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Percutaneous Renal and Ureteral Stone Removal

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Abstract. Percutaneous removal of upper urinary tract calculi has become an accepted alternative to surgical removal. Calculi may be removed through large nephrostomy tracts under fluoroscopic or endoscopic control. Close cooperation between the radiologist and urologist should increase the success rate of the procedure.

Key words: Kidney, percutaneous nephrostomy — Kidney, calculi — Catheters/Catheterization, technique.

Percutaneous removal of urinary calculi is rapidly gaining acceptance as a useful technique in the management of nephrolithiasis [1–3]. As with any new technique, methodology varies considerably from institution to institution. This paper reviews the methods used at the University of California, San Francisco.

Selection of Patients

To select patients properly for percutaneous renal stone manipulation, a thorough understanding of the collecting system anatomy and limitations of available endoscopic systems is essential. Accurate placement of the nephrostomy tube within the collecting system is often the key to success. Certain patients are ideal candidates for stone extraction by the percutaneous route. These include:

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1. Patients with medical problems which may contraindicate general or regional anesthesia, and/or an open operative procedure;
2. Patients who have had previous renal or ureteral surgery, making subsequent operative intervention more difficult;
3. Patients with active metabolic disease, who are at risk for recurrent stone formation;
4. Patients who have undergone primary stone chemolysis which failed or resulted in retained fragments;
5. Patients who present with obstructive pyelonephritis secondary to a renal pelvic or upper ureteral stone;
6. Selected patients who desire a percutaneous, rather than open, surgical procedure.

Preparation of Patients

The patient is admitted to the hospital on the morning of the procedure. Results of routine laboratory studies are obtained, including coagulation profile, and baseline serum creatinine and blood urea nitrogen levels. Blood is also sent for typing and crossmatching. The patient is allowed nothing by mouth on the day of the procedure, and an intravenous infusion of saline is started through a large-bore cannula. One hour prior to the procedure, 10 mg diazepam is given orally, and a broad-spectrum antibiotic is administered intravenously. Narcotic analgesia is given intravenously in small increments throughout the procedure.

Opacification of Urinary Collecting Structures

The majority of patients with urolithiasis have intact excretory function in the involved kidney. The intravenous administration of 100 ml 50–60% uro-

Fig. 1. Opacification of left-sided renal collecting structures by injection of contrast media through retrograde ureteral occlusion balloon catheter. Note forniceal distention and incidental lower-pole forniceal rupture

graphic contrast media therefore provides adequate visualization of the collecting structures in most cases.

In patients with significant hydronephrosis or reduced excretory function, antegrade pyelography with a 22-gauge needle from a direct posterior approach may be necessary. Ultrasound guidance is very helpful in directing the puncture in these cases.

Many patients with nonobstructing calculi have very attenuated, delicate collecting structures, making the puncturing of a specific calyx very difficult. To minimize this problem, an occlusion balloon catheter can be placed cystoscopically in the upper ureter prior to the procedure. When the balloon is inflated, the ureter is occluded and contrast injected through the endhole of the catheter distends the renal collecting structures (Fig. 1). Mixing methylene blue with the contrast material may be helpful to confirm that the collecting system has been entered. This is especially useful during difficult cases when blood obscures urine return upon aspiration.

Choice of Entry Site

Ideally, a transparenchymal puncture should be made into a minor calyx from a entry site below the 12th rib in the posterior axillary line. This entry site is preferable for several reasons. The transparenchymal course stabilizes the catheter and prevents retroperitoneal urinoma formation. A puncture through a minor calyx avoids the major vascular structures in the renal hilum and reduces the likelihood of renal pelvic laceration. If the needle is directed below the 12th rib, the possibility of a complicating pneumothorax from a transpleural puncture is greatly reduced. A tract established through the posterior axillary line is more comfortable for the patient, reduces radiation exposure to the operator during fluoroscopic manipulations, and facilitates visualization of the collecting structures through the nephroscope.

The precise calyceal entry site for each patient depends on the location of the stone. Ideally, a midpole calyx is selected for renal pelvic, upper ureteral, and midpole calyceal stones. A lower calyx is selected for lower and upper pole calyceal stones.

The entered calyx should offer the least complicated tract for manipulation of the endoscope to the stone. When the stone resides in a calyx, the ideal puncture site should be just peripheral to the stone. If this is not feasible, an entry site should be chosen that offers a relatively gentle angle to the stone-containing calyx.

Puncture of Renal Collecting Structures

After the collecting system has been opacified, the skin over the flank is cleansed with antiseptic solution and draped in a sterile manner. The appropriate skin entry site is selected fluoroscopically and generous skin anesthesia is administered with 1% xylocaine.

Many needle systems are available for percutaneous renal puncture. The simplest is an 18-gauge stylet with a 5 Fr polyethylene sheath (Cook Inc., Bloomington, IN LPN-40-25-RING) whose stiffness makes it easy to direct through the heavy back muscles [4]. Despite its size, bleeding complications are infrequent, even if multiple passes are required. A major advantage of this system is the ability of the sheath to conduct a 1-mm guidewire directly into the collecting structures after the stylet has been removed. Alternative systems such as coaxial needles in which an 18-gauge cannula is guided over a thin-walled, 22-gauge needle are also available [5].

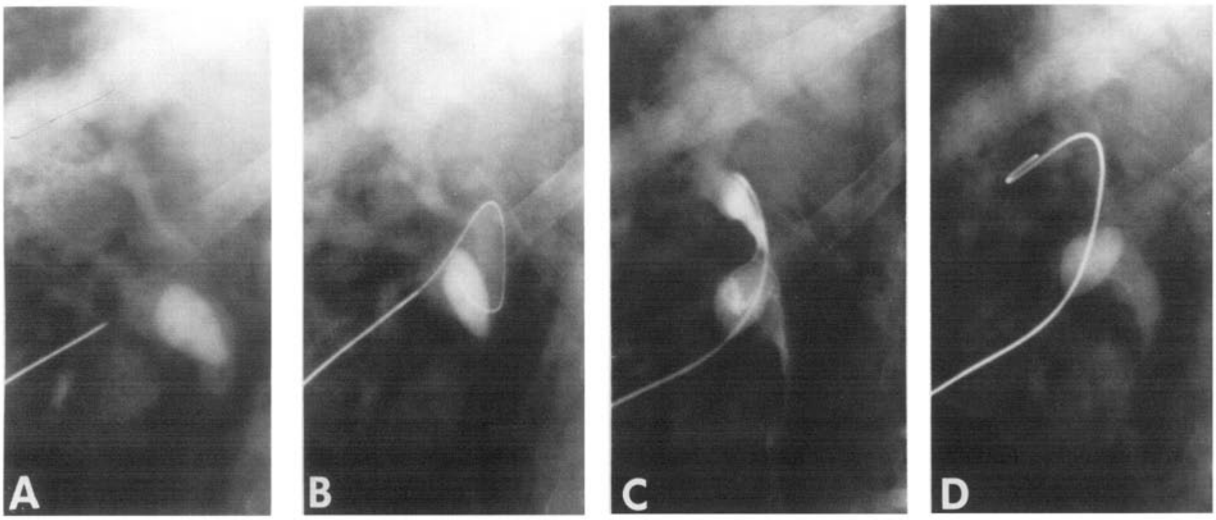


Fig. 2. Percutaneous nephrostomy performed with the Cope introducing system. **A** 21-gauge needle is used to puncture right lower pole infundibulum. **B** 0.5-mm guidewire is advanced through needle. **C** Specialized dilator is inserted over guidewire and contrast media is injected. **D** 1-mm guidewire is inserted and emerges through the sideport of the dilator

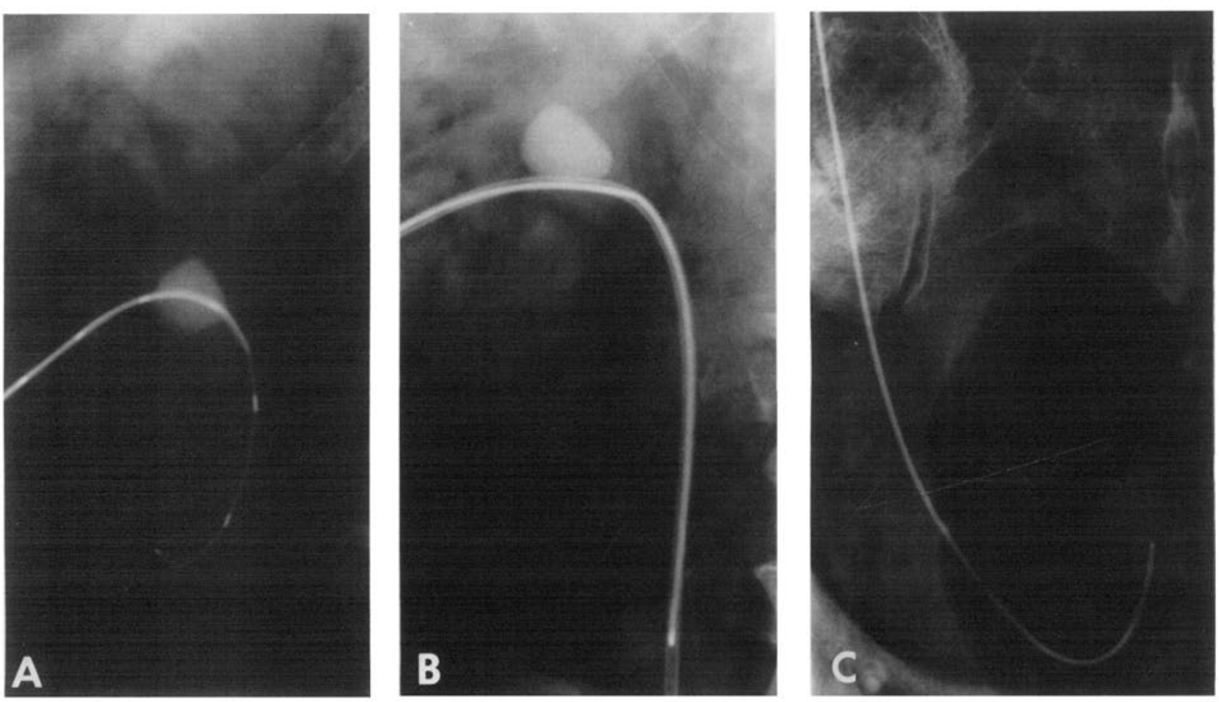


Fig. 3. Positioning the exchange guidewire. **A** A Lunderquist torque guide is manipulated into the proximal ureter. **B** After an angiographic catheter is placed, the torque guide is removed and replaced with an exchange guidewire, which is advanced through the catheter into the distal ureter. **C** Only the soft distal segment of the exchange guidewire is allowed to enter the bladder

Most commonly, we use the needle system developed by Cope [6] for percutaneous calyceal puncture (Fig. 2). This consists of a 21-gauge, thin-walled needle, 0.5-mm heavy-duty guidewire, and a specialized curved dilator tapered to 0.5 mm at the tip. A large sideport in this dilator allows passage of a curved 1-mm guidewire. A stiffening cannula facilitates passage of the dilator over the small guidewire.

Whatever needle system is selected, the angle of approach should be 20–30° away from perpendicular toward the midline. For unusually high kidneys, a variable degree of cephalad angulation may

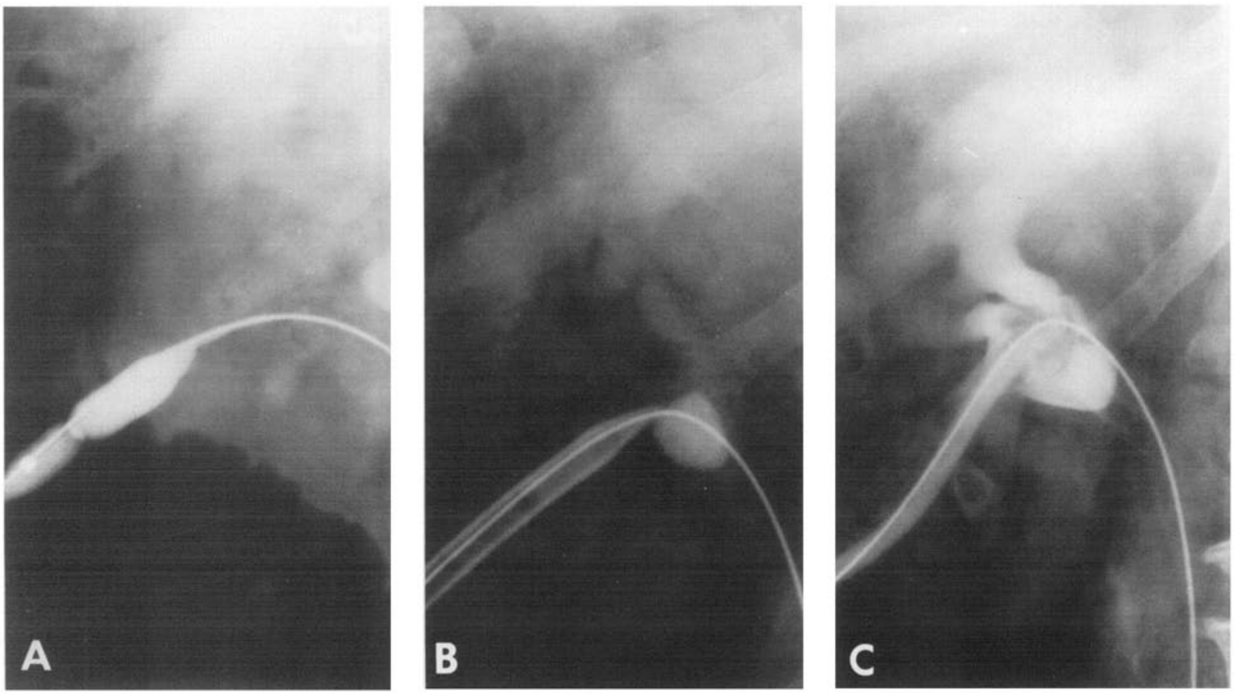


Fig. 4. Dilatation of the nephrostomy track. **A** 10-mm dilatation balloon inflated in nephrostomy track. Note indentation of balloon at Gerota's fascia. **B** 24 Fr polyethylene dilator is advanced over guidewire into the renal pelvis. **C** 24 Fr Malecot drainage tube is positioned appropriately

also be necessary; however, simultaneous triangulation in two planes is difficult and can be often avoided by performing the puncture while the patient maintains deep inspiration.

Dilatation of the Nephrostomy Tract

Manipulating Guidewires

Once a 1-mm guide wire has passed into the renal pelvis, a 5 Fr catheter is advanced over it. It is advantageous to maintain a rigid guidewire distally in the ureter to support passage of large dilators and nephrostomy tubes into the renal pelvis. Negotiating a guidewire through the ureteral pelvic junction may be difficult in the presence of large pelvic calculi. We have been very successful in engaging the ureter utilizing a torque control guidewire (Cook Inc., Bloomington, IN HSF-38-145-THG). This guidewire, developed by Lunderquist for biliary manipulations, differs from most others in 2 respects. The tip is malleable and can be shaped in accordance with the patient's anatomy, and the torque control is exceptional. If the external segment of the guide is coiled into a loop, delicate rotatory motions are transmitted directly to the curved tip (Fig. 3A). Once the guidewire has been passed into the proximal ureter and the 5 Fr catheter advanced over it, contrast medium is injected to demonstrate the ureteral anatomy. Generally, the Lunderquist torque wire can be advanced gently through the ureter into the bladder. If the torque control wire does not pass easily, a soft-tapered tip guidewire should be inserted.

Introducing Dilators

After the guidewire has reached the distal ureter or bladder, an angiographic catheter with multiple sideholes is placed. The original guidewire is then replaced with a rigid Lunderquist exchange guide (Cook Inc., Bloomington, IN SF-38-145-LUND) (Fig. 3B, 3C). This extremely stiff guidewire provides sufficient support for the ensuing tract dilatation.

When the exchange guidewire is in place, the multi-sideholed catheter is withdrawn into the percutaneous tract, and a side-arm adaptor is attached to the catheter's hub. Generous amounts of local anesthetic (15–20 cc 1% lidocaine) are injected through the side-arm adaptor to anesthetize the tract.

The angiographic catheter is removed, and the percutaneous entry site is widened considerably with sharp and blunt dissection. An 8 Fr Teflon catheter is then placed over the guidewire. If this advances easily, the tract is dilated with Amplatz polyvinyl dilators [7] (Cook Inc., Bloomington, IN DKS-12[to 30]-105-30) in 6 Fr increments (14 Fr, 20 Fr, 26 Fr). If the 8 Fr catheter is difficult to advance through the tract, it is removed and a dilating balloon catheter inserted.

Specially designed, wire-reinforced, 10-mm diameter, fascial dilating balloons are commercially available for this purpose (Surgimed 961010; Cook NTDS-30-10-13.0) (Fig. 4A). These balloons can be safely inflated to a pressure of 15 atm without rupturing. The advantages of using a dilating balloon include the ease of insertion and axial force of dilatation. This is particularly helpful in patients with dense scar tissue from previous surgical procedures.

Several other dilating systems are available [8–10]. The ultrasonic lithotripsy instruments are available with a set of metal dilators tapered to follow a 1-mm guidewire. Unfortunately, even stiff exchange guidewires are of insufficient strength to prevent extension of these dilators medially through the wall of the renal pelvis if they are excessively advanced. The same problem is encountered with polyethylene dilators tapered to a 1-mm guidewire (Fig. 4B).

To avoid this problem, Amplatz developed a system of polyvinyl dilators tapered to an 8 Fr catheter [7]. When the catheter is placed over the stiff Lunderquist exchange guidewire, there is considerable support for the larger coaxial polyvinyl dilators, which greatly diminishes the risks of inadvertent renal pelvic perforation.

Two technical features facilitate passage of the larger dilators. First, fluoroscopic observation should be utilized to ensure precise alignment with the supporting 8 Fr catheter and dilator. Second, a gentle twisting motion will often make the dilatation easier. Large dilators should be advanced into the renal pelvis and stopped just proximal to the ureteropelvic junction. If the stone is to be removed in a single stage, a 30 Fr dilator with an outer working sheath is inserted. When the stone is to be removed at a second stage, a large-bore drainage catheter is placed.

Drainage Catheter

Insertion

Several nephrostomy tubes are available for insertion through large nephrostomy tracts. We most frequently use a 24 Fr Silastic Malecot catheter (Fig. 4C) (Dow Corning Corp., Midland, MI), which is soft and well-tolerated by the patient. The wide openings between its distal wings allow blood clots to be evacuated from the renal pelvis easily.

To insert the 24 Fr Malecot catheter, a small hole is punctured in its distal tip with a 25-gauge needle. A 14 Fr urethral dilator (Cook Urological, Bloomington, IN 073814) coated with sterile water-soluble lubricating jelly is advanced through the Malecot catheter. This stiffens the catheter and effaces the terminal wings, making insertion possible. The lubricating jelly diminishes the friction between the urethral dilator and silastic catheter.

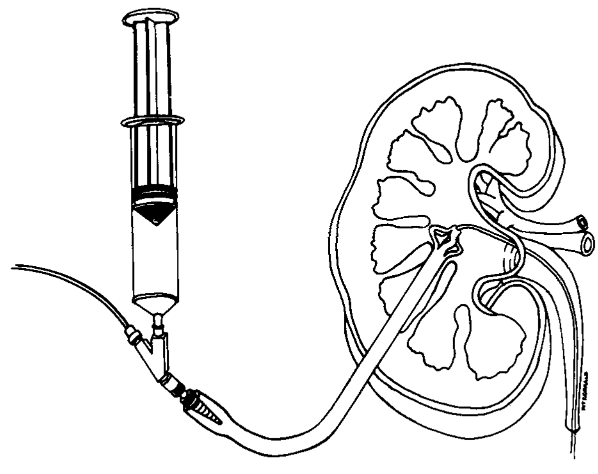


Fig. 5. Position of drainage catheter is confirmed by injection of contrast media through side-arm fitting and "Christmas-tree" adaptor into the nephrostomy tube

The proximal end of the stiff exchange guidewire is placed through the Malecot tip and guided through the lumen of the urethral dilator. Under fluoroscopic observation, the catheter is advanced into the renal pelvis. The stiffening dilator is removed and, if the drainage catheter is appropriately positioned, the 3 winged tip will spring into the open position.

To confirm the catheter position, a side-arm adaptor is attached to a "Christmas-tree" fitting and placed over the guidewire into the proximal end of the drainage catheter. Contrast medium can then be injected through the catheter to confirm its position before the guidewire is removed (Fig. 5).

Another drainage catheter that can be inserted is the 20 or 22 Fr rubber Councill catheter (C.R. Bard, Inc., 0196V Murray Hill, NJ). This has a Foley balloon and a large endhole, allowing it to be placed coaxially over an 8 Fr Teflon catheter. The advantage of the Councill catheter is the ease with which it can be placed. Disadvantages are that the balloon occupies an unacceptable amount of space in a nondilated collecting system, and that the small drainage ports at the distal tip may be of insufficient size to evacuate moderate to large blood clots; the balloon may also protrude into the ureteropelvic junction.

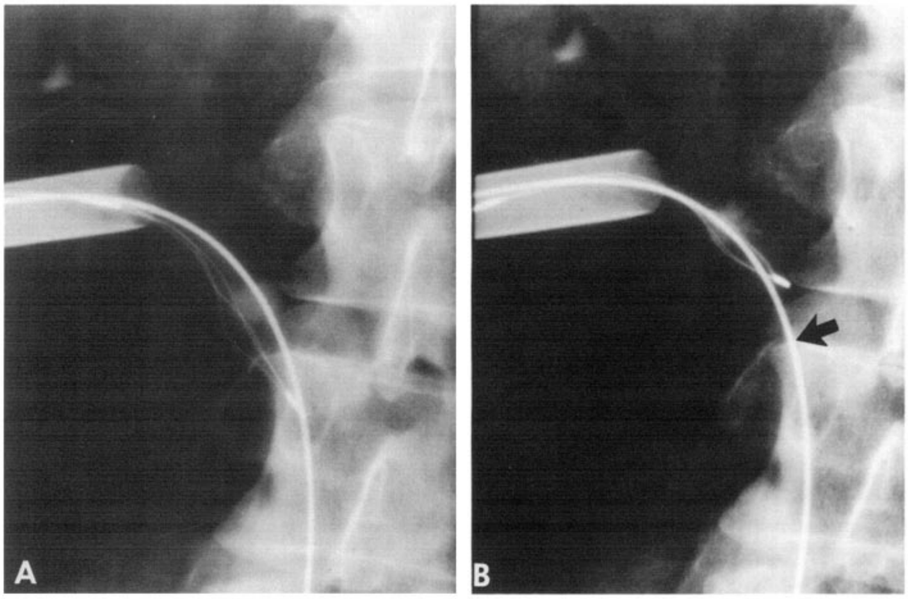


Fig. 6. Removal of calculus with retrieval basket. **A** Retrieval basket is opened adjacent to stone. **B** Stone is trapped and subsequently pulled out through working sheath. Note safety guidewire (*arrow*)

Anchoring

Because of the relatively large tract through the kidney, it is of critical importance that the nephrostomy catheter be securely anchored. Using the method described by Schoenfeld [11], we place a Sur-Fit® Stomahesive® Wafer (Squibb, Princeton, NJ) with a plastic ring and a central opening on the flank with the drainage tube positioned through its central hole. The skin surrounding the nephrostomy tract is wiped with tincture of benzoin solution, and the Stomahesive® is firmly applied to the skin. A short piece of water-resistant tape is wrapped eccentrically around the catheter where it crosses the plastic ring of the Stomahesive®. The tape is then sutured securely to the plastic ring with locking knots.

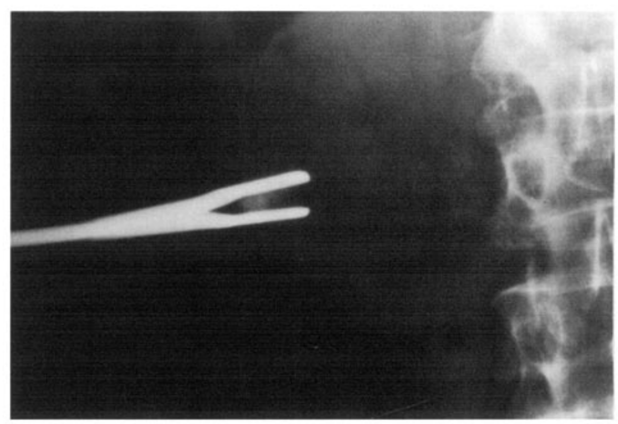


Fig. 7. Radiopaque calculus is extracted through a mature nephrostomy tract with Mazzariello-Caprini forceps under fluoroscopic guidance

Stone Removal

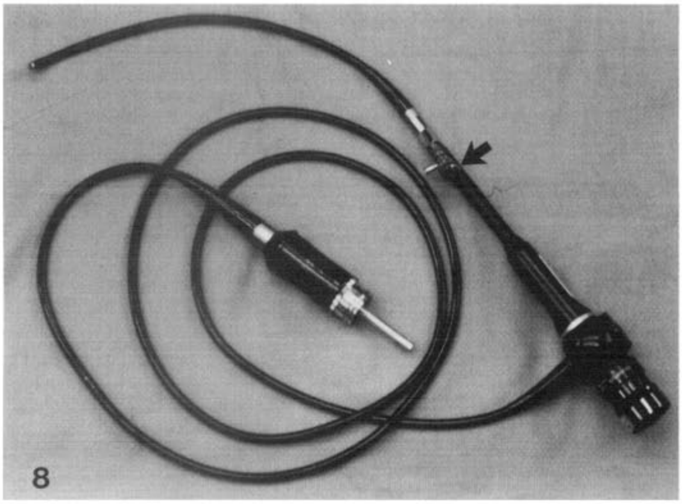
Once the nephrostomy tract has been established, 1 of 2 techniques can be employed for stone removal [12].

1-Stage

Following successful dilatation to the appropriate size, a working sheath, nephroscopy cannula, or nephroscope sheath is inserted into the collecting system. This provides continuous tamponade of the tract while providing access to the collecting system with the appropriate stone-retrieving instrument. Following stone removal, the sheath or cannula is removed, and a similar-sized nephrostomy tube is inserted to tamponade the tract and provide urinary drainage. The tube may be removed after 5–7 days if appropriate radiographs fail to reveal additional calculi.

An important technical feature of the 1-stage procedure is the placement of a second guidewire prior to track dilatation. This safety wire remains outside of the sheath or cannula during the entire procedure, but may be used if access to the collecting system is lost through the sheath or cannula. The safety wire is placed through a nontapered, 10 Fr or larger sheath down the ureter, with the tip of the safety wire positioned in the distal ureter or bladder.

Whether a 1-stage procedure is performed under



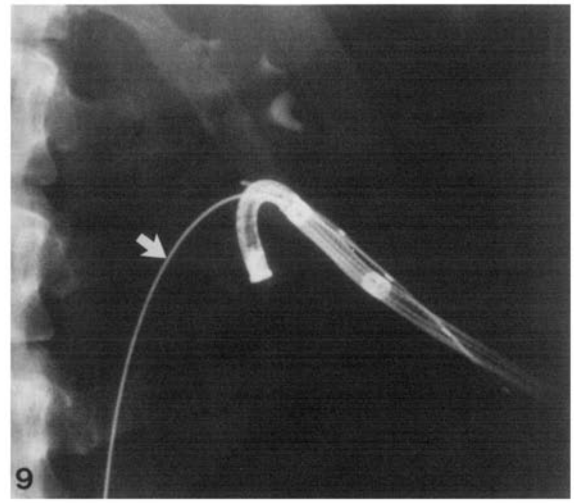


Fig. 8. 15 Fr flexible nephroscope. Sideport (*arrow*) allows for through-put of various stone retrieval devices

Fig. 9. 15 Fr flexible nephroscope positioned to inspect stone in lower pole calyx of left kidney. Note safety wire (*arrow*) extending down ureter

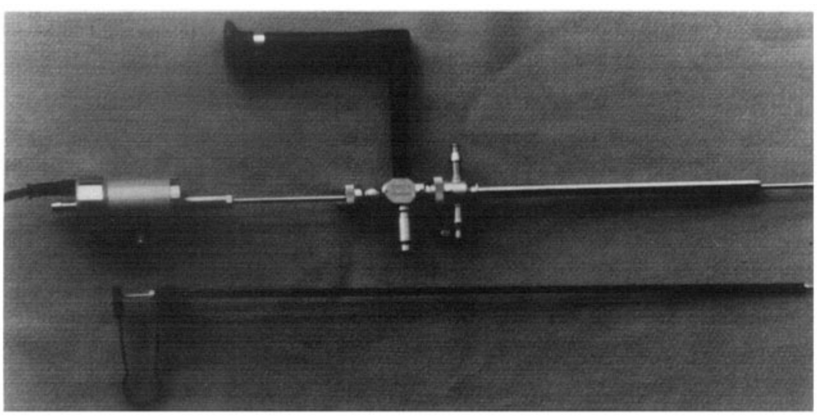


Fig. 10. Rigid 24 Fr nephroscope (STORZ) with ultrasonic lithotriptor inserted through its lumen. Grasping forceps are pictured alongside.

local or general anesthesia is primarily dependent upon the endoscope to be used and the size of the calculi.

2-Stage

A 2-stage procedure is performed by inserting the large-bore nephrostomy tube after tract dilatation. This tube remains in place for approximately 1 week while the tract matures. The tube is then removed and the track endoscoped in the operating room using the appropriate instrument. Following removal of the stone, replacement of the nephrostomy tube is dependent upon the patency of the ureter, presence or absence of collecting system perforation, and the amount of bleeding from the nephrostomy tract. In addition, whenever a lithotripsy has been performed or retained fragments are present, a nephrostomy tube is routinely replaced. Subsequently, appropriate radiographs, including tomography, may be performed before the nephrocutaneous tract is allowed to close.

A 2-stage procedure may be performed under local or general anesthesia. The majority of large nephrostomy tubes are inserted with local anesthesia in the Radiology Department. For the second stage, general anesthesia may be necessary for removal of large calculi requiring extensive manipulation. This part of the procedure is performed in the operating room.

Modified 1-Stage (Immediate 2-Stage)

This commonly performed variation of the 1-stage procedure is used primarily for patients undergoing an ultrasonic lithotripsy. If the rigid endoscope is to be used, the patient requires general or regional anesthesia. However, the initial steps of the procedure (puncture and manipulation into the ureter) are performed under local anesthesia in the Radiology Department. This diminishes the length of time the patient requires general anesthesia. An 8.3 Fr biliary drainage catheter with additional proximal sideholes is placed through the nephrostomy tract, down the ureter with its distal tip in the bladder. The most proximal sideholes are positioned within the renal pelvis. Immediately following the procedure, or on the next day under general anesthesia in the operating room, a Lunderquist exchange guidewire is placed through the catheter. The remaining steps of the 1-stage procedure are then performed.

Comparison of Procedures

The principle difficulties encountered with a 1-stage procedure are bleeding, which leads to poor endoscopic visibility, and the potential loss of percutaneous access, although this is minimized by the use of a safety wire.

The 2-stage procedure is performed with no or minimal bleeding and hence affords superior visibility. Since the track is well-developed, an endoscope can be introduced under direct vision during the second stage. Fluoroscopy therefore is optional and only necessary for retrieval of stones which cannot be easily visualized endoscopically. The obvious disadvantage of the 2-stage procedure is that 2 procedures must be performed. During tract maturation, the stones may move; however, in our experience, this has not been a problem. The 2-stage procedure should be used initially by physicians who are less experienced with endourologic technique, as it is technically easier than the 1-stage procedure.

With experience, a gradual progression in operator preference from two- to one-stage procedures usually occurs; however, we have found certain guidelines useful.

1-stage procedures are ideal for stones less than 10 mm in diameter located within the renal pelvis or upper ureter. These calculi are easily removed in the Radiology Department under local anesthesia through the large Amplatz sheaths.

Modified 1-stage procedures are most appropriate when a large stone exists in the renal pelvis and there exists minimal space to place a large nephrostomy tube. This problem is also encountered with staghorn calculi.

2-stage procedures are advantageous under the following circumstances: (1) stones to be removed lie within the calyx to be punctured; (2) complex cases involving multiple stones; (3) stones within solitary kidneys; and (4) stones that can not be extracted during the initial procedure.

Instrumentation for Fluoroscopically Guided Stone Removal

Retrieval Baskets

Stones less than 8–10 mm in short-axis diameter located in the renal pelvis or proximal ureter may be removed fluoroscopically with retrieval baskets. The technique is similar to removal of calculi from the biliary tree. The basket sheath is advanced immediately past the stone over a guidewire. The guidewire is removed and the retrieval basket inserted to the tip of the sheath. The sheath is retracted, opening the basket adjacent to the stone. The basket is then rotated, entrapping the stone, and the sheath is advanced, locking the stone within the wire mesh. Constant tension is maintained, and the stone is removed through the percutaneous tract.

When dealing with mature nephrostomy tracts, it is unnecessary to pull the stone through the working sheath. It may be removed directly through the percutaneous track. In 1-stage procedures, the stone is pulled through a 24 to 30 Fr Amplatz nephrostomy sheath that is inserted over the appropriate dilator (Fig. 6). It is imperative to have a safety guidewire alongside the nephrostomy sheath, extending down into the ureter to allow replacement of a nephrostomy tube if it becomes dislodged.

The specific basket size and configuration selected are dependent upon the size and location of the stone. As a general rule, the open basket size should approximate the size of the lumen where the stone is located. Short, wide baskets are appropriate for calculi located in the renal pelvis, whereas long, slender baskets are better for proximal ureteral stones. Large stones may be easier to entrap with 3- or 4-wire baskets. Six-wire baskets are particularly useful for small- to moderate-sized calculi within the proximal ureter.

Forceps

Depending upon the size and length of the nephrostomy tract, as well as the location of the calculus, various forceps may be used for stone retrieval under fluoroscopic guidance, including the Randall and Mazzariello-Caprini types (Fig. 7).

Instrumentation for Endoscopically Guided Stone Removal

Cystoscope

A standard 21 Fr cystoscope may be used through a nephrostomy sheath or mature track to retrieve renal pelvic calculi, calyceal calculi in the line of the track, and upper ureteral calculi if the ureter is of sufficient caliber and mobility.

Three types of retrieval devices can be used with the cystoscope: 7 Fr flexible alligator forceps or rat-toothed forceps can grasp stones approximately 1 cm in size and remove them; the 9 Fr electrohydraulic lithotripsy probe may be used to disintegrate stones too large to be removed in 1 piece; and standard filiform and nonfiliform basket retrieval systems can trap stones less than 1 cm. The 21 Fr cystoscope is well-tolerated under local anesthesia by most patients.

15 Fr Flexible Nephroscope

This nephroscope is 31 cm in its flexible length and deflects 110–160° in 1 direction and 90–110° in the other [13, 14] (Figs. 8, 9). By rotating the entire instrument, most of the inside of a sphere can be visualized, except for the area immediately parallel to the shaft of the instrument. It can therefore be used to inspect nearly all of the calyces and the upper two-thirds of the ureter. It has a 6 Fr irrigating channel which accommodates various 5 Fr retrieval devices. The irrigation capacity of this water channel is much less than that of a cystoscope and hence visibility is relatively poor. This can be compensated by using a Fenwall pressure bag on the irrigating solution reservoir. Also, the retrieval devices work less efficiently than those used through the cystoscope. For example, grasping forceps (biopsy forceps, 3- and 4-wire pronged graspers) are useful in manipulating only small (3–5-mm) stones. The 5 Fr electrohydraulic lithotripsy probe [15] may be used through this endoscope to disintegrate impacted calyceal stones. Various stone baskets may also be used through the working channel and appear to be the only way large calculi can be removed intact with this instrument. Despite these relative disadvantages, the major advantage of the flexible nephroscope is its maneuverability and its ability to be extremely well tolerated under local anesthesia.

Ultrasonic Lithotripsy

24 to 26 Fr Rigid Nephroscope

These endoscopes (Fig. 10) have superior optics and feature a continuous-flow irrigation system through the endoscope. The ultrasound probe disintegrates large calculi in a controlled fashion and provides simultaneous evacuation by suction through the core of the probe [16, 17]. The sheath of the nephroscope may be introduced over a guidewire using the tapered obturator. Various large grasping forceps and other accessories including a knife blade to incise a strictured infundibulum or ureteral pelvic junction may be used with these systems. However, because these endoscopes are quite large, the patient must receive general or regional anesthesia.

Ultrasonic vs. Electrohydraulic Technique

The advantages of electrohydraulic lithotripsy in our experience to date are that the probe is flexible and effective in disintegrating all calculi. Unfortunately, the procedure is dangerous and perforation of the collecting system can easily occur. One-sixth normal saline must be used with electrohydraulic lithotripsy, compared to normal saline which is generally used with ultrasonic lithotripsy.

Ultrasonic lithotripsy must be performed through a large rigid endoscope. This limits stone removal by this technique to large renal pelvic or calyceal stones in direct line with the nephrostomy track. The main advantage of ultrasonic lithotripsy is the continuous evacuation of fragments through the ultrasonic probe.

Anesthesia

There are three major categories of determinants for the type of anesthesia to be used.

Patients

Patients with medical problems that contraindicate general anesthesia must have their stone removed while under local anesthesia. Patients who are quite anxious or who cannot cooperate may require a general anesthetic.

Stones

Because patients cannot lie in one position for an extended period of time, large stones that require time-consuming lithotripsy should probably be removed under general anesthesia or in several stages. Also, if a stone is impacted in the ureter and considerable force is required to dislodge it, the procedure is best performed under general anesthesia.

Endoscopes

As mentioned above, the 21 Fr cystoscope and 15 Fr flexible nephroscope can be used easily with local anesthesia. Larger nephroscopes require the use of general, spinal, or regional block anesthesia.

Special Techniques and Considerations

Ureteral Stones

Ureteral stones [18] are often impacted, in which case a retrograde ureteral occlusion balloon catheter is placed prior to stone manipulation. The collecting system is opacified using dilute contrast material through this catheter under low pressure. Occasionally, the ureteral stone flushes into the renal pelvis. If this does not occur, a percutaneous nephrostomy is performed with eventual insertion of a working sheath. Higher-pressure retrograde flushing can then be performed. Although most ureteral stones, in our experience, flush upward toward the renal pelvis, some large, jagged, severely impacted stones do not. In these cases, a fluoroscopically guided, 3- or 4-wire biliary stone basket or flexible nephroscope with stone basket may be used in conjunction with simultaneous retrograde flushing. This distends the ureter and may enable the wires of the basket to engage the stone.

Staghorn Calculi

Careful study of the collecting system anatomy in relation to the stone configuration permits accurate placement of a nephrostomy tube that will give access to all calyceal branches. At times, a second nephrostomy may be necessary. In cases where there is no hydronephrosis, a ureteral occlusion catheter should be utilized. A staghorn calculus that completely fills the collecting system must be retrieved in a 1-stage procedure as there is no room for a large nephrostomy tube. A combination of endoscopes with ultrasound or electrohydraulic lithotripsy may be used. In cases where the stone composition is known and amenable to chemolysis, retained fragments may be dissolved using the appropriate solution.

Impacted Calyceal Stones

A 15 Fr flexible nephroscope with 5 Fr electrohydraulic lithotripsy probe may be used to dislodge and disintegrate most large calyceal stones. The infundibulum of the calyx may also be dilated with a short angioplasty balloon or cut with a thin wire placed through a ureteral catheter connected to an electrocautery unit.

Ureteropelvic Junction Obstruction

These stenotic areas may be incised with a cold knife using a standard direct-vision internal urethrotome or the blade provided with the rigid ultrasound nephroscope. The internal ureterotomy should be stented for several weeks.

Complications

Hemorrhage

Hemorrhage can be merely a nuisance and inhibit visibility, thereby causing premature termination of the procedure, or it can be massive and life-threatening [19, 20]. The source of bleeding is most commonly from parenchymal veins and is therefore best treated with insertion of a large-bore nephrostomy tube for tamponade. For serious arterial bleeding that is not tamponaded effectively by the tube, one may have to resort to arteriography and selective embolization. To stabilize clot formation from massive hemorrhage in the upper urinary tract, intravenous epsilon-aminocaproic acid has been useful. Although the clots persist for a long time, it is an effective measure and obviates further intervention. In our series of 167 renal units treated percutaneously, bleeding requiring transfusion occurred 7 times (4%). Most of these were concentrated in the first 50% of treated patients.

Long-Term Vascular Effects

Long-term vascular complications such as infarction, hypertension, and arteriovenous fistula are fortunately uncommon and should be dealt with appropriately.

Uroepithelial Perforation

Perforation of a collecting structure during removal of a stone results in massive extravasation and absorption of irrigation fluid. It is therefore necessary to use only normal saline as an irrigation solution to avoid dilutional hyponatremia. When a perforation is recognized, the procedure should be terminated and the nephrostomy tube replaced. Most perforations will heal within 3 days, thereby permitting subsequent stone manipulations. Our incidence of perforations requiring treatment was 0.6%. Stone fragments that have migrated outside of the collecting structures or into the nephrostomy track do not present a problem unless they are infected.

Pyelonephritis

Pyelonephritis can occur, despite continuous intravenous or oral antibiotic coverage during all phases of the procedure. It is more common in patients with stones caused by infection. Four (2.4%) of our patients had a spiking temperature which exceeded 101° F. One of these (0.6%) developed frank urosepsis.

Ureteral or Ureteropelvic Junction Stricture

The trauma of stone manipulation within the ureter or the shock and heat generated by the electrohydraulic or ultrasonic lithotripsy probes, respectively, may cause ureteral stricture. The more powerful electrohydraulic lithotripsy probe is not recommended for use within the ureter. No strictures have developed from the ultrasonic lithotripsy; however, it is important that the irrigating solution be adequately circulated and suctioned out through the probe.

Retained Stones

During any electrohydraulic or ultrasonic lithotripsy procedure, or in cases of multiple calyceal calculi, stones or fragments may be retained and serve as nidi for future stone formation. Careful nephroscopic and fluoroscopic inspection of the collecting system in addition to appropriate postoperative tomograms ensure that the system is stone-free. Also, procedures should be carried out only in those patients in whom it is expected that the kidney would be rendered stone-free. In our series, 87% of patients were rendered stone-free. Of the remainder, most were asymptomatic and had sterile urine. Thus, our clinical success rate was 96%.

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