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Review

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Bladder Draining Methods

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ABSTRACT The article provides a historical review of the literature describing the evolution of bladder drainage and the types of urinary catheters currently in use. Complications of various drainage methods are classified and described, and measures for their prevention are proposed.

AIM OF STUDY To study bladder draining methods, their advantages and disadvantages, possible complications of each method.

OBJECTIVES To assess the indications for use of each drainage method, to focus the attention of health workers on the possibility of choosing the optimal method for bladder draining, depending on the clinical situation.

Keywords: bladder drainage, transurethral catheterization, trocar cystostomy, review

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HISTORY OF THE CREATION AND TYPES OF URINARY CATHETERS

The word "catheter" comes from the ancient Greek kathie'nai, which literally means "to stick" or "to send down."

The first mentions of bladder drainage with a catheter date back to 1500 BC. The ancient Egyptian Ebers Papyrus describes the treatment of acute urinary retention using transurethral tubes made of bronze, reed stems, straws, and twisted palm leaves [1].

Hippocrates' writings dating back to 400 BC mentioned flexible lead tubes for bladder catheterization [2]. During excavations in Pompeii, a silver tube with an S-shaped tip was found, dating back to 70–80 AD, presumably used to relieve urinary retention in men [3]. In his treatises on ancient Arabic medicine, Albucasis (Abu al-Qasim Khalaf ibn al-Abbas al-Zahrawi) (936–1013) described the relief of ischuria using a forged silver tube with numerous end holes that improve the removal of fluid [4].

Chinese records from the 12th century were found that mentioned the transurethral insertion of hollow onion leaves (Allium fistulosum) [5]. If they failed to catheterize the bladder, rigid wooden or metal tubes were used as an alternative [6].

During the Renaissance, medicine developed alongside other fields of science and culture. The first known record is that of Fabricius ab Acquapendente (1537–1619) describing a cloth catheter impregnated with wax to reduce the risk of damage during repeated catheterization [7]. In 1564, Ambroise Paré (1510–1590) invented a silver tube with a long, smooth curve for easier insertion into the bladder [7]. In the 17th century, Jan Baptist van Helmont (1578–1644) used a catheter made of chamois leather, soaked in white lead and linseed oil, into which a whalebone stylet was inserted [8] (Fig. 1).

Fig. 1. Bladder catheterization during the Renaissance [9]

In 1684, Cornelius van Solingen (1641–1687) invented a spiral tube made of silver wire covered with parchment. It was fixed to the tube with a silk thread soaked in wax [10]. In the 1700s, Jean-Louis Petit (1674–1750) invented a silver tube with a double bend. However, its design proved to be inferior to the "models" of his predecessors, and the idea had to be abandoned [11]. In 1731, Jacques de Garengeot (1688–1759) invented a silver tube with a pronounced curve and a thin stylet with a small tip to close the lumen during insertion [12]. In the 1750s, Teden from Berlin and Bernard from Paris independently used natural rubber and silk coatings over a copper catheter [7, 13].

In 1752, Benjamin Franklin (1706–1790) invented a spiral tube made of silver wire rubbed with fat, which filled the grooves on the outside. It was used as a catheter for his brother John who had ischuria due to bladder stones. Later, Benjamin Franklin used it for himself when he suffered from the same disease [3].

In the 1850s, in parallel with the development of the chemical industry, not only natural materials were used. Auguste Nélaton (1807–1873) developed a vulcanized rubber (latex) catheter with a solid tip. It was held in place by adhesive tape or suture (although neither method was reliable in clinical practice) [10].

A new milestone in the history of urethral catheters came in 1855, when Jean-François Reybard (1795–1863) invented a self-retaining catheter consisting of a device with two channels. One was used to drain urine, and the second was used to inflate a balloon located close to the tip of the catheter. In this way, it could be fixed in the bladder cavity without additional devices [14].

Finally, 1929 was a turning point when the development of the "modern" balloon self-retaining catheter was completed. It was a device built by C.R.Bard, Inc. based on a design by Dr. Frederic Foley. A rubber balloon was attached with thin silk and waterproof cement near the tip of the rubber catheter.

The catheter had a longitudinal groove on the outside that held a thin tube for inflating the balloon with water. The Foley device was introduced to the market in 1933. Foley initially used his now eponymous catheter for hemostasis after prostatectomy. Due to its convenience, the catheter was soon used in other scenarios, although latex often caused urethritis and urethral strictures, and encrustation and infection were almost inevitable in longer catheterization [15].

Subsequently, the design of the urethral catheter did not change dramatically, but there was a constant search for new materials that were more resistant to the aggressive effects of urine. In 1968, catheters made of silicone elastomer were introduced. This significantly reduced the rate of their encrustation and infection [16]. In 2001, Maki and Tambyah proposed the introduction of chemical impregnation and "antimicrobial" coating, particularly silver, to inhibit the formation of surface bacterial biofilms and encrustation [17].

Currently, catheters can be installed both transurethrally and percutaneously. In the case of transurethral catheterization, due to the variety of materials used, diameters, and design features, it is possible to select the optimal catheter for a specific clinical case, as well as taking into account the individual characteristics of the patient.

The most common type in clinical practice is the double-lumen Foley catheter. One lumen serves to drain the fluid, the second - to inflate the fixing balloon in the bladder cavity. The catheters are made of latex, silicone, plastic or Teflon [18].

Requirements for materials: biological compatibility, chemical inertness, stability, hypoallergenicity, atraumatic.

Latex catheters are inexpensive and the most commonly used. However, latex may cause inflammation in the urethra, which may be due to protein and salt encrustation on the catheter surface [19]. Chronic inflammation from long-term catheter use may lead to urethral stricture. For this reason and because of the potential for latex allergy, silicone catheters are preferred for long-term catheterization [20].

In addition, catheters can be treated with a hydrophilic coating. It allows reducing the friction coefficient (for example, LoFric), so there is no need to use a lubricant during insertion. Such modified catheters are an option for intermittent catheterization. Patients report less discomfort when using them, but they are significantly more expensive than their analogues.

Specialized urethral catheters used in individual cases

Catheters with a curved tip (Tiemann modification)

The insertion is easier in men with obstructive uropathy due to benign prostatic hyperplasia. The curved tip is positioned in the direction from 6 to 12 o'clock on the conventional clock face, and thus, at the level of the prostatic urethra, it does not rest against the hyperplastic middle lobe of the prostate.

Triple-lumen catheters

Used for bladder irrigation and are available in larger diameters (20 to 28 Fr) to facilitate clot removal. Irrigation fluid is introduced into the bladder through the irrigation port and drained through the catheter.

In addition to transurethral drainage of the bladder, there are methods of puncture, open surgical and external drainage:

Suprapubic catheters

Cystostomy can be performed by puncture or open surgical method. Open suprapubic catheter placement is usually combined with other surgical interventions (e.g., after bladder trauma). The optimal diameter of the catheter is from 14 to 18 Fr in case of trocar cystostomy for ischuria, and 18–22 Fr for the purpose of bladder drainage after open surgery. A larger diameter of the catheter lumen will help avoid hemotamponade of the bladder in the postoperative period [21] (Fig. 2).

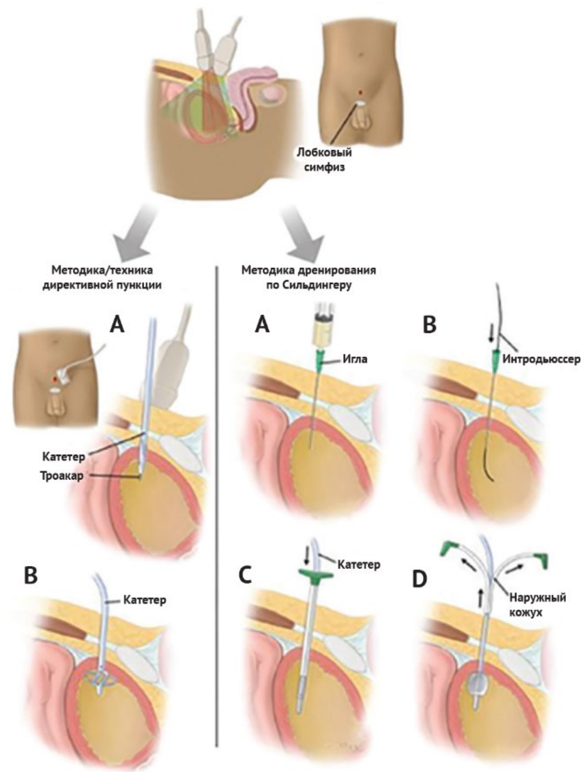

Fig. 2. Stages of performing trocar cystostomy [22]

Previously, Pezzer catheters with a reinforced head were used. They do not have a balloon for inflating the fluid and are fixed in the bladder cavity due to the expansion in the tip area. They do not allow rinsing or instillation of solutions into the bladder, and during installation, a larger skin incision is required due to the mushroom-shaped tip [23].

External catheters

These include urological condoms, which are used to collect urine from men without urethral catheterization (pronounced urinary incontinence, need to control diuresis in long-term bedridden patients with impaired voluntary urination). They come in latex and silicone. Most are pre-rolled and have a self-adhesive vertical strip that holds them to the penis. They cause fewer complications than those that require separate adhesive strips or other fixing devices.

COMPLICATIONS OF BLADDER DRAINAGE

Bladder catheterization is widely used in clinical practice: for drainage of the urinary bladder due to acute ischuria, assessment of diuresis in the intraand postoperative period, prevention of urethral strictures after endoscopic surgical interventions, and in many clinical situations it is indeed appropriate. However, it is often used unjustifiably without proper clinical indications, continues for too long; or the optimal drainage method is not used, errors are made during catheterization [24].

Complications of bladder drainage can be divided into two large groups: non-specific and iatrogenic.

Non-specific complications are associated with a long-term presence of a foreign body in the lumen of the bladder and urethra, and, as a rule, are infectious and inflammatory. They are united by the term of "catheter-associated urinary tract infection" (CAUTI). Iatrogenic complications arise directly during the drainage procedure itself, and are associated with trauma to the urethra, the prostate gland in men, and bleeding.

Non-specific complications

Bacterial colonization. Installation of a urethral catheter results in continuous drainage of the bladder, thereby disrupting the normal process of bladder emptying and elimination of bacterial agents. Additional seeding occurs through bacterial migration inside and outside the catheter wall. 95% of catheterized patients suffer from bacterial invasion within 1 month [25].

Antibiotic resistance. The use of antibiotics to treat catheter-associated infections contributes to the development of resistant bacterial strains. The most common are as follows:

— Escherichia coli (72% of cases) is closely associated with urinary tract infections. In five of the six WHO regions, the antimicrobial drugs used were found to be ineffective in 50% or more of cases.

— Klebsiella pneumonia (17% of cases), which is also found in the urinary tract and is antibiotic-resistant [26].

Source of chronic infection. Due to anatomical features, bacteriuria occurs significantly more often in women (70–80%) than in men (20–30%).

The balloon of the Foley catheter in an inflated state blocks the internal opening of the urethra, and, as a result, 10-100 ml of residual urine is formed in the bladder, which does not pass through the lumen of the catheter. It becomes infected and serves as a source of chronic infectious process in the bladder [27].

In addition, during catheterization, a biofilm – an accumulation of microorganisms and their extracellular products – is formed on the surface of the catheter. Bacteria within the biofilm are protected from mechanical removal with the urine stream, as well as from antibacterial and antiseptic drugs. Conventional methods of research are able to detect free-floating microorganisms in blood, urine, and sometimes tissues. However, it is impossible to detect microorganisms fixed on biofilms using routine methods.

Increased intravesical pressure. Invasion of the bladder by urease-producing bacteria, especially Proteus mirabilis, leads to the conversion of urea in the urine to ammonia. Subsequent alkalization of urine leads to the formation of struvite and hydroxyapatite crystals on the catheter biofilm [28]. As a result of the urease activity of microorganisms, a "crust" is formed both outside and inside the catheter, which can reduce its drainage function, thereby increasing intravesical pressure. And this is a direct path to vesicoureteral reflux [29].

Bacteremia. The mechanical action of the catheter tip can damage the urothelial lining, allowing bacteria to gain direct access to the bloodstream through the bladder wall with an increased risk of septicemia [30].

Formation of stones in the urinary bladder. Struvite crystals formed by Proteus mirabilis provide a matrix for the crystallization of salts and the formation of stones [31]. They are subsequently colonized by Proteus mirabilis, which maintains the infection process.

Formation of pseudopolyps. The catheter tip often comes into contact with the mucous membrane of the bladder wall, and sometimes, under the influence of negative pressure, areas of the mucous membrane enter the urine drainage holes on the catheter tip. In 22% of cases, this leads to trauma to the mucous membrane and the formation of hemorrhagic pseudopolyps [32].

Iatrogenic complications

Urethral trauma. The occurrence of severe pain and bleeding after an attempt to insert a catheter, and the subsequent inability to pass the catheter into the bladder suggest that a false urethral passage may have been created. Such injuries often result in urethral strictures and require major reconstructive surgery [33].

The cumulative percentage of patients who developed urethral stricture or erosion was 3.4% among seven published studies [34].

Non-specific complication of trocar cystostomy

Macrohematuria. Macrohematuria is often a transient condition after performing trocar cystostomy. In case of damage to only small-caliber vessels of the anterior abdominal wall and urinary bladder, it resolves on its own.

Iatrogenic complications of trocar cystostomy

Prostate injury. Bleeding from the vessels of the hyperplastic prostate gland – in 72% of cases it is stopped after conservative hemostatic therapy [24].

Intestinal damage. In 68% of cases, it occurs when performing trocar cystostomy with insufficient filling of the bladder. It requires surgical intervention to include suturing the walls of the bladder and intestines, sanitization and drainage of the abdominal cavity.

PREVENTION OF COMPLICATIONS OF BLADDER DRAINAGE

Considering the risk of the above-described complications, measures for their prevention at various stages of bladder drainage are proposed.

Prevention at the stage of urethral catheter installation

1. Defining clear indications for urethral catheter installation will minimize the number of unnecessary bladder drainages.
2. Compliance with the rules of asepsis and antisepsis, the use of sterile consumables, treatment of the glans penis (in men) and the periurethral zone (in women) with an antiseptic solution reliably reduces the number of infectious complications in the future.
3. For atraumatic first-try insertion, it is recommended to use catheters with a diameter of 16+ Fr in men; and if the anamnesis and/or instrumental examination data show infravesical obstruction, priority is given to more rigid silicone18–20 Fr catheters. In some cases, it is worth resorting to guidewire-assisted cannulation technique. The balloon should not be inflated until urine is released through the lumen of the catheter. After installation, it is necessary to perform ultrasound control of the position of the balloon in the bladder cavity in order to exclude localization of the balloon in the prostatic part of the urethra.

Care of the urinary catheter and urine bag

Maintaining unobstructed urine flow includes ensuring that the outer part of the catheter and the urine bag tube are not kinked; and that it is located below the level of the bladder. If the catheter and urine bag are faulty, they should be replaced immediately. This will help avoid vesicoureteral reflux and ascending urinary infection.

Removal of the catheter

Daily assessment of the need for further continuous drainage, and the earliest possible transition to intermittent catheterization or restoration of voluntary urination will significantly reduce the risk of complications. And, of course, it is important to evaluate the effectiveness of voluntary urination - for this, it makes sense to perform an ultrasound examination of the bladder to determine the volume of residual urine.

Thus, the most effective strategies to minimize complications of bladder drainage are as follows: avoidance of unnecessary catheterization, and timely cessation of bladder drainage.

CONCLUSION

The choice of bladder drainage method depends on the clinical indications and the expected duration of catheterization. During treatment, different catheters can be used to meet the changing needs of the patient.

Transurethral catheterization is often performed immediately, although external drainage or switching to intermittent catheterization may reduce the incidence of complications. According to a meta-analysis of 14 randomized trials, the risk of developing a catheter-associated urinary tract infection was comparable between urethral catheterization, trocar cystostomy, and intermittent catheterization if the duration of catheterization was less than 5 days. However, if the duration of drainage was more than 5 days, intermittent catheterization or placement of cystostomy drainage was associated with a reduced risk of developing urinary tract infection compared with transurethral catheterization [35].

At the same time, other factors besides the risk of developing a urinary tract infection may influence the initial choice of bladder drainage method.

Currently, a number of studies have been published, both confirming [17] the antimicrobial effectiveness of silver-coated catheters and refuting it [35, 36].

It has been proven that systemic antibacterial therapy reduces the risk of developing catheter-associated urinary tract infections in catheterized patients [37] (in clinical practice, some of them already receive antibacterial therapy for other indications). On the other hand, the disadvantages of this approach (the use of systemic antibacterial therapy as part of the prevention of catheter-associated urinary tract infections) include the emergence of resistant strains of microorganisms.

Having analyzed the literature, we can conclude that, at the moment, the results of studies on the topic of bladder drainage, prevention and control of its complications leave room for discussion. A unified concept, strategy and algorithms for action in various clinical situations have not yet been fully developed.

FINDING

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