Research Article / Araştırma Makalesi
doi: 10.18678/dtfd.1092474

Duzce Med J, 2022;24(2):136-141
Düzce Tıp Fak Derg, 2022;24(2):136-141

Endovascular Treatment of Acute Renal Artery Hemorrhages: Efficacy and Effect on Renal Functions

Akut Renal Arter Kanamalarında Endovasküler Tedavi: Etkinliği ve Böbrek Fonksiyonlarına Etkisi

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Received / Geliş Tarihi : 24.03.2022
Accepted / Kabul Tarihi : 01.06.2022
Available Online / Çevrimiçi Yayın Tarihi : 11.07.2022

ABSTRACT

Aim: The aim of this study was to investigate the efficacy and complications of endovascular treatment of acute renal artery hemorrhage and the etiology of the condition.
Material and Methods: Twenty-two patients who underwent endovascular embolization with renal acute artery hemorrhage between 2016 and 2020 were evaluated retrospectively. Etiologies of the acute renal artery hemorrhage were investigated. Laboratory and clinical follow-up information were analyzed for the efficacy and the complication of the treatment. The serum creatinine levels of the patients before and after the procedure were compared.
Results: Selective renal artery embolization procedures were performed in a total of 22 patients. Of the 22 patients, 10 (45.5%) were male and 12 (54.5%) were female. The patients' ages ranged from 5 to 79 years, and the mean age of the patients was 51.5±18.6 years. Clinical success was achieved in 91.7% of embolization procedures. A statistically significant increase was seen in the serum creatinine levels of the patients after the procedure compared to 24 hours before the angiography procedure (median: 0.97 vs. 0.93, p=0.046). No significant change was observed in serum blood urea nitrogen and the estimated glomerular filtration rate levels (p=0.338, and p=0.067, respectively). Acute renal failure and postembolization syndrome were observed in only one patient as complications. The complication rate was found to be 4.5%.
Conclusion: Selective embolization of the renal artery has high clinical success in acute renal artery hemorrhages without impairing renal function. The treatment has advantages such as no need for general anesthesia, and low complication rates.
Keywords: Embolisation; bleeding; endovascular; renal angiography; renal artery.

ÖZ

Amaç: Bu çalışmanın amacı akut renal arter kaynaklı hemorajilerin endovasküler tedavisinin etkinliğini ve komplikasyonlarını ile kanamaya neden olan etiyolojiyi araştırmaktır.
Gereç ve Yöntemler: 2016 ve 2020 yılları arasında akut renal arter kanaması nedeni ile endovasküler embolizasyon yapılan yirmi iki hasta geriye dönük olarak değerlendirildi. Akut renal arter hemorajisinin etiyolojisi araştırıldı. Tedavinin etkinliği ve gelişen komplikasyonlar için laboratuvar ve klinik takip bilgileri analiz edildi. Hastaların işlem öncesi ve işlem sonrası serum kreatinin düzeyleri karşılaştırıldı.
Bulgular: Toplam 22 hastaya selektif renal arter embolizasyonu işlemi uygulandı. Bu 22 hastanın 10 (%45,5) tanesi erkek ve 12 (%54,5) tanesi kadın idi. Hastaların yaşları 5 ile 79 yıl arasında değişmekteydi ve hastaların ortalama yaşı 51,5±18,6 yıl olarak saptandı. Embolizasyon işlemlerinin %91,7'sinde klinik başarı sağlandı. Hastaların işlem sonrasındaki serum kreatinin düzeylerinde, anjiyografi işleminden 24 saat öncesine göre istatistiksel olarak anlamlı bir artış görüldü (ortanca: 0,97'ye karşı 0,93; p=0,046). Serum kan üre nitrojeni ve tahmini glomerüler filtrasyon hızı düzeylerinde anlamlı bir değişiklik gözlenmedi (sırasıyla p=0,338 ve p=0,067). Komplikasyon olarak sadece bir hastada akut böbrek yetmezliği ve postembolizasyon sendromu izlendi. Komplikasyon oranı %4,5 olarak bulundu.
Sonuç: Akut renal arter kanamalarında renal arterin selektif embolizasyonu renal fonksiyonlarda bozulmaya neden olmadan yüksek bir klinik başarıya sahiptir. Tedavinin genel anesteziye gerek olmaması ve düşük komplikasyon oranları gibi avantajları vardır.
Anahtar kelimeler: Embolizasyon; kanama; endovasküler; renal anjiyografi; renal arter.

INTRODUCTION

The kidneys are one of the organs with a high blood supply. Although hemorrhages originating from the renal artery are not frequently seen, they can be life-threatening. The most common reasons include spontaneous rupture of renal tumors, trauma, and iatrogenic causes. Renal artery bleeding for iatrogenic reasons may be associated with major surgical procedures or may occur after minimally invasive procedures such as nephrostomy or renal biopsy. Most minor bleeding resolves with a conservative approach but a very small proportion may require an interventional procedure (1).

Although surgical procedures such as partial nephrectomy or radical nephrectomy have a place in the treatment of acute hemorrhages of renal artery origin, the less invasive method of selective renal artery embolization has started to be used in treatment more frequently. Despite the advantage of being able to make a pathological diagnosis by obtaining a specimen in surgical treatment, there are advantages to endovascular treatment such as a shorter stay in hospital and most importantly, greater protection of the nephron (2). However, complications can be observed in endovascular embolization such as non-target embolizations and associated nephron loss (3).

We aimed to investigate the efficacy and complications of endovascular treatment of acute renal artery hemorrhage and the etiology of the condition. We also investigated the effect of the procedure on renal functions.

MATERIAL AND METHODS

Approval for the study was granted by the Hatay Mustafa Kemal University Non-interventional Clinical Research Ethics Committee (dated 17.06.2021, and numbered 16). Patients who underwent renal artery embolization in the Hatay Mustafa Kemal University Interventional Radiology Unit were evaluated retrospectively. Acute renal artery hemorrhages causing impaired hemodynamics and laboratory results were accepted as inclusion criteria. Elective renal embolizations, such as unruptured angiomyolipoma or renal cell carcinoma, were excluded from the study. After inclusion and exclusion criteria 22 patients who underwent super-selective renal artery embolization between 2016 and 2020 in the Hatay Mustafa Kemal University Interventional Radiology Unit were included in the study.

The etiologies causing the hemorrhages were investigated. To evaluate the success of the treatment, the laboratory and clinical follow-up data were examined at least 6 months after the procedure. Patients with follow-up of less than one month were excluded from the study. The embolising agent and methods used in treatment were recorded. The pre and post-procedure urea and creatinine values of the patients were compared. Thus, the patients were evaluated in respect of acute renal failure which can develop secondary to endovascular treatment.

Before the angiography procedure, the extent of bleeding was investigated by abdominal computed tomography (CT), magnetic resonance imaging (MRI), or ultrasound (US) examinations. Renal artery images were obtained in all patients with a 5 French (Fr) diagnostic catheter entered via the femoral route. One vial of contrast agent (Kopaq, 350 mg/mL, Onko-Kocsel, Istanbul, Turkey) was diluted 1/2 with physiological saline for angiography. After the determination of pathologies causing the hemorrhage (pseudoaneurysm, arteriovenous fistula, tumoral vascularity), this localization was super selectively entered with a 1.9 Fr or 2.4 Fr microcatheter. Depending on the pathology causing the bleeding, particle embolising agent (Embozene, CeloNova Biosciences, Newnan, Georgia, USA), liquid embolising agents (Lipiodol, Guerbet, Princeton, USA) or detachable microcoil (Blockade/Balt, Montmorency, France) were used (Figure 1).

Blood samples were taken from the patients within 24 hours before the angio and 24 hours after the procedure, and comparisons were made of blood urea nitrogen (BUN) and creatinine values and the estimated glomerular filtration rate (eGFR) calculated with the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula.

Statistical Analysis

Data obtained in the study were analyzed statistically using IBM SPSS v.25 software. The conformity of continuous variables to normal distribution was assessed with visual (histogram) and analytical methods (Shapiro-Wilk test, Kolmogorov-Smirnov test). As variables did not show normal distribution, the descriptive statistics were stated using median, interquartile range, and minimum-maximum values. The Wilcoxon signed ranks test was applied in the comparisons of continuous variables not showing normal distribution measured at different time points. Correlations between numerical variables were evaluated using Spearman rank correlation analysis. A value of $p<0.05$ was accepted as statistically significant.

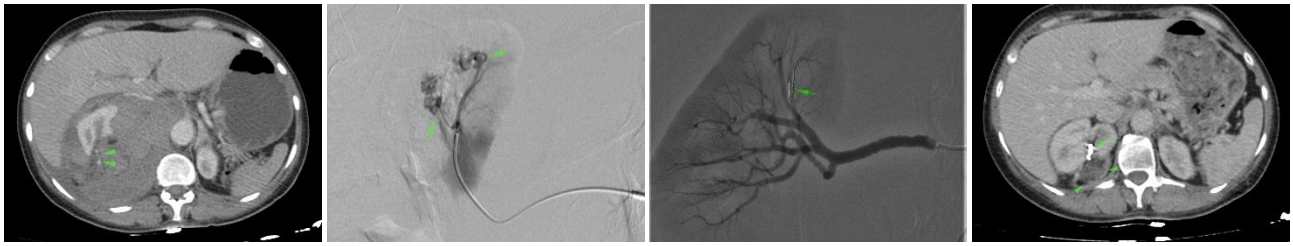

Figure 1. A) Axial section CT image of the patient admitted to the emergency department with acute abdominal pain. A large hematoma with active extravasation in the upper pole of the right kidney (arrows) is observed. **B)** In the renal artery angiography examination performed under emergency conditions; super selective images taken from the upper pole of the right renal artery show tumoral vascularity (arrows) due to angiomyolipoma in the upper pole of the right kidney. **C)** Postembolization angiography image showed the tumor was embolized completely with the coil (arrows) super selectively. **D)** In the control CT image of the patient 3 months later, it is seen that the coils (arrows) in the right kidney near the angiomyolipoma (arrowheads) and the hematoma disappeared after the embolization procedure.

RESULTS

In the Interventional Radiology Unit between 2016 and 2020, selective renal artery embolization procedures were applied to a total of 22 patients. The patients' ages ranged from 5 to 79 years, and the mean age of the patients was 51.5±18.6 years. Of the 22 patients, 10 (45.5%) were male and 12 (54.5%) were female. Of the 22 patients, the etiology of the hemorrhage was determined as ruptured angiomyolipoma in 9 (40.9%), percutaneous stone surgery in 6 (27.2%), percutaneous nephrostomy in 1 (4.5%), open stone surgery in 1 (4.5%), polycystic kidney disease in 1 (4.5%), and blunt trauma in 4 (18.2%).

Of the 4 patients with continuing hemorrhage, the procedure was converted to nephrectomy in 2 (9.1%). One of the patients who underwent nephrectomy had bleeding due to open stone surgery and the other due to angiomyolipoma rupture. Although the renal artery branches that cause bleeding in these patients were embolized super selectively, there was a decrease in hemoglobin values in the follow-up of the patients. However, both patients did not accept the re-embolization procedure. In the other 2 (9.1%) patients, the patient with polycystic kidney disease and a patient with abundant bleeding associated with iatrogenic causes, the embolization procedure was repeated and the bleeding was brought under control. Renal artery hemorrhages were treated with super-selective embolization in 22 of 24 procedures, with a clinical success of 91.7%. In one patient with tuberosclerosis and giant angiomyolipoma covering both kidneys, the serum creatinine level was high (1.8 mg/dl) at the start of the procedure, and after the procedure, acute kidney failure developed which required hemodialysis. During the subsequent follow-up, there was seen no longer a need for dialysis. In the same patient, pain and subfebrile fever lasting less than 24 hours were observed associated with the postembolisation syndrome. Acute renal failure was not observed in any other patient. The complication rate of the whole cohort was determined to be 4.5%. The etiologies of the patients, the embolic agents used, clinical success, and complications are shown in Table 1.

Angiography findings were seen as tumoral vascularity in 9 (40.9%) patients, active extravasation in 1 (4.5%) patient, pseudoaneurysm in 5 (22.7%) patients, arteriovenous fistula in 2 (9%) patients, and pseudoaneurysm together with arteriovenous fistula in 4 (18.2%) patients (Table 2). Accessory renal artery was not observed in any patient.

As findings suggestive of hemorrhage were not observed on the first angiography of the patient with polycystic kidney disease, Technetium-labelled (Tc-99m) erythrocyte scintigraphy was applied to the superior or

Table 2. Angiography findings in renal artery hemorrhages

Angiography findings	n (%)
Pseudoaneurysm	5 (22.7)
Arteriovenous fistula	2 (9.1)
Tumoral vascularity	9 (40.9)
Extravasation	1 (4.5)
Empiric	1 (4.5)
Pseudoaneurysm + Arteriovenous fistula	4 (18.2)

Table 1. Summary of patient characteristics, procedure details, and complications

No	Age/Gender	History	Embolic Agent	Additional Intervention	Clinical Success	Complication
1	41/M	PKD	Coils, 2nd time coils	TAE (4 days after 1st TAE)	Yes (2nd time)	No
2	60/F	Ruptured AML	Particles 100-200 µm	No	Yes	No
3	76/M	PNL	Coils	No	Yes	No
4	79/F	PNL	Coils	No	Yes	No
5	58/M	PN	Coils	No	Yes	No
6	73/F	PNL	Coils	No	Yes	No
7	68/F	Ruptured AML	Particles 200-400 µm	No	Yes	No
8	27/F	PNL	Coils	No	Yes	No
9	24/M	Blunt trauma	Coils	No	Yes	No
10	48/F	Ruptured AML	Particles 200-400 µm, Coils	No	Yes	No
11	37/M	Blunt trauma	Coils	No	Yes	No
12	51/M	Open stone surgery	Coils	Yes (Nephrectomy)	No	No
13	51/F	Ruptured AML	Particles 200 µm, Coils	No	Yes	No
14	59/M	Ruptured AML	Particles 400 µm, Coils	No	Yes	No
15	54/F	Ruptured AML	Particles 400 µm, Coils	Yes (Nephrectomy)	No	No
16	42/M	Tuberous sclerosis	Particles 400 µm, Coils	No	Yes	Yes (PES, AKI)
17	32/M	Blunt trauma	Coils	No	Yes	Yes
18	74/M	PNL	Lipiodol-glue	No	Yes	No
19	56/F	Ruptured AML	Particles 200 µm, Coils	No	Yes	No
20	63/F	Ruptured AML	Lipiodol-glue	No	Yes	No
21	5/F	Blunt trauma	Coils	No	Yes	No
22	55/F	PNL	Coils, 2nd time lipiodol-glue	TAE (8 days after 1st TAE)	Yes (2nd time)	Yes (AKI)

M: male, F: female, AKI: acute kidney injury, AML: angiomyolipoma, PES: postembolisation syndrome, PKD: polycystic kidney disease, PN: percutaneous nephrostomy, PNL: percutaneous nephrolithotomy, TAE: transarterial embolization

inferior pole localization of the bleeding kidney. According to the scintigraphy result, empirical embolization was performed without angiography findings of the pole of the bleeding kidney. No hemorrhage was observed during the follow-up of this patient.

A statistically significant increase was seen in the serum creatinine levels of the patients after the procedure compared to 24 hours before angiography (p=0.046). The change in serum creatinine levels after the angiography procedure showed no significant difference according to the patients' genders (p=0.488) and was not correlated with age (r_s=-0.233, p=0.296). No significant change was observed in serum BUN (p=0.338) and eGFR (p=0.067) levels (Table 3).

Table 3. Comparison of renal function tests of the cases before and after angiography

	Pre-Angiography	Post-Angiography	p
BUN, mg/dl	15.60 (12.00-16.20) [8.0-56.0]	13.90 (9.10-15.01) [8.4-52.0]	0.338
Creatinine, mg/dl	0.93 (0.67-1.16) [0.42-5.88]	0.97 (0.69-1.40) [0.41-6.09]	**0.046**
eGFR, ml/min	82.00 (61.28-103.55) [9.77-164.39]	77.82 (54.00-103.05) [9.36-164.39]	0.067

BUN: blood urea nitrogen, eGFR: estimated glomerular filtration rate, continuous variables were expressed as the median (25^{th} - 75^{th} quartiles) [minimum-maximum] values

DISCUSSION

In this study, we aimed to investigate the efficacy and complications of endovascular treatment of acute renal artery bleeding and the etiology of the condition. We also investigated the effects of super-selective renal artery embolization on kidney functions. The clinical success of selective renal artery embolization has been reported to be 85%-94% (4,5). Clinical success was achieved in 91.6% who underwent embolization in this study. This rate is similar to other studies in the literature. Although 4 of the patients had recurrent bleeding after the first procedure, clinical success was achieved by re-embolization in only 2 of these patients. A nephrectomy was performed in the remaining 2 patients. One of the patients who underwent nephrectomy had bleeding due to open stone surgery and the other due to angiomyolipoma rupture. Although the renal artery branches that cause bleeding in these patients were embolized super selectively, there was a decrease in hemoglobin values in the patients' follow-up. However, both patients did not accept the re-embolization procedure. We attribute the failure of the first procedure to the fact that vasospasm developing secondary to acute bleeding prevents the visibility of the bleeding arteries. Acute renal failure and postembolization syndrome were observed in only one patient as complications. The complication rate was found to be 4,5%. The most frequently seen complication is a post-embolization syndrome which progresses with pain, fever, and nausea (5). The majority of complications associated with renal artery embolization are self-limiting without the need for additional treatment. Although uncommon, arterial dissection, abscess formation and urinary infection, hypertension, and renal dysfunction are other complications which may be seen after embolization (2). In a previous study that investigated complications associated with renal artery embolization, the procedure was reported to be safe in respect of renal function disorder and hypertension (3).

Reasons for hematuria of renal artery origin include iatrogenic causes such as nephrostomy, biopsy, percutaneous stone surgery, and partial nephrectomy; abdominal trauma, and tumor ruptures, primarily angiomyolipoma. Hemorrhages associated with renal artery injuries are seen with clinical and laboratory findings such as side pain, hematuria, tachycardia, and falls in hemoglobin and blood pressure levels (2). When these hemorrhages are not treated, they can be life-threatening (6).

The prevalence of minimally invasive kidney surgery also increases the frequency of post-surgical renal artery injuries (6). While the majority of renal artery hemorrhages associated with surgical procedures such as percutaneous stone surgery and partial nephrectomy are self-limiting, approximately 5% of these will require an interventional procedure (6,7). Selective renal artery embolization is a safe and effective method in the treatment of post-surgical bleeding (8). In a study, a success rate of 95% was achieved after endovascular treatment of 22 patients with renal artery injury after percutaneous stone surgery (9). Of the 22 patients who received endovascular treatment in this study, iatrogenic causes were determined in 8 (%36.3).

Urinary system injuries occur in approximately 10% of abdominal traumas (10). It has been reported that approximately 10% of renal traumas may require an embolization procedure and up to 5% progress to nephrectomy (11). Renal artery embolization has high success rates, especially in low-grade kidney trauma (2). Endovascular treatment is recommended if active renal artery bleeding is detected in grade II and III kidney injuries according to the American Association for Surgery of Trauma (AAST) scoring (12). Even in hemodynamically unstable patients, super-selective renal artery embolization may be one of the treatment modalities of choice in experienced centers (13). The rates of post-traumatic nephrectomy have been reported to be between 5-12% in different studies (14,15). Endovascular treatments with super-selective approaches can preserve more nephrons, while high clinical success can be achieved. It was reported in a study that compared nephrectomy and angioembolisation, that endovascular embolization treatments are an effective and safe method in patients with high-grade kidney injuries (16). In the current study, renal artery injury associated with trauma was determined in 4 (18.1%) patients. Clinical success has been achieved in all trauma patients treated endovascularly.

Angiomyolipoma rupture is prominent in the etiology of renal artery hemorrhages. Although there are no clear data about the frequency of angiomyolipoma hemorrhage, rates of 0.4%-2.5% have been reported in the literature (17,18).

Spontaneous perirenal hemorrhage was reported to be caused by angiomyolipoma at the rate of approximately 20-40% and by renal cell carcinoma at approximately 25-35% (19). In the current study, angiomyolipoma rupture was determined to be the cause of hemorrhage in 9 (40.9%) patients. In a study which compared 42 patients treated with surgery with 17 patients treated with embolization, it was reported that 60% (25/42) of the surgically treated patients progressed to radical nephrectomy and 40% (17/42) to partial nephrectomy (20). Clinical success was achieved in 8 (88.9%) of 9 patients with bleeding due to angiomyolipoma rupture.

Surgical treatment is among the options for the treatment of hemorrhages of renal artery origin. Radical nephrectomy is an extremely invasive method in the treatment of renal artery origin hemorrhages, which are usually associated with benign causes. Although surgical treatment has the advantage of being able to make a pathological diagnosis by taking a specimen, endovascular treatment has started to be more preferred in renal artery injuries as there is less renal parenchyma loss (21,22). In a previous study, it was reported that selective renal artery embolization should be the treatment method first selected for hemorrhages that are not self-limiting or that are life-threatening (3). This method also has the advantages of being minimally invasive, not requiring general anesthesia, having fewer complications, and providing greater protection of the nephron (4,23).

Renal dysfunction does not occur when 34% of the total embolized area is exceeded. (24). There are also studies that have emphasized that in patients where there are concerns of acute renal failure, the chance of endovascular treatment should not be delayed (24). In the current study, although there was a slight increase in the creatinine values after the procedure compared to before (from 0.93 to 0.97), no significant difference was observed in the eGFR measurements, which are an important marker of kidney function. A patient with tuberous sclerosis (patient no. 16) with giant angiomyolipomas covering both kidneys developed acute renal failure requiring hemodialysis after the procedure. However, this patient had elevated creatinine levels (1.8 mg/dl) before the procedure. On the 9th day of follow-up, the creatinine levels had decreased to the pre-procedure levels and there was no longer any requirement for hemodialysis. As giant angiolipomas were covering almost all the renal parenchyma in both kidneys, this was accepted as a predisposing factor for renal failure in this patient. Acute renal failure was not observed in any other patient in this series.

Our study has some limitations such as the small number of patients and its retrospective nature. While investigating the effect of endovascular treatment on kidney functions as blood tests were used, separate information about the functions of the right and left kidneys could not be obtained.

CONCLUSION

Selective embolization of the renal artery has high clinical success rates in the treatment of acute renal artery hemorrhages. There are also the advantages of there being no requirement for general anesthesia, low complication rates, and the potential for greater protection of the nephron.

Ethics Committee Approval: The study was approved by the Non-interventional Clinical Research Ethics Committee of Hatay Mustafa Kemal University (17.06.2021, 16).

Conflict of Interest: None declared by the authors.

Financial Disclosure: None declared by the authors.

Acknowledgments: None declared by the authors.

Author Contributions: Idea/Concept: AK; Design: AK, SG; Data Collection/Processing: AK, SG; Analysis/Interpretation: AK, SG; Literature Review: AK; Drafting/Writing: AK; Critical Review: AK, SG.

REFERENCES

1. Poyraz N, Balasar M, Gökmen İE, Koç O, Sönmez MG, Aydın A, et al. Clinical efficacy and safety of transcatheter embolization for vascular complications after percutaneous nephrolithotomy. Wideochir Inne Tech Maloinwazyjne. 2017;12(4):403-8.
2. Muller A, Rouvière O. Renal artery embolization-indications, technical approaches and outcomes. Nat Rev Nephrol. 2015;11(5):288-301.
3. Sam K, Gahide G, Soulez G, Giroux MF, Oliva VL, Perreault P, et al. Percutaneous embolization of iatrogenic arterial kidney injuries: safety, efficacy, and impact on blood pressure and renal function. J Vasc Interv Radiol. 2011;22(11):1563-8.
4. Öcal O, Puhr-Westerheide D, Mühlmann M, Deniz S, Fabritius MP, Weinhold P, et al. iRESCUE - Interventional embolization of Renal artEries after SurgiCal or traUmatic injury with hEmorrhage. Eur J Radiol. 2021;136:109540.
5. Murray TE, Doyle F, Lee M. Transarterial embolization of angiomyolipoma: a systematic review. J Urol. 2015;194(3):635-9.
6. Inci K, Cil B, Yazici S, Peynircioglu B, Tan B, Sahin A, et al. Renal artery pseudoaneurysm: complication of minimally invasive kidney surgery. J Endourol. 2010;24(1):149-54.
7. Jain S, Nyirenda T, Yates J, Munver R. Incidence of renal artery pseudoaneurysm following open and minimally invasive partial nephrectomy: a systematic review and comparative analysis. J Urol. 2013;189(5):1643-8.
8. Hong Y, Xiong L, Ye H, An L, Huang X, Xu Q. Outcome of selective renal artery embolization in managing severe bleeding after percutaneous nephrolithotomy. Urol Int. 2020;104(9-10):797-802.
9. Jinga V, Dorobat B, Youssef S, Radavoi GD, Braticevici B, Filipoiu F, et al. Transarterial embolization of renal vascular lesions after percutaneous nephrolithotomy. Chirurgia (Bucur). 2013;108(4):521-9.
10. Morey AF, Brandes S, Dugi DD 3rd, Armstrong JH, Breyer BN, Broghammer JA, et al. Urotrauma: AUA guideline. J Urol. 2014;192(2):327-35.
11. Sauk S, Zuckerman DA. Renal artery embolization. Semin Intervent Radiol. 2011;28(4):396-406.
12. Salcedo A, Ordoñez CA, Parra MW, Osorio JD, Leib P, Caicedo Y, et al. Damage Control for renal trauma:

the more conservative the surgeon, better for the kidney. Colomb Med (Cali). 2021;52(2):e4094682.
13. Bryk DJ, Zhao LC. Guideline of guidelines: a review of urological trauma guidelines. BJU Int. 2016;117(2):226-34.
14. Salem MS, Urry RJ, Kong VY, Clarke DL, Bruce J, Laing GL. Traumatic renal injury: Five-year experience at a major trauma centre in South Africa. 2020;51(1):39-44.
15. Sarang B, Raykar N, Gadgil A, Mishra G, Wärnberg MG, Rattan A, et al. Towards Improved Trauma Care Outcomes TITCO-India. Outcomes of renal trauma in Indian urban tertiary healthcare centres: a multicentre cohort study. World J Surg. 2021;45(12):3567-74.
16. Sarani B, Powell E, Taddeo J, Carr B, Patel A, Seamon M, et al. Contemporary comparison of surgical and interventional arteriography management of blunt renal injury. J Vasc Interv Radiol. 2011;22(5):723-8.
17. Bhatt JR, Richard PO, Kim NS, Finelli A, Manickavachagam K, Legere L, et al. Natural history of renal angiomyolipoma (AML): most patients with large AMLs >4cm can be offered active surveillance as an initial management strategy. Eur Urol. 2016;70(1):85-90.
18. Ouzaid I, Autorino R, Fatica R, Herts BR, McLennan G, Remer EM, et al. Active surveillance for renal angiomyolipoma: outcomes and factors predictive of delayed intervention. BJU Int. 2014;114(3):412-7.
19. Liu L, Wu R, Xia Y, Wang J, Xiong Y, Qu Y, et al. A preliminary study on classification and therapeutic strategies for spontaneous perirenal hemorrhage. Int J Surg. 2018;54(Pt A):86-91.
20. Faddegon S, So A. Treatment of angiomyolipoma at a tertiary care centre: the decision between surgery and angioembolization. Can Urol Assoc J. 2011;5(6):E138-41.
21. Regine R, Palmieri F, De Siero M, Rescigno A, Sica V, Cantarela R, et al. Embolization of traumatic and non-traumatic peripheral vascular lesions with Onyx. Interv Med Appl Sci. 2015;7(1):22-9.
22. Sayani R, Azeemuddin M, ul Haq T, Hamid RS, Salam B. An institutional review of transarterial embolization in haemorrhagic urological emergencies. J Pak Med Assoc. 2012;62(2):107-11.
23. Strobl FF, D'Anastasi M, Hinzpeter R, Franke PS, Trumm CG, Waggershauser T, et al. Renal pseudoaneurysms and arteriovenous fistulas as a complication of nephron-sparing partial nephrectomy: technical and functional outcomes of patients treated with selective microcoil embolization during a ten-year period. Rofo. 2016;188(2):188-94.
24. Piasecki P, Ząbkowski T, Brzozowski K, Narloch J, Zięcina P, Dziuk M, et al. The assessment of the risk of acute kidney injury in patients undergoing an urgent endovascular treatment due to severe renal bleeding. Cardiovasc Intervent Radiol. 2018;41(3):398-405.