Percutaneous Nephrolithotomy Access Under Fluoroscopic Control (Prone and Supine)

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Abstract Percutaneous endourological procedures require an advanced level of skills and the techniques used should be understood by those treating patients with complex renal stone disease to improve their ability to manage these often challenging clinical problems. The bull's-eye and triangulation methods are the most commonly used approaches, but refinements in technique and applications of new technology offer the potential for improved access with reduced patient and surgeon morbidity. Percutaneous puncture, tract dilation, and antegrade nephrostomy sheath placement into the desired calyx can be achieved rapidly and with precision when fluoroscopy is adequately used. For this reason and for patient comfort access is best achieved in the operating room by the urologist even in special situations like staghorn stones requiring multiple or supracostal accesses, caliceal diverticulum and horseshoe kidneys.

Keywords Fluoroscopy · Guided · Percutaneous renal access · Nephrolithotomy · Kidney · Stones · Calyx

The last years of the 1970s and the early 1980s will probably be remembered by urologists as a time of tremendous changes, in particular the whole concept of minimally invasive surgery and the development of percutaneous surgery, which have shown spectacular clinical results and reduced the morbidity of open surgery (Smith et al. 1979a). Percutaneous stone extraction was first described more than 30 years ago and has become an increasingly common intervention for patients with stone disease (Lee et al. 2004), evolving into a safe and effective treatment for patients with large or otherwise complex stone disease. However, despite the increasing use of percutaneous renal surgery, Lee et al. reported that only a minority of urologists,

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27% of who have trained in percutaneous access, actually gain their own access for percutaneous nephrolithotomy (PCNL) (Miller et al. 2007). One of the more common reasons given by respondents for not doing so was inadequate skills in the techniques of access.

The placement of percutaneous access into the intrarenal collecting system is one of the most critical aspects of percutaneous renal surgery. Image guidance is a critical factor for the performance of percutaneous minimally invasive procedures, which are being used with ever increasing frequency. Procedures such as PCNL are not performed without image guidance. The puncture of the kidney, insertion of guidewires, establishment of the percutaneous tract, and the disintegration and removal of stones are based on appropriate image guidance. For percutaneous renal surgery using fluoroscopy, access must be gained: different forms of access have been developed, all with the indispensable assistance of the image intensifier (Lee et al. 2004).

The first percutaneous nephrostomy to decompress an obstructed kidney was described by William Goodwin in 1955 (Lee et al. 2004). However, removal of a renal calculus via a percutaneous tract established specifically for that purpose was not performed until 1976, when Fernstrom and Johansson used the technique successfully in three patients (Lee et al. 2004). In their series, the tract was slowly dilated under fluoroscopic control over a 7-day period to a size sufficient for stone extraction. Similarly, Alken et al. in their experience with PCNL established access to the renal collecting system over the course of weeks (Alken et al. 1982). He subsequently developed the metal telescope dilators, which accelerates the procedure and allows stone removal in a single session. In 1982, Smith et al. described the rapid dilation of the nephrostomy tract in minutes with no untoward effects, which revolutionized the field of percutaneous stone surgery and contributed to the demise of open surgery (Smith et al. 1979b). Since that time the percutaneous approach has generated wide interest among the pioneers of endourology, and they developed and popularized most of the basic principles in this area in the late 1970s.

Fluoroscopy

Imaging equipment in percutaneous renal surgery typically uses radiation for image formation and guidance during access and tract dilation.

Fluoroscopy is useful during the advancement of guidewires, tract dilation, stone removal, and nephrostomy placement, providing realtime depiction of the collecting system and the stones therein. Percutaneous renal surgery is performed with a combination of fluoroscopic and endoscopic visualization of the collecting system. Fluoroscopy is a two-dimensional (2D) method and provides limited information regarding the surrounding soft tissue. Nevertheless, it has proven to be an invaluable tool for the performance of percutaneous procedures of the kidney and collecting system.

1 Radiation Exposure

All parameters of fluoroscopy affecting image quality, reproducibility, and radiation output from each radiographic unit must be evaluated routinely to ensure optimal image quality while minimizing the radiation dose (Chen et al. 2015). The endourologist can improve their imaging techniques and minimize both their and the patient's radiation exposure with no concurrent loss of image quality.

When attempting to obtain a diagnostic-quality image and the image is underpenetrated, and given the choice between increasing the total number of X-rays (mA) or the penetrability of the X-rays already present (kVp) to improve the image, the kVp should be increased initially as this will not increase the radiation output (Chen et al. 2015). Collimating the image to the minimum size necessary for performing the work will reduce the amount of unnecessary radiation.

The radiation output from the X-ray tube should have been evaluated within the past year by a radiologic physicist, who determines whether the unit's radiation output is within legal limits as well as optimal for each examination.

There have been various reports evaluating the typical radiation exposure from fluoroscopy during PNL, with an estimated effective dose (ED) between 7.63 and 8.66 mSv. Certain risk factors increase radiation exposure during PNL. These include high Body Mass Index (BMI), increased stone burden, and increased number of access tracts (Chen et al. 2015).

Radiation "spreads out" in a three-dimensional space with a discrete or fixed number of photons spreading out into successively larger spaces. As a result, the area geometrically increases as a function of distance from the source. Increasing the distance from the source is one of the least expensive and most dramatic ways to reduce the dose of radiation to which operating personnel are exposed. By doubling the distance from the source, the radiation is reduced to one-fourth of its original intensity because the same number of photons is in a space that is four times larger. Similarly, by tripling the distance, radiation is reduced to one-ninth. Moving 3 feet further away from an initial distance will reduce the dose by 89%.

The principle of radiation exposure As Low As Reasonably Achievable (ALARA) should be followed during procedures that require fluoroscopy. A drape placed over or under the patient helps reduce scatter radiation (Chen et al. 2015).

Shielding, whether provided by lead aprons or thyroid shields, is a method of last resort. They provide excellent protection and should always be worn by those who work near the fluoroscopy table to limit the dose of radiation to which they are exposed. When fluoroscopy is performed, the radiation dosimeter badge is worn on the collar, outside the apron. As a result of this technique, the actual effective whole-body exposure is up to 99% lower than the dose measured by the badge (Chen et al. 2015).

Component positioning on the C-arm can significantly influence scattered radiation fields. The image intensifier should be as close to the patient as possible and the image should be collimated as much as possible over the area of interest. When the image intensifier is placed above the patient, and the tube is shielded by the table, both leakage and scatter radiation are minimized. Foot control must be entrusted to the operator and not to a third party, allowing better coordination and audible alarms with fluoroscopy locking system are very useful.

The introduction of digital radiography has contributed to the reduction of radiation exposure as well as to the improvement of image quality (Spelic et al. 2010).

Radiation exposure can be a deleterious problem in percutaneous surgery, especially for the surgeon (Yang et al. 2002). There are two types of generalizable effects from radiation exposure: deterministic and stochastic effects. Deterministic effects are dose-related, and stochastic effects are characterized by the absence of a threshold dose. Risk of malignancy from radiation exposure is a stochastic effect. The National Council on Radiation Protection and Measurements has recommended an annual occupational limit of 50 mSv (United States Nuclear Regulatory Commission 1991). In medicine, there are no suggested limits for patient exposure. Instead, the risks from radiation must be balanced with the clinical necessity and benefit of the imaging study or procedure (Chen et al. 2015). The use of ultrasonography can eliminate or reduce the side effects of radiation exposure during fluoroscopy-guided PCNL.

2 Ultrasound Versus Fluoroscopy-Guided Access

The advantages of ultrasound over fluoroscopy-guided access into the collecting system include reduction of exposure to radiation for the urologist and operating room personnel. In pregnancy and in patients with transplanted, horseshoe, or ectopic kidneys, ultrasound represents the modality of choice (Evans and Wollin 2001; Francesca et al. 2002). Another advantage is proper localization of the adjacent organs for prevention of injury. The main disadvantage of this modality is the difficulty and the need for greater care when the collecting system is only mildly dilated.

Ultrasound has been used by several groups for the guidance of PCNL, especially during the puncture of the collecting system (Skolarikos et al. 2005). The performance of puncture with ultrasound guidance and without use of fluoroscopy has also been reported (Skolarikos et al. 2005). While ultrasound can be a useful complement to access the kidney, it should be emphasized that fluoroscopy is an indispensable component of safe percutaneous surgery.

Preoperative images

Conventional computed tomography (CT) has been used for diagnosis of urologic diseases for many years. Recently, unenhanced helical CT has become a serious alternative to intravenous urography (Thiruchelvam et al. 2005). For preoperative planning, helical CT depicts the extent, orientation, and location of renal calculi, which are useful for access selection in percutaneous procedures. In addition, the anatomic relationships of the collecting system with surrounding organs are delineated, and the performance of a safe puncture is possible (Thiruchelvam et al. 2005).

Nevertheless, the inability to provide realtime imaging capability has prevented wider application of CT in interventional procedures (Thiruchelvam et al. 2005).

The three-dimensional (3D) reconstruction of CT images for planning of percutaneous procedures has been reported to be feasible and accurate. With the use of 3D rendering software, the anatomic relationships of the collecting system are provided, and access selection is facilitated. The usefulness of 3D-reconstructed CT images, however, is not widely accepted (Park and Pearle 2006).

Systems as Uro Dyna-CT (Siemens Healthcare Solutions, Erlangen, Germany) installed in the endourologic operating suite provides not only standard X-ray and fluoroscopy but also interventional 3D imaging and cross-sectional image reconstructions. It also offers a 3D planning and laser-guiding puncture tool called the syngo iGuide. It may be an additional instrument that allows the urologist to handle complex punctures (Ritter et al. 2015).

Magnetic resonance imaging (MRI) provides better depiction of the soft tissue in comparison with fluoroscopy and CT, but remains unreliable for the identification of stones in the collecting system or ureter.

Each of these new technologies offers several potential advantages over the traditional percutaneous approach under fluoroscopic control. It should, however, be stated that all of these technologies are in a nascent stage of development. For that reason it is necessary to reinforce the basic concepts governing the realization of a conventional procedural approach to the kidney under fluoroscopic control. While this conventional approach is appealing, only a small percentage of urologists are familiar with it (Miller et al. 2007), and various training models are essential for consolidating the use of this surgery (Häcker et al. 2007).

Percutaneous renal access under fluoroscopic control

The information provided by preoperative helical CT is very valuable at the time of puncture under fluoroscopic control (El-Nahas et al. 2004), as it identifies the most suitable place to set the path of the needle from the skin to inside the calyx that has been chosen for tapping. A CT scan can assess the presence of adjacent organs brought into the path of the needle. In this case, there is the option to change that path at the time of puncture under fluoroscopic control or to decide that percutaneous access is contraindicated.

When deciding where to make the puncture, areas of parenchyma should be considered that are thick enough to maintain a stable needle path and prevent subsequent development of a fistula. Also, it is desirable to identify those calyces for which surrounding thickness of parenchyma will promote their spontaneous closure of the puncture. Areas of kidney with an extremely thin parenchyma should be avoided.

Also, the information provided by helical CT will allow paths to be planned that avoid simple cysts, which sometimes are present in the renal parenchyma and are frequently not picked up on fluoroscopy.

The collecting system is opacified with direct injection through the ureteral catheter of contrast. A posterolateral transparenchymal puncture minimizes the chance of injury to the major renal vessels. The chosen posterior calyx is visualized with the C-arm fluoroscopy unit in the posteroanterior direction initially.

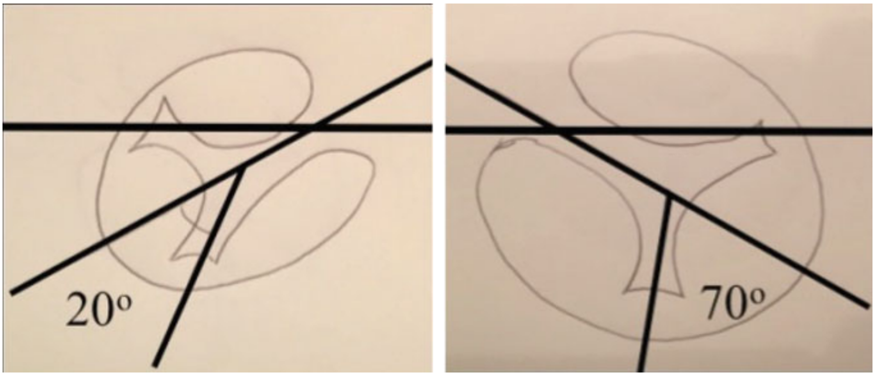

Fig. 1 Schematic view of both kidneys. Right kidney: posterior calyces positioned 20° posteriorly to the its own frontal plane. Left kidney: posterior calyces positioned 70° posterior to its frontal plane

The posterior calyces are positioned 20° posteriorly to the frontal plane of the kidney in most right kidneys, and 70° posterior to the frontal plane of the kidney in most left kidneys. In a normally rotated kidney, the frontal plane of the kidney is 30° posterior to the coronal plane of the body (Fig. 1).

In general, all patients undergoing any percutaneous renal procedure are given a general anesthetic.

2.1 PNL Position Variations

PNL may be performed in different positions, but some steps are common to the different techniques.

First step. A rigid cystoscope is used to place a 0.036-inch Teflon-coated guidewire into the upper collecting system. When a tortuous area blocks the progress of the guidewire, a wire with a hydrophilic guide-wire coating must be used. When the guidewire is in position, the 6F catheter is advanced over it to the renal pelvis, and the endoscope is removed.

To perform percutaneous access also some steps are common to every technique variations. The percutaneous access is created via an upper, middle, or lower calyx. Thorough evaluation of the renal collecting system anatomy is essential prior to definitive percutaneous puncture for access tract creation.

Percutaneous access to the upper urinary tract through a calyx must meet five conditions that guarantee safe access and avoid complications:

- Performed from a posterolateral position
- Performed through the renal parenchyma
- Toward the center of the calyx posterolaterally

- Toward the center of the renal pelvis
- As a result of these four conditions, the trajectory does not damage any major blood vessels.

2.2 PNL in Prone Position

The patient is placed in a lithotomy position for cystoscopy, with insertion of a 6F open-end ureteral catheter under fluoroscopy guidance.

A retrograde urogram then delineates the ureteral anatomy, as well as the exact stone location, degree of hydronephrosis, and the image of the selected calyx (Bernardo and Smith 2000).

After cystocopy, a 16F Foley catheter is inserted. Both catheters are tied with 2-0 silk to secure them in place. It is helpful to connect an empty syringe to the Luer lock adapter at the end of the ureteral catheter to prevent urine leakage.

The patient is positioned prone. The patient is moved slowly and gently to allow the body to adjust to the position change. A foam rubber pillow is placed under the head to prevent it from being angulated excessively in relation to the trunk. The endotracheal tube is placed in the side slot of the foam pillow, making sure that the tube is unobstructed and free from kinks. To reduce resistance to breathing, the chest and abdomen are elevated on two foam rubber rolls that extend from the shoulder to the hip. Knee donuts padded with sheepskin inside the ring are positioned between the knees and the operating table to protect the bony prominences. A foam rubber roll is placed anterior to the ankles. The arms are flexed and secured on padded arm boards, and the elbows are protected with sheepskin pads. At this time, the 2-0 silk tie securing the two catheters together is cut and discarded. The intravenous extension tubing is connected to a 60-mL syringe containing 25% diatrizoate (Hypaque) solution, and the tubing is primed and connected to the ureteral catheter.

Peercutaneous access. There are two primary methods used to gain fluoroscopy-guided percutaneous renal access: the "bullseye" technique and triangulation (Miller et al. 2007). Both techniques need a target, most commonly generated by opacification of the collecting system with iodinated contrast that is administered retrograde via a ureteral catheter. A calyceal entry point is selected to avoid the larger vascular structures that are found at the level of the infundibulum.

As with most percutaneous access techniques, the bullseye technique requires fluoroscopy to monitor and guide the procedure. To this end a ureteral catheter is placed and the patient is positioned as described above. With the C-arm in the 30° position, an 18G diamond tip access needle is positioned, so that the targeted calyx, needle tip, and needle hub are in line with the image intensifier, giving a bullseye effect on the monitor. In effect the surgeon is looking down the needle into the targeted calyx. The needle is advanced in 1–2-cm increments using a hemostat to minimize radiation exposure to the surgeon. Continuous fluoroscopic monitoring is performed to ensure that the needle maintains its proper trajectory. Needle depth is ascertained by rotating the C-arm to a vertical orientation. If the needle is aligned with the calyx in this view, the urologist should be able to aspirate urine from the collecting system, confirming proper positioning.

The triangulation technique is based on simple geometric principles and is guided by biplanar fluoroscopy; one plane is anteroposterior to the line of puncture and the other is oblique. The anteroposterior view may be considered to be in a plane parallel to the axis of puncture and is used to monitor mediolateral (left–right) adjustments. The oblique view gives information regarding depth to the site of puncture and is used to monitor needle adjustments in the cephalad–caudad (up–down) orientation.

The tip of the needle is oriented towards the calyx to be punctured in both the anteroposterior and oblique planes. Left–right adjustments are limited to the anteroposterior view only, and cephalad–caudad adjustments are limited to the oblique view. When making adjustments in the mediolateral axis, care should be taken not to inadvertently move the needle in the cephalad–caudad axis, and vice versa. In most cases, it is helpful for the surgeon to rest their arm on the patient during the access part of the procedure, as this minimizes unintended drifting of the needle away from the targeted axis and also provides additional needle stabilization.

To decrease the radiation exposure to the surgeon's hands, the C-arm should be oriented with the image intensifier angled toward the head of the patient. Whenever possible, the iris of the fluoroscope should be kept as small as possible, to further minimize stray radiation exposure. Once the needle is aligned with the targeted calyx in both the mediolateral and cephalad–caudad orientations, it is advanced with continuous fluoroscopy. The needle should always be advanced in the oblique view, which will allow for the assessment of the depth of the needle's penetration. It is helpful for the anesthesiologist to hold the patient's respirations while the needle is being advanced, to avoid having to "hit a moving target", as well as to minimize the risk of an inadvertent transthoracic puncture. After advancing the needle several centimeters in the oblique view, the anteroposterior view should be examined to confirm that the mediolateral trajectory of the needle is still properly aligned to the target. If necessary, the needle trajectory can be readjusted to maintain proper targeting. Again, it is critical not to alter the access needle's orientation in one plane while making adjustments in the other plane, particularly when advancing the needle.

Several groups have reported refinements in techniques, incorporating elements of the bullseye and triangulation methods, proposing new approaches, describing adjuncts, and using new technology. A geometric model was described to create a plane of coincidence between the C-arm and the needle, each at the same angle of 20–30° from the targeted calyx, but in opposite directions (Bernardo and Smith 2000). For lower pole access, the C-arm is rotated cranially 30° from the vertical plane, and a needle is advanced from a position distal to the calyx, rotated caudally 30° from the vertical plane. For mid-renal and upper pole calyceal access, the C-arm is rotated 20° away from the surgeon, and a needle is advanced from a position lateral to the calyx, at an angle of 20° toward the surgeon from the vertical plane. In either case, the C-arm remains fixed, and the needle is advanced until the point of coincidence between the calyx and the needle tip is reached. This technique purportedly eliminates the need for C-arm rotation, thus potentially reducing C-arm manipulation and fluoroscopic exposure time. This technique, however, requires a plumb, protractor, and ruler to calculate and confirm the necessary measurements.

Another recently proposed modification by Sharma and Sharma represents a hybrid of the bullseye and triangulation techniques (Sharma and Sharma 2009). The posterior calyx that provides the best access for stone clearance is selected. The initial puncture needle is held at this point. The needle with its overlying hub in the same line as the calyx creates a bullseye effect on the C-arm monitor. The site on the skin corresponding to the target calyx is thus determined, and its position is marked with a hemostat as point A. We place an intramuscular needle at this point instead of a hemostat. Then, under direct vision, the needle is placed vertically and the puncture is made at this point in the subcutaneous cellular tissue at a depth of about 1 cm (Fig. 2A). The visual control of the needle in the vertical position reduces fluoroscopic exposure to a few seconds. Subsequently, a brief fluoroscopic exposure is used to check the position of the needle and it is shown on the screen as a point. The trajectory of the line of puncture of the needle into the dorsal area represents an imaginary line through the selected calyx in the anteroposterior direction. However, this trajectory does not meet all five requirements for optimum puncture, described above, as the needle is not directed toward the center of the renal pelvis.

The C-arm is then angled toward the surgeon, 30° from the vertical in the axial plane. With the ventilation suspended in end expiration, the second puncture needle is held over the targeted calyx in such a way that the needle with its hub is in the same line with the calyx, which leads to a bullseye effect on the C-arm. This particular point on the skin is punctured with an intramuscular needle and is taken as point B (Fig. 2B). This position represents an imaginary line that is projected onto the center of the selected calyx. Again, all five requirements for safe renal puncture are not met because the trajectory is not toward the center of the renal pelvis. This position is checked in relation to the 12th rib. Visually observing the trajectory of the two small needles placed in the lumbar area, the intersection of two lines coincides with the desired calyx.

The distance between the two needles is measured (Fig. 3A). The C-arm is then brought back to its vertical position. Now the line of puncture is determined in alignment with the infundibulum from point A. Along this point line, the point B1 is marked. The distance between points A and B1 is equal to or greater than the distance between the intramuscular needles (points A and B) (Fig. 3B). The point B1 is the point where the skin is punctured for renal access. A small incision is then made at point B1 and the 18G needle is introduced for 1–1.5 cm (Fig. 4). Now, with the C-arm in the 90° vertical position (i.e. parallel to the line of puncture), the mediolateral (right to left) adjustments are made. Then the C-arm is tilted toward the head of the patient by 30° and adjustments are made in the cephalad and caudal orientation of the line of puncture. The needle orientation is maintained in one plane while making adjustments in the other plane. With the C-arm in the oblique orientation, the needle is advanced with ventilation suspended in full expiration. Under fluoroscopic control and from this position, the 18G needle is advanced towards the point of intersection of the two lines that project both intramuscular needles to reach the selected calyx.

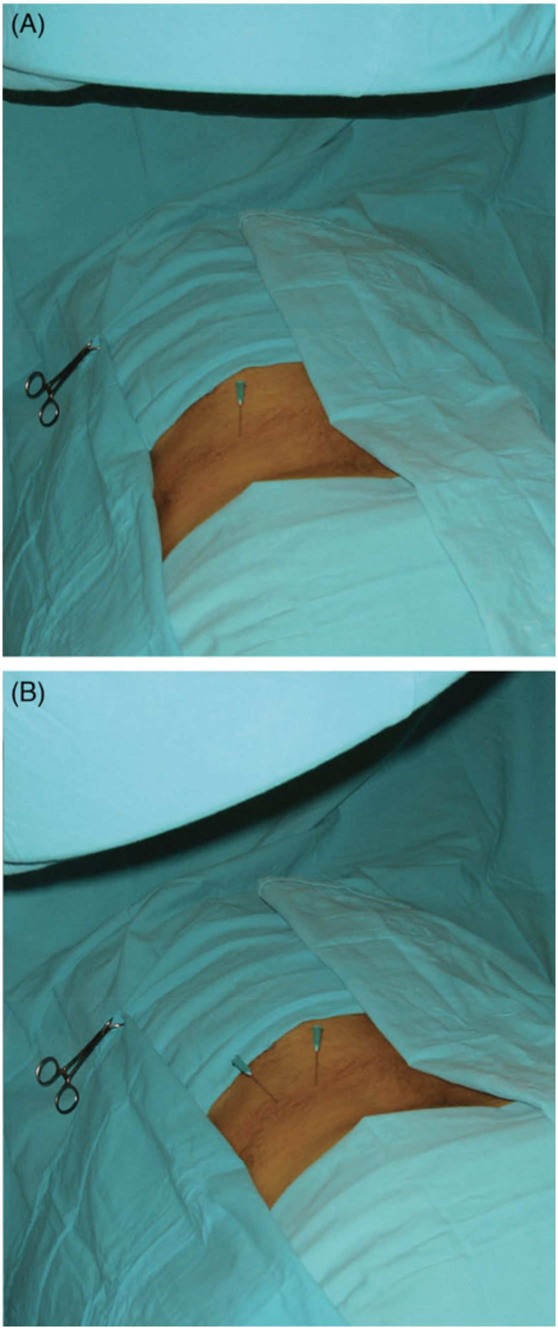

Fig. 2 (A) The intramuscular needle with its overlying hub in the same line as the calyx creates a bullseye effect on the C-arm monitor. The needle is placed upright and puncture is done at this point at a depth of about 1 cm in the subcutaneous cellular tissue. (B) The C-arm is angled 30° toward the surgeon. The second needle is held over the targeted calyx in such a way that the needle with its hub is in the same line with the calyx, which leads to a bullseye effect on the C-arm

This is the ideal path and the only one that meets the five requirements described above of a safe percutaneous renal puncture.

When the tip of the needle appears fluoroscopically to be within the collecting system, the needle trocar is removed, leaving only the needle cannula in place, and a small amount of urine is aspirated to confirm the needle's intraluminal position.

Definitive puncture of the renal collecting system with an 18G diamond needle permits the immediate introduction of a 0.038-inch guidewire into the collecting

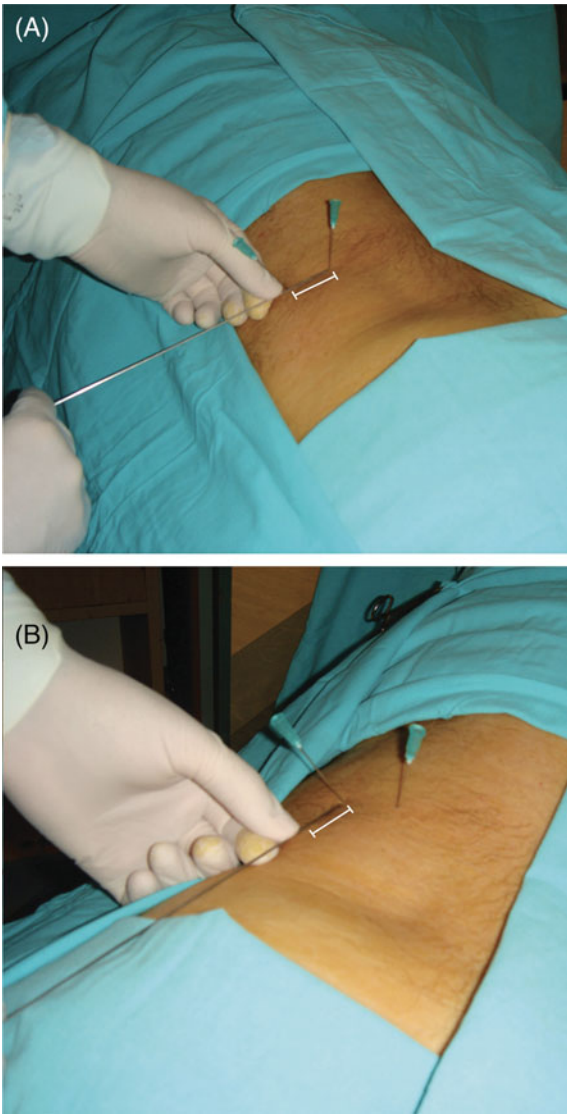

Fig. 3 (A) Distance between the two needles is measured (points A and B). (B) B1 is the point where the skin will be punctured for renal access. The distance between points A and B1 is equal to or greater than the distance between the intramuscular needles

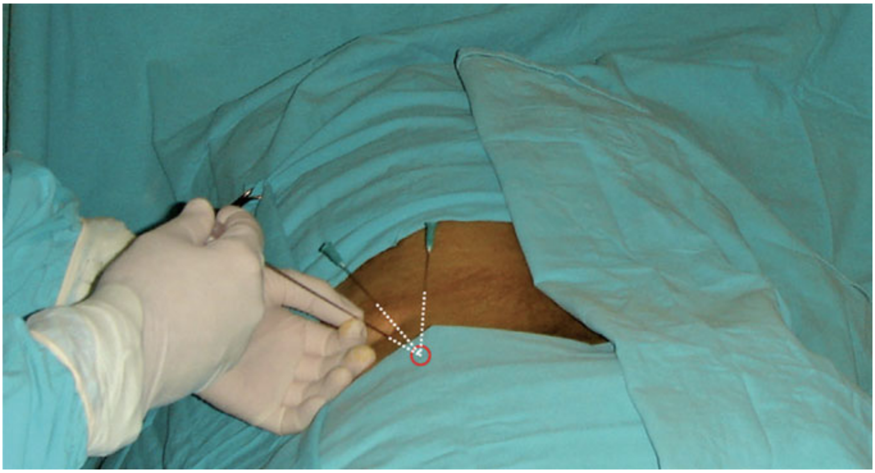

Fig. 4 The intersection of the two lines of small needles placed in the lumbar area coincides with the desired calyx. The 18G needle is advanced under fluoroscopic control towards the point of intersection of the lines that project both intramuscular needles in order to reach the selected calyx

system. The rigidity of this needle is advantageous for accurately directing the needle diamond tip as it is advanced through the fascial planes.

If at the point of withdrawing the trocar of the needle spontaneous output of urine has not been observed, it is advisable gently to try to introduce a hydrophilic guidewire, observing the advancement of the guidewire under fluoroscopy. Typically, it moves into the cavity of the calyx and progresses towards the renal pelvis. If for some reason the guidewire does not easily advance, it is advisable to inject an additional volume of contrast through the initially placed ureteral catheter with the intention of filling the calyx cavity and thereby facilitating the progression of the hydrophilic guidewire.

If no urine exits from the 18G needle, it is not advisable to inject contrast through the needle, since contrast can extravasate, creating a lake of radio-opaque material and making it difficult to visualize the shape of the kidney cavities.

2.3 PNL in Supine Position

Although PNL in prone position offers several advantages, as a larger surface area for the choice of puncture site, a wider space for instrument manipulation and a possibly a lower risk of splanchnic injury (Ibarluzea et al. 2007); in the last decades, several reports have been published of percutaneous renal surgery in the supine, modified supine or lateral position (Valdivia Uría et al. 1998). This has potential advantages over the prone position for PCNL and has been adopted by many urologists. The modified supine position preserves cardiovascular and ventilatory dynamics and allows better access to the respiratory tract. Additionally, the bowel slips away from the puncture area, lowering the risk of it being damaged. PCNL with the patient in a modified supine position may be considered for most patients, especially if concomitant ureteroscopy and Endoscopic Combined Intrrenal Surgery (ECIRS) is planned (Daels et al. 2009).

First descriptions of PNL in supine position were performed by Valdivia et al. in the late 80's (Ibarluzea et al. 2007). The key point in this surgery is to take time to locate the patient previous to initiate the surgery, instead of doing it at the time of position change (prone PNL). With the patient under general anesthesia, an inflated 3 L serum bag with water or air is placed under the patient's lumbar region of the side to be treated. This bag generates an intermediate lateral position. It is relevant to locate patient´s flank and the edge of the bag alongside the surgical table edge to allow a greater degree of movement to the nephroscope. The contralateral leg is flexed and located in a lower plane (this facilitates an eventual ureteroscopy access) on leg support 90 degrees, while the homolateral leg remains extended also on leg support. Ipsilateral arm is flexed and fixed. After locating the patient, simultaneous antisepsis to lumbar and genital regions are performed (Fig. 5A and B).

After cystoscopy (as descipted above), 6 Fr catheter is located and time to perform the access to the kidney has become.

With this technique it is possible to puncture the calyceal papilla without having to rotate the C-arm fluoroscope, fluoroscopic control is maintained perpendicular to the needle and renal access.

Initially a long metal instrument, as the nephroscope or Alken dilator, is overlaid on the patient's abdomen and under fluoroscopic control its distal tip is placed over the selected calyx. This point is marked on lumbar fossa of the patient and indicates the orientation of the needle. Entry point must be placed always behind the posterior axiallary line to avoid colonic damage.

Needle advances in an ascending direction in the search to the selected calyx papylla. Once kidney´s capsule is reached, calyx dilation with contrast is needed. At this point subjective perception of kidney movements is important. If backward kidney movement and/or calyceal distortion is perceived, the needle can advance and get into the selected calyx. If depth orientation is wrong, it is necessary to remove the needle from the kidney and retry to locate the calyx again in a higher or lower direction.

When the selected calyx has been reached and the first urine drops are obtained through the needle, the guidewire is introduced and the tract can be dilated (Valdivia Uría et al. 1998). After performing the needle access, procedure to check the correct location and to perform dilation are the same that were described above to PNL in prone position.

Many variation of the original supine position have been described. Some urologists prefer the "pure supine" position; to perform this technique, an special surgical table is needed (without metal bars) to locate the patient in the edge of the table and with no bag beneath the lumbar region. Other variant is to place two bags instead of one (in lumbar region and hip), what could allow more movement to the nephroscope. Finally, another variant of the way to locate the patient is to rotate the patient more

Fig. 5 View of patient in final position previous to initiate PNL in supine position. (A) punction view. (B) cystoscope view

than in original description; in this technique, the direction of the needle advance is more horizontal than ascending.

2.4 PNL in Lateral Position

When PNL is performed in lateral position it is important to consider the different degree of rotation presented by the posterior chalices of each kidney, as previously mentioned. In most right kidneys, the posterior calyces are positioned 20 degrees posteriorly to the frontal plane of the kidney, and in most left kidneys 70 degrees posterior to the frontal plane of the kidney (Fig. 1). This shows that in left stones the needle will be inserted in a direction almost parallel to the operating table, while, in right stones the needle will be inserted in downward position.

Triangulation technique is used, determining the cephalad-caudal axis with the C-arm in anteroposterior configuration, and determining the anteroposterior axis with the C-arm in oblique configurations (El-Husseiny et al. 2009).

Once reached the calyx, the wire is introduced and we can proceed to dilation.

2.5 Challenging Situations

In situations where the volume of the stone occupies the entire volume of the calyx selected to be punctured, the needle is advanced until there is the tactile sensation of the needle tip touching the hard surface of the stone. In this situation the tip of the trocar of the needle is in contact with the stone but the cannula of the needle is at a distance of 1–2 mm from the surface of the stone. It is advisable to then move the cannula on the trocar toward the stone until contact with the surface of the stone is felt. Then the trocar needle is removed and the hydrophilic guidewire is gently inserted into the narrow space between the urothelium of the calyx and the surface of the stone. Sometimes this allows the advancement of the guidewire to the renal pelvis, but in other situations it is only possible to locate the guidewire in the punctured calyx and attempting otherwise is risky because of the short length of the guidewire in the upper urinary tract. The guidewire is advanced carefully across the calyceal infundibulum.

2.6 Dilation

To perform the tracts dilation, 1-cm skin incision is made around the needle with a No. 10 blade, and the needle is removed. Then, in order to enlarge the defect in the lumbar fascia, a fascial incision needle can be used (No. 090070 Cook Urological). This instrument consists of an 18G needle fixed to a small, blunt, diamond-shaped blade that is passed over the puncture wire under fluoroscopic control, through the abdominal wall until it crosses the lumbar fascia. It is then withdrawn while gentle traction is placed on the puncture wire, and the tip of the blade is rotated 90° and then advanced again over the puncture wire in order to open the lumbar fascia more extensively. This action will facilitate the introduction of any of the available dilation systems.

Acute dilation of nephrostomy tracts can be performed with a variety of instruments. These instruments are inserted over a working guidewire. Because of the risk of perinephric guidewire kinking with loss of the nephrostomy tract and laceration of the renal parenchyma, all percutaneous dilator systems require fluoroscopic guidance (Falahatkar et al. 2009).

The nephrostomy tract is dilated to the desired width. In the serial dilation system, an 8F Teflon catheter is used as an obturator. Progressively larger dilators are then serially inserted over this guidewire. This additional obturator stiffness greatly reduces the risk of perinephric guidewire buckling.

With the access tract dilated, a working sheath is introduced into the collecting system. The renal pelvis is examined nephroscopically to identify the obstructed segment of the ureteropelvic junction (UPJ) and locate the previously placed ureteral catheter. If necessary, either the ultrasonic probe or the grasping forceps are passed into the renal pelvis to clean out clots.

The catheter is grasped and brought out through the nephrostomy tract. A 0.038-inch super-stiff wire, which is a fixed core guidewire with an extra-stiff shaft and a flexible tip, is advanced through the catheter. A surgical assistant removes the ureteral catheter, leaving the guidewire in place at the urethral meatus. This maneuver ensures the preservation of the nephrostomy tract, so that if the access route to the kidney is accidently lost, it is easily recovered by following the guidancedescribed above. Additionally, if for some reason the procedure has to be interrupted, placement of the nephroureteral stent will allow both drainage and subsequent easy access.

Special situations: multiple access

In the treatment of complex renal lithiasis with branches in multiple calyces, it is sometimes necessary to make multiple punctures through different calyces. The multiple punctures can all be made initially or after removing part of the stone burding.

If the planned multiple punctures are made at the beginning of surgery, the injection of contrast through the initially placed ureteral catheter facilitates visualization of all calyces and the most suitable for punctures can be chosen in accordance with the silhouette of the stone.

In contrast, if multiple punctures are made in addition to establishing a unique initial nephrostomy tract, the calyceal distention may be achieved by placing a Foley catheter and to inflate the balloon inside the Amplatz sheath to occlude its caliber. Thereafter it is possible to inject contrast either through the ureteral catheter placed at the beginning of surgery or the Foley catheter, and to place a clamp to prevent leakage of contrast from the distended renal cavity.

3 Conclusions

Percutaneous endourologic procedures require an advanced level of skill. The techniques used should be understood by those treating patients with complex renal stone disease to improve their ability to manage these often challenging clinical problems. The bullseye and triangulation methods are the most commonly used approaches, but refinements in technique and applications of new technology offer the potential for improved access with reduced patient and surgeon morbidity. Percutaneous puncture, tract dilation, and antegrade nephrostomy sheath placement into the desired calyx can be achieved rapidly and with precision when fluoroscopy is adequately used. For this reason and for patient comfort, access is best achieved in the operating room by the urologist, even in special situations like staghorn stones requiring multiple or supracostal accesses, calyceal diverticulum, and horseshoe kidneys.

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