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FULL PAPER

Renal artery embolization for iatrogenic renal vascular injuries management: 5 years' experience

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Objective: Evaluate the efficacy and safety of renal artery embolization (RAE) for iatrogenic renal vascular injuries (IRVI) management at Fondazione Policlinico Universitario "A. Gemelli" IRCCS, in the last 5 years.

Methods: Retrospective analysis of all RAE procedures performed from January 2013 to December 2017. Patients-related (age, sex, vascular variants, hemoglobin and serum creatinine), IRVI-related (type and vascular level of IRVI, presence and extension of hematoma), management-related (temporal interval between diagnostic imaging and RAE) and procedure-related (embolic materials, technical success, clinical success and complications) parameters were evaluated.

Results: 28 RAE procedures performed on 28 patients (21 males; 7 females) were included. 19/28 patients had pseudoaneurysm, 7/28 active bleeding and 1/28 arteriovenous fistula; 4/28 patients had a combination of 2 IRVI. The extent of perirenal hematoma showed correlation with the cause of IRVI ($p = 0.028$).

Technical success was achieved in all patients whereas clinical success in 25/28 (89.3%), with 3 patients requiring re-treatment. Minor complications were observed during 2/28 (7.1%) endovascular procedures. No major complications occurred. A longer procedural time was observed in patients with lower pre-procedural levels of hemoglobin ($p = 0.016$).

No differences were found in mean serum creatinine ($p = 0.23$) before and immediately after treatment, while values of creatinine at 1 week from the procedure were significantly lower ($p = 0.04$).

Conclusion: RAE is safe and effective for the management of iatrogenic IRVI showing high technical and clinical success rate and low complication rate.

Advances in knowledge: Low pre-procedural hemoglobin levels increase procedural duration time. Glue alone or in combination with other materials is as safe as coils.

INTRODUCTION

Laparoscopic nephrectomy (LPN) and percutaneous interventional procedures such as percutaneous nephrostomy (PN), percutaneous nephrolithotomy (PCNL) and renal biopsy (RB) are minimally invasive diagnostic and therapeutic procedures for the management of kidney diseases. The increased use of these techniques has led to the reduction of parenchymal and functional loss after renal surgery, allowing "nephron-sparing" management in these patients.¹ On the other hand, the risk of life-threatening iatrogenic renal vascular injuries (IRVI), such as active bleeding, pseudoaneurysm, arteriovenous fistula or a combination of them, has become inevitable in these patients,² frequently requiring prompt clinical evaluation and therapeutic action.

Renal artery embolization (RAE) was first described by Almgard in 1973.³ RAE is defined as the voluntary occlusion

of the renal artery and/or one or more of its branches, by means of definitive or temporary embolic agents injected through an endovascular catheter.⁴ The advent of new materials and embolic agents, as well as the development of the technique itself, have extended the indications of RAE over time, making this procedure an accepted and minimally invasive alternative to surgery in IRVI management, in clinically stable patients.^{5,6}

However, it is still unclear which is the best embolic agent to be used and there are few findings in the literature on the use of angiographic glue.⁷

This paper proposes a retrospective review of our experience over the last 5 years with RAE performed for IRVI management, in which angiographic glue was the most used embolic agent.

Figure 1. Institutional diagnostic and therapeutic work-up. CTA, CT angiography; IRVI, iatrogenic renal vascular injuries; RAE, renal artery embolization.

METHODS AND MATERIALS

This study was approved by the Institutional Review Board. The requirement for written informed consent for this study was waived due to the retrospective nature of the study.

The medical records of patients who received RAE procedures for IRVI management, from January 2013 to December 2017, were included in the study.

Diagnostic work-up

Each patient underwent clinical and laboratory evaluation followed by contrast-enhanced CT angiography (CTA), according to the standard internal multidisciplinary protocol (Figure 1). All CTA examinations were performed on a 64-slice CT scanner located in an emergency department (Optima CT660, GE Healthcare). The acquisition protocol consisted of a baseline unenhanced phase followed by a contrast-enhanced arterial, venous and late venous phases. Bolus tracking technique was used for arterial phase: a region of interest (ROI) was placed at the level of the suprarenal abdominal aorta and 80–120 ml of iodinated contrast medium (Ultravist 370 mgI ml⁻¹, Bayer, Leverkusen, Germany) were administered at a flow rate of 4 ml s⁻¹, followed by a flush of 60–80 ml of saline solution at the same injection rate (scan threshold: 100 Hounsfield units (HUs); acquisition delay: 6–7 s; slice collimation: 0.625 mm; pitch: 0.9; tube rotation time: 0.6 s).⁸ Venous and late venous phase were always performed at 40 and 120 s after the arterial phase respectively, in order to characterize the IRVI.

For each patient, a multidisciplinary team, composed by radiologist, interventional radiologist (on call), urologist (on call), emergency surgeon and anesthesiologist, decided the final management.

Embolization technique

All patients signed an informed consent before the RAE procedure.

The procedures were performed by four experienced interventional radiologists (>5 years of experience at the beginning of study enrollment) on a digital monoplane angiographic unit (Integris Allura FD 20, Philips). All patients received anesthesiology support, consisting of mild sedation or total anesthesia, according to patients' clinical status and collaboration capabilities; monitoring of basic vital parameters (cardiac frequency, oxygen saturation and blood pressure) was performed in all patients during the procedure. After local anesthesia (20 ml or less of Mepivacaine 2% solution) a percutaneous vascular access was obtained with an 18 gauge cannula through the right common femoral artery and a 5 French catheter sheath introducer was positioned by Seldinger technique. Through iliac and aortic retrograde catheterization, selective arteriography of the renal artery on the injured side was performed to identify type, size and location of the IRVI; when two or more renal arteries were evident at the pre-procedural CTA, selective catheterization of each was performed. Once the IRVI was identified, super-selective catheterization with a coaxial microcatheter (Progreat, 2.7 F, Terumo) was performed and subsequent embolization achieved with different embolic materials (Coils, N-Butyl-Cyanoacrylate or particles), according to angiographic findings and operator experience. Final angiographic controls were performed to confirm technical success and to exclude treatment complications. Hemostasis at the puncture site was obtained by manual compression. There were no absolute contraindications to RAE; relative contraindication were allergic diathesis to contrast medium and marked renal insufficiency.

Figure 2. Active bleeding: 64-year-old patient with rapid onset of anemia 4 days after partial nephrectomy. CT arterial phase (a) shows an extravasation (arrowheads) of contrast medium increasing during the portal phase (b) with a coexisting large perirenal hematoma (spot). Renal artery angiography (c–e) confirms the presence of an active bleeding of an interlobar artery of the inferior lobe (arrows) managed with selective catheterism of the bleeding vessel by a microcatheter (star) and embolization with angiographic glue (circle).

Post-operative period and follow-up

According to the institutional protocol, patient vital parameters were monitored in a post-operative recovery unit, after all RAE procedures, for a period of at least 3 h. Hemoglobin/hematocrit and serum creatinine were also monitored at post-procedure days 1, 7 and at the discharge. All patients underwent ultrasonography or CTA examination at 3–6 months post-RAE procedure, in order to confirm treatment success and to identify possible clinically silent complications. An additional CTA examination was performed, if necessary, in patients who showed a worsening of vital parameters or clinical status.

Data selection and definition of variables

For each patient, data from electronic clinical charts, radiological reports and images were reviewed. Data related to patient conditions (age; sex; clinical manifestation of IRVI; renal vascular variants; hemoglobin and creatinine values), lesions (underlying cause, type and site of IRVI; presence/extension of renal hematoma), management (time between CT examination and RAE procedure), procedure (site of embolization; type of embolizing material; procedure length; technical success; clinical success; complications) were obtained.

IRVI were defined as follows⁹:

- (1) Active bleeding was defined by the evidence of contrast medium extravasation during the arterial phase, expanding in the venous phase (Figure 2).
- (2) Pseudoaneurysm was defined by the presence of a perivascular contrast medium, with the same enhancement of the adjacent vessel and the same dimension during all the study phases (Figure 3).
- (3) Arteriovenous fistula was identified by the evidence of an early (arterial) localized renal vein enhancement (Figure 4).

IRVI involving main and segmental arteries were classified as proximal, those involving interlobar, arcuate and interlobular arteries were classified as distal¹⁰; the level of injury was defined on CT images and confirmed by the diagnostic runs during the RAE procedure.

The extension of renal hematoma was defined in accordance with the American Association for the Surgery of Trauma and Abbreviated Injury Scale classification systems¹¹: absence of hematoma; subcapsular; perirenal (up to Gerota's fascia); para-renal (out of Gerota's fascia).

Technical success was defined as complete intraprocedural vascular exclusion of the IRVI at the final post-procedure angiographic control; clinical success was defined by clinical stability in the follow-up period (stable hemoglobin/hematocrit levels and no evidence of re-bleeding).

Statistical analysis

A commercially available software (Medcalc 18, Medcalc Software) was employed for statistical analysis.

Variables with normal distributions were reported as mean $\pm$ standard deviation (95% confidence interval was calculated) and Student's *t*-test was adopted to assess significant differences.

For variables that are nominal, ordinal or without normal distribution, nonparametric tests (McNemar and Wilcoxon signed rank test) were employed for inferential statistics.

A *p*-value < 0.05 was considered as statistically significant.

Figure 3. Pseudoaneurysm: laparoscopic partial nephrectomy in a 72-year-old patient for a right kidney mass revealed to be a clear cell carcinoma. The patient presented with hematuria 17 days after surgery. CT images show a IRVI in the surgical cavity (arrow) with the typical pattern of enhancement of a pseudoaneurysm (a, arterial phase; b, venous phase; c, late enhancement phase). Selective renal angiography confirms the diagnostic suspect of pseudoaneurysm (Arrowhead) involving an interlobar artery (d-e), subsequently treated with N-Butyl-Cyanoacrylate. Control angiogram shows the complete exclusion of the IRVI (f). IRVI, iatrogenic renal vascular injuries.

A multivariate analysis was performed to assess any correlations among variables.

RESULTS

A total of 28 RAE procedures performed on 28 patients were finally included. Patient characteristics, vascular anatomy, clinical features and supposed cause of IRVI are summarized in Table 1.

Figure 4. Arteriovenous fistula: 43-year-old patient after laparoscopic partial nephrectomy. CT (a-b) shows a large arteriovenous fistula (arrow) at the site of surgery, confirmed by the blood theft from the parenchyma downstream the lesion (spot) and by the early venous enhancement during the arterial phase of the study (arrowhead). Renal artery angiography (c-e) confirms the presence of an arteriovenous fistula with early venous opacification (star) treated with super-selective catheterization (circle) and embolization with only minimal loss of normal parenchyma (brace).

Table 1. Patients demographic, anatomical and clinical features

Patients	
Patients	28
Procedures	31
Re-treatment	3
Age (years)	62.81 ± 12.69 (31-83)
Sex	21 M; 7 F
Side	13 R; 15 L
Vascular anatomy	
Single renal artery	20
Hilar accessory artery	5
Superior polar artery	3
Clinical features	
Anemia	14
Hematuria	9
Flank pain	5
Supposed cause of IRVI	
Laparoscopic partial nephrectomy	19
Nephrolithotomy	6
Nephrostomy	2
Renal biopsy	1

F, Female; IRVI, iatrogenic renal vascular injuries; L, Left; M, Male; R, Right.

Table 2. Type of IRVI, vascular level and embolic agents

Type of IRVI	
	No of patients
Pseudoaneurysm	16
Active bleeding	7
AVF	1
Active bleeding + AV fistula	1
Active bleeding + Pseudoaneurysm	1
Pseudoaneurysm + AV fistula	2
Vascular level	
Main renal artery	1
Segmental artery	4
Interlobar artery	15
Arcuate artery	3
Interlobular artery	3
Interlobar + Arcuate artery	2
Embolic agents	
N-butyl-cyanoacrylate	20
PVA particles	2
N-butyl-cyanoacrylate + Coils	4
N-butyl-cyanoacrylate + Gelfoam	1
PVA particle + Gelfoam	1

AVF, arteriovenous fistula; IRVI, iatrogenic renal vascular injury; PVA, polyvinyl alcohol.

All patients underwent CTA examination after the onset of symptoms and before RAE examination. The overall mean time between the supposed cause of IRVI and the CTA examination was 8.16 ± 7.30 days (range: 1–26 days); for patients undergoing LPN, mean time of onset of symptoms was 7.14 ± 6.64 , for patients undergoing interventional procedures mean time was 6.85 ± 7.13 .

Among patients undergoing LPN, in 2/19 patients (10.5%) there was no evidence of renal hematoma, in 8/19 (42.1%) CTA showed a subcapsular hematoma, in 6/19 (31.6%) a perirenal hematoma and in 3/19 (15.8%) a pararenal hematoma respectively. Among patients undergoing interventional procedures, in 3/9 patients (33.3%) there was no evidence of renal hematoma, in 2/9 (22.2%) CTA showed a perirenal hematoma and in 4/9 (44.4%) a pararenal hematoma respectively. A higher degree of extension of the renal hematoma was observed in patients undergoing interventional procedures (PN, PNL, RB), compared to laparoscopic partial nephrectomy ($p = 0.028$).

The mean time between CTA and RAE procedure was 170.1 ± 78.3 min (range: 23–323 min).

The type of IRVI, the vascular level and the embolic agents are summarized in Table 2.

Technical success was achieved in all the procedures (100%) with the evidence of complete exclusion of the vascular lesion at the end of each procedure. Clinical success was achieved in 25/28 (89.3%) patients at the first procedure. Three patients (10.7%) experienced re-bleeding at 5, 10 and 11 days after the first RAE procedure respectively. All these patients were affected by pseudoaneurysm; two patients were primarily treated with glue in combination with coils and one patient with coils alone. All of them were successfully re-treated with glue, raising the global clinical success to 90.6% (28 out of 31 procedures). No major complications^{12,13} were reported; two patients had a minor complication: one patient experienced migration of glue in the main renal artery, successfully managed with balloon-mediated fragmentation; another patient had a focal dissection of a segmental artery that spontaneously resolved with pharmacological systemic pressure reduction in the postoperative period (Figure 5). No late complications at 3–6 month at ultrasound or CTA imaging were observed.

General anesthesia was necessary in 2/28 procedures, as the consequence of patients' poor collaboration; for all the other procedures, mild sedation was performed.

The effect of RAE on renal function was evaluated assessing pre- and post-procedure serum creatinine values. CIN was defined as an elevation of serum creatinine of more than 25% or ≥ 0.5 mg dl⁻¹ (44 μ mol/l) from baseline within 48 h.¹⁴ Creatinine values were retrievable in 26/31 procedures. Patients developed CIN in 4 out of 26 (15.4%) procedures. There was no statistical difference between the mean value of serum creatinine before (1.58 ± 1.11 mmol l⁻¹; range: 0.6–5.56 mmol l⁻¹) and after (within 24 h) (1.68 ± 1.16 mmol l⁻¹; range: 0.54–5.6 mmol l⁻¹) RAE procedure ($p = 0.23$, paired, two tails *t*-test). No patients had renal failure or underwent dialysis after the procedure. An improvement in creatinine levels (1.27 ± 0.76 mmol l⁻¹; range: 0.46–3.4 mmol l⁻¹) compared with pre-procedural values ($p = 0.04$) was observed at 7 days after the procedure.

The mean value of hemoglobin before the procedure was 9.22 ± 1.62 g dl⁻¹ (range: 12.9–6.2 g dl⁻¹); a mean procedural time of 42.29 ± 27.19 min was observed with median value at 31.5 min. In patients with lower pre-procedure hemoglobin levels a longer procedural time (>31 min) was observed ($p = 0.00298$, Wilcoxon signed-rank test).

At multivariate analysis, considering increase of creatinine values after the procedure and at 7 days and presence of complications as dependent variables, none of the independent variables was statistically associated. Independent variables considered in multivariate analysis were: type of surgery; type and level of lesion; time elapsed from onset of symptoms to endovascular treatment; time elapsed from TC to endovascular treatment; time for endovascular treatment; presence of perirenal hematoma; presence of hematuria; amount of contrast medium administered during endovascular treatment; type of embolic material; presence of complications; technical and clinical success.

Figure 5. Treatment complication: renal artery angiography (a-c) in a patient with active bleeding (circle) at the inferior pole of the left kidney after renal biopsy, managed with N-butyl-cyanoacrylate embolization (star). A segmental artery dissection is evident at the end of the procedure (arrow). CT examination performed at 5 days (d) confirms the presence of the dissection, with no evidence of parenchymal ischemic injury. CT control after 1 month (e) demonstrates complete thrombosis of the false lumen (spot).

DISCUSSION

Minimally invasive diagnostic and therapeutic procedures, for the management of renal disease, increased the risk of IRVI and post-procedural bleeding, with a non-negligible incidence in the literature¹⁵; the underlying causes of IRVI may be multiple, such as inaccurate suture of the renal parenchyma during LPN or the crossing of renal artery branches during percutaneous procedures with needles or other devices.¹⁶ The main cause of bleeding in this study was LPN with a mean time between the surgical procedure and the clinical evidence of IRVI of 8.16 ± 7.30 days (range: 1–26 days); this result is comparable to those previously reported.⁴ The extent of the perirenal hematoma was on average higher in patients undergoing percutaneous procedures compared with LPN ($p = 0.028$); there are not comparative studies in the literature between the extent of hematoma and the underlying cause of IRVI. It is reasonable to interpret this result as a consequence of the direct visualization of the kidney during LPN, with the possibility of direct intervention, compared to percutaneous imaging-guided procedures that may fail to identify bleeding.

In this study, 28 patients underwent a total of 31 RAE procedures with a technical success of 100%, an overall clinical success of 90.6%, a retreatment rate of 10.7%, and a complication rate of 6.4%, considering also re-embolization procedures. Only two patients experienced minor complications: in the first patient a focal, non-occluding, dissection of a interlobar branch occurred during the procedure but complete thrombosis of the false lumen and vessel patency were observed at the follow-up CT examination, after conservative management with antihypertensive therapy. Retrograde migration of the glue in a segmental artery occurred in the second patient; in this case, intraprocedural management was achieved by balloon-mediated compression of the clot and subsequent

vessel lumen restoration. CT follow-up, performed at 3 and 4 months respectively, supported the absence of clinical sequelae in both cases. The results of our study are similar to those previously reported in the majority of studies. In particular, Sam *et al*¹⁷ obtained a 98% technical success rate and a clinical success rate varying from 83% at 24 h to 98% at 72 h, reporting a 6% of complication rate; in their series there was a predominant use of coils alone or in combination with other embolic agents for a total of 34 procedures. In the series of Wang *et al*,¹⁸ 46 patients underwent RAE with coils alone or in combination with particles; all procedures achieved technical success and the clinical success rate was 89.1%, without minor or major complications.

Most of the series in the literature report coil embolization as the technique of choice for RAE in various clinical settings.^{16–20} To the best of our knowledge, this paper reports the highest number of RAE procedures performed with N-butyl-cyanoacrylate (24 procedures), in the specific group of patients with IRVI; only few papers report a significant number of patients treated with N-butyl-cyanoacrylate alone or in combination with other embolic agents.^{5,7} Ząbkowski *et al*⁵ reported a 100% technical and 95% clinical success, respectively, even though they did not specify how many patients were treated with angiographic glue. In series by An T *et al*,⁷ all patients had clinical remission at the first attempt, without complications. The results of our study confirm those of previous studies and are comparable to those of the other studies in which coils, or other embolic agents, were the treatment of choice.^{16–19} In our experience, the use of glue allowed vascular exclusion of the IRVI at the site of the vascular lesion, reducing reperfusion rates. On the other hand, the liquid nature of N-butyl-cyanoacrylate increases the risk of reflux and distal migration, requiring operative confidence with glue and a high level of

attention during the embolization procedure; this aspect should probably limit the use of N-butyl-cyanoacrylate in large vessels and for the management of large IRVI, possibly combining embolization with coils, since late ureteral obstruction by migration of glue fragments has been described.²¹ Furthermore, in our study a case of glue reflux was observed and managed with balloon-mediated compression; this technique proved to be effective and could be a good option in select cases for preventing significant stenosis. As a corollary, even if there is lack of evidence in the literature, glue can potentially reduce the procedural costs in comparison to coils or particles; this aspect should always be taken into account when choosing the embolic agent for each single patient. Our results, compared to those in the literature, confirm that RAE performed with N-butyl-cyanoacrylate is as effective as coils and particles for IRVI management.

The clinical safety of RAE was confirmed by the non-significant variation of serum creatinine values immediately after the procedure, by the significant ($p = 0.04$) improvement of the same value at 7 days after the RAE procedure and by the absence of cases of renal failure. Super-selective embolization of the bleeding site, with subsequent protection of the renal parenchyma not involved, may possibly explain this good clinical result, as suggested by Hongjie Guo et al.¹⁶

Patients with lower pre-procedure hemoglobin levels experienced longer procedural time ($p = 0.00298$). To the best of our knowledge, there is lack of evidence in the literature concerning a possible correlation between hemoglobin levels and procedural time; a possible explanation may be the high degree of vasoconstriction in these patients and/or worse clinical conditions with motion artifacts that reduce vascular trackability and may hide the bleeding site.

This study has some undeniable limitations such as the retrospective nature and the relatively small population, which is nonetheless larger than in most published series. Nevertheless, since most procedures are performed in situations of urgency, it is difficult to design a prospective randomized clinical trial with a sufficient number of cases in this population of patients. Moreover, the use of multiple embolic agents and the relatively long time of enrolment, which may influence the learning curve of the operators, are a possible bias for this study.

In conclusion, our experience suggests that RAE is a minimally invasive tool, which is able to control bleeding subsequent to IRVI, with a low complication rate and with a positive impact on renal function preservation. A super-selective use of N-butyl-cyanoacrylate can give a high rate of technical success.

REFERENCES

- Withington J, Neves JB, Barod R. Surgical and minimally invasive therapies for the management of the small renal mass. *Curr Urol Rep* 2017; **18**: 61. doi: <https://doi.org/10.1007/s11934-017-0705-8>
- Gonzalez-Aguirre AJ, Durack JC. Managing complications following Nephron-Sparing procedures for renal masses. *Tech Vasc Interv Radiol* 2016; **19**: 194–202. doi: <https://doi.org/10.1053/j.tvir.2016.06.004>
- Almgård LE, Fernström I. Embolic occlusion of an intrarenal aneurysm: a case report. *Br J Urol* 1973; **45**: 485–6. doi: <https://doi.org/10.1111/j.1464-410X.1973.tb06809.x>
- Loffroy R, Rao P, Kwak B-K, Ota S, De Lin M, Liapi E, et al. Transcatheter arterial embolization in patients with kidney diseases: an overview of the technical aspects and clinical indications. *Korean J Radiol* 2010; **11**: 257–68. doi: <https://doi.org/10.3348/kjr.2010.11.3.257>
- Ząbkowski T, Piasecki P, Zieliński H, Wieczorek A, Brzozowski K, Zięcina P. Superselective renal artery embolization in the treatment of iatrogenic bleeding into the urinary tract. *Med Sci Monit* 2015; **21**: 333–7.
- Poulakis V, Ferakis N, Becht E, Deliveliotis C, Duex M. Treatment of renal-vascular injury by transcatheter embolization: immediate and long-term effects on renal function. *Journal of Endourology* 2006; **20**: 405–9. doi: <https://doi.org/10.1089/end.2006.20.405>
- An T, Zhang S, Xu M, Zhou S, Wang W. Transcatheter embolization of peripheral renal artery for hemorrhagic urological emergencies using FuAiLe medical glue. *Sci Rep* 2015; **5**: 9106. doi: <https://doi.org/10.1038/srep09106>
- Hazırolan T, Öz M, Türkbeğ B, Karaosmanoğlu AD, Oğuz BS, Canyigit M. Ct angiography of the renal arteries and veins: normal anatomy and variants. *Diagn Interv Radiol* 2011; **17**: 67–73.
- Tonolini M, Ierardi AM, Varca V, Incarboni GP, Petullà M, Bianco R. Multidetector CT imaging of complications after laparoscopic nephron-sparing surgery. *Insights Imaging* 2015; **6**: 465–78. doi: <https://doi.org/10.1007/s13244-015-0413-1>
- Urban BA, Ratner LE, Fishman EK, et al. Three-Dimensional volume-rendered CT angiography of the renal arteries and veins: normal anatomy, variants, and clinical applications. *RadioGraphics* 2001; **21**: 373–86. doi: <https://doi.org/10.1148/radiographics.21.2.g01mr19373>
- Kozar RA, Crandall M, Shanmuganathan K, et al. Organ injury scaling 2018 update: spleen, liver, and kidney. *J Trauma Acute Care Surg* 2018; **85**: 1119–22.
- Martin LG, Rundback JH, Wallace MJ, Cardella JF, Angle JF, Kundu S, et al. Quality improvement guidelines for angiography, angioplasty, and stent placement for the diagnosis and treatment of renal artery stenosis in adults. *Journal of Vascular and Interventional Radiology* 2010; **21**: 421–30. doi: <https://doi.org/10.1016/j.jvir.2009.12.391>
- Angle JF, Siddiqi NH, Wallace MJ, et al. Quality improvement guidelines for percutaneous transcatheter embolization: Society of interventional radiology standards of practice Committee. *J Vasc Interv Radiol* 1997; **21**: 1479–86.
- Mohammed NA, Rafie I, Mahfouz A, Achkar K, Hajar R, Mahfouz A, Nephropathy Contrast-induced. Contrast-Induced nephropathy. *Heart Views* 2013; **14**: 106–16. doi: <https://doi.org/10.4103/1995-705X.125926>
- Ramani AP, Desai MM, Steinberg AP, NG CS, ABREU SC, KAOUK JH, et al. Complications of laparoscopic partial nephrectomy in 200 cases. *Journal of Urology* 2005; **173**: 42–7. doi: <https://doi.org/10.1097/01.ju.0000147177.20458.73>

16. Guo H, Wang C, Yang M, Tong X, Wang J, Guan H, et al. Management of iatrogenic renal arteriovenous fistula and renal arterial pseudoaneurysm by transarterial embolization. *Medicine* 2017; **96**: e8187. doi: <https://doi.org/10.1097/MD.00000000000008187>
17. Sam K, Gahide G, Soulez G, Giroux M-F, Oliva VL, Perreault P, et al. Percutaneous embolization of iatrogenic arterial kidney injuries: safety, efficacy, and impact on blood pressure and renal function. *Journal of Vascular and Interventional Radiology* 2011; **22**: 1563–8. doi: <https://doi.org/10.1016/j.jvir.2011.06.020>
18. Wang C, Mao Q, Tan F, Shen B. Superselective renal artery embolization in the treatment of renal hemorrhage. *Ir J Med Sci* 2014; **183**: 59–63. doi: <https://doi.org/10.1007/s11845-013-0972-4>
19. Ierardi AM, Floridi C, Fontana F, Duka E, Pinto A, Petrillo M, et al. Transcatheter embolisation of iatrogenic renal vascular injuries. *Radiol Med* 2014; **119**: 261–8. doi: <https://doi.org/10.1007/s11547-013-0343-2>
20. Ghoneim TP, Thornton RH, Solomon SB, Adamy A, Favaretto RL, Russo P. Selective arterial embolization for pseudoaneurysms and arteriovenous fistula of renal artery branches following partial nephrectomy. *Journal of Urology* 2011; **185**: 2061–5. doi: <https://doi.org/10.1016/j.juro.2011.02.049>
21. Inchingolo R, Antonucci M, Pinto F, Cina A. Proximal ureteric obstruction caused by glue migration following selective renal artery embolization. *Journal of Vascular and Interventional Radiology* 2015; **26**: 448–50. doi: <https://doi.org/10.1016/j.jvir.2014.11.016>