Postpercutaneous nephrolithotomy bleeding: aetiology and management

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Purpose of review
Postpercutaneous nephrolithotomy (PCNL) bleeding is the most dreaded complication following PCNL. In this article, we refer to risk factors contributing to post-PCNL bleeding and the criteria to decide the line of management in such cases. We further discuss the treatment algorithm for the management of the complication.

Recent findings
A perfect puncture is a ‘key’ to avoid post-PNL bleeding. Superselective angioembolization (SAE) is an efficacious and well tolerated method of controlling post-PCNL bleeding, and the success rate of SAE is found to be greater than 80%. Pseudoaneurysm is the commonest finding of SAE, which is responsible for post-PCNL bleeding. A recent study suggested that multiple percutaneous accesses, more than two bleeding sites identified during renal angiography, and the use of gelatine sponge alone as the embolic material were high-risk factors for the failure of SAE. A significant number of patients experience postinfarction syndrome in varying degree of severity after SAE.

Summary
Post-PCNL bleeding is a life-threatening complication. Most of the post-PCNL bleeds subside with conservative management, and SAE is an effective means of controlling post-PCNL bleeding. A skilled interventionist can achieve successful control of bleeding with a variety of agents available. Multiple punctures and evidence of more than two lesions predict high risk of failure of SAE.

Keywords
bleeding, embolization, percutaneous nephrolithotomy

INTRODUCTION
Percutaneous nephrolithotomy (PCNL) for renal calculi was first described by Fernstrom and Johansson [1]. The complications of PCNL include fever, infection, and late complications, such as infundibular stenosis. The most dreaded one is bleeding that occurs in 14–24% of patients [2]. Simple supportive care and transfusion control most episodes of bleeding. However in 0.8% of cases, surgical intervention with angiographic embolization or open exploration is required [3]. The drop in haemoglobin level may exceed 2.1 mg% [4].

The key points in management of post-PCNL bleeding are as follows:

(1) Which patients are most prone to develop these problems?

(2) What should be the criteria to decide which subset of patients would benefit from conservative treatment and who benefit from aggressive surgical management?

(3) What is the preoperative imaging modality of choice to decide the line of management?

In this article, we discuss the aetipathology and management of post-PCNL bleeding.

Aetipathology of postpercutaneous nephrolithotomy bleeding
Bleeding after PCNL occurs as a result of either traumatized renal parenchyma or injury to the perinephric vessels [5]. Bleeding can also occur during...
needle puncture, tract dilatation, intraoperative instrument manipulation, or in the postoperative period [6]. Renal vessel damage with subsequent development of arteriovenous fistulas or pseudoaneurysms is a well known source of bleeding after PCNL. Arteriovenous fistulas and pseudoaneurysms of the renal arteries are formed by a high-pressure leak from a lacerated artery, which is transmitted through the tract into a lower-resistance system, such as a vein or a connective tissue space [7].

PCNL-related bleeding is believed to be the result of injury to either the anterior or the posterior segmental arteries rather than the smaller peripheral interlobular arteries, which are surrounded by dense parenchyma and therefore easier to tamponade with the nephrostomy tube [3].

A transparenchymal posterolateral puncture of a middle or lower pole calyx is the safest place because the puncture is most likely to pass through the area of Brodel’s avascular line.

Factors associated with postpercutaneous nephrolithotomy bleeding

The predictive factors for post-PCNL bleeding can be either preoperative or intraoperative.

Preoperative factor

Various multivariate analysis have correlated the association of patient age, sex, BMI, the presence of comorbidities, such as hypertension, diabetes mellitus, serum creatinine level, history of prior renal surgery and the type of the stone, stone burden, the degree of hydronephrosis, and the surgeon’s experience [8].

Patients with arteriosclerosis of the renal artery branches accelerated by ageing, hypertension, or diabetes are at a higher risk for post-PCNL haemorrhage. Arteriosclerosis may impair the self-healing properties of the arterial wall because of the loss of its normal muscle and elastic layers [9]. The presence of infection also prevents the formation of blood clot. Infections are also responsible for secondary haemorrhage.

Operative factors

Data suggest that patient age, American Society of Anesthesiology (ASA) grade, stone burden, and operative duration are associated with an increased risk of vascular complication. It is postulated that the treatment of large stone burdens with multiple punctures is associated with greater blood loss. Although extremely variable figures of between 3 and 46% have been reported, Martin and coworkers [10–14] documented a 28% increase in the incidence of bleeding when the number of punctures rose above two. In a similar study, the authors noted that operation time was a risk factor for both septic shock and severe haemorrhage. The patients without hydronephrosis before operation were more likely to suffer severe renal bleeding. Reducing intraoperative puncture time can reduce the probability of severe post-PCNL haemorrhage. The use of a comparatively large nephroscope passage was likely to result in severe renal bleeding [15].

In one study, significant risk factors for severe bleeding were upper caliceal puncture, solitary kidney, staghorn stone, multiple punctures, and inexperienced surgeon [16].

MANAGEMENT OF POSTPERCUTANEOUS NEPHROLITHOTOMY BLEEDING

The management of post-PCNL bleeding can be classified as follows:

(1) Conservative management
(2) Endovascular treatment of post-PCNL bleeding
(3) Surgical management.

Parameters that help in deciding the line of management are as follows:

(1) Complete blood count:
   The comparison of haematocrit levels (preoperative and postoperative) helps in assessing the severity of blood loss. Similarly, if there is a history of blood transfusion one should assess the serum calcium levels and the bleeding parameters. Haematocrit is a better indicator of postoperative blood loss than haemoglobin levels.

(2) Imaging:
   (a) Colour Doppler ultrasound has the advantage of diagnosing the cause of bleeding at the bedside; however, this is fraught with limitations of being subjective and having intraobserver and interobserver variations. A simultaneously done greyscale ultrasound will also report the loculated or generalized collection of residual calculi.
(b) Computed tomography (CT) imaging:
The application of contrast CT for diagnosing the cause of bleeding has been well described in gastrointestinal bleeding. The bleeding can be precipitated by drugs such as papavarine. There is limited literature available on the application of this imaging modality in the management of post-PCNL bleeding.

Since the past year at our institute, we have been deploying this imaging modality in the algorithm for the management of post-PCNL bleeding. Comparative studies are underway to assess the outcome.

The perceived advantages of CT angiography include the following:

1. Noninvasive nature
2. Ability to identify the exact site of bleeding
3. The CT angiogram may act as a ‘road map’ for the interventionalist to plan the intervention

**MANAGEMENT**

Bleeding after PCNL is a stressful situation for the patient and the operating surgeon alike. The algorithm for the management of bleeding after PCNL is described (Fig. 1) [18].

**Conservative treatment**
The management options depend upon whether the bleeding is arterial or venous. Venous haemorrhage is usually managed conservatively. The management depends on the time of presentation, namely intraoperative, immediate postoperative, or delayed postoperative.

**Intraoperative**
A perfect puncture is defined as a short, straight tract from the skin, subcutaneous tissue through the cup of calyx into the desired calyx. It generally avoids injury to anterior or posterior segmental branches. If the puncture is not an end-on puncture, it is likely to bleed, which manifests as hypotension and tachycardia (suggestive of arterial bleeding). The surgeon may also experience difficulty in intraoperative visualization of the stone. In such cases, the surgeon should opt for placing a nephrostomy tube and stage the procedure. A close watch on the vital signs is essential in such cases. The nephrostomy tube helps in arresting the bleeding in the pelvicalyceal system by the formation of clot and stops the bleeding in the tract by tamponade. A stitch, which secures the nephrostomy, should be placed posterior to the site of entry of the nephrostomy in the pelvicalyceal system. A typical way of arresting an immediate postoperative bleed from the tract is tamponade with the help of the fists of two hands, one placed...
over the back and the other over the abdomen (Fig. 2). This is particularly useful if a tubeless approach is employed.

**USE OF HAEMOSTATIC AGENTS**

Kumar et al. [19] used tranexamic acid in patients undergoing PCNL. They concluded that it is well tolerated and associated with reduced blood loss and complication rate. They administered 1 g tranexamic acid followed by three oral doses of 500 mg in 24 h. Mean haemoglobin drop was significantly lower in tranexamic acid group (1.39 vs. 2.31 g/dl, P < 0.0001). Blood transfusion rate was lower in the tranexamic acid group (2 vs. 11%, P = 0.0180). Cauterization of PCNL track at the end of procedure may reduce the chances of bleeding [20].

There are various other locally applied haemostatic agents described in the literature. These all aim to reduce the track-site bleeding.

TachoSil is a sterile equine collagen matrix coated with human fibrinogen, human thrombin, and fibrin glue. Studies showed that TachoSil-sealed tubeless PCNL significantly decreased urinary leakage rate and perirenal haematoma rate. However, the decrease in perirenal haematoma formation was not statistically significant.

Various other studies used absorbable porcine gelatine sponge of fibrin (Spongostan), oxidized cellulose (Surgicel), and bovine collagen granules (Floseal) for this purpose but did not achieve significance level. However, they significantly reduced analgesic requirements [21,22].

**Immediate postoperative**

The colour of output from the nephrostomy is an indicator of the severity of bleeding from the kidney. The nephrostomy should be kept clamped for at least 6 h after insertion to ensure adequate haemostasis if the surgeon suspects bleeding. At our centre, we declamp the nephrostomy after 6 h if the return from the urethral catheter is clear. This indicates that there is no bleed from the pelvicyalceal system.

**Selective angioembolization and other options**

The absolute indications for angioembolization are as follows [18]:

1. Haemodynamic instability due to life-threatening bleeding
2. Repeated clot evacuations
3. Repeated blood transfusions
4. Renal Doppler showing vascular lesions
5. Continuing haemoglobin and haematocrit drop.

**TECHNIQUE OF ANGIOEMBOLIZATION**

The personnel performing angioembolization varies; at our centre it is performed by an interventional nephrologist specialized in endovascular interventions. Angioembolization is usually done by an interventional radiologist [23].

**Access for vascular intervention**

The access can be gained either through the ipsilateral femoral route or through the brachial approach. The choice of access depends on the preference of the interventionalist and the presence and absence of peripheral vascular disease. The catheter is selectively advanced into ‘appropriate’ segmental renal artery; this is determined by flush arteriogram lateral and oblique views that are magnified. These help in exactly delineating the site of injury. The ‘road map’ functions available on digital subtraction angiogram help in ascertaining the exact site of bleed. The size and the number of embolic material to be used depend on the site and size of the lesion. Once the coil is deployed the successful deployment of coil is confirmed with intermittent angiograms. This step helps in embolization of the appropriate artery and inadvertent migration of the coil. The various agents used for embolization are as follows:

1. Metallic coils alone
2. Gelatine sponge alone
3. Gelatine sponge and metallic coils
4. Gelatine sponge with autologous blood.

In the experience of Jain et al. [18], the commonest embolization material used was gelatine sponge with metallic coils. When it is possible to
embolize a tertiary or quaternary branch of the renal artery it is called as SAE; if the main branch needs to be embolized it is termed ‘complete embolization’. The aim of any endovascular intervention for post-PCNL bleeding is to achieve SAE.

Outcome and findings of superselective angioembolization
The success of SAE has been described as the arrest of bleeding by blocking the offending vessel and maintaining normal vascularity to the surrounding normal kidney [22]. The success rates exceed 80% in most of the series [18,23**]. In the series by Somani et al. [24], SAE failed in one case requiring emergency nephrectomy. The histopathology subsequently showed renal cell carcinoma. A similar case is reported by Richstone et al. [23**], wherein after nephrectomy the authors report the presence of urothelial carcinoma. These cases highlight the fact that the treating physician should be aware that there can be a chance that a tumour is missed, which may be the cause for bleeding.

Angiographic findings
Richstone et al. [23**] reported pseudoaneuysm as the commonest finding in 53% of the patients; this was followed by lacerated renal vessels and arteriovenous malformations. In their series, Richstone found that in three patients, they could not notice any abnormal angiographic findings. Interestingly, they noticed that the negative angiographic findings came down from 12 to 3.5%, suggesting a learning curve in performing and interpreting angiographic findings. Jain et al. [18] also found arteriovenous fistula to be marginally commoner than pseudoaneuysm (43.9 vs. 41.5%). Jain et al. [18] noted that among the common bleeding sites identified the commonest was lower pole (48.6%), followed by the upper pole (31.4%) and last the midpole (7%). In a series by El-Nahas et al. [16], upper pole calyx puncture was associated with a higher incidence of vascular injury. The possible reason put forth by the authors was the possibility that an oblique longer tract was used resulting in torque and resultant bleeding. It was also speculated that a tract through the thick parenchyma increases the possibility of bleeding and resultant vascular injury.

In our opinion, the site of bleeding depends on the preference or choice of the surgeon to gain access. At our institute, the calyx of choice to gain access was the lower pole calyx and hence the incidence of vascular injury was skewed to the lower calyx.

Risk factors predicting the outcome of superselective embolization
A recent study suggested that multiple percutaneous accesses, more than two bleeding sites identified during renal angiography, and the use of gelatine sponge alone as the embolic material were high-risk factors for the failure of SAE [25]. In the study by Jain et al. [18], among the total 41 patients studied, 35 patients (85.3%) underwent successful embolization. Among these six patients, two subsequently underwent nephrectomy. The authors performed a review of these two patients; both patients had a large bulk of stone (staghorn calculi) and more than three punctures. Thus, the authors suggest that large stone bulk and multiple punctures are predictors of the failure of angioembolization, concurring with the findings of the recent study by Zeng et al. [18,25]. The second interesting finding noted by Jain et al. [18] was that both these patients had a comparatively larger arteriovenous malformation (6 vs. 3.7 mm in others). According to Richstone et al. [23**] in approximately 5–7% of patients no demonstrable angiographic findings were seen.

COMPLICATIONS OF SUPERSELECTIVE EMBOLIZATION
The complications of SAE include postembolization syndrome, coil migration, and risk of renal deterioration.

Postembolization syndrome
This has been described as flank pain and raised white blood cell count with nausea and vomiting [26]. Ninety percent of the patients experience this syndrome in varying degree of severity. Jain et al. [18], in their series, noticed an infarction syndrome in 63.4% but could not find any correlation to the material used for embolization. Somani et al. [24] described this syndrome in 50% of their cases. The most common symptom of concern for the patient is severe pain, which has an onset within an hour of embolization and may at times also require narcotic analgesics.

Coil migration
A potential serious complication of SAE is coil migration either into an undesired location or into an extranatomic site. The migration into peripheral circulation and the lungs has been reported [27]. It commonly presented after 1 year; however, in the case by Bhageria et al., it presented within 3 months with renal colic. Bhageria et al. [28] reported coil migration into the urinary tract, which caused

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urinary obstruction. Possible mechanisms for this coil migration are as follows: (1) the fistulous communication had a larger size than the embolization coil; (2) the arterial-calyceal communication became larger over a period resulting in migration; and (3) a rupture could have occurred in the pseudoaneurysm. The authors feel that the second mechanism was more likely for the occurrence of migration [28].

Postinfarction renal function

The concern of postinfarction deterioration of renal function had been addressed by El-Nahas et al. They noted that DMSA renograms post SAE did not reveal any photopenic areas in 20% of cases who underwent SAE and the DMSA uptake increased statistically in these renal units. The findings suggest that SAE, if selectively blocks the offending artery, is renoprotective [29].

CONCLUSION

Post-PCNL bleeding is a life-threatening complication. Most of post-PCNL bleeds subside with conservative management. SAE is an effective means of controlling post-PCNL bleeding. A skilled interventionist can achieve successful control of bleeding with a variety of agents available, which include gel foam and coils. Multiple punctures and evidence of more than two lesions predict high risk of failure of SAE.

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None.

Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as: ■ of special interest ■■ of outstanding interest