

Surgery Illustrated

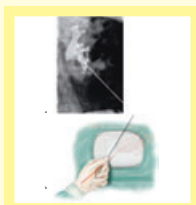
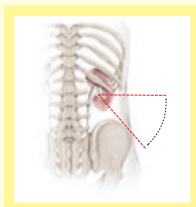
Surgical Atlas

Percutaneous nephrolithotomy: the Mannheim technique

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INTRODUCTION

Proper establishment of the percutaneous tract is the most important step in percutaneous stone removal. If appropriately done the efficacy is optimal, with low complication rates. Depending on the availability of fluoroscopic facilities, in different countries the tract is established either by radiologists or urologists; this is still under debate in reports in the American literature [1–5]. Recently, Watterson *et al.* [5] compared renal access acquired by urologist vs radiologist and showed a higher stone-free rate and fewer complications by the former. This confirms our data indicating that the urologist should obtain renal access to achieve the optimum renal access for later stone removal [6].

To establish proper access to the collecting system (CS), as much information as possible should be obtained about the stone and the patient's anatomy. For this, the combination of fluoroscopy and ultrasonography (US) is optimal. Opacification of the renal CS by i.v. injection with dye or by a retrograde ureteric catheter renders the CS visible and helps to identify its distribution accurately. US will visualize all other structures, e.g. the renal parenchyma, stones of all compositions and all surrounding organs like spleen, intestine, liver, pleura or ribs and, most importantly, simultaneously the needle during puncture. The advantage of this combined visualization is to obtain real-time pseudo-three-

dimensional information while establishing the percutaneous access [6].

PLANNING AND PREPARATION

Percutaneous nephrolithotomy (PNL) is recommended by the Guidelines of the European Association of Urology for the following indications [7]:

- Large stone burden >2 cm or 1.5 cm for lower calyceal stones.
- Staghorn stones.
- Stones that are difficult to disintegrate by ESWL (calcium-oxalate monohydrate, brushite, cystine).
- Stones refractory to ESWL or ureteroscopy.
- Urinary tract obstructions that need simultaneous correction (e.g. PUJ obstruction).
- Malformations with reduced probability of fragment passage after ESWL (e.g. horseshoe or dysplastic kidneys, calyceal diverticula).
- Obesity

All patients need preoperative imaging including a plain abdominal film and IVU. If the use of contrast agents is not possible, the CS can be opacified via a retrograde ureter catheter during the intervention. CT-guided access has been described for difficult cases but was never necessary in our experience [8]. Thorough US before intervention, to evaluate if the access to the stone can be established with no problems, is essential for planning of the procedure. Ideally, the urologist who will do the PNL should also do this.



Figure 1

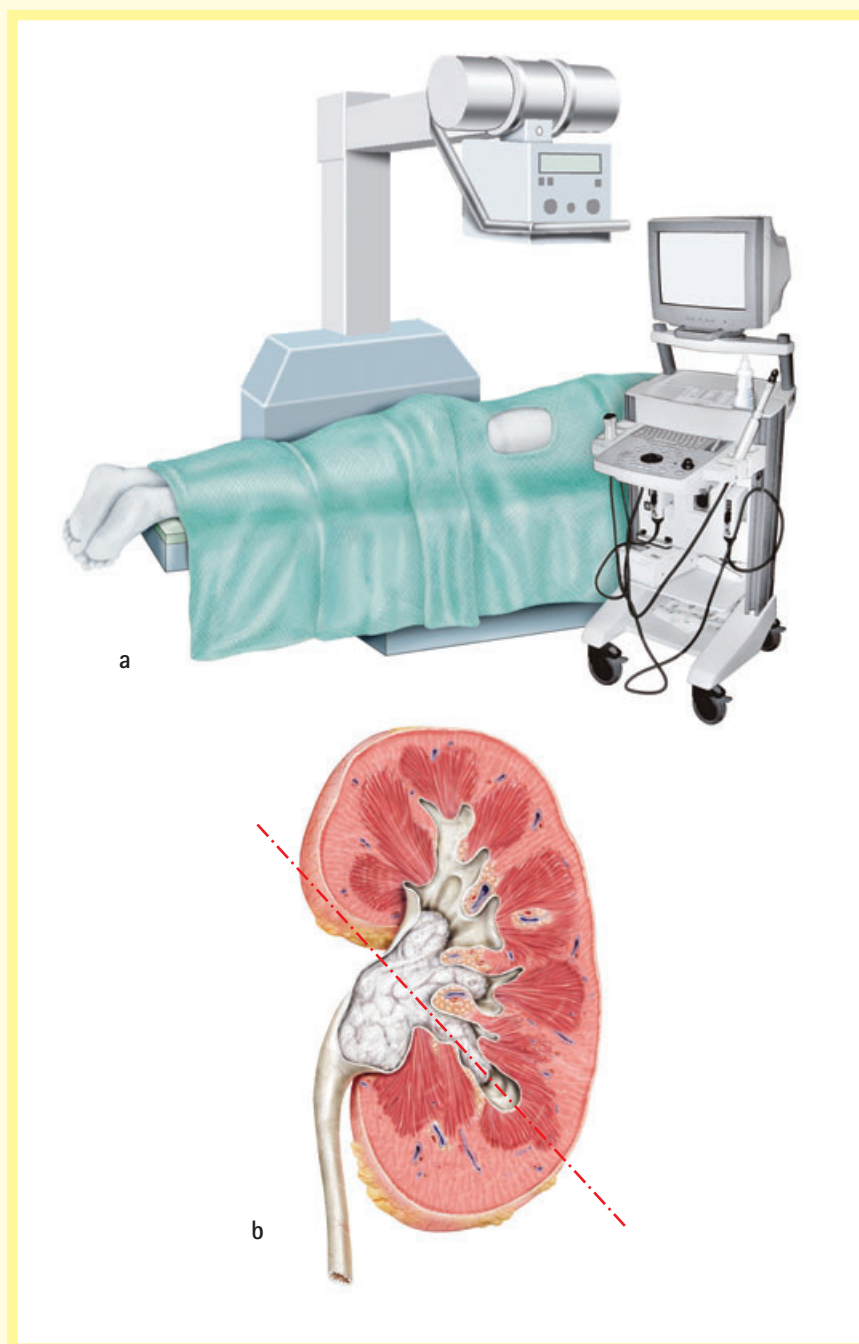
Equipment for PNL includes:

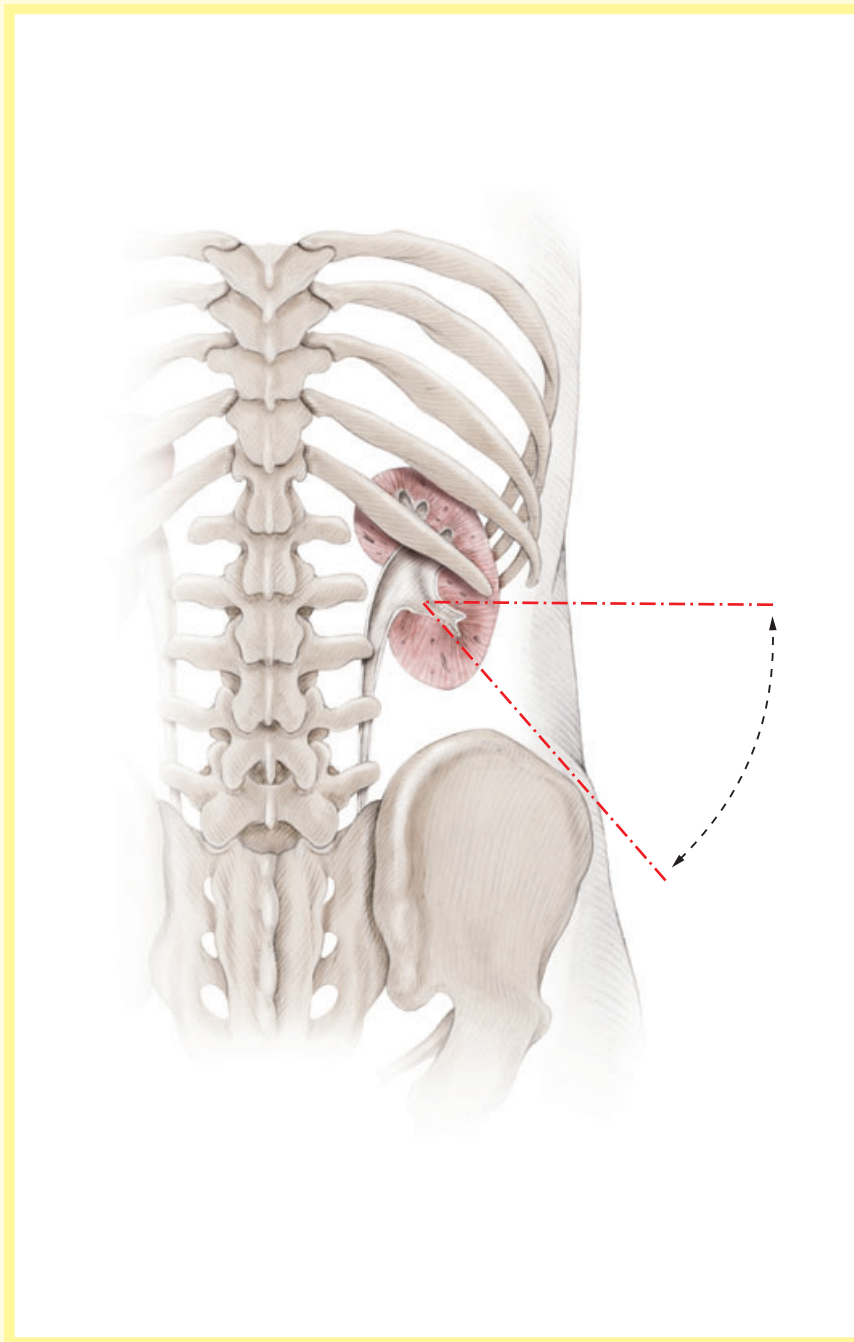
- Fluoroscopy unit (Fig. 2a).
- Video-endoscopy.
- US scanner with needle-guide adapter,
- Balloon occlusion catheter 5 F (i.e. #340–80, Rüsch, Germany).
- Foley catheter 18 F for fixing the occlusion catheter.
- Sterile coverings.
- Puncture needle 9 F (Fig. 1.1).
- Contrast dye,
- A set of guidewires (floppy tip J-guidewires, glide wires, Lunderquist wires).
- Metallic dilator cannula 9 F with metal sheath 11 F (Karl Storz Endoscopes, Germany, Fig. 1.4).
- Metal telescope dilators with hollow guide rod (9–24 F, Karl Storz; Fig. 1.5).
- Rigid nephroscopes 18 F and 26 F (6° telescope, Karl Storz; Fig. 1.6, 1.7).
- Sodium chloride irrigation fluid (0.9%).
- Ultrasound lithotripsy equipment with 9 F probe (Karl Storz; Fig. 1.4a–c).
- A set of stone forceps (9 F) and baskets.
- Flexible scopes 8 F and 15 F (Karl Storz).
- Ho:YAG laser and 220/365 μm laser fibres (i.e. Karl Storz).
- Half-open slotted cannula 22 F (Karl Storz; Fig. 1.8).
- Foley catheter 22 F (nephrostomy).
- Suture material.

Specific preparation of the patient before surgery is not necessary and depends on anaesthetic demands. Usually the patient is under general anaesthesia for PNL. Perioperative antibiotics are administered as a precaution (i.e. ciprofloxacin or cotrimoxazole). UTI should be excluded by dipstick analysis and urine culture before surgery if necessary. If there is active infection antibiotics should be adapted to specific testing and started some days beforehand. However, sterile urine can often not be obtained, especially in patients with infection-associated stones.

Figure 2

Fig. 2a: Operating room setting with the patient placed on the fluoroscopy desk, monitors for fluoroscopy, US and instruments. If the renal CS is unobstructed, a balloon occlusion catheter is initially placed, with the patient in the lithotomy position to facilitate the puncture. The balloon has to be blocked just below the PUJ. A Foley catheter is then placed and fixed together with the occlusion catheter with tape. The patient is placed prone on an X-ray table with all pressure points padded. The CS is opacified and slightly dilated by retrograde dye instillation. Fig. 2b: The ideal approach to the stone is achieved by a transpapillary puncture with straight access to the renal pelvis.

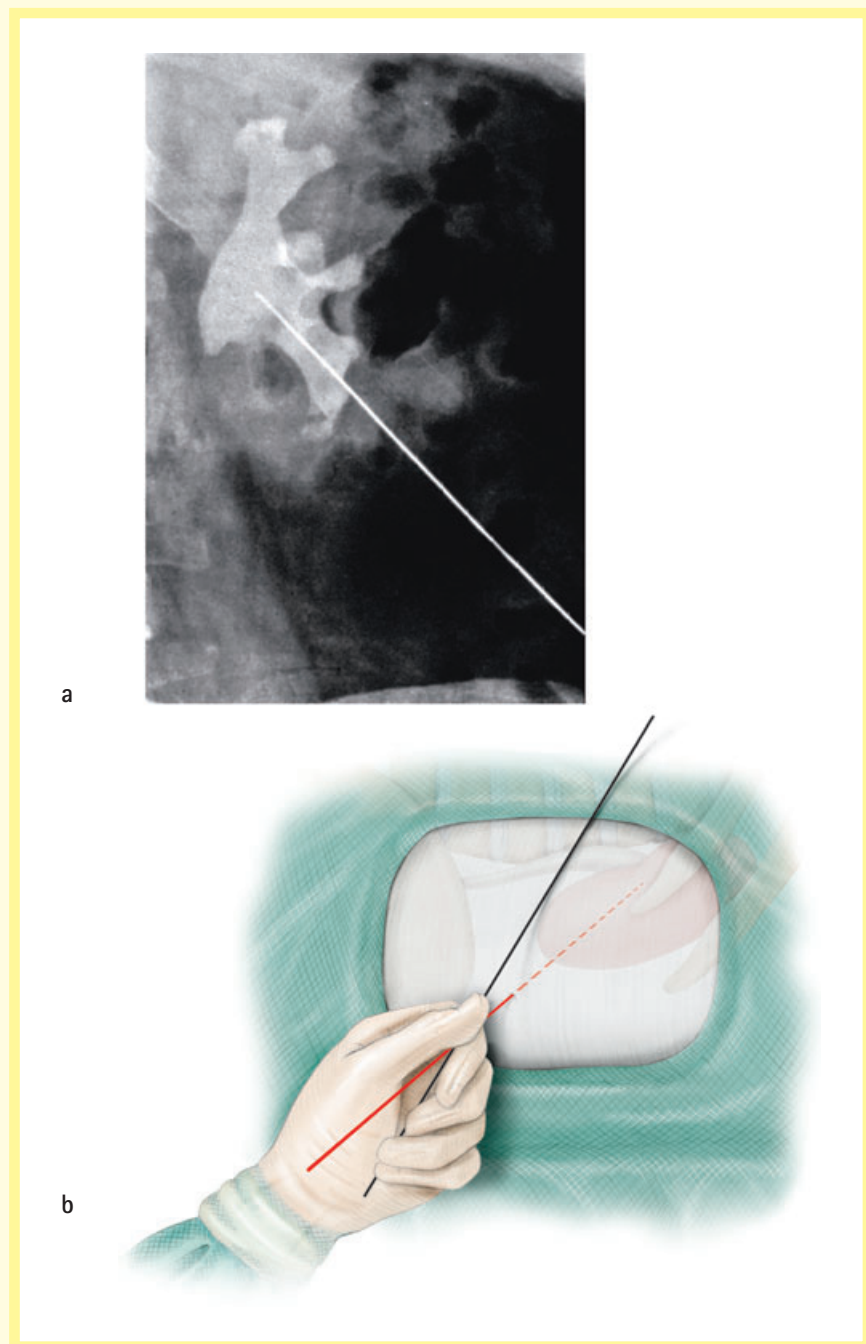


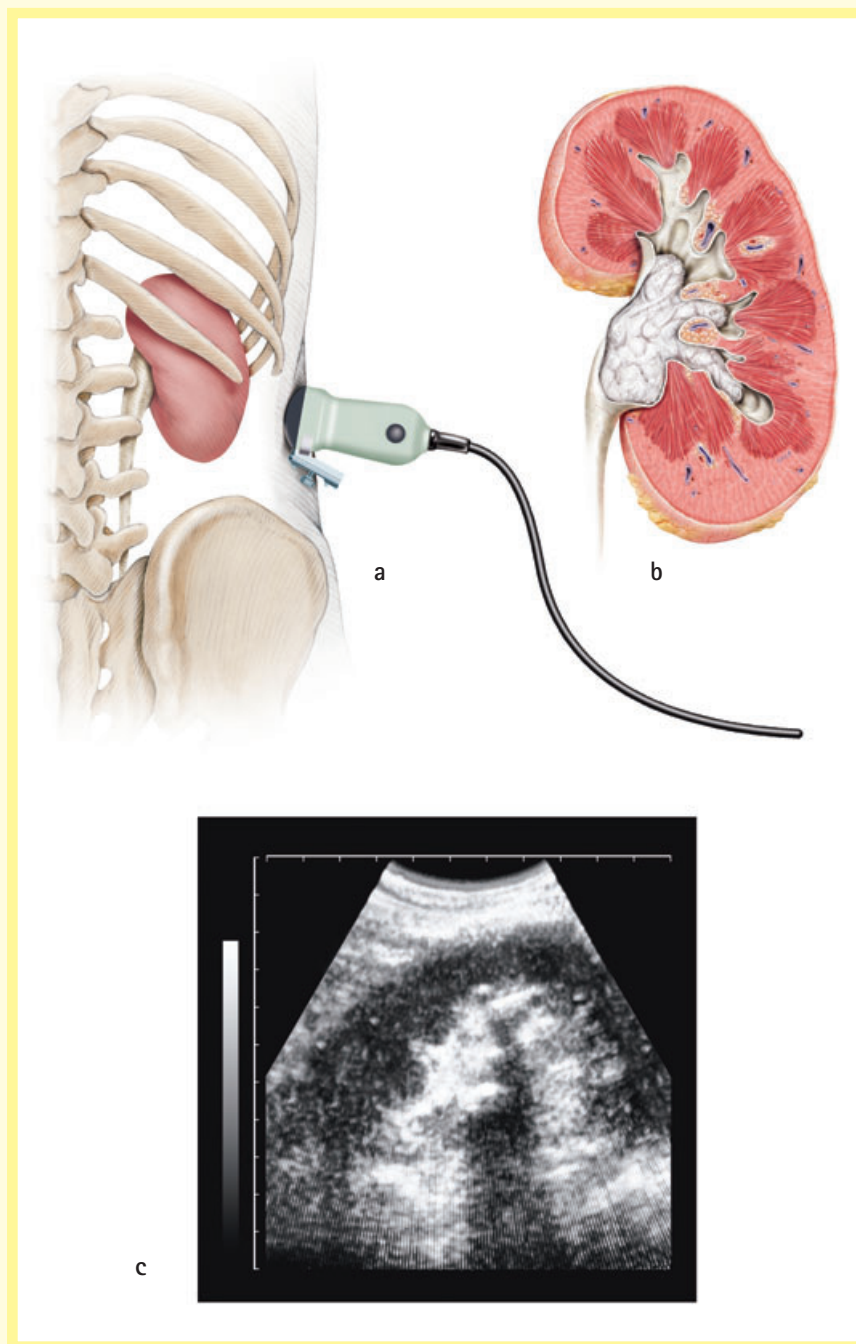
**Figure 3**

Area of access: The first step in preoperative planning of the procedure is to identify the ideal target calyx and to obtain three-dimensional knowledge of the kidney and the stone. It is essential to understand the anatomical location of the kidney. It is located anterior to the psoas muscle, between the 12th thoracic vertebral body and second/third lumbar vertebral body. Both kidneys are within the retroperitoneum at $\approx 30^\circ$ posterior to the frontal plane of the body. Access to the kidney is always established individually according to the particular anatomy. Frequently, the ribs or the iliac crest limit the space for access. In these cases, the area has to be shifted a few degrees (caudally or cranially $10\text{--}20^\circ$).

Figure 4

Determination of the target calyx and puncture plane, puncture site and puncture direction: (i) The long axis of the target calyx is identified by fluoroscopy (Fig. 4a); (ii) the plane between the calyceal axis and its perpendicular projection on the patients back is the ideal puncture plane (Fig. 4b); indicated by blue line in corresponding illustrations.

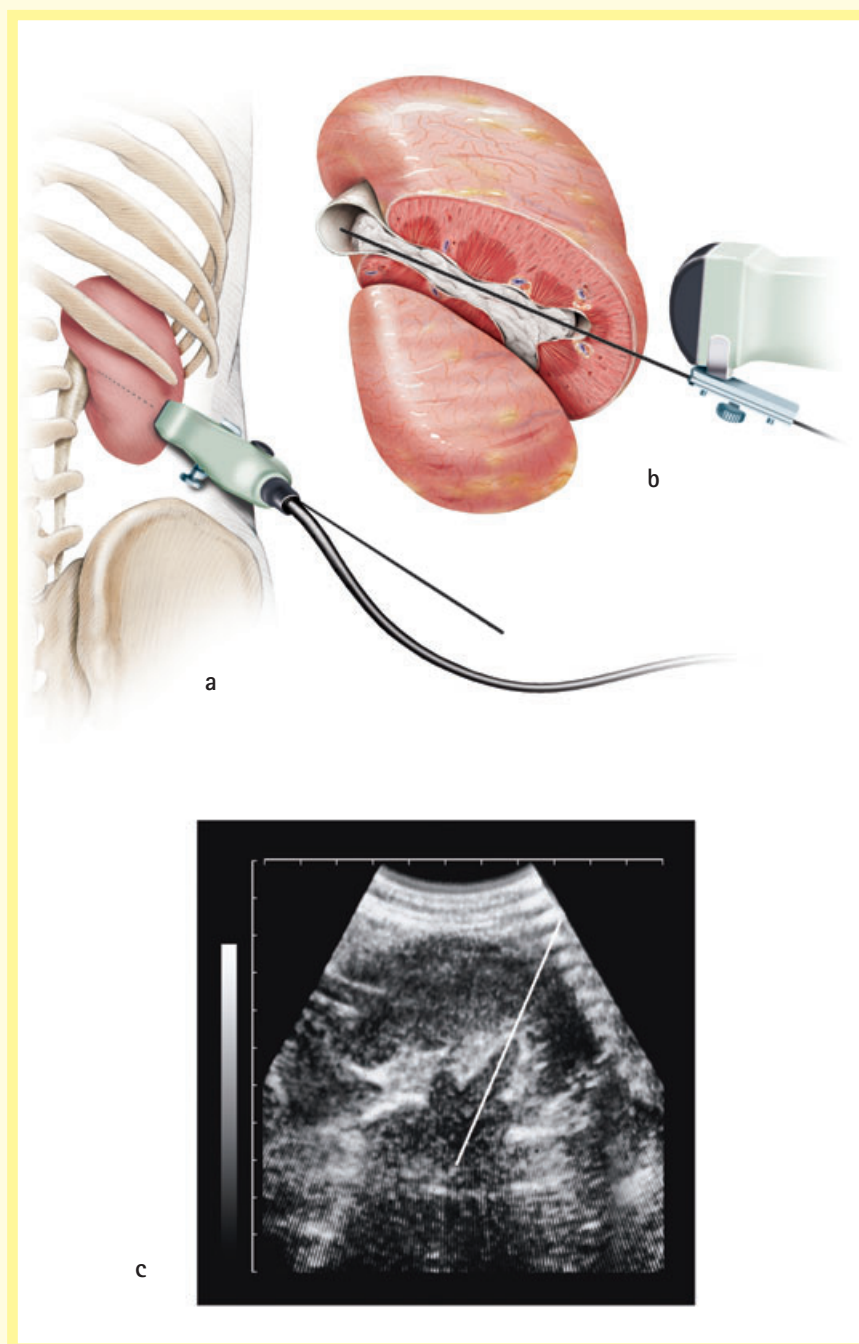


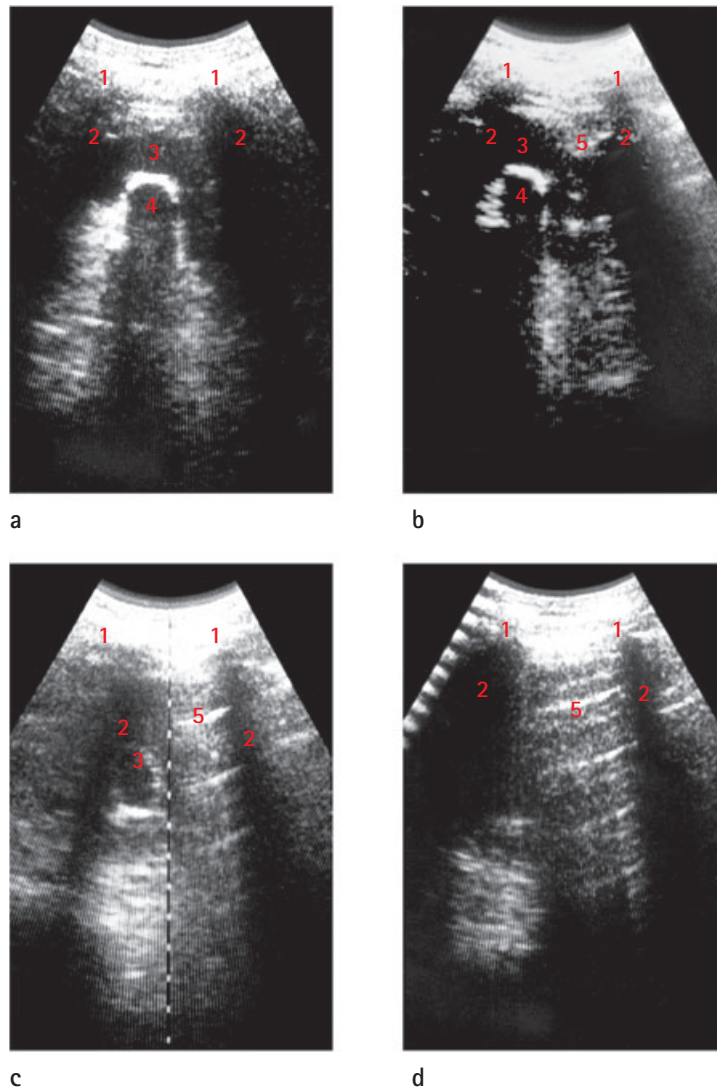
**Figure 5**

US of the kidney.

Figure 6

Determination of the puncture site and direction; within the puncture plane the puncture site is determined so that the puncture direction from that site is as close as possible identical to the extension of the long axis of the target calyx to the skin. This is achieved by moving the scanner head laterally on the predefined puncture plane while keeping the scanning plane within the predefined puncture plane. The image will change until the access calyx points directly towards the scanner head. An electronically generated line marks the puncture path from the needle guidance adapter to the stone. Puncture from this site will guarantee optimal access to the stone. At this moment the direction and depth to reach the CS can be determined. This is the least traumatic access because it establishes a direct and nearly avascular straight path through the parenchyma and the calyx to the renal pelvis.



**Figure 7**

How US helps to avoid mistakes [9]; US allows easy identification of the surrounding organs (lung, liver, spleen, intestine or liver) that are not visible in fluoroscopy.

(a) The US image of a stone-bearing kidney viewed from the 10th intercostal space; (1) surface 10th and 11th rib; (2) back-shadow of the ribs; (3) kidney parenchyma; (4) bright echo of stone with back-shadow.

(b) During inspiration diffuse reflections (5) caused by air in the lung obscures the view of the kidney, which moves caudally.

(c, d) During deep inspiration the intercostal space is completely filled by the lung, indicating that this access should be avoided, as it will lead into the lung or thoracic cavity.

Figure 8

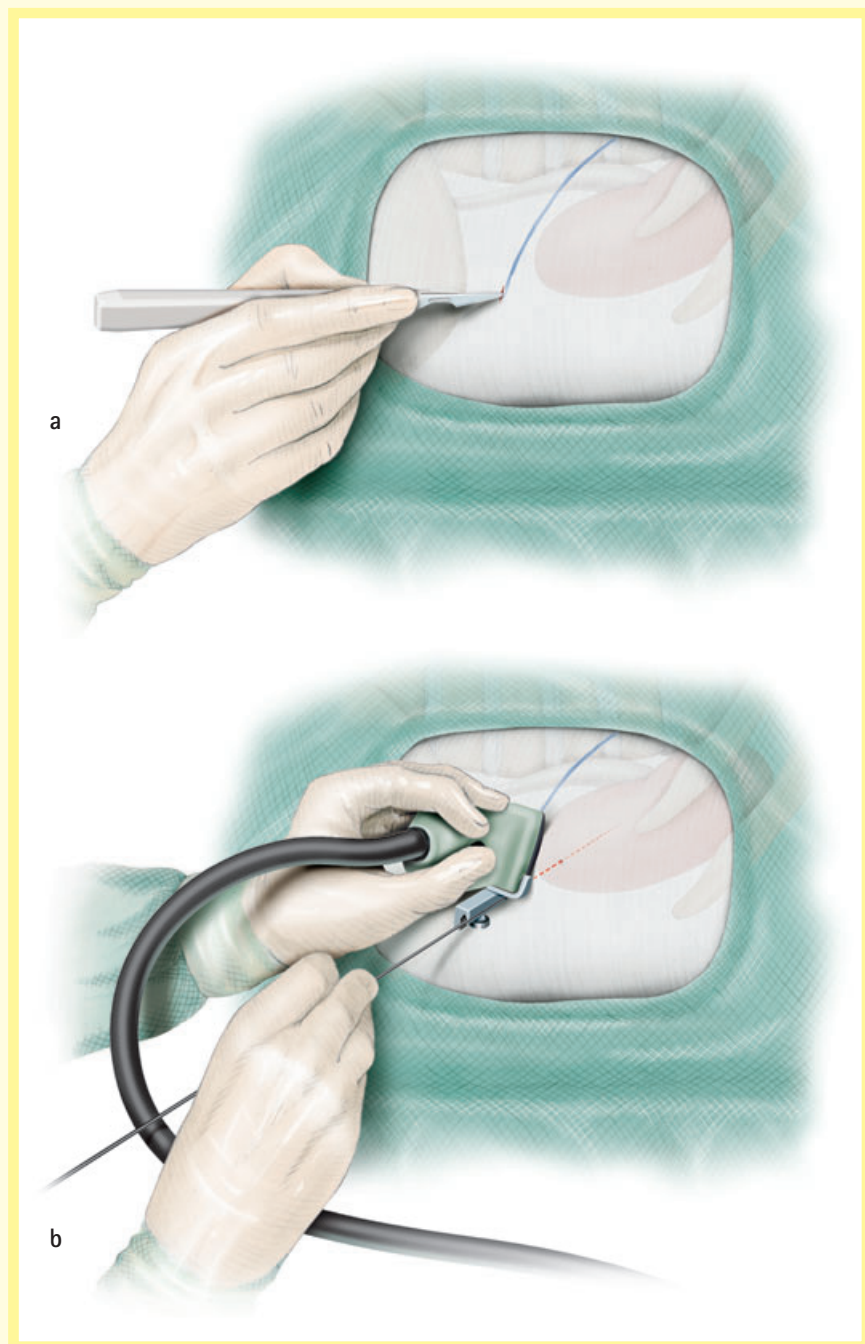
Puncture: A small incision is made at the selected puncture site after the scanner is temporarily removed. Two types of puncture are possible, either: (A) puncture with needle guidance; or (B) freehand puncture.

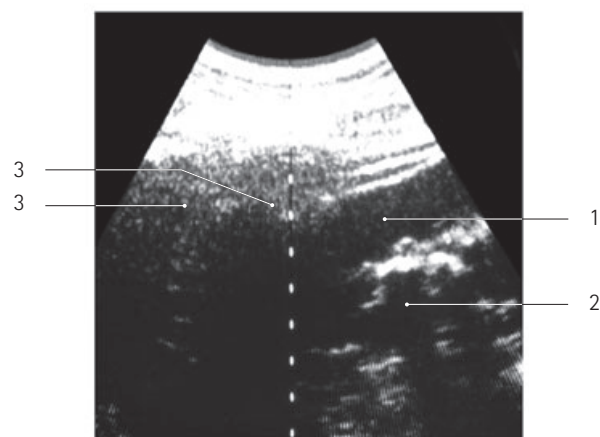
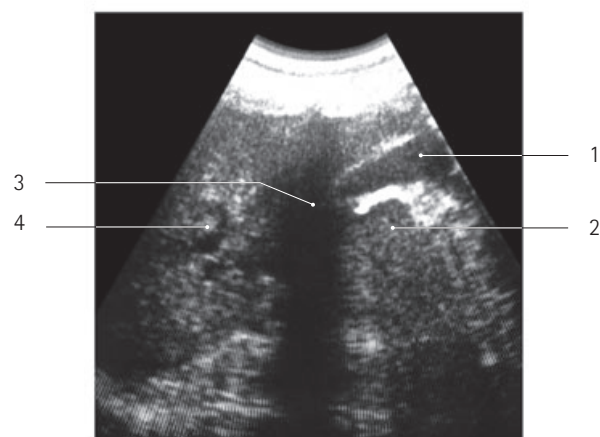
Using the needle guide adapter might be advantageous for the beginner, but frequently the needle will be deflected from the predefined path by different tissue consistencies. Freehand puncture allows easier detection and correction of the needle's direction. If a correction of the needle direction is necessary it must be moved outside the kidney, sometimes even out of the skin. Immediately before and during the puncture, needle advancement should be monitored by short intermittent fluoroscopy pulses to assess any deflection of the needle and to make sure the target calyx is indeed scanned. To reduce X-ray exposure of the physician, field reduction of the fluoroscopy should be used. The needle can be followed by US until it reaches the calyx. The puncture is usually made with a hollow open needle (with no obturator). When the CS is accessed, clear urine will flow out of the open needle.

In those cases where the stone completely moulds the target calyx, no urine will flow through the needle. Minimal amounts of dye must be injected to assure the optimum position of the needle tip. All further steps are then done under fluoroscopic control.

Once correct access to the CS is ascertained by dye injection, a floppy-tip J-guidewire is passed into the CS. With the aforementioned precautions followed, the guidewire will usually slip straight forward into the renal pelvis.

The access calyx leads to the renal pelvis like the urethra to the bladder.



**a****b****Figure 9**

(a) US image of the colon filled with gas (3) close to the lower pole of the kidney (1) containing a stone (2).

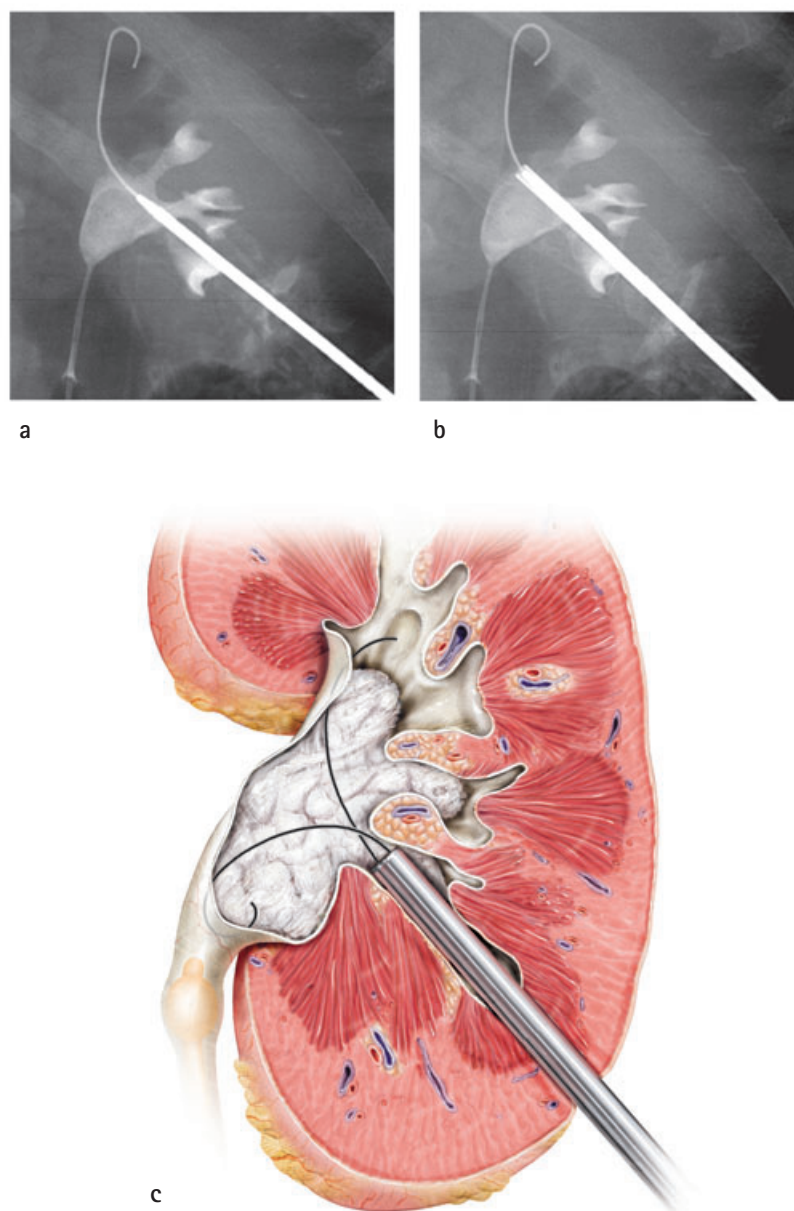
(b) US image of upper renal pole close to the spleen (4), back-shadow of the 11th rib (3), renal parenchyma (1) stone (2).

Figures 10 and 11

Dilatation: in this step it is possible to exchange the floppy J-guidewire for a Lunderquist wire, which has a lower risk of deviation and kinking during the subsequent dilatation. The tract is initially dilated with a 9 F PTFE dilator (Fig. 1.3). After a perfect transpapillary puncture, the plastic dilator passes easily with no resistance to the renal pelvis. If the puncture was not straight into the CS, resistance is felt while advancing the dilator and the degree of angulation can be determined by fluoroscopy.

This information is important for the subsequent insertion of the metal dilators. If the angularity is moderate, the tract will straighten with the metal dilators, but if the angularity is more pronounced, the dilatation should be terminated before inserting the metal dilators, to avoid traumatic disruption of the parenchyma. In these cases it is usually better to establish a new tract through a new puncture.

If an appropriate puncture was achieved the PTFE dilator is removed and replaced by the 9 F metal dilator (Fig. 10a, see also Fig. 1). Once the tip of the metallic dilator is properly positioned inside the CS, the 11 F introducer sheath is advanced over it until it reaches the CS (Fig. 10b), the 9 F dilator is then removed and a second safety wire can be placed through the introducer sheath (Fig. 10c). The 11 F metal sheath is then removed and while one wire is left as the safety wire the other is used to reintroduce the 9/11 F system (Fig. 11a,b). The 9 F dilator is then removed and the guide rod is introduced over the wire and through the 11 F sheath, the latter being then removed to start the telescope dilatation. The above steps can be omitted if no safety wire is used.



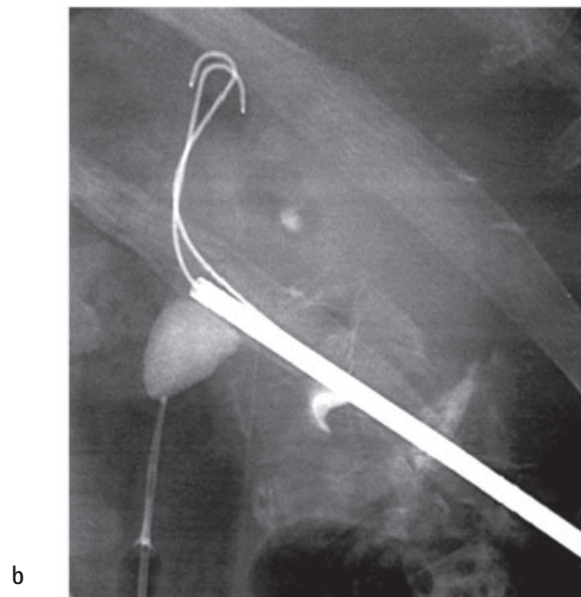
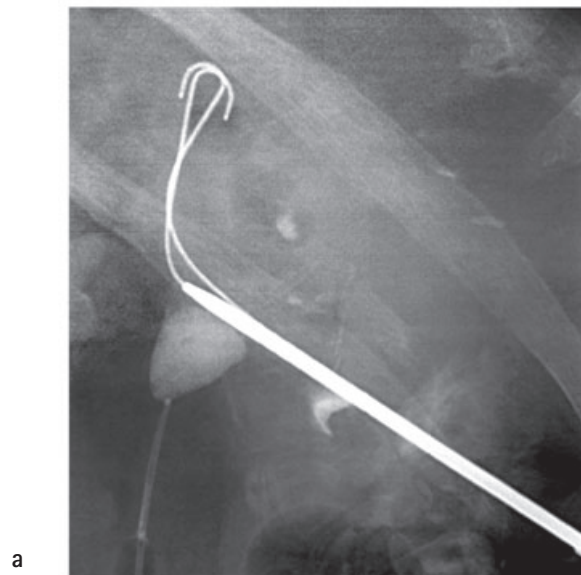


Figure 12

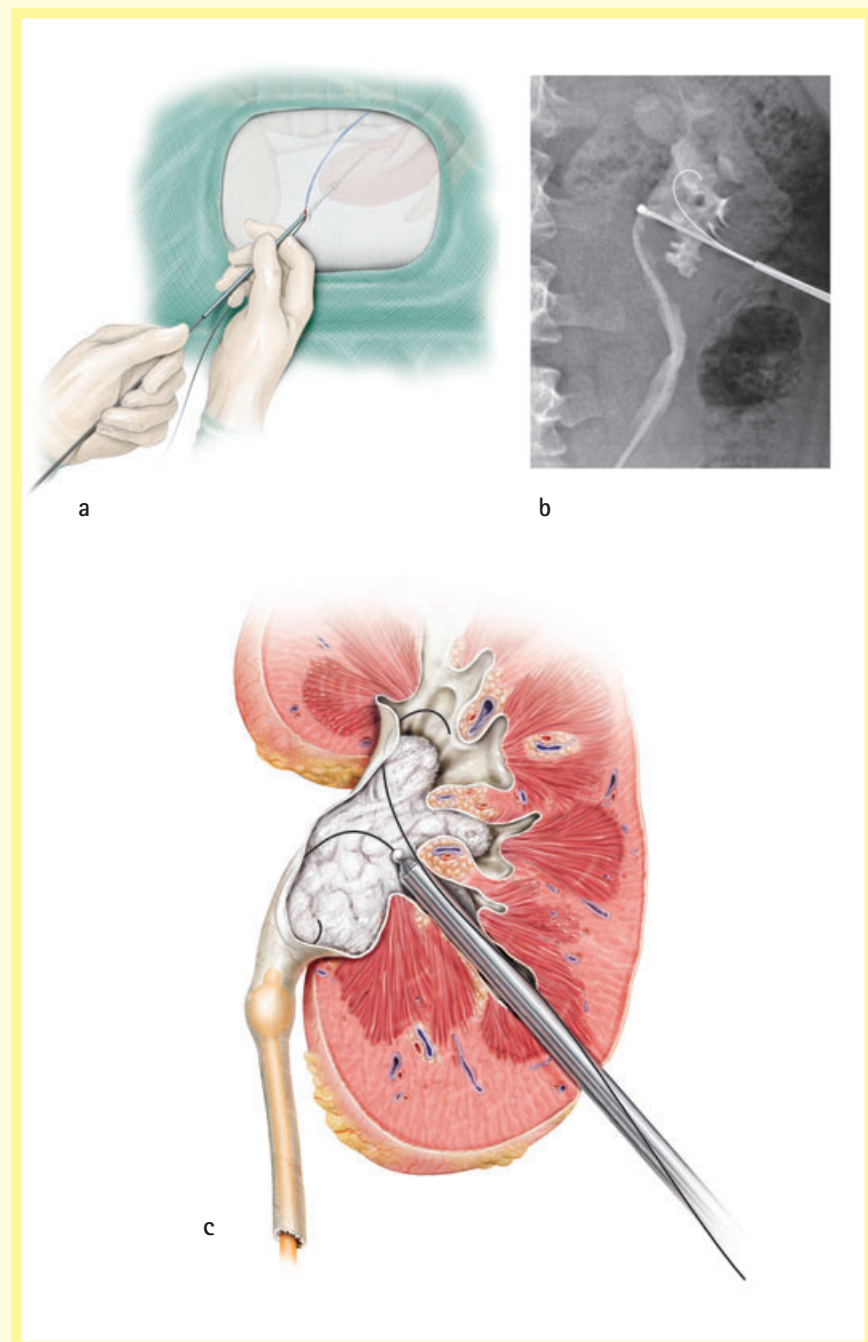
Dilatation: There are several tools for dilatation of the nephrostomy tract, e.g. the Amplatz system or balloon dilators [10]. We use stainless-steel coaxial dilators [11,12]; this system consists of a series of dilators mounted together in a telescopic system. The sheaths are passed one upon the other until the tract is dilated. As this system is very rigid, it is more effective even in patients with previous percutaneous renal surgery. Furthermore, it is reusable and saves costs. Bougie cores are available of 9/12/15/18/21/24 and 30 F.

To establish the access tract, the dilatation starts with the introduction of the rod of the dilators through the 11 F introducer sheath. Once the rod has reached the CS the 11 F introducer sheath is removed. The subsequent dilatation can be done over a guidewire.

We prefer to remove the in-lying guidewire, to be able to instil dye through the rod, to check its proper position within the CS during the subsequent dilatation process whenever this is regarded as necessary. The position of the rod must be maintained during the dilatation to avoid accidental perforation of the CS.

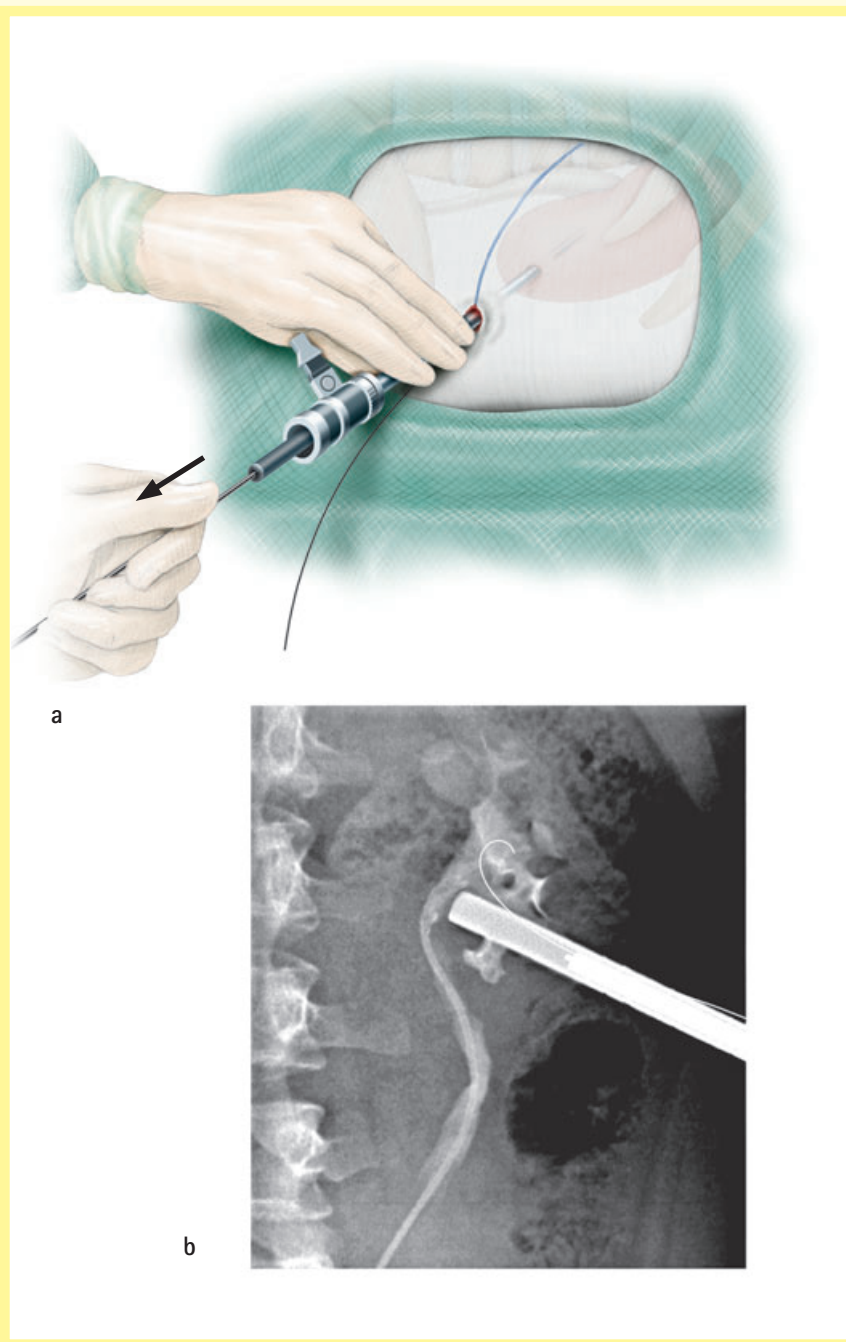
During the subsequent dilatation with the metallic coaxial dilators, one hand must hold the rod and the other hand advances the dilators. The dilators are advanced one upon the other and they are always advanced to the tip of the rod. During the dilatation it is preferable to use careful clockwise and counter-clockwise twisting (90°) rather than pushing the dilators. In those cases with severe perirenal scarring it might be necessary to advance the dilator very carefully with both hands while pushing and twisting. Especially when pushing the dilators, a safe distance to the medial renal pelvic wall of 1–2 cm must be maintained. After each push, the guide rod must be retracted until the safe distance is again achieved. Frequent ultrashort intermittent fluoroscopic checks are mandatory to avoid perforation.

Extra care is necessary in cases where the CS is completely moulded by the stone. Especially in patients with branched staghorn stones, the guidewire might not slip into the renal pelvis. The dilatation can then only be done to the peripheral extension of the stone with little space in the CS.



In these cases it is sometimes helpful to use an 18 F nephroscope after the fourth dilatation step. This 18 F examination sheath is advanced like a dilator and allows

examination of the CS. Sometimes an appropriate space between the stone and the calyceal wall can be identified where the dilatation can proceed more safely.

**Figure 13**

The dilatation is continued until the introduction of the 24 or 26 F nephroscope sheath, which is slipped in like a dilator or until a size is reached that allows the subsequent exchange against an Amplatz sheath of the same diameter. While the Amplatz sheath has the advantage of continuous low-pressure irrigation, inspection of peripheral parts of the punctured calyx is more difficult than with the nephroscope sheath, that is also a continuous-flow instrument. Dye can be injected through the hollow rod again, to ascertain the correct position of the sheath within the CS. The inlaying dilators are removed by pulling the guide rod (Fig. 13a,b).

Figure 14

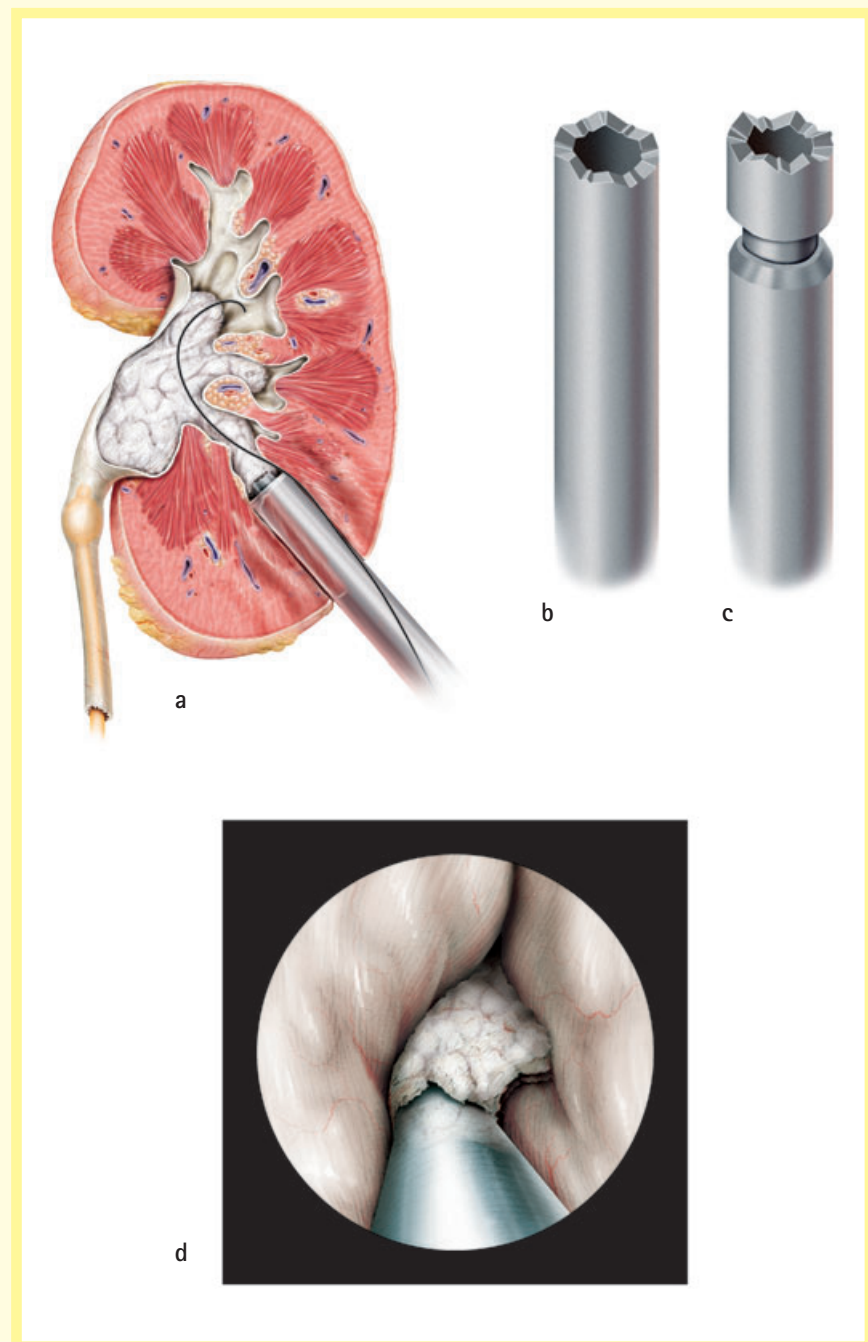
Nephroscopy and stone removal: Before starting with nephroscopy, contrast dye should be injected to finally secure the correct position of the instrument within the CS. During the next steps low-pressure irrigation must be maintained to prevent pyelotubular and pyelovenous reflux with consecutive septicaemia, especially in patients with infection stones. Mannitol can be administered i.v. (10%, 100 mL) to increase renal parenchymal pressure and reduce the risk of pyelotubular reflux.

After introducing the nephroscope, three situations are possible: (i) Direct visualization of the stone; (ii) 'White out'; the nephroscope has direct contact with the pelvic wall, and must be retracted until the CS can be visualized; (iii) 'Red out'; the CS is filled by blood. In this more complicated situation, it is helpful if previous dye injection has secured the right position of the nephroscope within the kidney. However, dye should be injected again to verify the position before the blood clots are extracted by suction through the US probe.

In general, all movements within the kidney must be done slowly, especially when the endoscopic image does not show a clear image of the CS or the stone. The nephroscope should ideally be kept within the primary puncture direction and not be bent against the patient's skin, as this movement might result in disruption of the pericalyceal vessels.

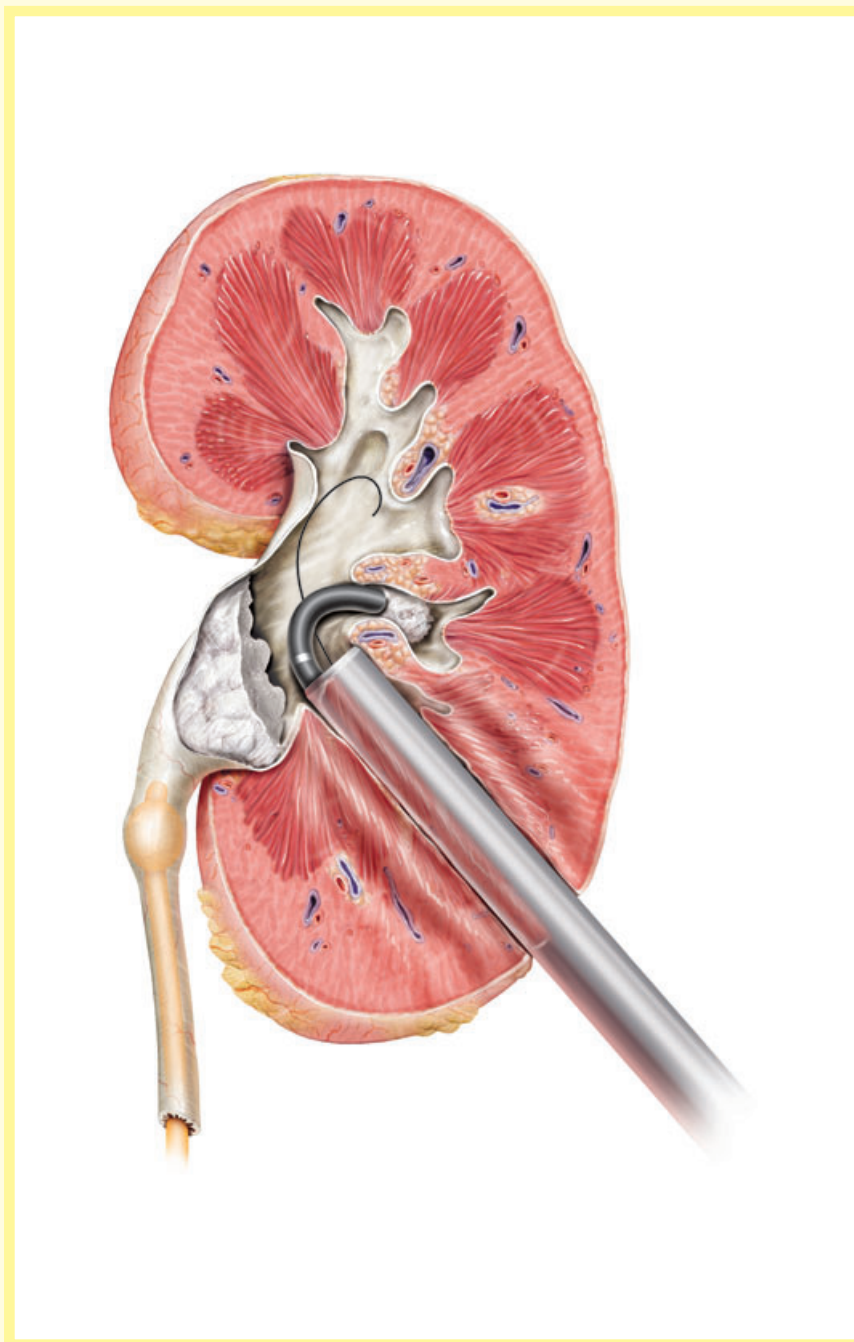
The aim of stone disintegration is not to achieve many small fragments as soon as possible, but to obtain a few fragments that can be extracted by forceps or baskets. Disintegration systems with additional suction at the tip of the instrument, like ultrasonic lithotripsy probes (9 F) with continuous fluid suction, facilitate the procedure as they reduce continuously the number of fragments [13].

The probes are available with two tips: The oscillating tip (c) is more efficient for stone disintegration than the rigid one (b), but has the disadvantage of less intense fragment aspiration. The latter is used for softer stones where the intense fragment aspiration helps to avoid dispersion of stone fragments into remote inaccessible parts of the CS.



In patients with staghorn stones the disintegration will start at the peripheral part of the stone to clear the way to the CS. Having reached the pelvis, the stone extension covering the PUJ is removed at the end of the

procedure, to prevent fragments from passing into the ureter. Furthermore, any calyceal extension should not be removed, as it might then be impossible to grasp and pull them to the pelvis for further disintegration.

**Figure 15**

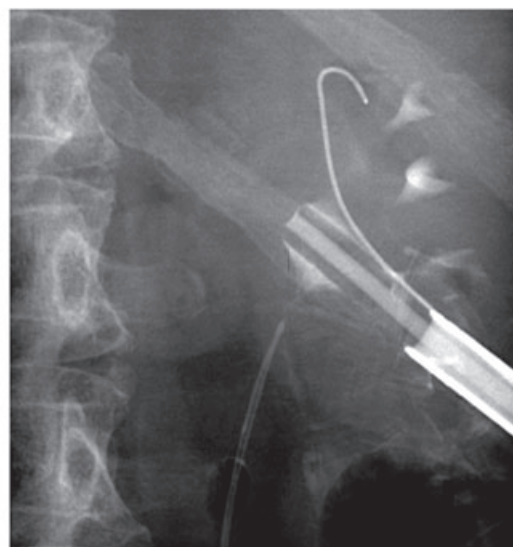
For flexible nephroscopy, a conventional flexible cystoscope is introduced through the nephroscope shaft. For stone disintegration, the Ho:YAG laser lithotripsy or electrohydraulic lithotripter probes can be used. However, electrohydraulic lithotripters have a significant risk of tissue injury, and considerably lower disintegration efficacy than the Ho:YAG laser.

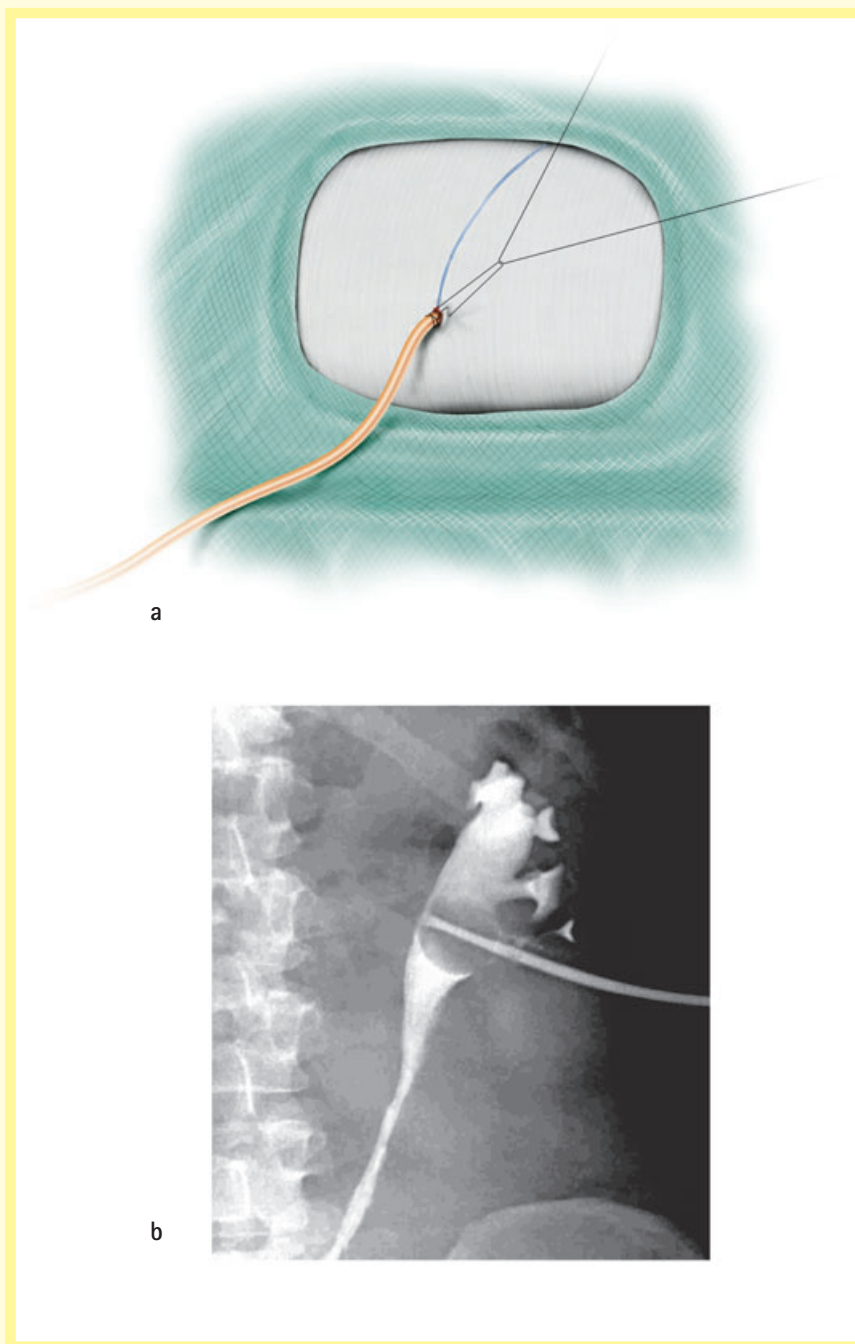
Use of a flexible cystoscope via the nephroscope shaft allows access to most calyces through one access. If complete removal of the stone is not possible with rigid or flexible nephroscopy, a second or third tract can be established either in the same or a second session. Alternatively, residual stones can be disintegrated by ESWL and removed by later 'second-look' PNL through the same access tract (so called 'sandwich therapy').

Figure 16

Nephrostomy: If endoscopy and fluoroscopy show no residual stones or if the procedure is terminated prematurely, a nephrostomy tube is placed for compression of the access tract or second-look access. Dye injection facilitates proper placement of the tube. To place the nephrostomy, a 22 F disconnectable nephrostomy can be placed directly through the 26 F sheath. Alternatively, a regular, tip-cut 22 F Foley catheter with a punched hole proximal of the balloon can be placed via a half-open slotted sheath (see also Fig. 1.8). In this case the dilators are reintroduced into the nephroscope sheath, which is then removed. Now the half-shaft, which has the same diameter as the nephroscope sheath, is introduced over the dilators under fluoroscopic control.

Previous filling of the empty catheter with contrast dye is helpful while placing the tube, which is regularly radiolucent. The catheter is then blocked carefully with 2–3 mL saline under fluoroscopic control and dye is again injected to be sure that the balloon obstructs no calyx.

**a****b****c**

**Figure 17**

Either type of nephrostomy is also sutured to the skin. Special care must be taken in very obese patients when suturing the tube, because the skin will move down when the patient is erect, and potentially pull the nephrostomy out of the CS. Coiling the tube inside the body before suturing can prevent this.

Postoperative venous bleeding can be controlled in most cases by clamping the nephrostomy for 40–60 min. Severe or delayed significant bleeding is mostly of arterial origin and can be managed by superselective angiographic embolization [14]. Open surgical revision is rarely necessary.

If the patient is considered stone-free, a plain film and dye injection into the nephrostomy is done the next day. When complete stone removal is confirmed and contrast dye passes to the bladder with no evidence of residual fragments in the ureter, the nephrostomy is removed.

FROM SURGEON TO SURGEON

The crucial step in PNL is establishing the percutaneous tract after careful identification of the anatomy and stone configuration. During the whole procedure, imaging should be done whenever necessary. Difficult cases are patients with former percutaneous operations and a distorted CS, peripheral stone mass, and renal malformations that require extra care. The beginner should avoid performing PNL in situations where only a little space (sometimes only a few millimetres) is available for manipulation, as in calyceal diverticula or calyceal staghorn stones.

Loss of the tract is most often due to wrong access, not following the geometry of the ideal access detailed above, creating a closed tract through the parenchyma into the target calyx but heading directly into the renal pelvis outside the renal hilum or into the renal pelvis through the parenchyma, but in between the calyces. Such catastrophes can be avoided by following the most important rule: respect and follow anatomy, and by anticipating complex situations during dilatation by using frequent fluoroscopy.

When vision is poor due to bleeding during the procedure, it is advisable to terminate the procedure to prevent septicaemia and to postpone stone removal, after placing a nephrostomy tube, to a safer session with better vision.

The technique described increases the information of the individual anatomy by making use of two imaging methods, adding safety to the procedure. The instruments used

fit together, from the beginning with the 9/11 F dilator, to the end with the slotted sheath for placing the nephrostomy.

All procedures like infra- or supracostal access are possible, safety guidewires can be used or not, just as a 'no-tube' technique is possible. The low complication rate makes the described PNL procedure our preferred technique for large renal calculi.

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Abbreviations: CS, collecting system; US, ultrasonography; PNL, percutaneous nephrolithotomy.