Pediatric Ureteral Stents

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1 Introduction

Ureteral stents are considered of the significant revaluations in endourological practice and have become an integral part of the contemporary urologic practice. The widespread utilization of ureteric stents in children has lagged behind that in adults because of difficulties encountered for design and sizes optimization manufacturing. However, ureteral stents are considered essential tools in the management of several pediatric urological conditions ranging from, but not limited to, ureteropelvic junction obstruction (UPJO), calculi, and ureteric obstruction [1].

2 Classification of Stents

There are different indications for ureteral stents insertion, and accordingly, there is no one ideal stent. Efforts are made to provide the highest stents quality and reduce potential complications (Table 1).

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Table 1 Characteristics of the ideal urinary stent

• Stiff to be inserted easily, flexible with tapering to avoid injury during insertion
• Maintaining coil strength to reduce migration
• Maintaining patency and urine flow
• Softer after insertion, when exposed to urine or kept within body temperature
• Tolerated well by the patients without causing irritation or discomfort
• Causes the least mucosal irritation by being inert, having a smooth surface and a surface coating with the least coefficient of friction
• Coated by a substance that prevents encrustation and reduces the possibility of infection
• Cost efficient
• Matching the durability according to the indication and easily removed or dissolvable

Table 2 Different design patterns, materials, and features of ureteric stents

	Type of stent	Advantage	Further readings
Upper coil design	Open end	Standard open end for maximal drainage	
	Closed end	Less reflux and pain	
	Flexible coil length	No need for length calculation	
Lower coil design	Tail stents	Thin strips instead of bladder loop to reduce bladder friction and cause less bladder irritation	No significant difference [2]
	Dual Durometer	Easy insertion due to the proximal part and softer bladder coil to cause less bladder irritation	No significant difference [2]
	Magnetic tip	Easier stent removal [3]	
Shaft	Rounded smooth	Standard. Used routinely in most cases	
	Grooved	Enhance passage of stone fragments	
	Spiral	Maintain patency with external compression [4]	In vivo study, no significant difference [5]
	Self-expandable Mesh stent	To increase flow, reduce reflux	The animal study did not show a significant difference [6]
	Endopyelotomy stent	Smooth transition from 14 Fr at the renal coil to 7 Fr taper at the bladder coil	
Material	Metallic	Resist blockage by external compression	[7]
	Polyurethane	Easy insertion, better drainage	
	Silicone	Less bladder irritation, resist encrustation	
Coating	PTFE	Easy insertion, low friction reduces bacterial colonization	
	PC/PVP	Hydrophilic ease insertion, less encrustation and bacterial biofilm formation	
	Antibiotic/triclosan/silver	Reduces bacterial colonization and growth	
	Heparin	Less encrustation and bacterial biofilm formation	

The ureteral stents design comprises three significant parts; renal coil, shaft, and bladder coil (Table 2). A string may be attached to the lower end to facilitate stent removal without an additional procedure. The stent circumference ranges, and the

Table 3 Different indications of ureteral stents insertion

• Intraluminal ureteral obstruction (e.g., stones, clots, tumor)
• Intramural obstruction (e.g., UPJO)
• Extramural obstruction (e.g., tumor, aberrant artery causing UPJO, retrocaval ureter)
• Post endoscopic surgery in ureteral orifice edema
• Ureteral or renal pelvis iatrogenic injury, and residual stones
• Post ureteral anastomosis and re-implantation
• Prior to extensive pelvic procedures to avoid ureteral injury
• Prior to external shockwave lithotripsy to avoid steinstrasse
• Prior to retrograde intrarenal surgery, if a tight ureter
• Ureteral and renal pelvicalyceal injury

length varies. Stents function by allowing urine flow within the stent lumen and alongside the ureteral lumen. Some different materials and designs will be discussed later in this chapter.

3 Indications of Upper Tract Drainage

The indications for stent usage in the pediatric age group are almost similar to that in adults, including relieve of obstruction that might be intrinsic or extrinsic causes, following ureteroscopy, especially complicated one, post reconstructive procedure for both upper and lower urinary tract and before shockwave lithotripsy. The most common encounters for insertion of ureteric stents in children are UPJO, calculi, and ureteric obstruction (Table 3). The double-J ureteric stent has been described to permit for efficient, reversible internalized drainage of children with primary non-refluxing megaureter (PNRM) [8].

4 Techniques of Ureteral Stenting

4.1 Insertion Approach

Ureteral stents can be inserted either retrogradely through the urethra or antegradely through a percutaneous tract. In children, retrograde double-J stenting seems more reliable and safer than antegrade stenting [9, 10] with greater success and lower complication rates [11, 12].

4.2 Retrograde Stenting

It is performed in a lithotomy position. Initially, starting by cystoscopy and localizing the ureteric orifice, which is then cannulated with a guidewire and open-ended ureteral catheter. A retrograde pyelogram can be obtained to examine the pelvicalyceal system and the stone. Replacement of a stiff bodied wired guidewire through the ureteral catheter and removal of the catheter. The self-retaining stent is then slide over the guidewire through the ureter under vision via a cystoscope sheath and fluoroscopy. Marks guide this along the stent that demarcates the ureteral length.

4.3 Antegrade Stenting

The guidewire is passed from the kidney through the ureter to the bladder under fluoroscopic guidance through the pre-formed percutaneous nephrostomy tract. Then, the stent is slide over the guidewire and checked its position by fluoroscopy.

5 Calculation of Stent Length

The selection of stent length is of high importance as it is needed to balance the risk between stent migration in case of using short stent versus stent irritation and stent-related pain that occurs with longer stents [13]. There are different methods to choose the most optimum length. This has been attempted by measuring the ureteral length from the UPJ to the ureteral orifice using a scaled ureteral catheter while performing pyelography [14]. Similarly, this has been tackled by measuring the length between two points; (from the center of the renal pelvis to the symphysis pubis in IVU or KUB X-ray [15]. CT scan can be utilized for the measurement by multiplying the number of slices by the interval cut the thickness of slices in the area between the renal veins to the vesicoureteric junction. A formula (stent length = age in years +10) has been introduced as a reproducible manner to predict JJ stent length irrespective of laterality or gender.

Concerning the management of ureteral stent implantation, antibiotic therapy appears to be essential to prevent infection [16], which can have rates as high as 28%.

6 The Current Problems and Limitations

The indwelling nature of ureteric stents is complicated by several unwanted effects including a feeling of pain, irritative voiding symptoms, and/or urinary tract infection (UTI). There are several potential complications in the currently utilized urinary catheters in general and ureteric stents in particular (Table 4).

Table 4 Potential early and late complications of ureteral stents insertion

Complications of the procedure	Potential post-procedural complications
• Infection	• Pain; renal, suprapubic, or groin
• Renal pelvis, ureteral, and bladder injury ranging from mucosal erosion, submucosal false passage to perforation	• Urinary symptoms; dysuria, hematuria, increased urinary frequency, nocturia, urgency, incontinence, sense of incomplete bladder emptying
• Extravasation of contrast	• Stent migration
• Stent dislodgment	• Stent encrustation
• Failure to insert the stent	• Stent fracture
	• Stent occlusion externally by tumor compression or internally by blood clots or encrustation
	• Forgotten stents

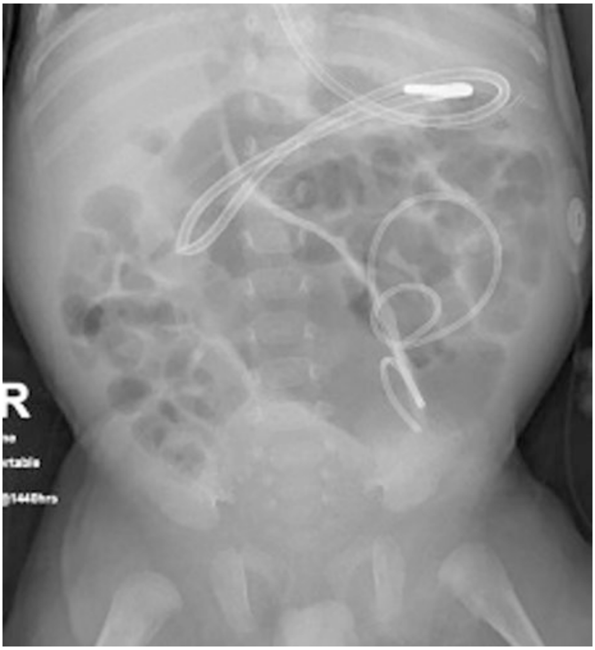

Fig. 1 Abdominal X-ray of 3 months old infant with migrated left JJ stent inserted post left open pyeloplasty

The straight catheters are used to migrate downwards towards the bladder or upwards towards the kidneys. Finney was the first to introduce indwelling ureteral stents with a double J pigtail design, each pigtail coils at one end of the stent [17]. This design reduced migration and is still used nowadays. Complications encountered include upward migration in 3.3%, slipping in 4.2% (Fig. 1). High urinary tract infection with the presence of stents and catheters as considered being foreign bodies.

Fig. 2 (**a**) Showing the gauze on top of the perinephric drain soaked with urine and blood with no accurate measurement and bothering both the baby and the parents. (**b**) Dislodegement of the perinephric drain with the first 24 h of surgery while the stitch is still in place

Complications encountered include febrile urinary tract infections in 10.8%, bacteriuria in 27.7% [18]. A recent prospective, randomized, controlled was conducted to investigate the effectiveness of continuous antibiotic prophylaxis in patients with JJ stent. The incidence of febrile urinary tract infections with CAP was significantly reduced [3.8% vs. 19% (p 0.015)]. A long stent with an extra length within the bladder cavity causes more irritation [19]. Stent irritation symptoms were found to be more if the stent crossed the midline [20].

A frequently encountered problem is the unreliability of post-operative contrast studies in the presence of the stent. This often occurs because of the inability to selectively control contrast opacification in the urinary tract that needs to be accurately tailored to each patient's situation. Drainage of the perinephric area is often needed and mandates an extra (separate) perinephric drain (e.g., Penrose) to monitor anastomotic leakage and bleeding. This has the drawback of extra wounds and scar and discomfort at the time of removal, which is the bedside (Fig. 2).

Traditional perinephric drains lack the efficacy draining of localized or small perinephric collections and are vulnerable to dislodgement. We have introduced a double-lumen externalized ureteral stent that can drain both the urinary tract and the perinephric space and better control the area of interest during contrast studies [21] (Fig. 3).

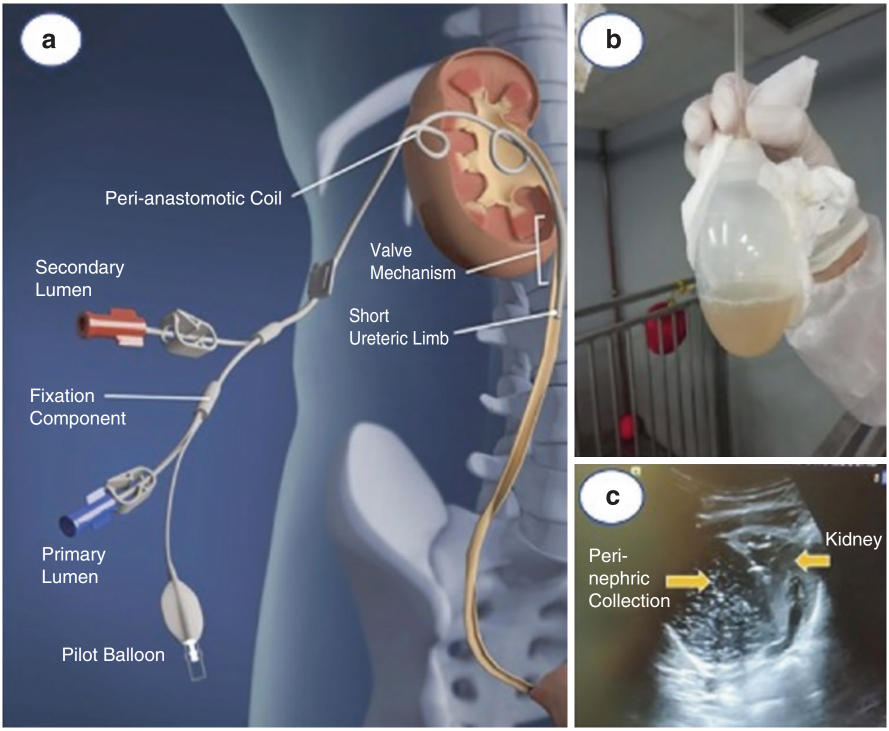

Fig. 3 (**a**) The stent is implanted in situ in a human. (**b**) Fluid collection. (**c**) US with perinephric collection demonstrated. (With permission (CC-BY) from [21])

7 Future Directions

Ureteral stents are encountering technological advancements to overcome the problems faced upon placement. Attempts to modify the traditional tube design have included changing the shape of the stent's ends even further to inhibit migration. Moreover, integrating an antibacterial component will ultimately decrease the associated high risk of acquired urinary tract infections.

Other attempts have involved replacing the bladder end of the stent with highly flexible strands or loops to reduce the stent's size in the bladder end to decrease the discomfort felt by a patient. In these designs, the stent may resemble a traditional tubular stent starting at the renal end and progressing for a significant distance, e.g., about 12 cm, or such a distance to start the flexible strands or loops about the iliac vessels of the patient. This significant distance was employed to prevent the migration of the stent further. Stents of this type suffer from the problem that stents of multiple sizes must be created, and then a physician must select what size stent to use based on approximations of the patient's physiology. In addition, even with the reduced size of the strands or loops, significant patient discomfort may result [22]. Efforts are undergoing to reduce current problems related to ureteral stents placement. Specifically, for the pediatric population, an additional procedure is needed to remove the stent under general anesthesia. Magnetic tip stents were introduced to facilitate the removal without the need for another anesthesia [23, 24].

Recently, biodegradable stents are being evaluated that would typically degrade from 15 to 30 days [25]. A mixture of materials was tried to gain maximum efficiency and the least complications. The mixture allowed the stent's gradual degradation so that the stents would dissolve from inside out and the body followed by the pigtails. This guarantees better stent stability without migration and keeps integrity till full resorption [26]. A novel design was recently introduced with an anti-reflux mechanism [27]. Likewise, coating materials would further improve the characteristics of stents and drug-eluting coating of biodegradable stents would widen the range of usage and reduce complications [28]. Antibacterial and anti-inflammatory coatings would reduce stents infection and irritation.

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