gigon considered ureterotomy to have the same effect as colostomy on the bowel. After animal experiments on dogs by Gluck and Zeller in 1881, the first cutaneous ureterostomy was performed for injured ureter by Hayes Agnew from Philadelphia. The patient died few months later. The progress was made by theoretical considerations of Verhoogen and Morris in 1885 and experimental work of Edmunds and Balance in 1886. The first unilateral cutaneous ureterostomy was carried out by Le Dentu, in 1889, due to obstructive anuria caused pelvic malignancy. The patient died after 14 days and postmortem, the kidney was normal. Pozzi, in 1890, sutured the right ureter to the skin using catheter drainage for 14 days. After nephrectomy on patient’s request, there was no evidence of kidney obstruction or infection. In 1897, Reginald Harrison performed right lumbar cutaneous ureterostomy. Patient died six months later due to infective complications. In 1892, Rydygier performed the first bilateral cutaneous ureterostomy. At the end of 19th century, Bovee, Albarran and Lotheissen were disappointed with the results of this urinary diversion. In 1906, Rowsing made a modification of the technique, by performing a nipple after exteriorization of ureter. Over the nipple, he applied a small silver cup for the urine. In 1909, Rowsing performed bilateral operation. In 1913, Papin carried out the first bilateral cutaneous ureterostomy after total cystectomy for bladder cancer. In 1925, Papin reported a series of 100 total cystectomies with cutaneous ureterostomy or nephrostomy following by lethality rate of 28.7% and 81 cystectomies with ureterosigmoidostomy following by lethality rate of 59.2%. The morbidity and lethality following skin implantations were caused by poor methods of anastomosis which had led to obstruction and infection. Different techniques by Heckel in 1945, Schinagel and Sewwel in 1948 and Mc Donald and Heckel in 1957, have been designed to support an adequate nipple of ureter by skin flaps. De Vries reported, in 1955, that 33% of American urologists prefer cutaneous ureterostomy than implantation into the bowel. A novel modifications of the technique by implantation of ureters side by side and double ureterostomy, have been advocated by Eckstein (1963) and Chutte and Sallade in 1961. In 1961, Sturdy described cutaneous trigonostomy.

URETEROINTESTINAL ANASTOMOSIS

The first attempt to divert urine flow from the ureters to the intestine was performed in July 1851, by John Simon, senior surgeon of St. Thomas’ Hospital in London. It was undertaken on 13 years old boy suffering from bladder exstrophy. After performing animal experiments, Simon designed a silver catheter with a stilet and with this instrument he created a urinary diversion by establishing two ureterosigmoidal fistulas. One year later, the boy died of

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Event</th>
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<tr>
<td>John Simon</td>
<td>1851</td>
<td>First urinary diversion</td>
</tr>
<tr>
<td>Thomas Smith</td>
<td>1878</td>
<td>First direct ureterointestinal implantation</td>
</tr>
<tr>
<td>Karl Maydl</td>
<td>1892</td>
<td>Implantation of the trigone into the sigmoid</td>
</tr>
<tr>
<td>George Fowler</td>
<td>1896</td>
<td>First antireflux ureterointestinal implantation</td>
</tr>
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<td>Robert Coffey</td>
<td>1911</td>
<td>First successful antireflux ureterointestinal implantation</td>
</tr>
<tr>
<td>Wyland Leadbetter</td>
<td>1951</td>
<td>First ureterointestinal implantation avoiding reflux and stenosis</td>
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</tr>
<tr>
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<td>Borelius</td>
<td>1905</td>
<td>Sigmoid</td>
<td>Mainz Pouch II</td>
</tr>
<tr>
<td>Fosch et al</td>
<td>1990</td>
<td>Sigmoid</td>
<td></td>
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<tr>
<td>Atta</td>
<td>1996</td>
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<th>Author</th>
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<tr>
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renal failure. Postmortem, renal damage and bilateral ureteric calculi were found. Later in 1851 similar operation was performed by Loyd from St. Bartholomew’s Hospital in London and the patients died of peritonitis on the seventh day. Another patient operated using the same technique by Athol Johnson in 1852, ended lethally from peritonitis.

In 1878, Thomas Smith from London performed the first ureterocolonic anastomosis in a seven years old boy suffering from exstrophy. Fourteen months later, the patient died from uremia secondary to stenosis of both ureters. In 1881, Karl Thiersch made an artificial vesicorectal fistula using bowel clamp. The patient was well for the eight months. After Simon’s failure, during the next forty years, only attempts in ureterointestinal anastomosis were done by Smith and Jones. In the last two decades of 19th century, on behalf of experimental study of Gluck and Zeller and finally achievements of Karl Maydl, ureterointestinal anastomosis gained broad popularity.

Tuffier considered in 1890, that the rate of infective and obstructive complications could be decreased by implantation of ureters along with its normal orifice. In 1891, Küster performed total cystectomy for bladder cancer following by implantation of ureters into the anterior rectal wall. Death

TABLE 3

<table>
<thead>
<tr>
<th>Author</th>
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<td>Ileum</td>
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<td>Couvelaire</td>
<td>1951</td>
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<td>1977</td>
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<td>Yes</td>
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<td>Le bag</td>
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<td>Marshall</td>
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</tr>
<tr>
<td>Pagano</td>
<td>1990</td>
<td>Ileum</td>
<td>Yes</td>
<td>Vesica Ileale Padovana</td>
</tr>
<tr>
<td>Iwakiri &amp; Freihia</td>
<td>1990</td>
<td>Ileum</td>
<td>Yes</td>
<td>Stanford Pouch</td>
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TABLE 4

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<th>Contience</th>
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<tbody>
<tr>
<td>Glichrist</td>
<td>1950</td>
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<td>Ileocaecal valve</td>
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<td>Benchekroun</td>
<td>1982</td>
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<td>Ileal flutter valve</td>
<td>Ileocaecal reservoir</td>
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<td>Ileum</td>
<td>Intussusception valve</td>
<td>Kock pouc</td>
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<tr>
<td>Thuroff</td>
<td>1985</td>
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<td>Appendicostomy</td>
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</tr>
<tr>
<td>Rowland</td>
<td>1987</td>
<td>Ileum &amp; caecum</td>
<td>Plicated ileum</td>
<td>Indiana pouc</td>
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<td>Lockhart</td>
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<td>Colon</td>
<td>Plicated ileum</td>
<td>Florida pouc</td>
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<td>Bejani</td>
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<td>Plicated ileum</td>
<td>Miami pouc</td>
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<td>Ileum</td>
<td>Ileal valve</td>
<td>Rome pouc</td>
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<tr>
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<td>Ileocolon</td>
<td>Appendicostomy</td>
<td>Charlestown pouc</td>
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<td>Ileocolon</td>
<td>Ileal valve with colonic cuff</td>
<td>Bellevue pouc</td>
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from infection occurred on the fifth postoperative day. In 1892, Chaput anastomosed ureter to the colon in patient suffering from urerovaginal fistula and the result was excellent. Based on work of Tuffier, in 1892, Karl Maydl from Prague, transplanted the bladder trigone carrying both orifices into the sigmoid colon. The outcome was successful. Bergenheim, in 1894, modified this technique by implanting ureteral orifices separately into the rectum, extraperitoneally. Further, this technique was used worldwide by Trendelenburg in Germany, Pozza in Italy, Martin in America, London in Australia etc. Attempts of Simon Duplay and Rein, in 1894, to perform bilateral ureterosigmoidal anastomosis, were not successful. In 1896, Achille Boari introduced special metal buttons ("Boari button") and reported several successful operations afterwards. In the same year, Fowler constructed valve-flap from mucosa and submucosa trying antireflux implantations of ureters into the rectum, but the operation was not successful. Chalot introduced copper tubes as mechanical device to secure ureterosigmoidal anastomosis. It was the first successful bilateral ureteral implantation due to malignancy. The first total cystectomy for bladder cancer following by successful bilateral ureterosigmoidal anastomosis was performed by Krause in 1899. During that year, Geo L. Lotheissen reviewed the literature related to ureterointestinal anastomosis and found a total of 41 cases. The lethality rate following ureteral implantation due to bladder exstrophy was 27%, while it raised to 60% for implantations following bladder cancer and fistulas. He found lower lethality rate in patients underwent Maydl’s or Bergenheim’s operation compared to other urinary diversion methods. He emphasized the role of the age, since patients from exstrophy group were of younger age.

In 1910, Robert Coffey introduced a new method for ureteric implantation in dogs, using submucosal tunnel through the bowel wall. His technique was based on previous work of Krynski in 1896 and Stiles in 1907. The technique was successfully applied in 1912 by Charles Mayo on 3 patients suffering from bladder exstrophy. The technique became known as the Coffey-Mayo operation. It was used by several surgeons, such as Carl Back in 1913, Edmond Papin in 1925, Georges Marion in 1928 and Walker-Taylor in 1931, with or without some modifications.

Encouraged by favorable results of the technique, Coffey introduced two further techniques. In Coffey II procedure from 1925, both ureters were implanted simultaneously with inserted ureteric catheters which have been brought out through the anus. In Coffey III procedure in 1930, the ureters were anastomosed one at a time into the submucous gutter, closed by ligature. In 1937, Weyrauch and Hinmann published a review of entire subject and concluded that there were eleven surgical principles associated with ureterosigmoidostomy have been overcome, and the Coffey’s technique became the gold standard for the next 35 years, without substantial changes until today.

ILEAL CONDUIT

The earliest experience with this type of diversion occurred from 1911, by Zaayer. He performed cutaneous ileostomy in two patients, due to vesicovaginal fistula and bladder cancer. The first patient died after eleven days and the second et 6th postoperative day of peritonitis. The operation was technically successful. Early experiments on animals were conducted by Bollman and Mann in 1927. They reported electrolyte disturbances and death because of excessive absorption from the long ileal loop (25) L. Steiffert from Neunkirschen carried out two similar operations with the use of jejunal conduit, in 1935. The first patient survived for three years, while the second one died of renal failure.

After failed attempts in creating continent cutaneous ileocecal bladder substitute, Eugene Bricker established the use of the ileal conduit in 1950. However, the first ileal conduit was performed by Heinz Haffner from Bricker’s group. Afterwards, Bricker reported a series of 307 patients, with lethality rate of 12.4% and only 3.4% related to procedure. Since the metabolic shortcomings associated with ureterosigmoidostomy have been overcome, Bricker’s technique became the gold standard for the next 35 years, without substantial changes until today.

COLONIC CONDUIT

In 1940, Bricker performed sigmoid conduit, but since cutaneous stoma was near the colostomy stoma, it was followed by complications. In 1951, Scott and Rawich
anastomosed sigmoid conduit to a trigone. After an description of sigmoid conduit made by Übelhör in 1952, Richard Mogg performed and standardized the technique from 1965. Although several advantages of this technique regarding reflux and renal impairment have been confirmed in animal experiments, it couldn’t replace the ileal conduit as a standard urinary diversion.

CONTINENT URINARY DIVERSION

In 1888, Guido Tizzoni and Alfonso Poggi performed cystectomy on animal model and two stage operation of bladder substitution by an isolated ileal loop which was anastomosed to the ureters and to the urethra. The first reservoir-type ileal loop urinary diversion was performed by Cuneo in 1911. He isolated 20cm of terminal ileum and closed the proximal end. Then, proximal end was brought through the anal sphincter. Finally, at the second stage, the ureters were implanted into the proximal end. A total of 3 patients underwent the procedure. Of these, one died from peritonitis and the remaining 2 had urinary fistula. Afterwards, Theodor Kocher advocated this method of urinary diversion. Following the technique Tizzoni and Poggi, Bisgard in 1943 and Rubin in 1948, performed successful attempts on dogs. The technique was performed clinically for the first time in 1951 by Couvelaire by creation of continent ileal bladder substitute. Pyrah and Raper, in 1955, created ileal "U" loop to the urethra as a modification of the Couvelaire’s technique, with excellent results. Afterwards, the procedure was popularized by Maurice Camey.

ILEOCAECAL RESERVOIR

The first attempts of ureterorectal anastomosis with proximal colostomy occurred from 1894 by Giordano, who performed it on dogs. In 1895, Mauclaire performed experiments on dogs, creating a bladder substitute from rectum along with the left iliac colostomy. Following his principles, Enderlen and Walbaum performed a series of similar animal experiments. Remedi introduced the technique into the clinical practice in 1905 for bladder exstrophy, but his attempt was unsuccessful.

Later, in 1907, Krönig reported four months survival in patient underwent similar procedure. In 1916, Rovsing reported successful operation on dogs. The technique was modified by Heitz-Boyer and Hovelacque, who pulled the sigmoid behind the rectum to preserve blood supply. The interest in Gersuny operation was renovated by Levitsky and Johnson in 1953, and Stonington and Eiseman in 1956 with favourable results. To avoid complications that arise from direct ureterointestinal anastomosis, several techniques of ureteral implantation into a partially excluded portion of the alimentary tract have been proposed. The first attempts in that manner have been performed by Nagano in 1901. Nagano isolated a loop of ileum and excreted it partially in the form of blind pocket in which the trigone was implanted. Goldenberg conducted an animal experiment in 1904, in which anastomosis of ureters to partly excluded terminal ileum was performed. Both experiments have been unsuccessful. In 1903, Borelius and Berglund isolated sigmoid loop by its side to side anastomosis. Than, the ureters were implanted to the summit of the loop by Maydl’s technique of the technique was made by Mysch in 1907, by a ligature to the colon proximal to ureteral anastomotic site. Müller created a blind sigmoid pouch and implanted the trigone into the proximal end of the pouch. Afterwards, the end to side anastomosis was made between sigmoid pouch and pouch. This technique was used by Enderlen in 1907, and Floercken in 1922. Since it was the high rate of complications, such as pyelonephritis and urinary tract infection, these techniques didn’t gain much popularity. Georges Lemoine in 1912, during the surgical revision of ureterosigmoidostomy, carried out sigmoid loop to the urethra, but the patient died from sepsis complications. It was the first performed isolated rectum to urethra anastomosis.

STOMACH

In 1908, Verhoogen made urinary reservoir from terminal ileum and caecum, anastomosed the ureters to the caecum and drained through the cutaneous appendicostomy. In 1920, Makkas successfully performed this technique on patient as a two stage procedure. In 1912, Lengemann introduced an ileocaecal reservoir with appendicostomy with ileocaecal valve for protection from infection and stasis. The "ileocaecal bladder" was extensively performed by Gilchrist, Merrics and co-workers, from 1950. The ureters were implanted into the urinary ileocaecal reservoir which was drained through the ileal segment to the skin. These reservoirs were emptied by regular catheterization to overcome stasis, infection and reflux. Gilchrist reported 55 cases until 1955.
MODERN CONCEPT OF CONTINENT URINARY DIVERSION

Several attempts of bladder capacity increasing by use of bowel or other structure have been described. The early experiments were made by Tizzoni and Poggi in 1888, and Rosenberg in 1893 on animal models. The first ileocystoplasty was performed by Mikulicz, in 1898, on a patient with bladder extrophy. Following his principles, various modifications have been described by Rutkowski in 1899, Kausch in 1907, Schoemaker in 1909, Scheele in 1923, and Sebening in 1932. The interest in this type of operation was renewed during the 1950’s by Couvelaire and was widely used by several authors, including Cibert in 1956, Wells in 1956, Pyrah and Gil-Vernet in 1957. In 1953, Tasker opened the ileal loop and applied it to the opened bladder wall. Giertz and Franksson created bladder substitute from detubularized bowel loops, in 1957. Goodwin, Winter and Barker, in 1959, have demonstrated the superior "cup-patch" graft technique with folded segment of detubularized bowel. By better understanding of principles of detubularization, based on works of Ekman and Kock in 1969, it was used for continent urinary diversion. The first successful clinical attempt was continent ileal urinary diversion, performed by Leisinger in 1976. Following work of Perl and Pearse, Kock constructed an intussusception valve principle in order to prevent reflux and to achieve continence. He created a Kock pouch as the first clinically performed continent ileostomy. In 1978, Kock reported the preliminary results of the technique. The initial results have been disappointing regarding high early complication rate. However, along with a learning curve, the rate of complications decreased and the Kock pouch became the first established continent low-pressured urinary reservoir.

Since disappointing results of early forms of continent diversion have been addressed to high intraluminal pressures, as demonstrated by Kock and Leisinger, the creation of low-pressure, high capacity reservoir became prevalent regarding high early complication rate. However, along with a learning curve, the rate of complications decreased and the Kock pouch became the first established continent low-pressured urinary reservoir.

The use of intermittent self-catheterization occurred to high intraluminal pressures, as demonstrated by Kock and Leisinger, the creation of low-pressure, high capacity reservoir became preferred procedure for modern urinary diversion.

The technique of ureterosigmoidostomy, using the anal sphincter for continence, has been modified by Mainz and Kock in 1969, it was used for continent urinary diversion. In 1998, Marshall reported the results of this reservoir. As described, the first continent form of urinary diversion by detubularized bowel segments was Kock pouch. By plication of the ileocaecal valve and tapering of a part of the terminal ileum, continence was achieved in Indiana pouch. Afterwards, numerous ileal and ileocecal reservoirs have been described, including Rome pouch, Miami pouch, Charleston pouch, Florida pouch, Bellevue pouch and T-pouch (Table 4).

In recent years, the technique of ureterosigmoidostomy, using the anal sphincter for continence, has been modified by Mainz group and a low pressure sigmoidorectum pouch (Mainz-II pouch) has been created by detubularization of the rectosigmoid. It combined principles of the first method of urinary diversion with modern urinary diversion techniques.

ORTHOTOPIC CONTINENT URINARY DIVERSION ILEAL BLADDER SUBSTITUTES

In 1958, Maurice Camey, using an ileal segment, performed an orthotopic ileal bladder substitute to the urethra. In the next years, he demonstrated a new technique using detubularized ileal segment. After animal experiments in 1983 and 1984, UE Studer from University of Bern introduced ileal orthotopic bladder substitute ("Studer pouch") with afferent ileal loop. Later, he reported excellent functional results and good patient acceptance. In 1985, Hautmann created detubularized ileal neobladder, which gained much popularity, especially in female patients. During the 1980s and 1990s, various orthotopic ileal neobladder urinary diversion techniques have been described, such as the Kock ileal neobladder in 1986, Vesica Ileale Padovana in 1990, or Stanford pouch ileal neobladder (Table 3).
Complications following incorporation of the intestinal segments into the urinary tract include three approaches: regeneration of the bladder, replacement of the intestinal mucosa by cultured urothelial cells and alloplastic replacement of the bladder. The first report of the use of deepithelialized bowel segments occurred from 1955, by Schoemaker and Marucci. They reported overgrowth of deepithelialized bowel segments with urothelium. Later, some authors reviewed major contracture of bowel segments. New advances in molecular biology regarding tissue culturing and genetic engineering have led to new methods of cell harvesting, growth and replication, which could allow transplantation of in vitro urothelium to methods of cell culturing and genetic engineering have led to new developments in biocompatible materials, alloplastic bladder regeneration have been conducted by Tizzoni and Poggi in 1888. Recently, Kropp and Sutherland used acellular collagen biomaterial, such as small intestinal submucosa or gastric and bladder tissue matrix, in order to achieve regeneration of urothelium, muscle, nerves and blood vessels. However, they are still limited to the bladder augmentation, since initiation of regeneration need a source of urothelium. Recent studies of bladder alloplastic replacement using silicone rubber prosthesis in sheep, achieved encouraging results. Regarding improvements in biocompatible materials, alloplastic bladder replacement could be the next step for the bladder replacement in the future. Nevertheless, various items, related to physiology, biostability, immunocompatibility and risk of malignant transformation of regenerated or transplanted tissue, should be considered, for the further developments in urinary diversion.

**SUMMARY**


**Ključne reči:** ureterosigmoidostomija, urinarna derivacija, kontinentni urinarni rezervuar

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