Percutaneous nephrolithotomy

Experience with renal and proximal ureteral calculi at Tygerberg Hospital

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Summary

Percutaneous nephrolithotomy (PCN) enables the urologist to remove upper urinary tract stones through a percutaneous nephrostomy tract. The principal advantages of PCN are the low morbidity, shortened hospital stay and rapid recovery. Percutaneous puncture failed in 5 (11%) of the first 44 patients with upper tract urolithiasis treated by PCN at Tygerberg Hospital. In 35 patients (80%) PCN cleared the kidney of stones but in 4 patients (9%) all stone fragments were not removed during the procedure. If the puncture and dilatation was successful, then 90% of patients were stone-free after PCN. Complications were minimal except for a diabetic who died of septicaemia.

PCN is an alternative to open renal surgery in the management of most upper urinary tract stones. The technique is readily mastered by any urologist experienced in endoscopic surgery.

S Afr Med J 1988; **73**: 5-8.

Percutaneous nephrolithotomy (PCN) entails the removal of upper urinary tract calculi through a percutaneous nephrostomy tract. Although the technique of percutaneous nephrostomy (PN) was described in 1955 by Goodwin *et al.*,[1] two decades lapsed before Fernstrom and Johansson[2] electively established and dilated a tract to the kidney for stone removal. Subsequently it has been extensively used alone or in conjunction with extracorporeal shockwave lithotripsy (ESWL) as an alternative to 'open' surgery to treat upper urinary tract stones.

The results of PCN performed on 44 consecutive patients between November 1985 and September 1986 at Tygerberg Hospital are reported.

Patients and methods

Forty-four patients (22 males and 22 females) aged between 14 and 73 years (mean 41 years) underwent PCN. Previous ipsilateral renal stone operations had been performed on 7 patients, of whom 3 had had more than one operation. The indications for PCN were identical to those for 'open' stone surgery:[3] pain (88%), hydronephrosis (66%), infected urine (34%) and deteriorating renal function (7%). Patients with urinary infection without hydronephrosis either had a staghorn calculus, caliceal stones or a stone in a caliceal diverticulum. Contraindications were bleeding disorders or active urinary tract infection.[4]

The selection of patients was left to the discretion of the urologist, who had to consider his level of competence in PCN and the difficulty of the particular case.

The stones were located in the pelvis (55%), a calyx (18%), a caliceal diverticulum (5%), pelvis and calyx (11%) or ureter (11%).

Pre-operative investigations included intravenous pyelography, urine culture and microscopy, determinations of plasma urea, electrolyte and creatinine levels, full blood count and, if indicated, a clotting profile.

Patients with a staghorn calculus or pre-operative urinary tract infection were treated with appropriate antibiotics before PCN. Patients with infected hydronephrosis underwent a preliminary PN under local anaesthesia and received intravenous antibiotics until the urine was free of infection.

In all other cases puncture, tract dilatation and stone removal were attempted in one session under a general anaesthetic. A cephalosporin or aminoglycoside was given prophylactically. In patients with significant hydronephrosis percutaneous puncture of the selected calyx was performed under ultrasonographic guidance alone, but in most other cases an artificial hydronephrosis was established to facilitate the puncture.[5] Immediately before puncture, with the patient in the lithotomy position, cystoscopy and retrograde ureteropyelography were performed. A large diameter ureteral catheter was advanced until the distal tip was positioned in the upper calyx, the proximal end being secured to a transurethral Foley's catheter. A balloon ureteral catheter was used to occlude the pelvi-ureteric junction in patients with a small undistended collecting system. A hydronephrosis was then created by retrograde infusion of 30% urografin (mixed with methylene blue).

Ideally, in patients with a proximal ureteral stone the calculus was displaced into the renal pelvis.[6] When passage of a catheter failed to dislodge the stone, it was approached by retrograde ureterorenoscopy or antegrade pyelo-ureteroscopy via a middle or upper pole calyx.[7]

At this stage the patient was placed in the prone position with the pelvis and chest elevated, thus freeing the abdomen to prevent undue restriction of ventilation.

An essential prerequisite for PCN is the creation of an adequate PN tract (Fig. 1).[5] The site of entry into the renal collecting system is hence chosen according to the patient's habitus, the kidney position, spatial configuration of the collecting system and location of the stone. Exact localisation of caliceal stones is essential and oblique views before and after contrast injection are used to see whether a stone is located in an anterior or posterior calyx. Ultrasonography or computed tomography will help to locate poorly opacified stones.[8]

The initial step in planning a PN tract is to study the patient's caliceal anatomy on an intravenous pyelogram. Usually the contrast-filled anterior calices are situated more laterally and are seen as 'cups side-on' while the posterior calices are perceived more medially and appear as 'end-on discs'. The posterior-inferior calyx is preferred for access in uncomplicated cases. The axis of the posterior calices to the sagittal plane is 30° for the right kidney (a Brodel-type kidney in 69% of cases) and 10° for the left kidney

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Accepted 27 Oct 1986
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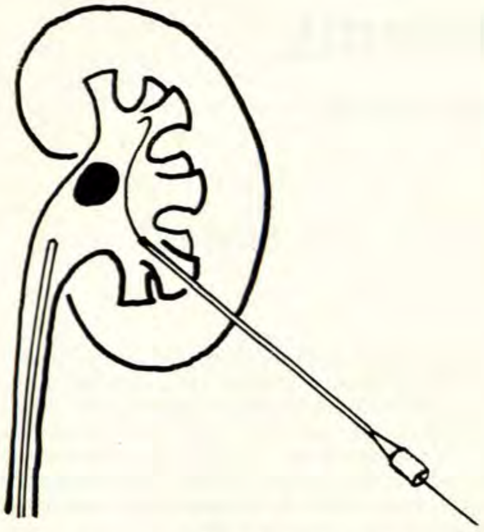

Fig. 1. A percutaneous puncture of a selected calyx is performed using ultrasonography and fluoroscopy in combination. A Lunderquist wire is inserted through the needle into the renal pelvis.

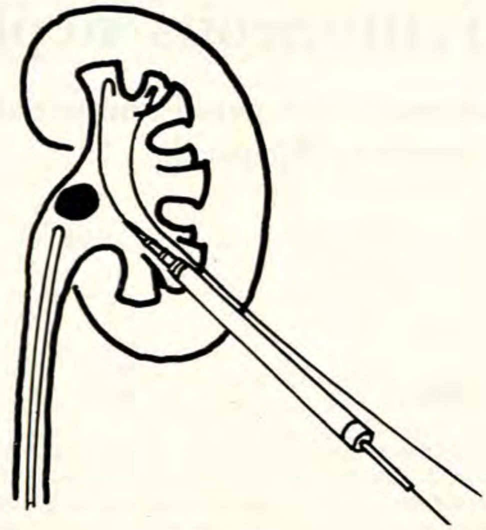

Fig. 2. After initial dilatation a second wire, the safety wire, is passed before further dilatation with metal telescoping dilators up to F24 is begun. The nephroscope sheath (F26) will subsequently be passed as the final dilator.

(a Hodson variant in 79% of patients).[9] The specific calyx selected for the puncture should afford direct access to the renal pelvis and, ideally, is punctured under ultrasonographic and fluoroscopic control.

We used real-time ultrasonography to determine the position of the puncture site (usually inferior and medial to the tip of the twelfth rib) and to direct the course of the needle to the selected calyx. An infracostal puncture was generally performed during the mid-inspiratory cycle of quiet breathing to ensure a straight tract from the skin to the collecting system. Where a supracostal puncture was indicated, it was done during mid-expiration.[5] An 18-gauge 20 cm long Mitty-Pollack trocar needle was placed in the sonar biopsy attachment and the needle advanced under ultrasonographic guidance. In some cases the puncture was performed under ultrasonographic guidance alone, but in the majority of cases the final entry of the needle into the selected calyx was controlled fluoroscopically and confirmed by methylene blue-stained fluid dripping from the cannula on removal of the trocar. Screening was performed with a single plain C-arm fluoroscopy unit. If required, an oblique view was used to demonstrate the position of the needle relative to the calyx chosen for puncture. When a successful puncture had been performed, a Lunderquist guidewire was introduced through the cannula (Fig. 1). A careful incision with a No. 11 surgical blade was made next to the needle, cutting the muscle and fascial layers surrounding the kidney. After an initial dilatation to F9 with a metal cannula passed over the guidewire, a second guidewire (the safety wire), was passed into an upper calyx to ensure safe re-entry into the collecting system should the tract be unintentionally lost during the dilatation or endoscopy. Further dilatation was performed with a metal telescoping dilatation set (Fig. 2). A F26 Storz nephroscope sheath was used as the last dilator before the dilator set and Lunderquist wire were withdrawn. Visual inspection of the collecting system was performed after insertion of the nephroscope.

We used 0,9% sodium chloride for irrigation during nephroscopy, although 5% mannitol could be used for electrocautery procedures.

Small stones (up to 8 mm in size) were removed by flushing, grasping (Fig. 3) or basket techniques while larger stones required fragmentation by ultrasonic lithotripsy (Fig. 4). The ultrasonic lithotripter is designed with a central hollow channel connected to a suction pump. Irrigation fluid and stone fragments are continuously removed through this channel. The lithotripter ('burr') does not damage the urothelium.

Additional nephrostomy tracts may have to be established when residual stone fragments cannot be visualised or removed. On completion of the procedure a control radiograph is done to confirm the removal of all stone fragments and a nephrostomy catheter (usually F22) passed through the nephroscope sheath and fixed to the skin after radiographically confirming its position.

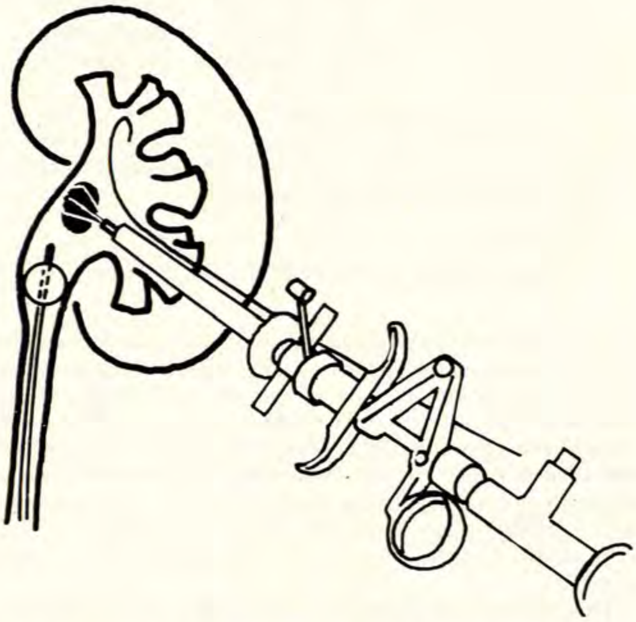

Fig. 3. Extraction of a stone smaller than 8 mm with a grasping forceps through a lower pole posterior calyx.

A chest radiograph is obtained in the immediate postoperative period to diagnose possible pneumothorax, atelectasis, pleural effusion or lung oedema.[4] On the first and third postoperative days the haemoglobin, plasma creatinine, urea and electrolyte levels are routinely determined. After PCN patients are regularly assessed for excessive bleeding, hypotension, abdominal signs and fever.

A control abdominal radiograph and a nephrostogram are obtained when the urine is macroscopically clear. If there is any doubt about the presence of stone fragments, renal tomography is performed, and the residual fragments subjected to another PCN session or to chemolysis.[10] In the absence of extravasation or obstruction, the nephrostomy tube is clamped. It is removed a few hours later if no subsequent pain or fever develops. The patient is discharged the next day if urinary leakage, haematuria, pain and fever are absent.

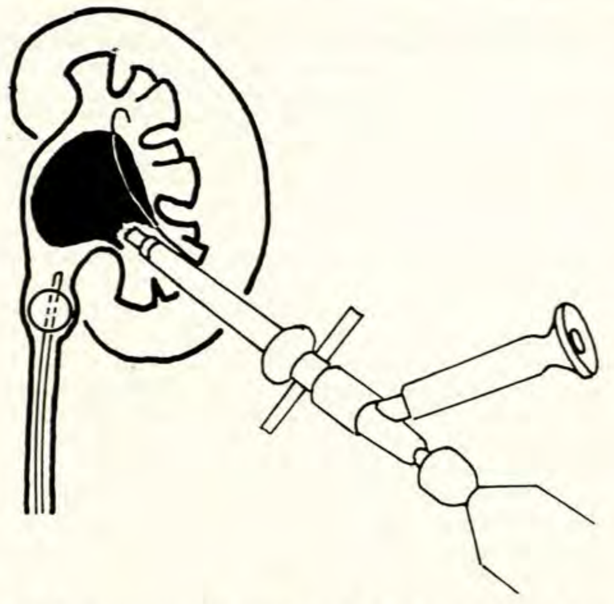

Fig. 4. Ultrasonographic lithotripsy of a large pelvic stone. Small fragments are removed by the central hollow suction channel of the sonotrode. A balloon catheter and safety wire are in position.

Results

Success rate. PCN was attempted in 44 cases, 29 (66%) with hydronephrosis. Access to the renal pelvis was established in 39 cases (89%). Hydronephrosis was absent in 4 of the 5 failed punctures. PCN achieved a stone-free state in 35 patients (80%); in a further 2 cases (5%) small residual fragments are expected to pass spontaneously. If the puncture and dilatation were successful, 90% of patients were stone-free after the procedure. The success rate of PCN according to stone location was 88% for pelvis stones, 60% for stones in the renal pelvis plus calyx, 60% for proximal ureteral stones and 50% for stones in a calyx or a caliceal diverticulum.

Duration of PCN. The average total duration of PCN, including the puncture time but excluding the induction of anaesthesia, was 2 hours 10 minutes. PCN lasted more than 3 hours in 6 cases; between 2 and 3 hours in 20 procedures; between 1 and 2 hours in 13 patients and less than 1 hour in 5 cases. Longer procedures were due to renal pelvis perforation, the removal of multiple stones, inability to localise or visualise the stone, when an additional PN had to be performed or more than one session was necessary for the complete removal of stones.

Number of sessions. PCN was performed in 1 session in 39 patients (89%), in 2 stages in 4 patients (9%) and in 3 sessions in 1 case (2%). A preliminary PN under local anaesthesia was performed because of an infected hydronephrosis (2 cases) or severe pain from a stone impacted at the pelvi-ureteric junction (2 patients).

Duration of nephrostomy tube drainage and hospital stay. Nephrostomy tubes were removed after a median of 4 days and a mean of 5,2 days. Most patients were discharged the day after removal of the nephrostomy tube. Urinary leakage lasting more than 1 day occurred in 1 patient only. Average hospital stay was 7 days.

Follow-up of unsuccessful cases. Of the 5 patients in whom percutaneous access could not be established, 2 have undergone and 1 is awaiting open surgery. The other 2 will again be subjected to PCN. Two of the 4 patients in whom PCN failed to clear all stones are awaiting spontaneous passage of small residual fragments and 2 patients are scheduled for further attempts at PCN.

Complications

Perforation of the upper tract. The renal pelvis was perforated in 7 cases (16%), usually after dilatation, and this resulted in extravasation or bleeding which led to a difficult or a terminated procedure.

Bleeding. Intra-operative haemorrhage obscuring vision necessitated termination of PCN in 1 case. Significant bleeding through the nephrostomy tube was seen in 5 patients, all of whom responded to clamping of the nephrostomy tube. In no instance was balloon tamponade (Foley or angioplasty balloon compression), angiography and selective embolisation or nephrectomy necessary.

Ileus. Ileus was seen after long or difficult procedures and occurred in 3 cases (7%).

Fluid overload. Systemic fluid absorption was seen in a 46-year-old man after PCN (lasting 2 hours 45 minutes) during which extravasation occurred.

Organ damage. Pneumothorax or injury to the lung, liver, spleen, colon or duodenum were not experienced.

Postoperative fever. Temperature rose in excess of 38°C postoperatively in 25% of cases, but urine cultures were positive in only 7% of patients.

Septicaemia. Two cases of septicaemia occurred. One patient recovered on treatment but the other (a 73-year-old female diabetic) died of septicaemic shock.

Nephrostomy tube displacement. The nephrostomy tube was displaced down the ureter in 1 case and outside the kidney in 1 case.

Urinary leakage (fistula). Urinary leakage lasted more than 24 hours after nephrostomy tube removal in 1 case but resolved spontaneously 3 days later.

Discussion

Until recently the management of symptomatic upper urinary tract calculi has relied on standard 'open' surgical procedures, but there is no doubt that PCN has definite advantages for the patient.[3] There is limited morbidity, fewer complications, a short hospital stay and a return to work within 1 week from discharge.[11,12]

The equipment for PCN can be obtained for approximately R25 000 and standard operating theatres, operating tables and fluoroscopy units can be used.[4] If ultrasonography is preferred for the percutaneous puncture this will entail additional expenditure if it is not available in the operating theatre.[5]

PCN can be difficult or relatively contraindicated when the patient is pregnant, has marked hepatosplenomegaly, extreme obesity, severe skeletal deformities or kidney abnormalities (kidney too high, kidney too mobile, a malrotated kidney, a pelvic kidney, a transplant kidney and a duplex or bifid collecting system).[5] We have used the technique successfully in a patient with ankylosing spondylitis and severe kyphosis. A kidney previously operated on is fixed to the lateral abdominal wall and this may make further stone surgery difficult. However, the perirenal scarring after previous renal surgery may facilitate PCN since a fixed kidney will result in a stable nephrostomy tract.[13] Access to the collecting system is usually achieved by a percutaneous puncture, but a retrograde nephrostomy approach, whereby the urologist passes a catheter and needle through the ureter and posterior renal calices to emerge in the flank, has been described.[14] This procedure achieves access in most cases but manoeuvring the catheter into the selected calyx can be time-consuming.

Expertise in percutaneous puncture can readily be gained by urologists and radiologists and the endoscopic experience of the urologist ensures a rapid learning curve for PCN.[8] As one-stage procedures are routinely preferred it would be more cost-effective if the puncture and endoscopic procedure were performed by one person.

A definite learning curve is experienced by all urologists involved with PCN.[12] In large series a success rate of 95% for renal calculi and 85% for upper ureteral stones is reported.[11] In pilot studies (the first 23 - 50 cases at an institution), the authors have noted a successful outcome in 70 - 79% of cases (Table I).[8,12,15]

TABLE I. PERCENTAGE SUCCESS RATE OF PN AND PCN IN PILOT STUDIES

	Tygerberg Hospital	Wickham[15]	Clayman *et al.*[12]*	Whitfield[8]
No. of patients	44	50	23	48
Hydronephrosis	66	55	—	—
Successful PN	89	84	—	89
Successful PCN	80	70	76	79
PCN success if access available	90	83	—	80

*Group 1 of Clayman *et al.*'s[12] series.

Impacted ureteral stones present a special problem. A ureteral stone that has not progressed in 6 weeks is usually impacted but is amenable to retrograde flushing if located above the pelvic brim.[5,6] If successfully flushed into the renal pelvis it can be treated by PCN. When a proximal ureteral stone cannot be dislodged it should be treated by ureterorenoscopy and ultrasonographic lithotripsy if necessary.[16] Prograde ureteroscopy, usually through a middle calyx, may be possible if the length of the nephroscope and the course to the stone will allow it.[7]

Stones larger than 8 mm in diameter are fragmented by ultrasonographic lithotripsy. Very large stones may need up to 60 minutes to disintegrate. Stones are gradually reduced in size by starting and continuing disintegration along the periphery. Matrix and struvite stones fragment easily whereas calcium oxalate dihydrate, calcium phosphate and cystine stones are harder to disintegrate and some uric acid and calcium oxalate monohydrate stones may be refractory to ultrasonographic lithotripsy.[5] Acoustic trauma can occur and requires urgent investigation.[8]

The 1-year stone recurrence rate after PCN is reported to be 8% after fragmentation procedures, and 2% when the stone is extracted intact.[5] This compares favourably with the recurrence rate of 10 - 15% after open renal surgery.[12] The stone recurrence rate is expected to rise as the duration of follow-up increases. Stone analysis should be routinely performed and a metabolic cause for stone formation sought in order to determine and treat the cause of the patient's urolithiasis.

Renal pelvis perforation during dilatation of the puncture tract was relatively frequent in our series. Insufficient 'fixation' of the beaded metal guide was held responsible for pelvic perforation during the advancement of the coaxial metal dilators. The progress of each dilator which is advanced with a twisting and turning action should be monitored fluoroscopically to prevent this complication.

Bleeding was not a problem in our series but serious vascular complications can occur in 0,5% of cases necessitating arteriography and embolisation or nephrectomy. Venous bleeding is easily manageable and is not a serious complication.[17] Septicaemia is a grave complication and was fatal in 1 patient in our series. Other deaths after PCN have been reported by Wickham and Miller[4] (massive haemorrhage in a patient with liver cirrhosis and a normal pre-operative clotting profile) and by Korth[13] (septicaemia in a cirrhotic patient).

The extent to which PCN will be used depends on the urologist's dexterity with this technique. Simple stones (pelvic stones and single, middle or lower pole caliceal stones) can easily be extracted but complicated stones (partial or complete staghorn stones, multiple caliceal calculi and a stone in a caliceal diverticulum) may require the ability to perform transpleural-, double- or y-punctures and experience of intrarenal electrocautery and flexible nephroscopy.[18,19] Multiple sessions may be necessary to remove all the stone fragments.

Further adjustments in the indications for PCN will come with the future availability of ESWL. ESWL is highly efficient in the treatment of most renal and proximal ureteral stones but morbidity is in proportion to the size of the stone treated. Larger ($>$ 2 cm) stones with a predominant pelvic stone mass can be optimally managed by an initial 'debulking' PCN followed 2 - 3 days later by ESWL.[20] It seems ironic that PCN, initially advocated for the treatment of simple stones will, with the introduction of ESWL, be used mainly for larger stones and complicated calculi, e.g. debulking of large pelvic and staghorn stones, treatment of stones in a caliceal diverticulum and percutaneous incision of stenotic caliceal necks if stone fragments are not passed after ESWL.

Open surgery is still preferred in patients with larger stones with a predominant caliceal stone mass or when renal stones are associated with infundibular stenoses, pelvi-ureteric junction stenosis or a caliceal diverticulum.[20]

In conclusion, PCN is a technique in its own right and a viable alternative to open surgery. Once ESWL is widely available in the RSA, PCN could be performed in up to 20% of upper tract stones either as a preliminary or adjuvant procedure and will therefore be a necessary adjunct and complementary procedure to ESWL.[20] Ultimately we seek to render our patients stone-free after a reasonable time period and with the minimum morbidity.

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