REVIEW

Complications of percutaneous nephrolithotomy: classification, management, and prevention

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Purpose of review
Percutaneous nephrolithotomy (PCNL) provides the highest stone-free rate after one session and low morbidity rates in cases of large or multiple renal calculi. The classification, management, and prevention of complications of PCNL are reviewed.

Recent findings
PCNL is a well tolerated and very effective procedure for the management of renal stones. Specific complications limit the surgical outcome of PCNL whereas the majority of the complications are resolving with conservative or minimally invasive management. Experience with the technique is important for minimizing complications. There is an ongoing effort to classify the complications and to achieve a consensus in reporting the complications and surgical outcome of the procedure.

Summary
The knowledge of risk factors, complications, and their management is important for every endourologist. Establishing of a PCNL-specific classification system for reporting outcomes and complications could set the basis for further improvement of the PCNL technique and outcomes.

Keywords
complications, nephrolitrotripsy, percutaneous nephrolithotomy

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) provides the highest stone-free rate after one session and low morbidity rates in cases of large or multiple renal calculi [1,2▪]. Nevertheless, serious but infrequent complications have been reported for PCNL [3▪]. Herein, the classification, management, and prevention of complications of PCNL are reviewed.

CLASSIFICATION OF COMPLICATIONS

Despite the performance of PCNL for more than 20 years, the literature is still lacking a specialized, for PCNL, outcome reporting and complications grading system [4▪▪,5]. The complication severity and morbidity rates cannot be directly compared among the reports. Minor, clinically insignificant complications such as a transient postoperative hematuria could be either considered by some investigators as normal postoperative course, whereas others would consider them as complications [6–8]. The aforementioned lack of homogeneity of the studies and consensus on the classification of complications represents a significant issue in the PCNL literature and result in a high variety of the reported complication rates, which range between 4 and 50.8% [3▪,5]. In an attempt to provide an objective, unified classification of PCNL complications, the modified Clavien–Dindo classification system of surgical complications was adopted. A large prospective study used the above system and complications were reported to be present in 20.5% (grade I or II: 16.4%, grade IIIa or IIIb: 3.6% and grade IV: 0.5%) [9].

Recently, two scoring systems have been proposed for the prediction of the surgical outcome and complications of PCNL. The S.T.O.N.E system predicts the stone-free rate based on the following criteria: stone size (S), tract length (T), obstruction

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KEY POINTS

- Most complications are managed conservatively.
- Risk factors should be carefully considered preoperatively and postoperatively.
- Classification of outcome reporting and complications require further development.

(O), number of involved, calices (N), and essence or stone density (E) [10]. The Guy Stone Score uses the total number of stones present in the kidney and any abnormal renal/collecting system anatomy in order to provide four specific grades [11]. The systems were found to be also useful for preoperative planning and patient counseling [10,12,13▪,14▪]. Their comparison showed that they are accurate with high interobserver concordance [15▪].

RISK FACTORS

Risk factors for increased morbidity of PCNL have been identified and should be considered before performing the procedure. Patient selection is important and PCNL should be avoided in patients with untreated coagulopathy, urinary tract infection, or pyonephrosis. Comorbidities such as diabetes may result in suboptimal outcome whereas skeletal deformities, complex renal anatomy, horseshoe, and malrotated kidneys increase the difficulty of the procedure [6]. A recent study revealed that an age more than 55 years and an upper pole access are independent predictors of major complications [16▪]. When the impact of previous surgery (PCNL or open surgery) was evaluated in terms of complications, only an increase in the need of embolization was noted for the cases that had previously undergone open surgery [17].

Surgical skill influences the complication rate of PCNL and centers with high experience have low incidence of complications [18–20]. Studies estimating the learning curve of PCNL have shown that, approximately, 60 cases are necessary to achieve competence in terms of operative time [18–20]. It is not clear whether the performance of the access by the urologist eventually contributes to a lower morbidity rate [21]. Prone or supine positions for PCNL do not have an impact on the overall complication rates [19,20,22]. A higher rate of bleeding, sepsis, pulmonary injury, and renal pseudoaneurysm, have been documented when performing multiple tracts [23]. In a recent study, factors such as the female sex, complexity of the stone and duration of surgery at least 120 min represented independent factors of complications. The high Charlson comorbidity score was related to Clavien complications of Grade at least 3. [24▪]. Factors such as BMI have not been well documented to have an impact on morbidity [21]. The performance of tubeless PCNL does not represent a factor for higher complications rate [25,26]. A meta-analysis showed that there was no significant difference in fever, hemoglobin concentration drop, transfusion rates, prolonged urinary drainage, need for additional procedures between the totally tubeless, and the standard PCNL [26]. Risk factors, incidence, and complication management are summarized in the Table 1 [3▪,6,8,9,19,21,23,27▪▪,28–31,32▪,33–47,48▪▪,49,50].

MANAGEMENT AND PREVENTION

Bleeding

Hemorrhagic complications (preoperative, immediate, and postoperative) related to PCNL occur in variable entities in almost one-third of the cases [27▪▪]. The incidence of bleeding requiring blood transfusion ranges between 0 and 20% with an overall rate of 7% [21]. Risk factors for hemorrhage are multiple punctures, use of large bore access sheaths, staghorn calculi, and prolonged operation time [27▪▪,28,29].

During and after PCNL, bleeding may be venous, acute due to the injury of an anterior or posterior segmental artery or delayed due to interlobar and lower pole arterial lesion, arteriovenous fistula or pseudoneurysm [27▪▪]. These injuries take place during the dilation of the track or the excessive bending of the access sheath. Access sheaths tend to tamponade such bleeding and the procedure can be successfully completed [8]. Any excessive bleeding hindering the intraoperative visibility could be addressed by moving the access sheath close to the wall of the pelvicalyceal system. Otherwise, the procedure should be aborted, a nephrostomy tube should be placed and clamped [6]. Accessing the renal collecting system through the Brodel's avascular plane is considered the most advisable site for minimizing bleeding. The use of flexible nephroscopes reduces the need for acute angles of the instrument and access sheath.

Similarly, the subcostal vessels could be injured during tract dilation in accesses over the 12th or 11th rib. Bleeding from parenchymal or subcostals vessels as well as from vessels in the nephrocutaneous tract may not be as obvious intraoperatively and may be detected just after access sheath removal. The majority of these hemorrhages are easily controlled with external pressure at the site of the access tract

Table 1. Summary of complications in percutaneous nephrolithotomy, incidence, risk factors and possible management options

Complication	Incidence	Risk factors	Management
Bleeding [3■,6,8,19,23,27■■, 28–31,32■,33,34]	0–20% (overall 7%)	Multiple punctures	Clamped nephrostomy tube
		Large bore access sheath	External pressure and hemostatic agents
		Staghorn stone	Osmotic dieresis
		Prolonged operation	Computed tomography angiography and embolization (fistulas, pseudoaneursms)
		Supracostal access	Percutaneous drainage (persisted hematomas)
Infection [6,21,35–39]	Fever: 2.8–32.1%	Bacteriuria	Preoperative antibiotic treatment (Bacteriuria)
		Renal abnormalities	Prophylactic single-dose or short-term antibiotics (sterile urine)
		Vesical neurological problems	Broad spectrum antibiotics and electrolytes and diuresis and renal drainage (urosepsis)
		Prolonged operative time	Abort procedure and nephrostomy (purulent urine)
		High irrigation flow pressure	
Pneumothorax, Hydrothorax, Hemothorax, Urinothorax [3■,9,27■■,39–42]	<2%	Supracostal access	Conservative (small pneumothorax)
			Prolonged renal drainage (small pneumothorax)
			Thoracic drainage (Significant pneumothorax or pneumothorax)
			Thoracic and renal drainage (urinothorax)
			Thoracic drainage (Hemothorax)
Persistent nephrocutaneous fistula [8,43–45]	1.5–4.6%	Large diameter drainage tube	Double-J ureteral stent
		Prolonged catheterization	
		Absence of ureteral stent	
Rupture of the Pelvicalyceal system [6,21,46]	Injury: $\leq$5.2%; urinoma: 0.2%	Forceful use of material and equipment	Double-J ureteral stent or nephrostomy tube
			Cutaneous drainage (urinoma)
			Abort procedure and nephrostomy
Small bowel perforation [47]	nine cases	Right sided cases	Nephrostomy tube and stop oral intake and parenteral nutrition and I.V antibiotics
			Abdominal exploration
Liver injury [48■■]		Supracostal access	Hemostatics and prolonged renal drainage
		Upper pole access	Abdominal exploration
Splenic injury [48■■]	11 cases	Supracostal access	Hemostatics and prolonged renal drainage
		Hepatomegaly	Abdominal exploration – splenectomy
Colonic perforation [3■,21,46,47,49,50]	<0.5%	Left sided cases	Removal of nephrostomy tube and Insertion of ureteral stent and Parenteral nutrition and I.V antibiotics
		Lower calyceal access	Surgery and colostomy (persisted peritonitis)
		Older patients	
		Colonic distension	
		Horseshoe kidney	
		Retroperitoneal colon	

and/or clamping of the nephrostomy tube and rarely is a hemostatic agent injected into the tract [3▪].

Life threatening hemorrhage requiring emergent nephrectomy could happen by injuring the main renal vessels during the dilation of the tract. If blood is aspirated through the puncture needle, the needle should be withdrawn and another puncture should be performed. The insertion of a stiff guidewire in the ureter directs the forces of the dilation toward the ureter and away from the renal vessels and is advisable whenever possible. After the removal of the nephrostomy tube, reactivation of bleeding from an unhealed vessel is possible. Direct pressure on the cutaneous orifice and insertion of a Foley catheter should take place [3▪].

Causes of significant, delayed hemorrhage are arteriovenous fistulas and arterial pseudoaneurysms. Both complications are rare (1.2%) [30,31]. A recent study evaluating the incidence and risk factors in a series of 3300 PCNLs, showed an incidence of 0.48% and no specific risk factors were identified [32▪]. Cases of fistulas and pseudoaneurysms are usually characterized by persistent heamaturia, slow decrease in hemoglobin and rarely by hypotension. Computerized tomography (CT) will verify the diagnosis and set the indication for a selective embolization of the bleeding vessel [3▪].

Perinephric hematomas with a minimal or moderate amount of blood are observed in one-third of the patients after PCNL [27▪▪]. The majority of the cases are subcapsular hematomas. Less than 1% of the cases require selective embolization and the majority of the hematomas are mostly silent and uneventful [27▪▪,33]. CT will provide information regarding the presence of active bleeding [34]. A very late complication of the perinephric hematomas is the 'Page kidney', which refers to the development of hypertension due to renal compression, ischemia, and hypoperfusion by the inadequate reabsorption of the hematoma. Thus, cases of persisting liquefied hematomas should be managed by percutaneous drainage [19,23].

Infectious complications

The incidence of fever after PCNL ranges between 2.8 and 32.1% [21]. Urosepsis is a rare but severe complication [6,21]. Factors predisposing to urosepsis include bacteriuria before the operation, renal abnormalities, vesical neurological problems, prolonged operative time, and high intraoperative irrigation flow pressure [35]. Renal insufficiency increases the risk for postoperative fever [6]. Patients with preoperative bacteriuria should undergo urine cultures and treated accordingly with antibiotics [36]. Patients with sterile urine could either be managed with single-dose or short-term antibiotic prophylaxis in order to prevent infection [37,38]. According to a recent meta-analysis, prophylactic antibiotic administration reduces the incidence of postoperative urinary infection, whereas the extended antibiotic therapy reduces the incidence of fever and bacteriuria [39]. When the duration of the procedure remains below 102 min and the amount of the irrigation fluid used is less than 23l, the risk of postoperative fever is also reduced [21,38]. PCNL cases with purulent urine at the initial puncture should be aborted, a nephrostomy should be placed and the procedure should be performed after a course of antibiotics. Cases of urosepsis should be managed by intensive care treatment with administration of antibiotics, electrolyte control, forced diuresis, and optimal renal drainage [6].

Thoracic complications

Pneumothorax, hydrothorax, hemothorax, and urinothorax are uncommon complications with an incidence less than 2%. These complications happen by intraoperative puncture of the pleura and are usually diagnosed just after the removal of the access sheath or nephrostomy tube. Studies evaluating the incidence of pleural complications showed that supracostal punctures (over the 12th rib) are related to higher incidence of thoracic events in comparison to the subcostal punctures [9,39,40]. As a general rule, an access above the 12th should be carefully selected and above the 11th should be avoided [3▪].

Postoperative pneumotharax is usually small and resolves without intervention in the majority of the cases. Nevertheless, strict radiological follow-up is recommended to ensure the resolve of the condition [3▪]. Hydrothorax is caused by accumulation of the irrigational fluids in the pleural cavity intraoperatively. The access sheath tends to tamponade any pleural injury during the procedure and blocks the entrance of fluid in the thorax. Therefore, access sheaths should be removed only after the irrigation flow has been stopped. A small volume hydrothorax could be treated with prolonged renal drainage. Significant fluid accumulation should be managed by thoracic drainage [3▪].

Urinothorax is caused by passing of urine through a pleural lesion or by the leakage of urine in the retroperitoneum and passage through the lymphatic of the diaphragm in the peritoneal cavity [27▪▪]. A pleural fluid-serum creatinine ratio more than 1 is confirmatory for the presence of urine. The drainage of the both systems is recommended (nephrostomy and chest drain) [41,42]. Pleural drain should be removed first when the urine drainage has stopped. The nephrostomy is removed a couple of days later. Hemothorax occurs after the puncture of an intercostal artery and rarely after direct injury to the lung. Gently bypassing ribs on their upper borders could limit the incidence of the complication [3▪].

Persistent nephrocutaneous fistula

Typically, the removal of the nephrostomy will result in a urine draining nephrocutaneous tract. This tract is usually occluded within the first 12 h after the removal [43]. The incidence of persistent nephrocutaneous fistula with urine leakage varies from 1.5 to 4.6% [8,43,44]. Predisposing factors include the use of large diameter renal tubes, prolonged catheterization period, and the absence of internal ureteral drainage [45]. Radiological assessment for possible existence of ureteral clot or stone fragment is advisable. The insertion of a ureteral stent is deemed necessary in the majority of cases [3▪].

Injuries of the pelvicalyceal system

PCNL may result in injury of the collecting system, extravasation of fluid and urine and eventually the formation of an urinoma. Lesions of the pelvicalyceal system have been reported in up to 5.2% of the cases, whereas the formation of an urinoma remains low at 0.2% [21,46]. Adequate drainage with nephrostomy or double-J stent and urethral catheter are usually enough [21]. Placement of a drain at the site of the urinoma may occasionally be necessary. Risk factors for major pelvicalyceal rupture resulting in urinoma formation include high intrarenal pressure during operation, forceful use of stiff wires and access sheaths, as well as forceful use or extreme angulation of the instruments [3▪]. When a perforation of the collecting system is detected intraoperatively, the procedure should be kept as short as possible with low flow pressures [21]. Some investigators advocate to abort the procedure when perforation of the collecting system has occurred and more than 500 ml of irrigation fluid has been used [6].

Small bowel injuries

There are in total nine cases of either duodenum or jejunum injury during PCNL in the literature. These lesions mostly occur during the puncture and dilation of right-sided cases. Intraoperative nephrostomography shows communication of the collecting system with the bowel and is important for the detection of the complication. Otherwise, an abdominal exploration may not be avoided. Conservative treatment includes the insertion of a nephrostomy tube, seization of oral intake, and parenteral nutrition [47].

Colonic perforation

Injury of the colon has an incidence of 0.5% [48▪▪] and is more common in procedures performed in the left side, lower calyceal accesses, older patients, colonic distension, and horseshoe kidneys [46]. A preoperative abdominal CT is important for the preoperative planning [3▪]. Retrorenal colon is observed in up to 1.9% of the patients in the supine position. Punctures lateral to the posterior axillary line are related to colon injuries [47]. Colonic perforation is detected intraoperatively by the opacification of the injured colon. Otherwise, the complication is diagnosed by CT performed in a patient who develops unexplained fever, hematochezia or diarrhea, peritonitis or sepsis postoperatively [21]. Colonic injuries could be managed conservatively by separating the nephrocolic communication [49]. Thus, the insertion of a drain in the pelvicalyceal system and another in the colon is highly recommended. Colonic drainage can be gradually withdrawn (1 cm/day) after the seventh postoperative day [3▪]. Close follow-up either with CT will ensure the colonic integrity [50]. In cases of delayed diagnosis, parenteral nutrition, administration of broad spectrum antibiotics, and temporary colostomy for 3 months are necessary [21].

Liver/spleen injuries

The documented cases of splenic injury are only 11 in the literature. Intercostal and upper pole accesses have a higher probability for splenic injury. An 11th or 12th rib subcostal approach during expiration minimizes the risk for the above injury. Splenic injuries are diagnosed after a CT conducted due to hemodynamic instability, hemoglobin drop, and abdominal pain. It is important to have an early diagnosis of a splenic injury as the delayed diagnosis may result in a fatal postoperative course. Conservative management includes close monitoring, use of coagulant agents, and prolonged nephrostomy drainage to ensure proper healing of the injured site [48▪▪]. There is only one case of liver injury reported in the literature [48▪▪,51]. Cases of supracostal access and hepatomegaly pose a higher risk for liver injury [51,52]. Liver injuries represent a lower risk for serious or fatal consequences [48▪▪]. Their conservative management is similar to splenic injuries. Cases of liver or splenic injury with hemodynamic instability demand surgical exploration [51,53,54].

CONCLUSION

Specific complications limit the surgical outcome of PCNL, whereas the majority of the complications are resolving with conservative or minimally invasive management. Experience with the technique is important for minimizing complications. Moreover, the knowledge of risk factors, complications, and their management is important for the endourologist. Establishing of a PCNL-specific classification system for reporting outcomes and complications could set the basis for further improvement of the PCNL technique and outcomes.

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Conflicts of interest

There are no conflicts of interest.

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