ORIGINAL RESEARCH
General Urology

Doi: 10.4274/jus.galenos.2023.2022.0097
J Urol Surg 2023;10(4):326-333

Safety and Efficacy of Selective Renal Artery Embolization in the Management of Postprocedural Acute Renal Bleeding: Experience of A Tertiary Care Center

Sajad Ahmad Para, Saqib Mehdi, Suhail Malik, Salim Wani, Arif Bhat, Naseer Choh, Sajad Lone, Faiz Ansari

Sher-i-Kashmir Institute of Medical Sciences, Department of Urology, Srinagar, India

What's known on the subject? and What does the study add?

Any intervention on the kidney may cause disruption of arteriovenous system and pose acute renal bleeding. In the present study we evaluated selective renal artery embolization. The study shows that selective renal artery embolization is a safe and highly effective method to control postprocedural acute renal bleeding.

Abstract

Objective: Our objective was to evaluate the safety and efficacy of selective renal artery embolization in the management of post-procedural acute renal bleeding.

Materials and Methods: This was a prospective observational study that included all patients who presented to us with acute renal bleeding the following kidney procedures. Demographic, radiological, and invasive angiographic data of patients were recorded. Selective renal artery embolization was performed by an interventional radiologist, and patients were observed for any complications.

Results: We received 20 patients with an average age of 46.2±13.18 years having bleeding following procedures done on the kidney. Fifteen (75%) patients had undergone procedure for renal stone disease, 3 (15%) had bleeding following nephron-sparing surgery (NSS), 1 (5%) patient had undergone percutaneous nephrostomy tube placement, while another patient had undergone biopsy of renal allograft. The average drop in hemoglobin recorded before the embolization was 2.45±0.69 mg/dL in percutaneous nephrolithotomy patients, 3.05±1.28 mg/dL in nephrolithotomy patients and 3.32±0.82 mg/dL following NSS. Renal pseudoaneurysm was the most common vascular lesion identified on angiography in 50% of patients, followed by arteriovenous fistula (AVF) in 30% of patients. A combination of pseudoaneurysm and AVF was seen in 10% of patients, and 10% of patients had active extravasation from injured vessels. One (5%) patient required emergency nephrectomy after two failed attempts of angioembolization. There were no major complications recorded except for urosepsis in 2 (10%) patients and acute kidney injury in 1 (5%) patient.

Conclusion: Transarterial selective renal artery embolization is a safe and highly effective method to control postprocedural acute renal bleeding.

Keywords: Arteriovenous fistula, nephron sparing surgery, percutaneous nephrolithotomy, renal pseudoaneurysm, selective renal artery embolization

Introduction

Kidneys are highly vascular organs that receive 20% of the cardiac output. This blood flow is mainly distributed in the high-flow arteriovenous system found in close proximity to the renal collecting system. Any intervention done on the kidney, such as open renal surgeries, percutaneous nephrolithotomy (PCNL), or renal biopsy, which causes disruption of this arteriovenous system poses a potential risk of post-procedural acute renal bleeding. The most dreaded complication following PCNL is bleeding occurring in 14-24% of cases. Conservative management with supportive care and blood

Correspondence: Sajad Ahmad Para MD, Sher-i-Kashmir Institute of Medical Sciences, Department of Urology, Srinagar, India
Phone: +916006399671 **E-mail:** sajadpara96@gmail.com **ORCID-ID:** orcid.org/0000-0001-8450-369X
Received: 30.12.2022 **Accepted:** 09.05.2023

Cite this article as: Para SA, Mehdi S, Malik S, Wani S, Bhat A, Choh N, Lone S, Ansari F. Safety and Efficacy of Selective Renal Artery Embolization in the Management of Postprocedural Acute Renal Bleeding: Experience of A Tertiary Care Center. J Urol Surg 2023;10(4):326-333.

transfusion is usually sufficient in most of the cases; however uncontrolled and life-threatening bleeding may warrant urgent angioembolization or renal exploration in 0.8% of cases (1,2). With widespread use of imaging modalities, small renal tumors are usually diagnosed incidentally. Nephron-sparing surgery (NSS) is now considered as standard treatment for renal tumors up to the size of 7 cm when technically feasible (3). Postoperative hemorrhage occurs in 3-10% of cases following NSS and typically presents 7-14 days postoperatively. These bleeding are usually attributed to pseudoaneurysms and arteriovenous fistulas (AVF). Re-exploration or selective renal artery embolization is often required to control bleeding in such cases (4). Re-exploration usually ends with nephrectomy in most of these cases. Open nephrolithotomy is still being practiced in developing countries for the management of renal calculi and is sometimes associated with life-threatening secondary hemorrhage requiring emergency nephrectomy. Transarterial angioembolization is a minimally invasive procedure that precisely controls bleeding, salvage renal function, and avoids the more invasive and morbid renal exploration in such cases.

In this study, we evaluated the safety and efficacy of selective renal artery embolization (RAE) in the management of postprocedural acute renal bleeding.

Materials and Methods

The current study was conducted at our institute, which is a tertiary care referral center that receives patients from different parts of the state. It is a prospective observational study over a period of 3 years from August 2019 to August 2022 and included all patients who presented to us with continuous bleeding of renal origin following various open or percutaneous surgical procedures performed on the kidney and were managed with selective transarterial renal angioembolization. Written informed consent was obtained from each patient, and the study was approved by the Sher-i-Kashmir Institute of Medical Sciences Institutional Ethics Committee with protocol no. IEC/SKIMS protocol #245E/2022. As our hospital is one of the few centers in the region where the facility of angioembolization is available, the study included patients in whom the procedures had been performed in our hospital as well as patients referred from other hospitals. The demographic, clinical and radiological data of the patients at the time of primary procedure were recorded (Table 1). Standard PCNL was defined as tract circumference of more than 20-Fr, while mini-PCNL was defined as tract circumference of less or equal to 20-Fr. All patients underwent computed tomographic angiography (CTA) to identify the source of bleeding and the dimensions of the affected vessel. Clinical, radiological, and invasive angiographic findings that included the site of the bleeding vessel, size, and number of bleeding pathologies (pseudoureurysm/AVF) were recorded (Table 2).

Angioembolization was performed by a single interventional radiologist after obtaining written informed consent from all patients. All procedures were performed in the intervention radiology suite under local anesthesia. After placement of the femoral arterial access sheath, a renal double curve (RDC) 5-Fr angiographic catheter was navigated into the main renal artery over the hydrophilic guide wire (Terumo guide wire) under fluoroscopic guidance. Angiographic films were recorded to identify the bleeding vessel. A 2.9-Fr vascular microcatheter was navigated through the RDC into the bleeding vessel under fluoroscopic guidance. Repeated angiographic films were taken to positively identify the bleeding vessel that was selectively embolized with platinum embolization coils. The size and number of coils to be deployed was determined by the size of the vessel affected by pseudoaneurysm or AVF. Subsequent angiographic films were taken to confirm the sealing of the bleeding vessel. Patients were observed in the ward for the next 24-48 h for any post-procedure complications. A final Doppler study was conducted 24 h after embolization to confirm the resolution of pseudoaneurysm/AVF.

Results

In this prospective study, 20 patients presented to us with severe bleeding of renal origin the following kidney procedures. There were 75% male and 25% female patients with an average age of 46.2±13.18 years (range 28-75 years). Diabetes with hypertension was recorded as a comorbidity in 10% of patients; hypertension alone was reported as a comorbidity in 20% of patients and 5% of patients had chronic kidney disease with hypertension. Renal stone disease was the primary pathology in 75% of patients admitted for angioembolization, among which 80% had undergone PCNL and 20% underwent open nephrolithotomy. The average stone size was 5.06±2.8 cm^2 and 13.5±3.9 cm^2 in the PCNL and the open nephrolithotomy group, respectively. Among the renal stone patients, 60% had undergone standard PCNL with more than one tract dilated in 3 (33.4%) patients and 20% had undergone mini PCNL. 15% of patients with renal bleeding had undergone NSS with an average tumor size of 13.16±5.96 cm^2. One (5%) patient had developed pseudoaneurysm in the graft kidney following renal biopsy and another patient had renal bleeding following percutaneous nephrostomy (PCN) placement for obstructive uropathy. Bleeding in the form of hematuria was reported on an average postoperative day 7 in PCNL patients, 3rd day of nephrolithotomy, 8th day of NSS, 3rd day of graft biopsy, and 13th day of PCN.

The average drop in hemoglobin recorded before the embolization was 2.45±0.69 mg/dL in PCNL patients, 3.05±1.28 mg/dL in nephrolithotomy patients and 3.32±0.82 mg/dL following NSS. The average number of blood transfusions required in our study was 0.8±0.83 units per patient. Blood transfusion was predominantly required in patients following NSS (1.67±057 units/patient). In post-PCNL patients, pseudoaneurysm was the most common vascular pathology noted in 6 (50%) patients (Figure 1), while AVF was identified in 3 (25%) patients. One (8.3%) patient had pseudoaneurysm with AVF and 2 (16.7%) patients had active extravasation demonstrated on angiography (Figure 2a, b). Renal angiography of post-nephrolithotomy patients revealed double pseudoaneurysm in 1 (33.4%) patient, solitary pseudoaneurysm in 1 (33.4%) patient and pseudoaneurysm with AVF in another (33.4%) patient (Figure 3a, b). The predominant bleeding source identified in NSS was AVF in 2 (66.7%) patients and double pseudoaneurysm in another (33.3%) patient. Post renal biopsy patient had a bleeding pseudoaneurysm in the territory of the lower segmental artery of the allograft.

Embolization was done using soft platinum embolization microcoils (0.018 inch core diameter). Embolization in post PCNL bleeding required a single 3 mm coil in 4 (33.4%) patients, double 3 mm coils in 4 (33.4%) patients, single 5 mm coil in 2 (16.7%) patients, and double 5 mm coils in 2 (16.7%) patients.

Table 1. The demographic, clinical and radiological data of the patients at the time of primary procedure done on kidney

S no.	Age (years)	Sex M/F	Comorbidity	Primary pathology	Primary procedure	Time of presentation
1.	32	M	Nil	3×2 cm lower calyceal calculus	Standard PCNL Two tract dilatation	4th day
2.	41	F	Nil	1×1.5 cm lower pole calculus	Mini PCNL	10th day
3.	50	M	Hypertension	3×3.5 cm partial Staghorn calculus	Nephrolithotomy	3rd day
4.	28	M	Nil	1.5×1.3 cm upper pole renal calculus	Mini PCNL	12th day
5.	61	M	Diabetes & hypertension	3×3.5 cm mid pole renal mass, predominantly endophytic	Nephron spring surgery	8th day
6.	43	F	Nil	4×3 cm Staghorn calculus	Nephrolithotomy	5th day
7.	36	M	Nil	1.5×1.9 cm upper calyceal calculus	Standard PCNL	8th day
8.	51	M	Nil	3×3 cm Staghorn calculus	Standard PCNL Two tract dilatation	1st
9.	55	F	Hypertension	2×3 cm renal calculus	Standard PCNL	13th day
10.	33	M	Nil	2×2.2 cm lower calyceal calculus	Standard PCNL	4th day
11.	72	M	Hypertension	4×5 cm upper pole renal mass	Nephron sparing surgery	5th day
12.	38	M	Nil	2×2.8 cm renal pelvic calculus	Standard PCNL	13th day
13.	56	F	Diabetes & hypertension	Renal tumor-upper pole 3×3 cm mid pole predominantly endophytic	Nephron sparing surgery	11th day
14.	75	M	Hypertension	2.5×2.8 cm renal calculus	Standard PCNL	1st
15.	48	F	Nil	3×3.5 cm staghorn calculus	Standard PCNL Two tract dilatation	9th day
16.	29	M	Nil	1×1.6 cm mid calyceal calculus	Mini PCNL	6th day
17.	52	M	Nil	2×2.2 cm upper calyx calculus	Standard PCNL	6th day
18.	44	M	Nil	4×4.5 cm Staghorn calculus	Nephrolithotomy	1st
19.	45	M	Hypertension with chronic kidney disease	Post renal transplant rejection	Graft kidney biopsy	3rd day
20.	35	M	Nil	Carcinoma rectum with obstructive uropathy	Percutaneous nephrostomy	13th day

M: Male, F: Female, PCNL: Percutaneous nephrolithotomy

Table 2. Clinical, radiological and invasive angiographic findings at the time of transarterial angioembolization

S. no	Drop in hemoglobin	Blood transfusion required	Angiographic findings	Size (coiled embolus diameter) & number of coils deployed	Ancillary procedures required	Outcome and complications
1.	1.52 mg/dL	0	Pseudoaneurysm in lower segmental artery territory	3 mm/1 coil	Nil	Hemostasis secured without any complication
2.	2.2 mg/dL	0	Pseudoaneurysm in apical segmental artery territory	3 mm/1 coil	Nil	Hemostasis secured, post embolisation syndrome
3.	2.12 mg/dL	1	Two pseudoaneurysms in posterior segmental artery territory	3 mm/1 coil 5 mm/1 coil	Percutaneous nephrostomy	Hemostasis secured, urosepsis managed with antibiotics
4.	1.92 mg/dL	0	Arteriovenous fistula in upper segmental artery territory	3 mm/2 coils	Nil	Hemostasis secured, post embolisation syndrome
5.	3.22 mg/dL	2	Pseudoaneurysm with AVF in lower segmental artery territory	5 mm/1 coil	Clot evacuation	Hemostasis secured without any complication
6.	2.52 mg/dL	1	Pseudoaneurysm in middle segmental artery territory	3 mm/2 coils	DJ stenting	Hemostasis secured, urosepsis managed with antibiotics
7.	2.72 mg/dL	0	Pseudoaneurysm with AVF in upper segmental artery territory	5 mm/1 coil	Nil	Hemostasis secured without any complication
8.	4.12 mg/dL	3	Active bleeding from posterior segmental artery territory	5 mm/2 coils	Clot evacuation	Hemostasis secured, post embolisation syndrome
9.	2.72 mg/dL	0	Arteriovenous fistula in middle segmental artery territory	3 mm/2 coils	Nil	Hemostasis secured without any complication
10.	2.62 mg/dL	0	Pseudoaneurysm in lower segmental artery territory	3 mm/1 coil	Nil	Hemostasis secured without any complication
11.	3.12 mg/dL	1	Two pseudoaneurysm in upper segmental artery territory	3 mm/1 coil 5 mm/1 coil	Nil	Hemostasis secured without any complication
12.	2.22 mg/dL	0	Pseudoaneurysm in middle segmental artery territory	3 mm/2 coils	Nil	Hemostasis secured without any complication
13.	3.62 mg/dL	2	Pseudoaneurysm with AVF in upper segmental artery territory	5 mm/2 coils	Clot evacuation	Hemostasis secured, post embolisation syndrome
14.	3.2 mg/dL	2	Active bleeding from posterior segmental artery territory	5 mm/2 coils	Clot evacuation, hemodialysis	Urosepsis with acute kidney injury managed & patient discharged with normal creatinine
15.	2.22 mg/dL	0	Arteriovenous fistula in posterior segmental artery territory	3 mm/2 coils	Nil	Hemostasis secured without any complication
16.	1.82 mg/dL	0	Pseudoaneurysm in middle segmental artery territory	5 mm/1 coil	Nil	Hemostasis secured without any complication
17.	2.12 mg/dL	0	Pseudoaneurysm in apical segmental artery territory	3 mm/1 coil	Nil	Hemostasis secured, post embolisation syndrome
18.	4.52 mg/dL	3	Pseudoaneurysm with Arteriovenous fistula in posterior segmental artery territory	5 mm/2 coils	Clot evacuation with repeat embolisation	Failed to achieve hemostasis, nephrectomy done
19.	2.32 mg/dL	1	Pseudoaneurysm in lower segmental artery territory	3 mm/2 coils	Nil	Hemostasis secured without any complication
20.	2 mg/dL	0	Arteriovenous fistula in posterior segmental artery territory	5 mm/1 coil	Nil	Hemostasis secured, post embolisation syndrome

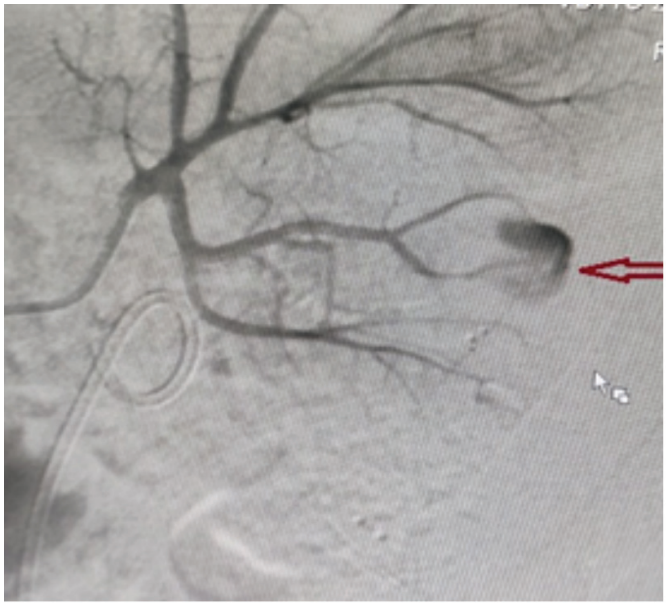

Figure 1. Post percutaneous nephrolithotomy solitary pseudoaneurysm (red arrow) in middle segmental artery

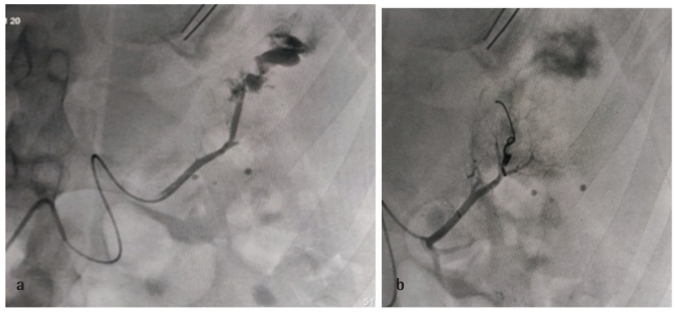

Figure 2. a, b. Active extravasation in apical segmental artery (a) and sealing of bleeding vessel by embolization coil (b)

Post-nephrolithotomy angioembolization required two 3 mm coils in 1 (33.4%) patient, a single 5 mm coil in 1 (33.4%) patient and two coils (3 mm/5 mm) in another (33.4%) patient. NSS patients required a single 5 mm coil in 1 (33.4%) patient, double 5 mm coils in one (33.4%) patient (Figure 4) and 2 coils (3 mm/5 mm) in 1 (33.4%) patient. Post renal biopsy patient required two 3 mm coils while post PCN patient required single 5 mm coil. The ancillary procedures required post embolization were cystoscopic clot evacuation in 25% of patients, PCN in 5% of patients, and Double J (DJ) stenting in 5% of patients. One patent received two sessions of hemodialysis to treat acute kidney injury (AKI).

The hemostasis was secured in all patients for 1 (5%) patient who underwent two unsuccessful attempts of angioembolization. Emergency nephrectomy was done to control bleeding. Post embolization syndrome consist of mild fever and flank pain

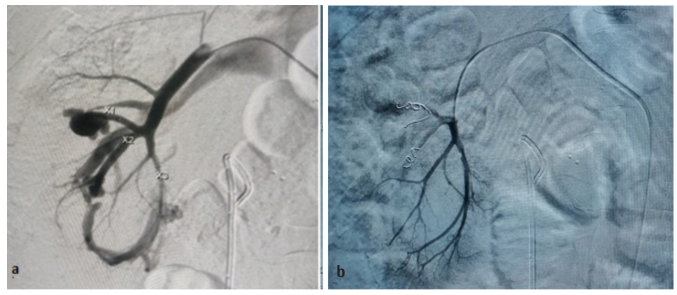

Figure 3. a, b. Double pseudoaneurysm with arteriovenous fistulas (a) and post coiling closure of double pseudoaneurysm (b)

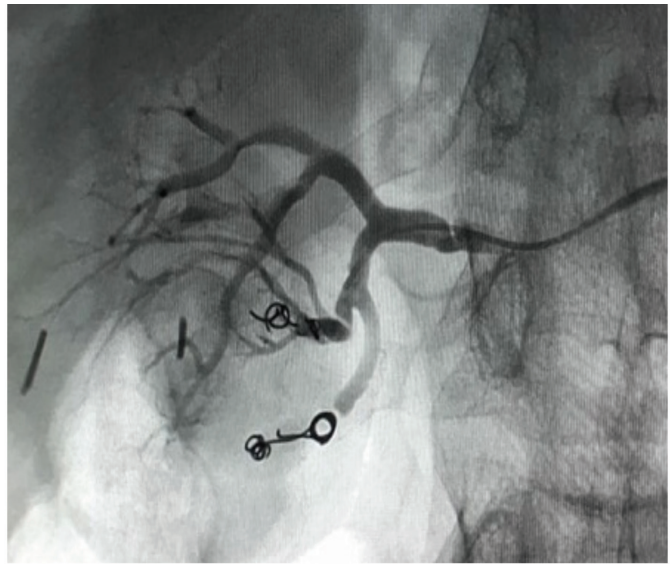

Figure 4. Post coiling sealing of double pseudoaneurysm in nephron sparing surgery

with tachycardia were reported in 30% of patients. There were no major complications except for urosepsis in 10% of patients that was managed by PCN tube placement in one patient and stenting with antibiotics in another patient. One (5%) patient had AKI with urosepsis requiring two sessions of hemodialysis and the patient was discharged in stable condition with normal serum creatinine level.

Discussion

Bleeding represents a common complication of the following procedures performed on the kidney such as PCNL, nephrolithotomy, and NSS. Bleeding may occur during or immediately after the procedure, or the patient may present in a delayed manner usually after an interval of few days, which is commonly secondary to formation of a pseudoaneurysm or AVF (5). Most of the patients in our study had bleeding following PCNL because nephrolithiasis is predominant in our region

and PCNL is performed very frequently. Multiple factors have been attributed to increased risk of bleeding following PCNL, including large stone size, multiple tract dilatations, prolonged operative time, hypertension, and presence of diabetes mellitus (6). Isolated hypertension as a comorbidity was reported in 20% of patients and hypertension with diabetes was present in 10% of patients in our study. The increased risk of renal bleeding in diabetes has been related to its association with atherosclerosis and microangiopathies. Kukreja et al. (7) attributed the increased risk of renal bleeding in hypertension to atherosclerosis. Most post PCNL bleeding was recorded in patients who underwent standard PCNL (tract circumference >20 Fr). Deng et al. (8) reported an increased risk of bleeding in standard PCNL compared to mini PCNL. Postoperative bleeding following NSS remains the most serious complication with an incidence of about 6%. Large tumor size, centrally located tumor, and hypertension have been associated with increased risk of bleeding following NSS (9). Among patients with post NSS bleeding in our study, 66.7% had predominantly endophytic tumors located at the mid pole. Image-guided needle biopsy of the allograft kidney is usually safe with a low incidence of symptomatic AVF of about 0.4% (10). 5% of patients in our study had AVF following renal allograft biopsy. PCN is associated with serious vascular complications in 1-2% of cases. We had only 5% patients with pseudoaneurysm following PCN tube placement.

Bleeding the following kidney procedures is conservatively managed in most cases. Most severe cases of bleeding are those of intrarenal arterial origin with pseudoaneurysm, AVF, or an injured segmental artery demonstrated on imaging studies. These cases usually present 4-15 days after the procedure (11). Our patients presented on average 7 days following PCNL, 3 days following nephrolithotomy, and 8 days following NSS. The average drop in hemoglobin in our patients was 2.45±0.69 mg/dL following PCNL, 3.05±1.28 mg/dL following nephrolithotomy and 3.32±0.82 mg/dL following NSS. The transfusion rate after PCNL is reported to range from 3% to 23% (12). The average transfusion required in our study was 0.8 units/patient. The clinical diagnosis of pseudoaneurysm or AVF should be confirmed by non-invasive imaging modalities. CTA is a sensitive noninvasive imaging modality for the diagnosis of renal bleeding and is recommended as a roadmap for managing these patients (13). All of our patients underwent initial CTA to diagnose the cause of bleeding.

Significant bleeding the following procedures on the kidney usually intrarenal in origin. This complication is the result of AVF or intrarenal pseudoaneurysm formation and usually presents after weeks from the primary procedure (14). In most cases, bleeding can be managed conservatively. However, for severe and persistent bleeding, selective RAE is required to stop bleeding and salvage renal function (15). All of our patients underwent selective RAE in the interventional radiology suite. Since 1970s when RAE was first introduced, the technique has been refined with better embolic agents, smaller delivery catheters allowing precise cannulation of smaller vessels, and better fluoroscopic equipment. Though invasive compared to CT angiography, it provides a more detailed anatomy of the bleeding vessels with the provision to control bleeding at the same time (16). Renal pseudoaneurysm are the most common vascular lesion identified on angiography in these patients. They are formed as a result of arterial injury with contained hemorrhage within the kidney. The associated hematoma is surrounded by the fibrous inflammatory tissue that is very unstable and prone to rupture, leading to massive bleeding. They may occur isolated or in association with AVF (11). Pseudoaneurysm was the most common vascular lesion identified in our study occurring in 50% of post PCNL bleeding patients, 66.7% of post nephrolithotomy patients, 33.4% of post NSS bleeding patients. AVF is a rare pathological communication between renal arteries and veins without interconnecting capillaries that is seen as a source of renal bleeding. They are fragile communications that open under high arterial pressure leading to torrential bleeding (17). Isolated AVF were recorded in 25% of post-PCNL bleeding cases and 66.7% of post-NSS bleeding cases. Pseudoaneurysm with AVF were recorded in 10% of our patients. Active bleeding of the segmental artery without the formation of pseudoaneurysm or AVF were recorded in 10% of our patients.

The success rate of endovascular treatment of renal pseudoaneurysm ranges from 71-100% (18). The success rate in our study was 95%, with a single patient failing two attempts of embolization required emergency nephrectomy. The rate of nephrectomy after PCNL is extremely low (0.2%) because of the high success rate of angioembolization (14). Super selective embolization of a vessel as distal as possible, at least at the interlobar arteries, is mandatory to preserve the renal parenchyma and minimize complications. This can usually be achieved by using microcatheters as delivery devices and microcoils as embolic agents (18). We used microcatheter for the deployment of platinum embolization microcoils (0.018 inch) in our patients. Impaired renal function, difficult vascular anatomy, and stenosis of the main renal artery are some limitations and technical challenges for angioembolization. In one of our patients embolization failed because of the difficult tortuous anatomy of the renal vessels.

Selective RAE is a safe procedure with minimal complications. It precisely seals bleeding vessels without collateral damage to the rest of the renal parenchyma. Chatziioannou et al. (19) reported that selective RAE leads to permanent cessation of bleeding and prevents serious renal parenchymal infarction.

None of our patients had permanent renal impairment following embolization, indicating the limited loss of renal parenchyma. Post embolization syndrome consisting of fever, flank pain, vomiting, and leukocytosis has been reported in over 90% of patients following angioembolization. 30% of our patients had transient fever and flank pain following renal artery embolisation. Treatment consists of analgesics, antipyretics, and antiemetics until symptoms resolve (20). More serious complications reported in RAE are coil migration and inadvertent non-target embolization leading to spine, bowel and limb infarction (21). None of these serious complications was reported in our study.

Study Limitations

The limitations of our study are that it is a single-center study with a relatively small sample size.

Conclusion

Severe and persistent hemorrhage is the most feared complication that can occur following kidney procedures. Selective RAE is safe and highly effective in the control of renal origin bleeding. The procedure is associated with minimal complications; it salvages renal function and avoids more invasive renal exploration or nephrectomy.

Ethics

Ethics Committee Approval: The study was approved by the Sher-i-Kashmir Institute of Medical Sciences Institutional Ethics Committee with protocol no. IEC/SKIMS protocol #245E/2022.

Informed Consent: Written informed consent was obtained from each patient.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: S.A.P., S.M., S.M., S.W., A.B., N.C., S.L., F.A., Concept: S.A.P., S.M., S.M., S.W., A.B., N.C., S.L., F.A., Design: S.A.P., S.M., S.M., S.W., A.B., N.C., S.L., F.A., Data Collection or Processing: S.A.P., S.M., S.M., S.W., A.B., N.C., S.L., F.A., Analysis or Interpretation: S.A.P., S.M., S.M., S.W., A.B., N.C., S.L., F.A., Literature Search: S.A.P., S.M., S.M., S.W., A.B., N.C., S.L., F.A., Writing: S.A.P., S.M., S.M., S.W., A.B., N.C., S.L., F.A.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declare that they have no relevant financial.

References

1. Kessaris DN, Bellman GC, Pardalidis NP, Smith AG. Management of hemorrhage after percutaneous renal surgery. J Urol 1995;153:604-608.
2. Stoller ML, Wolf JS Jr, St Lezin MA. Estimated blood loss and transfusion rates associated with percutaneous nephrolithotomy. J Urol 1994;152:1977-1981.
3. Lapini A, Serni S, Minervini A, Masieri L, Carini M. Progression and long-term survival after simple enucleation for the elective treatment of renal cell carcinoma: experience in 107 patients. J Urol 2005;174:57-60; discussion 60.
4. Negoro H, Kawakita M, Koda Y. Renal artery pseudoaneurysm after laparoscopic partial nephrectomy for renal cell carcinoma in a solitary kidney. Int J Urol 2005;12:683-685.
5. Sommer CM, Stampfl U, Bellemann N, Ramsauer S, Loenard BM, Haferkamp A, Hallscheidt P, Richter GM, Kauczor HU, Radeleff BA. Patients with life-threatening arterial renal hemorrhage: CT angiography and catheter angiography with subsequent superselective embolization. Cardiovasc Intervent Radiol 2010;33:498-508.
6. Akman T, Binbay M, Sari E, Yuruk E, Tepeler A, Akcay M, Muslumanoglu AY, Tefekli A. Factors affecting bleeding during percutaneous nephrolithotomy: single surgeon experience. J Endourol 2011;25:327-333.
7. Kukreja R, Desai M, Patel S, Bapat S, Desai M. Factors affecting blood loss during percutaneous nephrolithotomy: prospective study. J Endourol 2004;18:715-722.
8. Deng J, Li J, Wang L, Hong Y, Zheng L, Hu J, Kuang R. Standard versus mini-percutaneous nephrolithotomy for renal stones: a meta-analysis. Scand J Surg 2021;110:301-311.
9. Nadu A, Kleinmann N, Laufer M, Dotan Z, Winkler H, Ramon J. Laparoscopic partial nephrectomy for central tumors: analysis of perioperative outcomes and complications. J Urol 2009;181:42-47; discussion 47.
10. Byon JH, Han YM, Jin GY, Song JS. Risk Factors Related to Hemorrhage Necessitating Renal Artery Embolization after Percutaneous Nephrostomy. Journal of the Korean Society of Radiology 2015;73:375-80.
11. Massulo-Aguiar MF, Campos CM, Rodrigues-Netto N Jr. Intrarenal pseudoaneurysm after percutaneous nephrolithotomy. Angiotomographic assessment and endovascular management. Int Braz J Urol 2006;32:440-442; discussion 443-444.
12. El-Nahas AR, Shokeir AA, El-Assmy AM, Mohsen T, Shoma AM, Eraky I, El-Kenawy MR, El-Kappany HA. Post-percutaneous nephrolithotomy extensive hemorrhage: a study of risk factors. J Urol 2007;177:576-579.
13. Kitase M, Mizutani M, Tomita H, Kono T, Sugie C, Shibamoto Y. Blunt renal trauma: comparison of contrast-enhanced CT and angiographic findings and the usefulness of transcatheter arterial embolization. Vasa 2007;36:108-113.
14. Keoghane SR, Cetti RJ, Rogers AE, Walmsley BH. Blood transfusion, embolisation and nephrectomy after percutaneous nephrolithotomy (PCNL). BJU Int 2013;111:628-632.
15. Somani BK, Nabi G, Thorpe P, McClinton S. Endovascular control of haemorrhagic urological emergencies: an observational study. BMC Urol 2006;6:27.
16. Ginat DT, Saad WE, Turba UC. Transcatheter renal artery embolization: clinical applications and techniques. Tech Vasc Interv Radiol 2009;12:224-239.
17. Maleux G, Messiaen T, Stockx L, Vanrenterghem Y, Wilms G. Transcatheter embolization of biopsy-related vascular injuries in renal allografts. Long-term technical, clinical and biochemical results. Acta Radiol 2003;44:13-17.
18. Sauk S, Zuckerman DA. Renal artery embolization. Semin Intervent Radiol 2011;28:396-406.

19. Chatziioannou A, Brountzos E, Primetis E, Malagari K, Sofocleous C, Mourikis D, Kelekis D. Effects of superselective embolization for renal vascular injuries on renal parenchyma and function. Eur J Vasc Endovasc Surg 2004;28:201-206.

20. Schwartz MJ, Smith EB, Trost DW, Vaughan ED Jr. Renal artery embolization: clinical indications and experience from over 100 cases. BJU Int 2007;99:881-886.

21. Gang DL, Dole KB, Adelman LS. Spinal cord infarction following therapeutic renal artery embolization. JAMA 1977;237:2841-2842.