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Review – Endo-urology

Complications in Percutaneous Nephrolithotomy

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Abstract

Objective: This review focuses on a step-by-step approach to percutaneous nephrolithotomy (PNL) and its complications and management.
Methods: Based on institutional and personal experience with >1000 patients treated by PNL, we reviewed the literature (Pubmed search) focusing on technique, type, and incidence of complications of the procedure.
Results: Complications during or after PNL may be present with an overall complication rate of up to 83%, including extravasation (7.2%), transfusion (11.2–17.5%), and fever (21.0–32.1%), whereas major complications, such as septicaemia (0.3–4.7%) and colonic (0.2–0.8%) or pleural injury (0.0–3.1%) are rare. Comorbidity (i.e., renal insufficiency, diabetes, gross obesity, pulmonary disease) increases the risk of complications. Most complications (i.e., bleeding, extravasation, fever) can be managed conservatively or minimally invasively (i.e., pleural drain, superselective renal embolisation) if recognised early.
Conclusions: The most important consideration for achieving consistently successful outcomes in PNL with minimal major complications is the correct selection of patients. A well-standardised technique and postoperative follow-up are mandatory for early detection of complications.

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1. Introduction

Percutaneous nephrolithotomy (PNL) was established as a minimally invasive treatment option for removal of kidney stones in the 1970s and was further developed in the ensuing years [1–3]. However, PNL frequency diminished with the introduction of extracorporeal shock wave lithotripsy (ESWL) in the early 1980s [4]. In recent years, as clinical experience with ESWL revealed its limitations, the role of PNL for treating urolithiasis was redefined [5–7]. Today, PNL should be the first-line treatment for large or multiple kidney stones and stones in the inferior calyx [8]. Furthermore, improvements in instruments (i.e., flexible pyeloscopes and ureteroscopes) as well as lithotripsy technology

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(i.e., ultrasound/pneumatic devices, holmium/yttrium-aluminum-garnet laser) increased the efficacy of percutaneous stone disintegration yielding stone-free rates of >90% [9,10].

Recently, a survey of urologists in Europe revealed that percutaneous procedures are performed by 69.6% of the respondents with a mean of 16.8 PNL procedures a month, clearly underlining the importance of the procedure [11]. Ultrasound renal scanning and PNL are performed more frequently outside of Europe, possibly because of larger stone burdens of the affected patients.

PNL is generally a safe treatment option and associated with a low but specific complication rate [12]. Many complications develop from the initial puncture with injury of surrounding organs (e.g., colon, spleen, liver, pleura, lung). Other specific complications include postoperative bleeding and fever.

Based on personal experience with >1000 cases [1,3,13,14] and an overview of the literature, we present PNL as a step-by-step approach including the description of possible complications and their origin and management.

2. Materials and methods

Experience gathered at three German centers (Stuttgart, Mannheim, Heilbronn) since 1984 includes >1000 cases, for which the results have been published previously [3,13–15]. In addition, a Medline search was performed reviewing the literature published between 1982 and 2006.

2.1. *Mannheim experience*

Recently, the series from Mannheim have been intensively studied for intraoperative and postoperative complications [14] including 315 PNL treatments (156 men, 159 women; average age, 54.7 yr [13–85 yr]) for renal or impacted proximally ureteric stones from 1987 to 2002.

2.2. *Preparation of patients*

The careful selection and preparation of patients is of utmost importance to decrease the complications of PNL. All patients underwent the following diagnostic work-up:

- Definition of stone size (kidney-ureters-bladder [KUB] and ultrasound)
- Anatomy of the collecting system (intravenous pyelogram)
- Urine analysis and culture
- Serum creatinine, clotting parameters
- Isotope renogram if indicated (i.e., staghorn calculus)

In case of a staghorn calculus or existing urinary tract infection (UTI), the patients were treated with antibiotics according to the testing (i.e., gyrase inhibitors, gentamicin) at least 1 d prior to the procedure. Patients with decreased renal function were pretreated with intravenous infusion of normal saline.

2.3. *Technique of PNL*

The entire procedure, particularly the initial puncture, is performed in the urology department with the patient under general anaesthesia. Prior to the procedure, a retrograde study is performed and a ureteral balloon catheter placed at the ureteropelvic junction. The collecting system is moderately filled with contrast dye (i.e., with addition of methylene blue).

2.3.1. *Positioning of the patient*

As previously published in detail [1,3,15], PNL is carried out with the patient placed in the prone position. One may use a specially designed cushion enabling a deflected position to place the patient flat on the fluoroscopic table. Some authors prefer an oblique prone [8] or oblique supine position [16,17].

2.3.2. *Puncturing of the collecting system*

For the puncture of the collecting system, we use a combination of ultrasound (freehand technique, fully guided system) and fluoroscopy. Based on sonographic imaging, the puncture is carried out to the desired calyx. The final placement of the needle is mostly performed under fluoroscopic control. A peripheral puncture to transverse a minimum of cortical tissue has to be accomplished, to avoid injury to major intrarenal vessels, to avoid fistula injury, to establish the shortest tract between the skin and calyx, and to minimise radiation exposure, as verified in a similar study [16].

Afterwards, a 0.97-mm floppy-tipped guidewire is passed through the needle into the collecting system. A working channel is then established using the Alken telescope metal dilators system (Storz, Tuttlingen, Germany) under X-ray control to 24–26F [18]. Then, a standard 26F nephroscope is placed directly into the kidney over the established tract. Alternatively, a dilatation balloon system together with an Amplatz sheath can be used.

The number and type of access depend on the treated stone size (i.e., staghorn stone) and localisation (upper pole, lower pole) as well as on the treatment strategy (single-session PNL vs. combination with ESWL). Whereas some authors prefer a standardised access through the lower calyx with additional treatment of stones not reachable via this access by subsequent ESWL [3,13], other authors advocate multiple tracts (i.e., upper pole) to clear the collecting system in a single session [19–21]. Advantages of upper pole access include optimal manipulation in case of stone burden in the upper and lower calices; however, this has a slightly increased complication rate (i.e., pleural injury) [21,22].

2.3.3. *Stone manipulation*

For stone disintegration we prefer using an ultrasound lithotripsy probe. Except for very hard stones (i.e., calcium oxalate monohydrate) it enables fragmentation with simultaneous evacuation of the gravel. Other alternatives include the use of ballistic devices or holmium/yttrium-aluminum-garnet laser. Flexible nephroscopy is used when stone fragments migrate into other calyces or in case of additional stone burden in other calyces not accessible by the rigid nephroscope.

2.3.4. *Postoperative care*

At the end of the procedure, a 22F Foley catheter is used as a nephrostomy tube and blocked with 1–2 ml in the renal pelvis. Alternatively, a red rubber catheter or a detachable silicone balloon catheter can be placed. An antegrade nephrogram is taken 24–28 h after the procedure (depending on the clarity of urine). The tube is removed if no extravasation or retained calculi are present.

3. Results

3.1. *Mannheim experience*

Overall, early complications occurred in 50.8% of the primary PNL (160 patients). Most of the early complications resolved without sequelae. Minor complications in our series included transient fever (32.1%), clinically insignificant bleeding (7.6%), or both (3.2%). A total of 3.5% of the patients developed UTI without signs of urosepsis, and 3.2% of patients suffered from renal colic. Major complications included septicaemia in 0.3%, renal haemorrhage requiring angiographic intervention in 0.3%, and acute pancreatitis in 0.3%. The 30-d mortality rate was 0.3% (Table 1).

Table 1 – Complications in PNL: an overview of literature and the Mannheim experience

	Literature	Mannheim series (n = 315 [14])
Extravasation	7.2% (n = 582 [24])	NA
Renal haemorrhage	0.6% (n = 318 [25]) 1.4% (n = 1854 [27])	0.3%
Transfusion	11.2% (n = 582 [24]) 17.5% (n = 103 [30])*	0%
Fever	21.0% (n = 81 [29]) 21.4% (n = 103 [30])* 22.4% (n = 582 [24])	32.1%
Sepsis	0.8% (n = 582 [24]) 0.97% (n = 103 [30])* 2.2% (n = 318 [25]) 4.7% (n = 128 [31])	0.3%
Colonic injury	0.2% (n = 1000 [2]) 0.2% (n = 582 [24]) 0.29% (n = 5039 [32]) 0.8% (n = 250 [34])	0%
Pleural injury	2.3% (n = 128 [31]) 3.1% (n = 582 [24])	0%
Acute pancreatitis	NA	0.3%
Perioperative mortality	0.3% (n = 318 [25]) 0.3% (n = 582 [24]) 0.78% (n = 128 [31])	0.3%

PNL = percutaneous nephrolithotomy; NA = not available.
* Multitract PNL due to large staghorn stones.

3.2. *Review of the literature*

In the current literature, the total complication rate is up to 83% [2,19–24]. These complications are mostly clinically insignificant bleeding or fever. The number of significant bleedings is reported as <8% [19–27]. Conservative treatment is successful in most of these cases and in our series no blood transfusion was required. However, a 5–18% blood transfusion rate is reported in the literature [19–28]. The frequency of major complications was 0.9–4.7% for septicaemia and 0.6–1.4% for renal haemorrhage requiring intervention [19–31]. Rates of access-related complications were 2.3–3.1% for pleural and 0.2–0.8% for colonic injury (Table 1) [19–34].

4. Discussion

Significant complications in PNL can be divided into complications related to the access and those related to the stone removal.

The sources of intraoperative complications are generally attributable to:

- Incorrect patient selection
- The lack of adequate equipment
- Technical errors

4.1. *Patient selection*

Correct patient selection is important for all percutaneous endourologic procedures, but particularly when selecting patients for PNL. Surprisingly, reports suggest that PNL in pretreated kidneys is not associated with a higher morbidity but the procedure may take longer and usually leads to a higher percentage of auxiliary procedures [36].

- PNL is contraindicated if the patient has an untreated coagulopathy, UTI, or pyonephrosis.
- The presence of concomitant disease such as diabetes or pulmonary disease or cardiovascular disease enhances the risk of a suboptimal outcome for PNL; a similar situation occurs in the presence of malfunctioning kidneys or infected stones.
- If the patient is grossly obese or has a spinal deformity, a branched collecting system, or a horseshoe or malrotated kidney, the procedural difficulty is increased. There might be a controversy about obesity; however, at least in the authors' experience gross obesity increased the risk of complications. It is technically more

demanding (i.e., length of nephroscope sheath) and the patients usually suffer from associated diseases (i.e., diabetes mellitus).
- Large stone size will increase rate of complications.

4.2. *Correct preparation and equipment*

4.2.1. *Positioning of the patient*

Precise access to the kidney during PNL is facilitated by careful positioning of the patient and reduces the possibility of subsequent intraoperative complications. The following positions are described:

- The flat prone position on a fluoroscopic table
- The deflected prone position on a cushion
- The oblique prone position on a fluoroscopic table
- The oblique supine position on a fluoroscopic table

The deflection of the patient placed on special cushion may increase the distance between the 12th rib and iliac spine, thereby enlarging the area for adequate puncturing of the kidney. On the other hand, this leads to a higher position of the patient on the fluoroscopic table, which may interfere with the handling of the nephroscope and probes. Urologists favouring the oblique supine position claim it facilitates an easier access for the subsequent PNL [16,17]. It is important to note that with the patient in the oblique supine position, the axis of the kidney will not be the same as in the flat prone position.

4.2.2. *The type of needle and sheath*

Needles with a facette-cut tip are preferable because of improved visibility during ultrasound scanning [37]. The use of a flexible silicone sheath enables easier manipulation when inserting the guidewire.

4.2.3. *Instruments for PNL*

Urologists have to check all instruments (i.e., dilators, graspers, nephroscope) properly prior to the procedure, especially the functionality of the lithotriptor devices (i.e., ultrasonic, ballistic, laser). Moreover, it is advisable to have at least two different devices for stone disintegration available.

4.3. *Technical aspects*

4.3.1. *Puncturing of the collecting system*

Although in the United States and United Kingdom, renal access is established by radiologists, in some European centres, urologists do the puncture, using combined ultrasound/fluoroscopic guidance systems such as a sector scanner or semicurved scanner [38]. This technique allows a more sophisticated approach because it is possible to determine the axis of the kidney exactly and, by injecting a contrast dye, ensures that the needle is correctly positioned (Fig. 1).

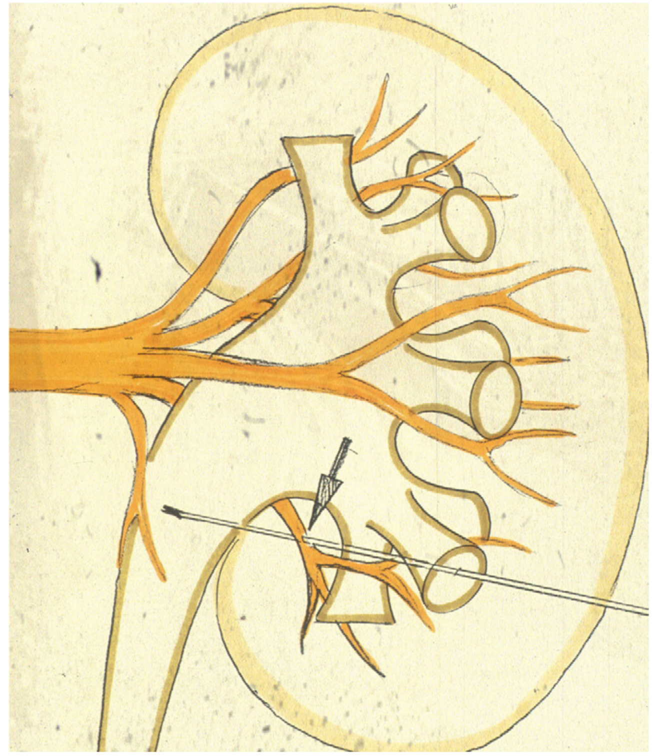

Fig. 1 – Renal vascular anatomy. Puncture of renal pelvis or through caliceal infundibulum leads to an increased risk of vascular injury.

It is also possible to perform an ultrasound-guided freehand puncture using a sector scanner and with the patient in an oblique supine position, but this freehand technique, and its use particularly in the oblique supine position, requires a greater degree of experience than when using a fully guided ultrasound system.

None of the ultrasound-based techniques requires any additional diagnostic imaging techniques, such as a computed tomography urogram. However, these might be useful to determine the choice of the calyx for optimal stone manipulation.

Usually, a subcostal approach is used, although a supracostal approach is preferred for certain indications such as superior calyx stones, staghorn stones, or stones of the proximal ureter [22]. A significant chest complication rate of about 5% must be considered when choosing the supracostal approach [22].

4.3.2. Placement of the guidewire

It is important to avoid perforation of the renal pelvis when introducing the guidewire after puncturing the calyx. In the literature, perforation rates up to 7.2% are reported [20]. This potential problem can be avoided by using a J guidewire, which has a soft tip. We prefer a guidewire with an inner core. It is also vital to incise the fascia parallel to the needle to avoid problems with the dilatation process. In some problematic cases (i.e., previous renal surgery), it may be preferable to use a more rigid guidewire such as the Lunderquist wire.

4.4. Complications related to the access

4.4.1. Parenchymal bleeding

A common source for a bleeding during PNL is the nephrostomy tract itself. These bleedings can be prevented if the kidney is strictly punctured through a calyx and a minimal angulation of the dilation system and nephroscope shaft is used (Fig. 1). To avoid extensive angulation, a flexible nephroscope should be used for stone parts in other calyces. If bleeding significantly impairs the endoscopic view, the procedure should be terminated; a nephrostomy should be placed [25] and clamped for 40–60 min to provide a tamponade within the collecting system to provide haemostasis. The second procedure can be carried out after 24 or 48 h if macrohaematuria has cleared to provide optimal precondition for the reintervention. In a case of persistent relevant bleeding, renal angiography should be performed with the possibility of a superselective embolisation (Fig. 2A and B).

Lacerations can occur during the dilation of the tract and during definitive surgery in terms of stone removal. Fluoroscopic monitoring of the dilation process (metal dilator, balloon) can minimise the risk of laceration. If lacerations occur, intraoperative bleeding can be induced and is likely to hamper the further procedure. If significant bleeding in terms of decreased visibility or haemoglobin-relevant bleeding occurs, a nephrostomy tube should be placed and reintervention planned 48 h later. The nephrostomy may tamponade further bleeding.

Lesions of the vascular system can also lead to late bleeding complications arising from pseudoaneurysm or arteriovenous fistulas and usually need therapeutic intervention (i.e., embolisation) [27]. These complications are rare but can occur up to 3 weeks after PNL. Stone size was identified by Srivastava et al. as a risk factor for these complications. Urologists have to keep them in mind because they are present in about 1% of the patients [27].

4.4.2. Organ injuries

4.4.2.1. Pleural injury. The risk for an injury of the pleura and the lung increases if the puncture is above the 12th rib (10%). Puncture using ultrasound control or a puncture after exhalation may prevent pleural injury. If the puncture is through the pleura, extravasation of irrigation fluid or the entry of air into the pleural space should be prevented. If a hydrothorax (pleural effusion) or haematothorax occurs, a chest tube has to be inserted. Thoracoscopy or thoracotomy is only very rarely necessary. Of course, the preference of lower calyx access in combination with flexible nephroscopy or ESWL practically avoids this complication [13,15,19,21,22].

4.4.2.2. Injury of the duodenum, colon, and other abdominal organs. More than 30 published papers report on colonic injury during PNL. The largest, recently published series of 5039 procedures [32] identified several risk factors including left-side procedure, horseshoe kidney, and advanced patient age. The risk of perforation can increase up to 1%. Further risk factors are an inflated colon and extreme thinness of

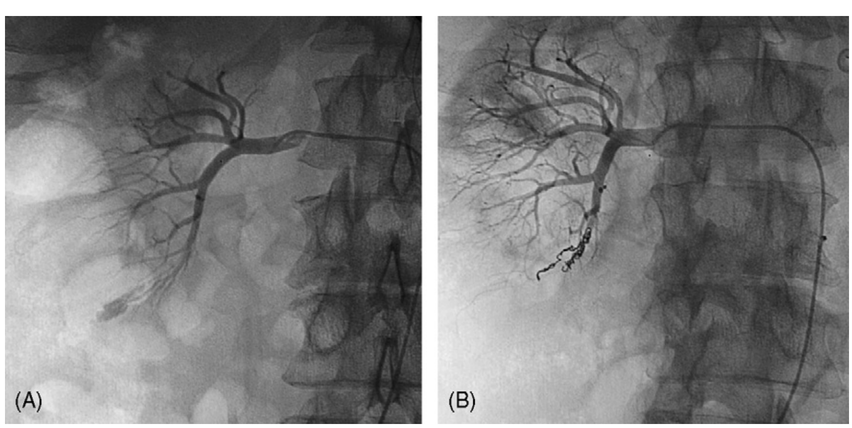

Fig. 2 – Arterial bleeding after percutaneous nephrolithotomy from a lower pole artery (A) and occlusion of the lower pole artery by superselective coiling (B).

Fig. 3 – Colonic injury after failed renal puncture for percutaneous nephrolithotomy. Clearly, filling of the intestine by contrast agent is detected after filling of the nephrostomy.

the patient. Additionally, the urologist should be cautious if the patient has had previous bowel surgery, which increases the potential risk for injury of the duodenum or the colon. If an extraperitoneal perforation occurs, the gastrointestinal tract must be separated from the urinary tract (Fig. 3). Therefore, a catheter has to be placed into the colon and conservative treatment with antibiotics can be performed. Conservative treatment of colonic injury is successful in most cases [32–35]. In case of an intraperitoneal perforation, open surgery has to be performed immediately. The risk of puncturing of the colon can be minimised by the use of sonographic control (visualisation of the bowels) and correct patient selection (as the risk factors have been identified).

An injury of the spleen is very unlikely if the puncture is below the 12th rib; however, the presence of splenomegaly increases the risk. Injury to the spleen can be prevented by puncture under ultrasound control. Spleen injuries are, in most cases, associated with relevant bleeding and therefore emergency exploration and splenectomy must be performed.

4.5. *Complications related to the stone removal*

4.5.1. *Septicaemia*

Septicaemia can occur as a result of infection introduced via the access to the kidney or if the stones are infected. Following PNL, fever is significantly higher and more frequent in patients with infected urinary stones than in those with sterile stones [35]. Renal insufficiency increases the risk. Prophylactic antibiotics and draining of a pyonephrotic kidney before performing PNL is mandatory [15]. Antibiotics can be applied by single-dose or short-course prophylaxis protocols with no significant differences between them in case of sterile urine [26]. The duration of surgery and the amount of irrigation fluid are significant risk factors for postoperative fever [29]. It is also important to prevent a high pressure in the collecting system [35] and to keep the duration of operating time to a minimum (i.e., $<$90 min).

Sepsis rates reported in the literature vary from 0.97% [30] to 4.7% [31]. In our series, one patient (0.3%) died from urosepsis despite adequate antibiotic treatment [14]. In cases where septicaemia has occurred, the patient should receive intensive care therapy including forced diuresis, antibiotic treatment, optimal renal drainage, and electrolyte control [15]. The observed pathophysiologic origin of an observed acute pancreatitis remains unclear.

4.5.2. *Extravasation and fluid absorption*

The common source for extravasation and fluid absorption is a perforation of the collecting system. Methods of prevention include manipulation only under X-ray or endoscopic control, use of an open or continuous flow system, and use of normal saline as irrigant. However, even with these precautions a high-fluid volume syndrome may develop. Therefore, if the fluid discrepancy (inflow/outflow) exceeds 500 ml, the procedure should be stopped and a nephrostomy placed. Monitoring of the serum electrolytes is mandatory.

Urine extravasation following PNL may occur in case of severe perforation of the collecting system or the nephrostomy tract (extraperitoneal). Problems are flank pain or signs of infections under antibiotic treatment. Percutaneous drainage of the urinoma and the collecting system (i.e., additional double-J or mono-J stent) may become necessary.

Table 2 – Most important factors to prevent complications in percutaneoul nephrolithotomy

• Preoperative radiologic/sonographic evaluation
• Optimal puncture through the calyx
• Ultrasound control if possible
• Atraumatic dilation under continuous X-ray control
• Minimal angulation of nephroscope
• Use of a flexible pyeloscope for stone parts in upper calices
• Know when to stop and when to retreat

5. Conclusions

To avoid the complications associated with percutaneous endourologic procedures and to ensure optimum outcomes for patients, urologists must consider a number of factors when planning or performing PNL (Table 2). Therefore, training and experience of the urologist are critical, as is careful patient selection, accurate positioning, and use of the best available instruments.

Conflicts of interest

In this article there is no funding or any disclosure to companies, except for the fact that the study was sponsored by the EUSP of the EAU.

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Editorial Comment

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This is a well-written review on the complications of percutaneous nephrolithotomy (PNL) for large renal and impacted proximal ureteral stones and the authors are to be commended for their accurate and honest analysis. The authors present their large experience with an overall complication rate of 50.8%, including a minor complication rate of 49.6%. This finding corresponds to their literature review. After >30 yr of worldwide experience, PNL remains a milestone technique in the urologic field with a very low percentage of major complications and with a very high success rate [1].

Of note, the incidence of big staghorn calculi has drastically decreased, and more stones in the 2-cm range are seen. The new generation of flexible ureteroscopes has been significantly improved in terms of therapeutic and diagnostic efficacy [2]. Also the advances in lithotripsy, in particular, the holmium laser, have resulted in increased treatment success for stones and reduced procedure-related morbidity [3]. The success rate for intrarenal stones >2 cm after the first or second treatment has been reported as ranging from 75% to 95% [2]. The complication rate reported varies from 1.5% to 12% [3–5], including major and minor complications. Of note, the incidence of major complications such as ureteral avulsion or perforation has decreased to the 0% range in the most recently published data [2]. The disadvantage of ureteroscopy to PNL is that ureteroscopy may require multiple procedures to clear a big stone and to extract the fragments, as opposed to PNL, which can offer a 95% stone-free rate after the first treatment [1]. The cost to pay for this high success rate is, indeed, a higher complication rate. Further studies need to be done to assess the advantages of one procedure versus the other.

References

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