Complications associated with percutaneous nephrolithotomy

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The increasing global prevalence of nephrolithiasis continues to burden the healthcare delivery systems of industrialized nations and exact a disproportionate humanitarian toll on populations of the developing world (1). In the United States alone, the prevalence of nephrolithiasis is nearly twice the rate reported in the 1960s (2-5). The subsequent rise in surgical interventions for nephrolithiasis has resulted in the development of new minimally invasive technologies and techniques, but it has also led to the resurgence of established methods such as percutaneous nephrolithotomy (PNL).

Percutaneous entry into the renal collecting system was first described in the 1950s, but it wasn't until the mid 1970s and 1980s that percutaneous access to the renal collecting system was routinely utilized for the removal of nephrolithiasis (6-8). Although PNL initially proved to be an effective technique, the near-concurrent introduction of shockwave lithotripsy (SWL) resulted in a rapid and marked decrease in the utilization of PNL (9). There has been, however, a recent increase in the utilization of PNL, largely attributed to the limitations of newer SWL equipment, an increase in stone prevalence, and the refinement of PNL indications, techniques and instrumentation (10-14).

PNL is considered the standard treatment for staghorn and large-volume renal calculi, as well as upper tract calculi refractory to other modalities, difficult lower pole stones, cystine nephrolithiasis, and calculi in anatomically abnormal kidneys. PNL is typically a very safe and well-tolerated procedure, but as with any surgical intervention, PNL is associated with a specific set of complications (15,16).

Complication rates for PNL reportedly range from 20-83% (16-21). The true complication rates of PNL are difficult to determine and compare because most contemporary reviews of PNL outcomes report only rates of specific complications of the procedure. Other authors have attempted to standardize the reporting of complications of PNL by utilizing the modified Clavien complication grading system, or by assigning Clavien grading system scores to the complications most commonly associated with PNL (22,23).

An international multi-center study of 5,803 patients undergoing PNL reported an overall complication rate of 21.5%. The study, conducted by the Clinical Research of the Endourological Society (CROES), utilized the modified Clavien system for reporting complications. The majority of complications were minor, with rates of 11.1%, 5.3%, 3.6%, 0.5% and 0.03% of for grade I, II, III, IV and V complications, respectively (21). The most common minor complications included nephrostomy tube leakage (15%) and transient fever (10-30%) (21,22,24). Major complications (grade III, IV and V) of PNL are often associated with the performance of percutaneous access into the renal collecting system, and may include injury to adjacent organs, violation of the pleural space, bleeding or infection. We present a review of the contemporary literature concerning complications of PNL, with comments aimed at prevention and mitigation (*Table 1* summarizes relevant studies included in this review).

Diaphragmatic/associated organ injury

The overall rate of pleural violation during percutaneous access for PNL ranges from 0.3% to 1% (17,22,28). Because the diaphragm and associated pleura predominately reside near the upper pole of the kidney, injury during percutaneous access for PNL is far more common with upper pole percutaneous access than lower pole percutaneous access. Among 240 patients with

Table 1 Relevant studies on complication of PNL

Series (citation)	Shin (22)	Mousavi-Bahar (17)	El Nahas (19)	de la Rosette (21)	Lee (25)	Rana (26)*	Osman (27)
Patient number	88	671	241	5,803	582	667	315
Complication (%)							
Transfusion	6.9	0.6	16	5.7	11.2	1.49	0
Hemorrhage requiring intervention	1.4	0.15	2	NA	NA	0.14	0.3
Fever	11	1	1.2	10.5	22.4	NA	32
Sepsis	0.6	0	0.4	NA	0.8	1.79	0.3
Colonic injury	0.7	0.3	NA	NA	0.2	0	0
Pleural injury	1.1	0.7	2.4	1.8	3.1	0.14	0
Extravasation/urine leak	0.4	5.2	8	3.4	7.2	NA	NA
Mortality	0.4	0.3	0.4	0.3	0.3	0	0.3

*81% of patients underwent PNL.

300 percutaneous access tracts for PNL, Preminger and colleagues reported eight intrathoracic injuries, including seven injuries that occurred during supracostal access. The overall pleural injury rate with supracostal access was 16%, compared to 4.5% with an infracostal approach (29). Pleural injury during PNL commonly results in hydrothorax, pneumothorax or hydropneumothorax, and as many as 64% of patients with pleural injury require chest tube drainage (30-32). Pleural injury presents in the immediate postoperative period with clinical symptoms and radiologic signs. Among the 214 PNL patients reviewed by Bjurlin and colleagues, 51% had upper pole percutaneous access and two of these patients were diagnosed postoperatively with hydropneumothorax and required thoracostomy. Both patients had radiographic evidence of pleural injury on chest x-ray and overt clinical symptoms including difficulty with ventilation, shortness of breath, and fever (28).

Injury to surrounding solid organs during percutaneous access for PNL occurs less frequently than pleural injury, but may include injury to the spleen or liver. Injury to the spleen or liver often occurs in the setting of associated anatomic abnormalities, such as splenomegaly or hepatomegaly. Injury to hollow viscera, such as the colon, can occur in 0.2% to 1% of patients undergoing percutaneous access for PNL (17,22,25,33). Several factors are associated with an increased risk of colonic injury, including left percutaneous renal access, female gender, thin body habitus, horseshoe kidney, and a history of bowel or renal surgery resulting in heterotopic positioning of the bowel (33,34). A careful pre-operative review of cross-sectional imaging may aid in the avoidance of solid organ or hollow viscus injury. In addition to injury to the pleura, solid organs and hollow viscera, the great vessels are at risk for injury during percutaneous renal access for PNL due to their proximity to the kidneys.

Bleeding

Bleeding may occur during any aspect of a PNL, but acute hemorrhage due to injury to the great vessels or main renal vessels is uncommon and occurs in less than 0.5% of cases (17). Most incidents of great vessel or main renal vessel injury occur during initial percutaneous access. Great vessel injury is best avoided by the use of a systematic approach to percutaneous renal access. The renal collecting system should be accessed along a line extending from the infundibulum into the fornix of a posteriorly oriented calyx. Percutaneous renal access performed in this manner allows direct access to the majority of the renal collecting system and avoids the hypervascular regions adjacent to the infundibulum. Percutaneous renal access directly into the renal pelvis should be avoided. The potential for major bleeding during direct percutaneous access to the renal pelvis is greater due to the proximity of large renal hilar vessels, and the paucity of renal parenchyma to provide tamponade.

Bleeding with initial percutaneous access and tract dilation is often venous in nature and may arise from the percutaneous tract, renal capsule or renal parenchyma. Minor to moderate bleeding can often be controlled by

tamponade with a balloon dilator or Kaye tamponade catheter. Placement of a larger nephrostomy tube, judicious intravenous hydration or the intravenous administration of mannitol can also be helpful. With refinement of techniques and equipment, the overall transfusion rate for PNL has fallen significantly from 6.9% in early series, to less than 2% in contemporary reports (21,22,26,35,36). Significant delayed renal hemorrhage requiring intervention is also rare, and occurs in less than 2% of patients (17,19,22).

Several studies have attempted to identify clinical factors predictive of significant perioperative blood loss, the need for blood transfusion, or other intervention. Multiple attempts at initial percutaneous renal access for PNL significantly increases the risk of severe bleeding. A retrospective review of 3,878 patients undergoing PNL found a 1% rate of severe bleeding and an accompanying transfusion rate of 5.5%, with a median of 3 (1-6) units of blood transfused (37). This relatively low rate of significant bleeding requiring intervention is comparable to the rates reported for other percutaneous renal surgeries (17,22,38-41). All 39 patients with severe bleeding after PNL in this series by El Nahas *et al*. underwent arteriography and superselective angioembolization. One or more pseudoaneurysms were discovered in 20 patients, arteriovenous fistulae in 9, and the presence of both complications in 8. Superselective angioembolization was successful in 36 (92%) of these patients, but urgent exploration was required in three patients, and one of these patients required nephrectomy. The authors reported that multiple renal punctures, upper pole renal access, an inexperienced surgeon, a solitary kidney, and staghorn calculus all significantly increased the risk of major bleeding (37). Srivastava and colleagues similarly experienced a 1.4% rate of severe hemorrhage requiring angioembolization among 1,854 patients undergoing percutaneous renal access and PNL. Pseudoaneurysm was the most common finding at angiography, and 91.6% of patients were successfully treated with angioembolization. Increased stone size (>4.1 centimeters) was the only perioperative factor found to be related to the risk of severe bleeding, but fewer potential risk factors were examined in this study than in series from El Nahas and others (39,42). Additional clinical factors shown to increase the risk of bleeding during or after PNL include diabetes mellitus, prolonged operative time, utilization of a mature nephrostomy tract, concomitant surgical complications, modality of access guidance (ultrasound versus fluoroscopic), and access tracts which traverse atrophic parenchyma (41,42).

SIRS/sepsis

Transient post-operative fevers occur in up to 30% of patients after PNL, but the rate of sepsis is much lower, ranging from 0% to 3% in patients treated with appropriate perioperative antibiotics (17,19,22,27,41,43,44). Systemic inflammatory response syndrome (SIRS) may precede other signs of severe infection, and as many as 30% of patients with signs and symptoms of SIRS will eventually require intensive care treatment (44). Korets and colleagues attempted to identify contributory clinical factors among 9.8% of post-PNL patients diagnosed with SIRS. In addition to demographic and procedural factors, clinical risk factors assessed included culture specimens from bladder urine, renal pelvic urine and calculi. Univariate analysis revealed female gender, multiple renal punctures, struvite calculi, and positive pelvic urine or stone culture were associated with the post-PNL development of SIRS. On multivariate analysis controlling for gender, total stone burden greater than 10 cm^2, positive pelvic urine or stone cultures, and multiple renal pelvic punctures were risk factors (44). Results of culture specimens obtained at the time of surgery are often not available to guide antibiotic therapy in the immediate postoperative period, and the organisms are commonly different than species isolated from preoperative voided urine cultures. Korets found that 33% of patients with positive pelvic urine cultures at the time of surgery had negative preoperative voided urine cultures. Furthermore, when patients' preoperative urine cultures were positive, only 64% of positive pelvic urine cultures contained the same species (44). Similarly, Margel reported 25% of patients had positive stone cultures and negative preoperative urine cultures (45). In Korets's series 16% of patients had a positive stone culture, but 48% of those patients had negative preoperative voided urine cultures and 75% had negative renal pelvic urine cultures (44). Discordant culture results complicate the selection of perioperative antibiotics and the diagnosis and treatment of post-PNL sepsis is challenging. Morbidity is high even with aggressive fluid resuscitation and broad-spectrum antibiotics, and a multidisciplinary approach with consultants from infectious disease and critical care services is often required.

Renal collecting system injury and obstruction

Renal collecting system injury during PNL occurs in up to 8% of patients. The resultant extravasation and absorption of irrigation fluid can lead to electrolyte abnormalities,

mental status changes, or intravascular volume overload (17,19,21,24,25,46). Intraoperative signs of renal collecting system injury include direct visualization of perinephric structures or fat, abnormal hemodynamic parameters, and a decrease in drainage of irrigation fluid (24). The use of fluoroscopy for percutaneous renal access can decrease the risk of renal collecting system injury and isotonic irrigation fluid and open or continuous irrigation systems can reduce intraoperative extravasation and fluid absorption. Minor extravasation associated with small renal collecting system injury typically does not require early cessation of the procedure, but large disruptions including perforation of the renal pelvis require prompt cessation and adequate drainage via a nephrostomy tube, ureteral stent or percutaneous drain.

Renal collecting system obstruction associated with PNL is rare, but may result from ureteral avulsion or stricture, transient mucosal edema, blood clot, or infundibular stenosis (18,47). Transient renal collecting system obstruction due to edema or blood clot often resolves without intervention or long-term sequelae. Renal collecting system obstruction associated with ureteral stricture or avlusion can lead to nephrocutaneous fistulae, hydronephrosis or hydrocalyx. Prolonged operative time, large stone burden, and extended postoperative nephrostomy tube drainage are risk factors for infundibular stenosis (47). Prompt recognition and treatment of renal collecting system obstruction decreases significant complications.

Renal dysfunction

Renal dysfunction following PNL is uncommon and is typically secondary to other operative complications. For example, intraoperative or postoperative bleeding may lead to decreased renal blood flow and transient renal insufficiency, or angioembolization may result in permanent parenchymal infarction. Transient increase in creatinine occurs in less than 1% of patients after PNL (22). This rate is similar to that of patients undergoing SWL, and not clinically significant (48). Preoperative and postoperative MAG3 studies confirm stable differential renal function at 22 days after PNL, and the volume of renal scarring in patients with single or multiple percutaneous access tracts amounts to less than 1% of total renal parenchyma (49-52).

Death

Death after any modern surgical intervention for nephrolithiasis, including PNL, is rare, with rates ranging from 0.1-0.7%. Only two (0.03%) Clavien grade V complications were reported in the CROES that included 5,803 patients from multiple centers around the world (21). Death associated with PNL is typically secondary to complications such as pulmonary embolus, myocardial infarction or severe sepsis. Pulmonary embolus and myocardial infarction occur in less than 3% of patients undergoing PNL (17,18,22,25,53).

Positioning

Patient positioning for PNL is dependent upon surgeon preference and experience and includes supine, modified supine, prone and flank. Complications associated with positioning are rare. Proper padding of pressure points and minimizing stretch on extremities can avoid peripheral nerve injury, and appropriate head and neck positioning can prevent injuries such as visual disturbances and pressure necrosis. Obese patients and patients with extremity contractures require greater care and effort to obtain proper positioning and padding, but there appears to be no difference in overall surgical complications in these patients, including those related to positioning (54,55).

Conclusions

Percutaneous nephrolithotomy is a well-tolerated procedure with a low risk of major complication or death. Common minor complications such transient fever or nephrostomy tube leakage often resolve spontaneously. Advancements in PNL technology, increased utilization of the procedure and continued perfection of technique will likely result in continued decrease of complication rates.

Acknowledgements

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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