Evolution of the Ureteral Stent: The Pivotal Role of the Gibbons Ureteral Catheter

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OBJECTIVE To review the pioneering contributions of Dr. Robert Gibbons of Virginia Mason Medical Center to the evolution and development of the modern ureteral stent.

METHODS We reviewed Dr. Gibbons' extensive work through primary sources, including interviews, projector slides, radiology images, stent prototypes, his personal writings, and archived documents. In addition, we performed a review of historical texts and manuscripts describing important innovations in the development of the ureteral stent.

RESULTS In 1972, motivated by a desire to provide his patients with a long-term alternative to open nephrostomy and inspired by Drs. David Davis and Paul Zimskind, who in 1967 had described the use of indwelling ureteral silicone tubing, Dr. Gibbons began to experiment with modifications to improve upon existing stents. To address distal migration, Dr. Gibbons added "wings" that collapsed as the stent was advanced and expanded once in proper position to secure the stent in place. Barium was embedded into the proximal tip to facilitate radiographic visualization. A flange was added to the distal end, preventing proximal migration and minimizing trigonal irritation, and a tail was attached to aid in stent removal. The result was the original Gibbons stent, the first commercially available ureteral stent, and the establishment of Current Procedural Terminology code 52332, still used today.

CONCLUSION The ureteral stent is a fundamental component of urologic practice. In developing the Gibbons stent, Dr. Gibbons played a pivotal role in addressing the challenge of internal urinary diversion particularly for those who needed long-term management. Urologists and the patients they serve owe Dr. Gibbons and other surgeon-inventors a debt of gratitude for their innovative work. UROLOGY 115: 3–7, 2018. © 2018 Elsevier Inc.

Ureteral stents are a fundamental part of the modern urologist's armamentarium. Annually in the United States, about 92,000 ureteral stents are placed for treatment of kidney stones and ureteral obstruction. Stents are utilized for ureteral reconstruction, kidney transplants, and other indications.[1] Virginia Mason Medical Center in Seattle, Washington, had a unique role in the development of the ureteral stent through the pioneering work of urologist Dr. Robert Gibbons, developer of the first modern, commercially available ureteral stent. Dr. Gibbons' work was a turning point in addressing the challenges of long-term urinary diversion and creating new options for patients needing lifelong care. This paper places the pivotal contribution of Dr. Gibbons within the context of the historical development of this important medical device. Dr. Gibbons' story is part of a larger account illustrating the drive of physician-inventors to create innovation and propel improvements in urological clinical practice.

METHODS

Dr. Gibbons kept an archive of documents and materials detailing the development of the Gibbons stent, including projector slides, radiology images, stent prototypes, academic documents, personal writings, and correspondence. We reviewed these primary sources and conducted personal interviews with Dr. Gibbons. In addition, we performed a literature search and reviewed historical texts and manuscripts to identify important stages in the development of the ureteral stent.

RESULTS

Background

The ureter is a trilayer tube approximately 25 cm in length that transports boluses of urine via peristalsis from the kidney

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to the bladder. A ureteral stent is a tube that facilitates drainage of urine into the bladder and passive dilation of the ureter and the ureteral orifice. In current urologic practice, ureteral stents are used for many medical and surgical indications including (1) relief of ureteral obstruction caused by intrinsic or extrinsic factors, such as cancer, stones, or inflammation; (2) intraoperative identification of the ureter(s); and (3) drainage for treatment of ureteral leak or injury. Before the development of the ureteral stent, addressing ureteral obstruction required invasive measures for supravesical diversion such as open nephrostomy, ureterosigmoidostomy, or cutaneous ureterostomy.[2] These methods carried significant morbidity and mortality, including urinoma, stenosis or obstruction, hemorrhage, dehiscence, and ileus. In contrast, ureteral stents are internally placed and do not disrupt normal anatomy.

Early Historical References

Numerous failures, collaborations, experimentation, and developments by other surgeon inventors set the stage for the development of the ureteral stent. In the 19th century, Gustav Simon became the first to cannulate the ureter during a cystotomy. In 1885, Joaquín Albarrán developed the first catheter intended for ureteral cannulation and drainage,[3-5] and in 1897, he introduced the first catheter deflecting mechanism allowing for lateral angulation during ureteral cannulation.[6] During the same time period, James Brown (1893) performed the first cystoscopic catheterization of the ureters in a male patient using the "Brenner-Leiter cystoscope."[7] The Brenner-Leiter cystoscope (1889) incorporated a working channel that allowed for a single catheter to be passed through the scope. It also allowed drainage of urine without removal of the scope. Brown first performed bilateral catheterization in a male paraplegic and diagnosed "double chronic pyelitis" after microscopic urinary examination. His aim was to evaluate both kidneys individually to guide a decision regarding unilateral nephrectomy. At the time, evaluation for nephrectomy was predominately based on symptomatology and urine obtained from the bladder. Dr. Brown demonstrated that ureteral catheters could aid in collection of urine from a single kidney, independent of the contralateral kidney. He later developed a double catheter cystoscope allowing for the "synchronous catheterization" of both ureteral orifices.[8]

For several decades during the early 20th century, many leading urologists of the time, including Foley, Davis, Gibson, Cabot, and Kendall, reportedly passed soft rubber catheters through the ureter in an antegrade fashion during open upper urinary tract reconstructive operations.[9,10] Following this, it was reported that "stints" could be placed cystoscopically pre- or postoperatively.[9] The development of minimally invasive stent placement facilitated treatment modality evolution.

Advances in Stent Materials

In the wake of the industrial revolution, critical advances in technology, such as the development of more advanced plastics, allowed for easier and more effective cannulation. In the early 1900s, the first ureteral catheters were composed of woven silk coated in varnish.[5] Specialized catheters were also created, such as those varnished with a radio-opaque material ("shadow or X-ray catheters") and others with a glass ear piece on the distal end to facilitate detection of ureterolithiasis.[11] After World Wars I and II, chemical advancements and infrastructure for mass production allowed for the rapid development of new medical devices. Numerous materials were investigated in animal studies. Most prototypes were ultimately deemed ineffective because of issues such as encrustation (vitallium, polythene, polyvinyl), softening at core body temperature (rubber), stiffness and brittleness with a tendency to fragment (synthetic polymer, polyethylene), and high reactivity causing desmoplasia of surrounding tissue (polytetrafluoroethylene).[12] One material, silicone, was found to have suitable characteristics. Compared with other substances, silicone rubber was sufficiently rigid and resistant to encrustation and therefore became the leading material used.[5,10]

Evolution of the Early Ureteral Stent

In 1967, urologist Dr. Paul Zimskind first described the use of cystoscopically placed indwelling ureteral silicone tubing for up to 19 months, effectively demonstrating device durability.[13] In 1970, Dr. Joel Marmar modified these initial silicone implants using silastic adhesive to close the proximal end of the silicone tube to aid in retrograde advancement.[14] This modification allowed a guide catheter to be introduced into the silicone tube, enabling the surgeon to push it up the ureter. Dr. Orikasa (1973) described the use of a "pusher" to hold the stent in place while withdrawing a guidewire.[15] Although this allowed the stent to be placed over a guidewire, and the wire to be withdrawn while maintaining the position of the stent, downward migration remained a challenge.

Dr. Gibbons: Inspiration and Index Patient

Dr. Robert Gibbons was a urologist at the Virginia Mason Medical Center in Seattle, Washington, from 1969 to 2000. He was inspired by a talk given by Dr. Paul Zimskind in 1966, in which Dr. Zimskind reported on several cystoscopically placed silicone ureteral tubes. Subsequently, Dr. Gibbons treated a 58-year-old man with bilateral distal ureteral obstruction secondary to retroperitoneal fibrosis after aorto-iliac bypass grafting. The patient would only consent to 1 "external appliance" and recalling Dr. Zimskind's presentation, Dr. Gibbons performed a right cutaneous ureterostomy and left ureteral stent placement. The patient then underwent intravenous urography to compare the stented side with the cutaneous ureterostomy (Fig. 1). The patient was followed up closely by Dr. Gibbons until passing away from an aortoduodenal fistula 44 months after he was originally stented. He remained asymptomatic from his ureteral obstruction, his upper tracts were without radiographic compromise, and the original stent remained patent almost 4 years later, in contrast to Marmar stents which frequently failed by 1 year after placement.[16]