

This History of Percutaneous Nephrolithotomy



Gregory Mullen, David Hoenig, and Arthur Smith

Abstract Previously, the standard treatment for patients with renal calculi was open nephrolithotomy, which was associated with significant morbidity. The need for a minimally invasive procedure to remove renal stones was ultimately met by the establishment of percutaneous nephrostomy, which became popular in the 1950s with the advent of X-ray. The first true percutaneous nephrolithotomy was performed in 1973 by Fernström and Johansson at the Karolinska Institute in Sweden, which required a prolonged hospital stay due to serial dilation and maturation of the nephrostomy tract. At the 1980 AUA meeting, Dr. Arthur Smith and colleagues presented new techniques using a percutaneous renal approach in a poster titled “Endourology.” In the 1980s, percutaneous nephrolithotomy underwent modifications including rapid dilation, which was aided by the development of a variety of new medical devices. Percutaneous techniques were subsequently disseminated at educational courses and with the founding of the Endourological Society. Percutaneous nephrolithotomy is now the gold standard for treatment of large renal calculi and continues to undergo innovations.

Keywords Percutaneous nephrolithotomy history · Endourology history

1 Open Stone Surgery

Up until the 1950s, the standard treatment for patients with renal calculi was open nephrolithotomy. This was done via either the avascular plane made popular by Hyrtl and Brödel, or via pyelolithotomy, first done by Czerny. These procedures

G. Mullen · D. Hoenig · A. Smith (✉)

The Arthur Smith Institute for Urology, Northwell Health, New York, NY, USA

e-mail: asmith0733@gmail.com

G. Mullen

e-mail: gmullen1@northwell.edu

D. Hoenig

e-mail: dhoenig@northwell.edu

required large incisions and were associated with significant morbidity including pneumothorax, hemorrhage, urinary leakage, loss of renal parenchyma, and even death (Pettersson 2000). The need for a highly successful minimally invasive procedure to remove renal stones was ultimately met by the establishment of percutaneous nephrostomy. Like most innovations, its origins are fascinating to explore.

2 The First Percutaneous Nephrostomy

The first recorded percutaneous nephrostomies were performed by Thomas Hillier in the 1860s. Dr. Hillier was caring for a four-year-old boy with presumed uretero-pelvic junction obstruction and hydronephrosis causing difficulty ambulating and breathing. In attempt to alleviate the boy's suffering, Dr. Hillier performed multiple percutaneous aspirations over the course of several years in an attempt to create a permanent fistula to the skin, however, the nephrostomy sites repeatedly closed and the child eventually died at the age of eight (Bloom et al. 1989). Percutaneous nephrostomy did not become widely accepted for almost another 100 years, aided by the development of X-ray and a few opportune accidents.

3 Image Guided Nephrostomy

Wilhelm Röntgen discovered X-ray in 1895 which later earned him the Nobel Prize. Over the next 50 years, innovations in X-ray technology paved the way for modern fluoroscopy, which expanded the possibilities for diagnostic and therapeutic procedures (Seibert 1995). Willard Goodwin was a urology trainee at Johns Hopkins in the 1940s with an interest in angiography. During an attempted percutaneous arteriogram for a nonfunctioning kidney, Dr. Goodwin instead punctured a hydronephrotic kidney. Unsure of what to do, he removed his needle and hoped there would be no untoward consequences (there weren't any). A few years later, now the chair of the urology department at UCLA, Dr. Goodwin was presented with a similar scenario. William Casey, a urology resident at UCLA under the watchful eye of Dr. Goodwin, was attempting to perform a percutaneous renal biopsy when he too punctured a hydronephrotic kidney. This time though, Dr. Goodwin injected contrast and performed one of the first recorded antegrade pyelograms. Sensing the potential of this procedure, Casey and Goodwin began performing antegrade pyelograms on patients with hydronephrosis. Their presentation at the 1954 American Urological Association meeting (which was awarded first prize in the essay competition) generated excitement, and paved the way for modern percutaneous nephrostomy. They described their experience and technique in 55 patients, with the optimal puncture site usually being "about five fingerbreadths lateral to the midline and at a level where

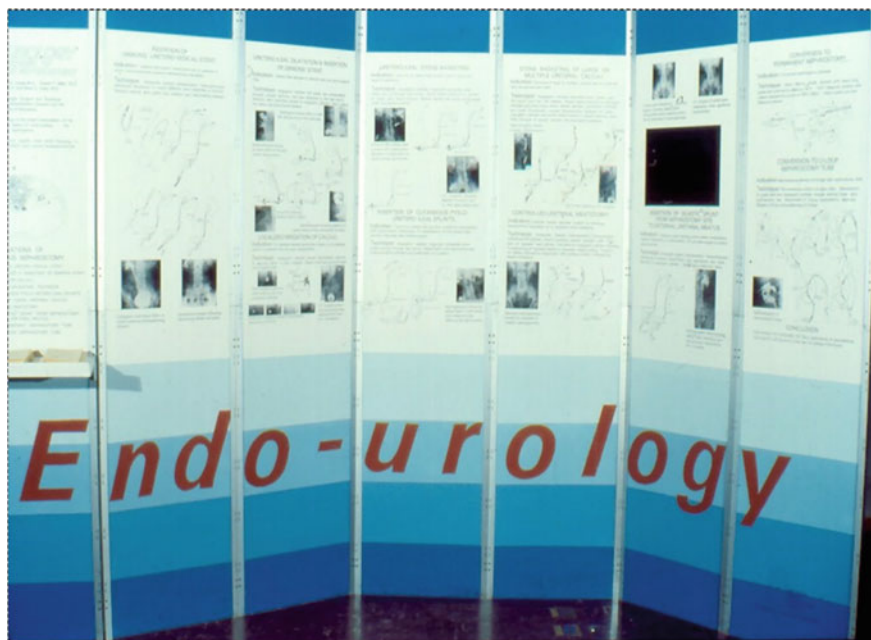


Fig. 1 Endourology Poster at 1980 AUA. Arthur Smith personal collection

a 13th rib would be”. Their follow up study of percutaneous nephrostomy tube placement in 16 patients was a natural progression of antegrade pyelography and highlighted the safety of the procedure with notably minimal bleeding risk (Goodwin 1991; Casey and Goodwin 1955; Goodwin et al. 1955). Over the next 20 years, percutaneous nephrostomy become more widely used. At the same time ultrasound technology advanced significantly and in 1974 Pedersen reported on the first use of ultrasound guided percutaneous nephrostomy (Seibert 1995; Pedersen 1974). With percutaneous nephrostomy now well established, the next logical progression was to utilize a percutaneous nephrostomy to eventually perform percutaneous nephrolithotomy (Fig. 1).

4 The First Percutaneous Stone Extraction

Believe it or not, the first percutaneous renal stone extraction actually predated Dr. Goodwin’s percutaneous nephrostomy. In 1941, Rupel and Brown performed a nephrectomy on a 44-year-old woman with a nonfunctioning, infected right kidney. Notably, her left kidney had a large nonobstructing stone. One month after her right nephrectomy, the woman returned with anuria and an open nephrostomy tube was emergently placed on the left side after retrograde catheter placement failed. After

two weeks recovery, Drs. Rupel and Brown contemplated open nephrolithotomy, but instead decided to try something novel. They removed the patient's nephrostomy tube and placed a rigid cystoscope through the nephrostomy tract where they were able to visualize the stone. The stone was too large to grab with graspers through the cystoscope, so the scope was withdrawn and the stone was removed with rigid forceps under radiographic control. The procedure was bloodless and successful; the patient was discharged home four days later totally tubeless (Rupel and Brown 1941). Despite the success of the procedure and the subsequent development of percutaneous nephrostomy in the 1950s, it wasn't until the 1970s that percutaneous nephrolithotomy was more formally attempted.

5 The First Percutaneous Nephrolithotomy

The first true percutaneous nephrolithotomy was performed in 1973 by Fernström and Johansson at the Karolinska Institute in Sweden. They adapted an established technique to percutaneously remove common bile duct stones at their institution to treat three patients with recurrent renal stones. First, a percutaneous nephrostomy was performed at a suitable site for eventual stone removal. Next, the nephrostomy tract was serially dilated by 0.5 mm each day until the caliber of the tract was large enough for stone extraction. Prior to stone extraction, the nephrostomy tract was left to mature with a nephrostomy tube for 14 days. Stones were extracted with either a Dormia stone basket or rigid grasping forceps. After stone extraction, a nephrostomy tube was maintained for at least three days until the patient was radiologically free of stone and had no evidence of obstruction (Fernström and Johansson 1976). While the procedure required a prolonged hospital stay with multiple interventions, the morbidity associated with it was far less than open nephrolithotomy. Over the next several years, percutaneous nephrolithotomy became more common and a variety of other percutaneous renal procedures were developed.

6 The Birth of Endourology

Arthur Smith was a practicing urologist in South Africa in the 1970s when percutaneous renal procedures became popular. At that time in South Africa, it was common practice for urologists to perform percutaneous aspiration and sclerotherapy of renal cysts. When he emigrated from South Africa to the United States to work at the VA Hospital in Minnesota, he discovered that radiologists commonly performed these procedures in America. This led to a collegial relationship with an interventional radiologist, Dr. Robert Miller, who together with Dr. Smith started performing a variety of new percutaneous renal procedures (Smith 2002). Their first collaboration was to treat a patient with an anastomotic leak after a ureteral reimplantation. Because Gibbons stents were the only available stents at the time, and were difficult to place

after reimplantation, they devised a technique to pull the Gibbons stent up from the kidney. They placed an angiographic catheter through a percutaneous nephrostomy, maneuvered the angiographic catheter antegrade down the ureter into the bladder, connected the angiographic catheter to the Gibbons ureteral stent, and finally pulled the Gibbons stent up into the desired position (Smith et al. 1978). Using similar principles, Drs. Smith and Miller published a variety of techniques including percutaneous ureteral stone removal in a patient with an ileal conduit, percutaneous dilation of a ureteroileal anastomotic stricture, percutaneous antegrade ureteral meatotomy, conversion of a percutaneous nephrostomy to a U-loop nephrostomy, and percutaneous dissolution of cystine, uric acid, and struvite stones, to name a few. These procedures convinced Dr. Smith that percutaneous nephrostomy gave more direct access to the kidney and ureter than retrograde access did, allowing for many novel treatments. At the 1980 AUA meeting, Dr. Smith and colleagues presented many of these new techniques in a poster titled “Endourology,” which was then defined as “closed controlled manipulation within the genitourinary tract” (Smith 2002).

During this same 1980 American Urological Association meeting, Peter Alken presented his German groups initial experience with percutaneous nephrolithotomy. Like Fernström and Johansson, Dr. Alken described serially dilating percutaneous nephrostomy tracts over the course of several days after which a nephrostomy tube was left in place for several more days to mature the nephrostomy tract prior to stone extraction (Alken et al. 1981). Over the next few years, the progression of percutaneous nephrolithotomy was enhanced both in Europe and America, notably by Dr. Alken’s group in Germany, Michael Marberger’s group in Vienna, John Wickham’s group in London, Dr. Smith’s group at Long Island Jewish Medical Center, Joseph Segura’s group at the Mayo Clinic and Ralph Clayman at the University of Minnesota.

7 Medical Devices for Percutaneous Nephrolithotomy

Around this time, Dr. Smith moved from the Minnesota VA Hospital to the University of Minnesota campus where he began working with two other interventional radiologists, Drs. Kurt Amplatz and Wilfrido Castaneda-Zuniga. Together, they performed rapid dilation of the nephrostomy tract in a single procedure for percutaneous nephrolithotomy (Castaneda-Zuniga et al. 1982a). Dr. Amplatz oversaw a lab that would eventually manufacture many devices still used for percutaneous renal procedures today. Initially they attached a filiform follower to the end of a 5 Fr angiographic catheter to dilate the tract, but this proved too difficult. Instead, they designed dilators to fit over the angiographic catheter, however, the tip of the dilator was not easily distinguished via X-ray causing potential for overdilation and damage to the ureteropelvic junction. This led to creation of a dilator with a radiopaque metal band at the tip for easy radiologic identification. Various different tract sizes were tried, up to 50 Fr, but ultimately the size of a standard tract was set to be 30 Fr, as it would allow for intact removal of a 1 cm stone. The initial sheaths produced by Dr. Amplatz’s lab were simply round tubes which had a tendency to adhere to the

tissue when suction was applied, so the tips were cut at oblique angles which were less likely to adhere to tissue (Fig. 2) (Smith 2002; Castaneda-Zuniga et al. 1982b).

A variety of different medical devices were developed to further facilitate percutaneous nephrolithotomy. Initially, percutaneous tracts were dilated with Couvelaire catheters and tapered plastic dilators (Fernström and Johansson 1976). Over time, these dilators were replaced by polyurethane, metallic, and balloon dilators still used today (Alken et al. 1981; Castaneda-Zuniga et al. 1982a, b; Clayman et al. 1983). When percutaneous nephrolithotomy began, rigid cystoscopes limited the ability of stone removal to various baskets, graspers, or chemolysis. The introduction of the offset nephroscope in the 1980s provided a straight working channel allowing for the treatment of bigger, more complex stones using larger, rigid instruments as such electrohydraulic and ultrasound lithotripters (Alken et al. 1981; Castaneda-Zuniga et al. 1982a, b; Clayman et al. 1983). After completing percutaneous stone extraction, patients were typically left with nephrostomy tubes of various sizes. Dr. Smith's group preferred a Malecot nephrostomy tube, which was modified so that it could be flattened to fit through a narrow tract. Further modifications led to the addition of a ureteral tail which crossed the ureteropelvic junction and allowed for easy reentry into the collecting system should a second stage procedure be needed.

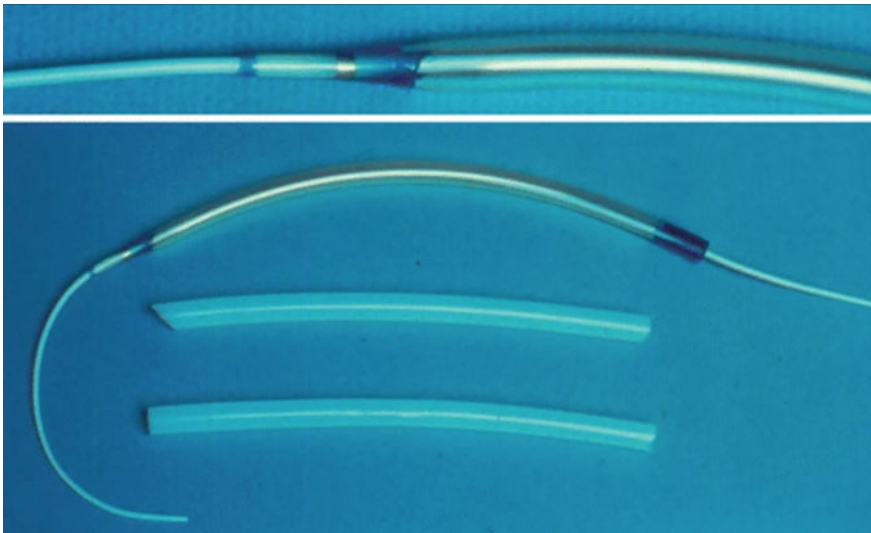


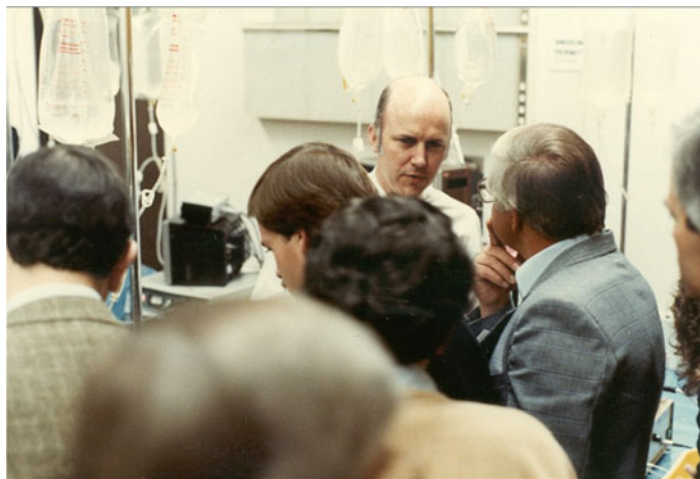
Fig. 2 Original dilators and nephrostomy sheaths (Smith 2002)

8 Dissemination of Percutaneous Nephrolithotomy

In 1982, Dr. Smith moved to New York to become chair at Long Island Jewish Medical Center. That year, Ralph Clayman organized the first course in Endourology at the University of Minneapolis. The goal was to teach general urologists the new methods of performing percutaneous renal procedures, which was aided by the use of a novel porcine model. The course was a great success and was the beginning of a slew of courses offered by the American Urological Association at many centers throughout the United States (Fig. 3) (Smith 2002).



Ralph Clayman



Joseph Segura

Fig. 3 Pioneers teaching the first course on Percutaneous Nephrolithotomy. Arthur Smith personal collection



Kurt Amplatz



Robert Miller

Fig. 3 (continued)



Arthur Smith

Fig. 3 (continued)

In 1983 John Wickham arranged the first World Congress on Percutaneous Renal Surgery in London, which engendered great enthusiasm. At this meeting, it was decided that Dr. Alken would host the second World Congress and Dr. Smith the third. Shortly after the meeting, Dr. Smith formed the Endourological Society along with Joseph Segura as vice-president, Ralph Clayman as secretary, and Gopal Badlani as treasurer. The guiding principles of the society were to encourage international collaboration, develop and train younger urologists, establish and maintain high quality fellowships, and exchange ideas at yearly international meetings. It was decided that this would not be an exclusive society, but rather all-inclusive with the goal to propagate minimally invasive techniques for the benefit of all patients. Members throughout the world were encouraged to develop their own branches of the Endourological Society, to have local meetings, and to attend the World Congress. A few years after the creation of the Endourological Society, Mary Ann Liebert persuaded Drs. Clayman and Smith to become co-editors and founders of the *Journal of Endourology*. Initially there were six issues per year, which rapidly

increased to monthly issues and has since been in press for over 40 years (Smith 2002). Shortly thereafter, Endourology fellowships were established, which have since trained almost 600 fellows in the United States, over 40% of whom have remained in academic medicine, further advancing the field (Patel and Nakada 2022).

9 Percutaneous Nephrolithotomy Innovations

Percutaneous nephrolithotomy has remained the gold standard treatment for large renal calculi and has undergone dramatic improvements in the fifty years that have passed since the first percutaneous nephrolithotomy. Dr. Wickham's group was the first to report on the omission of a nephrostomy tube after percutaneous renal stone extraction, instead opting for a 'totally tubeless' approach in some patients (Wickham et al. 1984). Gary Bellman and colleagues were the first to study the 'tubeless' approach, which involved leaving a double J stent instead of a nephrostomy tube at the conclusion of the procedure (Bellman et al. 1997). Aside from innovative exit strategies, additional modifications have been proposed as well. Whereas most percutaneous renal procedures were performed in the prone position, José Gabriel Valdivia Uría and his group in Spain were the first to report on the safety and efficacy of performing percutaneous nephrolithotomy in the supine position (Valdivia Uría et al. 1987). Years later, Guohua Zeng and colleagues in China were one of the first groups to report on reducing the tract size for percutaneous nephrolithotomy (Zeng et al. 2013). More recently, percutaneous nephrolithotomy has been performed as an ambulatory procedure with low rates of complications (Chong et al. 2021). Finally, and as should be expected, as percutaneous nephrolithotomy evolved, so too have the number and type of percutaneous renal procedures.

10 Other Percutaneous Renal Procedures

Dr. Smith's presentation of various endourology procedures at the 1980 American Urological Association meeting certainly inspired the development of future percutaneous renal procedures. A few years later at the first World Congress in 1983, Dr. Wickham introduced his experience performing percutaneous incision of a ureteropelvic junction obstruction, which he termed "pyelolysis" (Wickham and Kellet 1983). Dr. Smith subsequently published a series on percutaneous full-thickness incision of the ureteropelvic junction followed by stenting which he termed "endopyelotomy," a name that has remained (Badlani et al. 1986). Shortly thereafter, Stevan Stroom at the Cleveland Clinic published the first reports of percutaneous treatment of upper tract urothelial carcinoma, which is now recognized by the National Comprehensive Cancer Network as an acceptable treatment option for select patients (Stroom and Pontes 1986; National Comprehensive Cancer Network 2022). The number of

percutaneous renal procedures now offered is even greater, and all trace their roots back to the first percutaneous nephrostomy of the 1860s.

11 Conclusion

Percutaneous nephrolithotomy remains the gold standard for removal of large and complex renal stones. While its origins can be traced, one cannot underestimate the incredible vision which ensured its development. From clinical trials to technological development to education and dissemination of the techniques to all parts of the world, the history of endourology is a marvel. The legacy of the pioneers of percutaneous nephrolithotomy continue to live on at endourology meetings, fellowships, and international collaborative research settings.

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