CardioVascular and Interventional Radiology

Published Online: 26 October 2004

Cardiovasc Intervent Radiol (2005) 28:39–47
DOI: 10.1007/s00270-004-0042-4

Angiographic Findings and Embolotherapy in Renal Arterial Trauma

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Abstract

Purpose: To evaluate the angiographic findings and embolotherapy in the management of traumatic renal arterial injury.
Methods: This is a retrospective review of 22 patients with renal trauma who underwent arteriography and percutaneous embolization from December 1995 to January 2002. Medical records, imaging studies and procedural reports were reviewed to assess the type of injury, arteriographic findings and immediate embolization results. Long-term clinical outcome was obtained by communication with the trauma physicians and by clinical chart review.
Results: Arteriography was performed in 125 patients admitted to a State Trauma Center with suspected internal bleeding. Renal arterial injury was documented in 22 and was the result of a motor-vehicle accident (10), auto–pedestrian accident (1), gunshot (4) or stab wounds (6) and a fall (1). Percutaneous renal arterial embolization was undertaken in 22 of 125 (18%) patients to treat extravasation (11), arterial pedicle rupture (5), abnormal arteriovenous (3) or arteriocalyceal (2) communication and pseudoaneurysm (3). One of the pseudoaneurysms and one of the arteriovenous fistulae were found in addition to extravasation. All 22 patients (16 men, 6 women) were hemodynamically stable, or controlled during arteriography and embolotherapy. Selective and/or superselective embolization of the abnormal vessels was performed using coils in 9 patients, microcoils in 9 patients and Gelfoam pledgets in 3 patients. In one patient Gelfoam pledgets mixed with polyvinyl alcohol (PVA) particles were used for embolization. Immediate angiographic evidence of hemostasis was demonstrated in all cases. Two initial technical failures were treated with repeat arteriography and embolization. There was no procedure-related death. There was no non-target embolization. One episode of renal abscess after embolization was treated by nephrectomy and 3 patients underwent elective post-embolization nephrectomy to prevent infection. Follow-up ranged from 1 month to 7 years (mean 31 months). No procedure-related or delayed onset of renal insufficiency occurred.
Conclusion: In hemodynamically stable and controlled patients selective and superselective embolization is a safe and effective method for the management of renal vascular injury.

Key words: Embolization—Aneurysm—Arterial injuries—Arteriography—Renal trauma—Arteriovenous fistula—Angiography—Extravasation—Arterial bleeding

Non-iatrogenic renal arterial injury is a potentially life-threatening emergency that can require immediate diagnosis and therapeutic intervention. Injury can occur secondary to stab and gunshot wounds, falls, motor-vehicle accidents (MVAs) and auto–pedestrian accidents. Aortography in conjunction with selective and superselective renal arteriography with subsequent embolization has emerged as an alternative method to surgical management [1–8]. A small number of series have described the utilization of renal arterial embolization in patients with vascular renal injuries secondary to iatrogenic and non-iatrogenic trauma [1–8]. This report describes our experience with the use of

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embolization for the management of non-iatrogenic renal arterial injuries. The immediate and long-term results of percutaneous embolization are presented and discussed.

Materials and Methods

We performed a retrospective review of all patients suffering non-iatrogenic renal trauma who underwent angiography and percutaneous embolization. All patients with renal arterial trauma resulting from MVAs, auto–pedestrian accidents, falls, stab and gunshot wounds who underwent arteriography and embolization from October 1995 to January 2002 were included in the study. Institutional Review Board (IRB) approval was obtained. The medical records, radiologic reports and corresponding images were reviewed to assess the patients' symptoms, the type of injury, the presence of radiographically functioning renal parenchyma, the presence of retroperitoneal, perirenal and pelvic hematoma, as well as the presence of multiorgan injury. The immediate and post-embolization angiographic findings and corresponding reports were reviewed and the site and type of the bleeding lesion and the results of the embolization procedure were recorded. Clinical outcome and complications were obtained by review of the medical records, communication with the referral physicians and follow-up of laboratory data such as the serum creatinine level, hemoglobin and hematocrit, and repeated imaging studies.

Indications for angiography included any of the following:

1. Abdominal computed tomographic (CT) examination, suggestive of vascular renal injury including parenchymal laceration, contrast extravasation, perirenal hematoma or foreign body trajectories through the kidney, as well as pseudoaneurysm in the presence of clinical suspicion of ongoing hemorrhage.
2. Intraoperative findings such as a large or expanding hematoma with a possibility for angiographically assisted renal salvage.
3. Persistent symptomatology, as well as laboratory findings (decreasing hemoglobin/hematocrit levels) suggestive of vascular renal injury including prolonged hematuria.

Technique

Arteriography was performed with standard percutaneous technique from a common femoral artery (CFA) approach. A 5.5–6 Fr arterial sheath was placed in the CFA with the tip positioned at the level of the external iliac artery. This afforded rapid and safe exchange of angiographic catheters for aortography (5 Fr omniflush or pigtail, AngioDynamics, Queensbury, NY, USA) and selective catheterization of the main renal artery (4–5 Fr, Sos 2 and C-2, AngioDynamics). Initially, diagnostic digital abdominal aortography was performed to identify aberrant or polar renal arteries, followed by selective renal arteriography which was directed to the injured kidney by the clinical (stab wound, hematoma, bullet entry and/or exit sites) and imaging findings (available in 20/22) and by findings noted in surgical exploration when this preceded imaging in patients who were initially hemodynamically unstable due to multiple intra-abdominal and pelvic injuries (2/22). Selective catheterization of the main renal artery was performed with 4–5 Fr Sos Omni or Cobra 2 catheters (AngioDynamics). All catheter advances were performed over a 0.035-inch guidewire (Benson, 15 J, Angled Glide, Terumo).

In 10 patients superselective catheterization with a coaxial microcatheter (Tracker, Boston Scientific, Watertown, MA, USA) was required to embolize the identified lesion. Extravasation of the main artery, proximal and interlobar branches was controlled by transcatheter 0.035-inch coil embolization.

In 12 patients embolization of the arterial lesion was feasible using a 4–5 Fr diagnostic catheter, while in 10 patients the distal location or the presence of vessel tortuosity necessitated the use of a coaxially placed microcatheter (Tracker, Boston Scientific, Natick, MA, USA). Distal arterial branch injury (interlobar) was followed by superselective catheterization and embolization with the use of microcoils (Vortex, Boston Scientific, Natick, MA, USA) via a Tracker microcatheter (Boston Scientific, Natick, MA, USA) in a coaxial manner ($n = 10$). The embolization was performed in 9 patients with 0.035-inch coils (Cook, Bloomington, IN, USA), in 9 patients with 0.018-inch microcoils (Vortex, Boston Scientific, Natick, MA, USA; Tornado, Cook, Bloomington, IN, USA), in 3 patients with the use of gelatin sponge pledgets (Surgifoam or Gelfoam, Ethicon, Somerville, NJ, USA) and in 1 with a suspension of polyvinyl alcohol (PVA) particles (PVA, Cook, Bloomington, IN, USA) mixed with gelatin sponge pledgets and contrast using flow-directed techniques ($n = 3$) via a 4–5 Fr, C-2 catheter (Angiodynamics; Cook). The choice of the embolic agent was based on the operator's preference. Patients were covered with antibiotics prior to the embolization procedure.

Definitions

Angiographic findings suggestive of arterial trauma included: active extravasation, transection, arterial spasm, arterial wall irregularity, abnormal arteriovenous and arteriocalyceal communication, pseudoaneurysm.

Technical success of embolotherapy was defined as immediate cessation of flow into the area of extravasation and/or the abnormal arterial branch.

Clinical success was defined as the sustained cessation of symptomatology and clinical findings suggestive of hemorrhage as the result of embolization alone.

Long-term clinical success was defined as sustained absence of symptomatology suggestive of hemorrhage, preservation of hematocrit and hemoglobin levels within normal limits and no evidence of delayed complication. This combines the effects of embolization and surgical management.

Post-embolization estimated parenchymal loss was a gross estimate of renal parenchyma as seen in the post-embolization arteriogram.

Immediate complications were defined as:

- non-target vessel embolization or injury,
- hemodynamic compromise during or immediately after the procedure,
- repeated extravasation from the embolized site within the next 72 hr.

Delayed complications were defined as:

- repeated delayed extravasation, pseudoaneurysm or arteriovenous fistula formation at the site of embolization,
- loss of renal function or parenchyma as evidenced by follow-up creatinine levels and imaging studies,

– infection including abscess formation.
– new onset of hypertension.

Results

Between December 1995 and January 2002, 125 patients were referred for angiography for suspected arterial trauma. Renal arterial injury was demonstrated in 22 patients (Table 1). Ages ranged from 14 to 73 years: 16 males (median age 37 years, range 17–73 years) and 6 females (median age 43 years, range 14–66 years). The mechanisms of injury were 10 MVAs, 6 stabbings, 4 gunshot wounds 1 fall and 1 pedestrian accident (Table 1). Selective and superselective angiography demonstrated extravasation in 13: 4 at the main artery (Fig. 1), 1 at the surgical stump after nephrectomy and 8 from a lobar or interlobar branch. [Abrupt cutoff of arterial branch in 1, pseudoaneurysm formation in 3 (Fig. 2), arterial calyx fistula in 2 (Fig. 3), arteriovenous communication in 2 (Fig. 4) and pseudoaneurysm with an arteriovenous fistula component in 1 patient.] One of the pseudoaneurysms and one of the arteriovenous fistulae were seen in addition to area of arterial wall irregularity (Table 1). Arterial wall irregularity and arterial narrowing (vasospasm) were often accompanying findings. CT allowed the detection of renal lacerations and fractures in hemodynamically stable or controlled patients (9) and directed the arteriogram and embolization procedure to the area of injury, thus shortening the interventional procedure time and effort. Abnormal angiographic findings were followed by selective and superselective embolization. In 12 of 22 patients the angiographic findings were demonstrated only after selective catheterization at the area of the injury demonstrated by CT. Six of the 22 patients underwent additional embolization of concurrent liver (3), splenic (2) and both liver and splenic (1) lacerations. One patient with multiorgan injury from a gunshot wound underwent bowel resection with colostomy creation and packing of left renal injuries change prior to superselective embolization of left renal arterial branches. All additional injuries for each patient are shown in Table 1.

Immediate or technical success was achieved in 20 of 22 (91%) of the embolized patients without the need for further surgical or interventional procedure for treatment of the bleeding vessel. In one patient the initial arteriograms failed to demonstrate an injured vessel. The patient returned for arteriography within 24 hr due to decreasing hematocrit and hemoglobin level (Table 1, patient 8). At that time repeat arteriograms demonstrated extravasation from a distal interlobar branch, which was superselectively catheterized and embolized without sequelae. In a second case embolotherapy was performed without incident to treat extravasation of a lower-pole interlobar branch; however, the patient returned 48 hr later for additional treatment of a separate mid-polar branch which was not identified as injured in the first study (Table 1, patient 15). When including the two additional procedures to treat the two initial failures, secondary technical success of embolization was achieved in all 22 cases.

Clinical success attributed to the embolization procedure alone was documented in 18 of 22 patients (82%). In 3 of the 22 patients (Table 1, patients 4, 6 and 21) elective nephrectomy was undertaken to prevent the development of renal abscess and sepsis after embolization of the main renal artery. In the fourth patient nephrectomy was performed after development of renal abscess in an embolized kidney (Table 1, patient 9).

Mean follow-up was 31 months (range 1 month to 7 years). Death was the result of associated neurologic injury in one patient (Table 1, patient 5). Two patients were lost 1 month after the procedure and 2 died during follow-up from non-related causes. There was no death directly related to the embolization procedure. No recurrence of bleeding was observed in the 19 patients available for long-term follow-up, resulting in 100% long-term clinical success (combining the results of embolization and nephrectomy). Renal abscess developed on the 10th post-embolization day in a multitrauma patient who had undergone selective embolization of multiple arterial branches. The patient was taken to the operating room where he underwent multiple operations for concomitant intestinal injuries, as well as nephrectomy of his infected kidney (Table 1, patient 9).

Four of the 5 patients, who suffered main renal artery injury in this series, underwent primary coil embolization resulting in immediate control of bleeding and loss of the parenchymal filling, in the post-embolization arteriogram. One patient with main renal artery injury had undergone previous surgical ligation followed by embolization due to persistent bleeding at the surgical stump. Although there was successful control of the hemorrhage after embolization, she eventually died due to her neurologic trauma (Table 1, patient 5). One of the patients who underwent embolization of the main renal artery had suffered a gunshot injury to the posterior right chest with the bullet going through the right lobe of the liver and the right posterior kidney. He initially underwent surgical exploration, which included packing at the renal bed. He was at that point hemodynamically stable and underwent arteriography and percutaneous embolization of the right main renal artery. Thirty minutes after embolization and while having a CT examination he went into ventricular tachycardia and was successfully resuscitated. It is unknown whether this was related to the embolization that took place earlier. It was later found that he had a history of cocaine-induced cardiomyopathy. Elective right nephrectomy was performed on him the next day. There was no evidence of continuing bleeding of the embolized organ at surgery. He eventually recovered from his injuries and was discharged from the hospital in good condition (Table 1, patient 6). The third patient who had main renal artery embolization had also suffered liver and colon injuries as well as thoracic vertebral fractures. She underwent multiple operations including post-embolization elective nephrectomy. She underwent multiple

Table 1. Demographics, clinical, technical and follow-up information

Patient no.	Hemodynamic status	Sex	Age (years)	Type of trauma	Additional injury	Angiogram findings	Embolic agent	Comments	Catheter used for embolization	Follow-up (months)	% gross estimate parenchymal loss[a]
1	Crc	F	62	Pedestrian accident	Pelvis, tibia,vertebral fracture, spleen	Right interlobar branch extravasation	Microcoils		Microcatheter	48, died	25%
2	Stable	F	14	MVA	No	Right main extravasation	Coils	No nephrectomy	C-2, 4 Fr	30	100%
3	Stable	F	66	Stabbing	No	Left interlobar AVF, PSA	Microcoils		Microcatheter	52	30%
4	Crc	F	23	MVA	Liver, T4–8 fracture, colon	Left main extravasation	Coils	Nephrectomy; Fig. 1	C-2, 5 Fr	20	100%
5	Crc	F	61	MVA	CNS, spleen	Left main extravasation, surgical stump	Coils	Post-nephrectomy bleeding	C-2, 5 Fr	Died from CNS injuries	100%
6	Crc	M	30	GSW	Liver	Right main extravasation	Coils	Nephrectomy	C-2, 5 Fr	40	100%
7	Stable	M	33	Stabbing	No	L interlobar arteriocalyceal fistula	Gelfoam	Fig. 3	C-2, 5 Fr	3	30%
8	Stable	M	32	MVA	No	Initial negative; L distal interlobar branch extravasation	Microcoils	24 hr re-embolization	Microcatheter	35	20%
9	Crc	M	73	MVA	Colon, spine	Multiple right interlobar branches: extravasation vasospasm irregularity	Gelfoam-PVA	Nephrectomy abscess	C-2, 5 Fr	49; died	60%[b]
10	Stable	M	54	MVA	No	2 × L interlobar lpb/mpb extravasation, wall irregularity	Microcoils	48 hr re-embolization	Microcatheter	1; LTFU	30%
11	Stable	M	23	GSW	Colon, spleen	R interlobar branch extravasation, wall irregularity	Microcoils		Microcatheter	35	20%
12	Stable	M	48	Stabbing	No	R interlobar arteriocalyceal fistula	Coils		C-2, 5 Fr	84	25%
13	Stable	M	37	Stabbing	No	R interlobar PSA	Microcoils	Fig. 2	Microcatheter	50	20%
14	Stable	M	58	Stabbing	No	L interlobar AVF	Coils	Fig. 4	C-2, 5 Fr	58	25%
15	Crc	M	22	GSW	Diaphragm, R pleural effusion, liver	R 2× interlob branches extravasation, vasospasm	Microcoils		Microcatheter	25	25%
16	Crc	F	20	Fall	Retroperitoneal bleeding, pelvic extravasation, vertebral fractures	Right lobar branches extravasation	Coils		C-2, 5 Fr	20	40%
17	Stable	M	17	MVA	No	R 2× L p interlobar wall irregularity, small PSA	Microcoils		Microcatheter	26	20%
18	Stable	M	32	MVA	Face, thorax	R lobar AVF	Coils		C-2, 5 Fr	30	35%
19	Stable	M	23	MVA	Colon	Left mid-upper-interlobar branch extravasation, wall irregularity, vasospasm	Microcoils		Microcatheter	28	20%
20	Stable	M	26	Stabbing	Hemothorax, atelectasis	R interlobar branch wall irregularity, vasospasm, extravasation	Gelfoam		C-2, 4 Fr	1; LTFU	20%
21	Crc	M	47	MVA	Spleen, humeral/femoral fractures, lower extr lacerations, lung, DVT	L main extravasation	Coils	Nephrectomy	C-2, 5 Fr	20	100%
22	Crc	M	40	GSW	Liver, bilious ptx, lung contusion	Right interlobar branch extravasation	Gelfoam		C-2, 5 Fr	23	20%

Abbreviations: Crc, hemodynamically controlled or metastable; MVA, motor-vehicle accident; GSW, gunshot wound; R, right; L, left; CNS, central nervous system; DVT, deep venous thrombosis; AVF, arteriovenous fistula; PSA, pseudoaneurysm; PVA, polyvinyl alcohol; LTFU, lost to follow-up

[a] Angiographically grossly estimated renal parenchyma loss as an immediate result of embolization

[b] This patient had a gross estimated parenchymal loss of 60% after embolization; however, eventually he underwent nephrectomy which resulted in 100% loss of renal parenchyma in the embolized organ

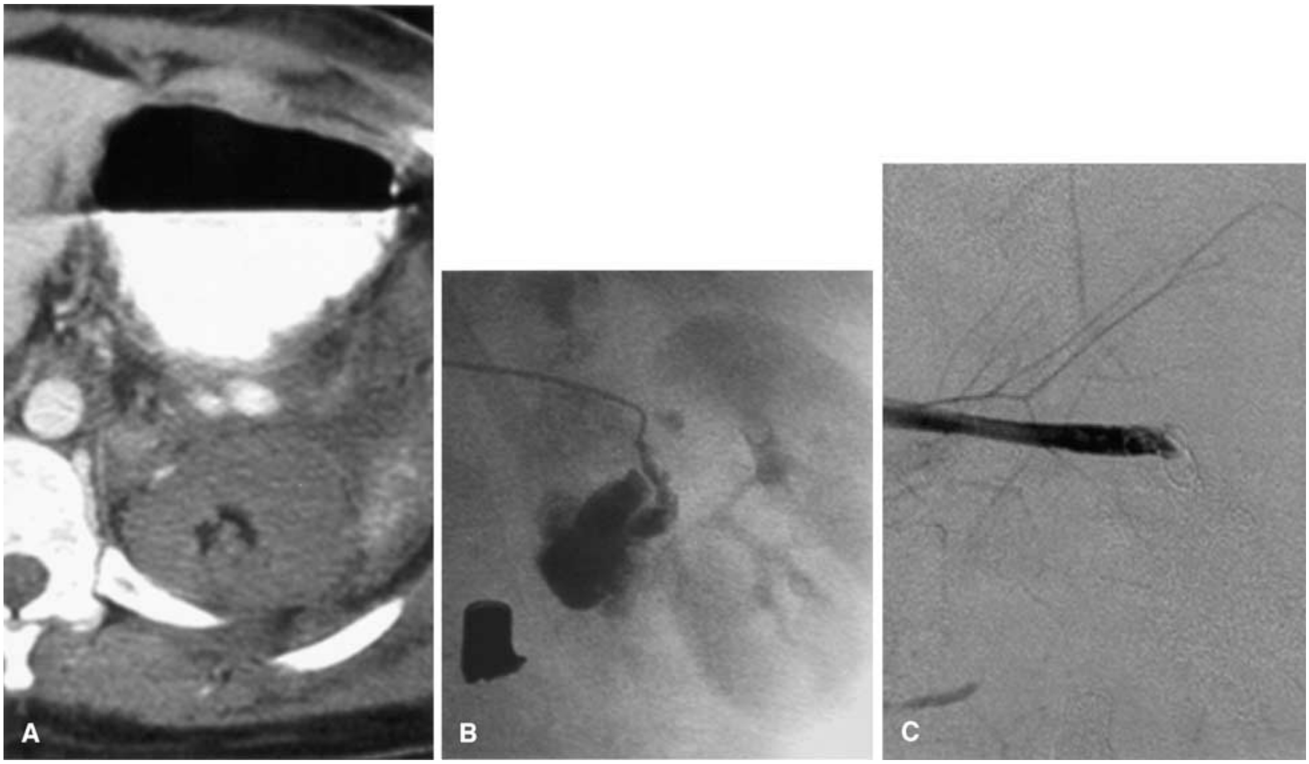

Fig. 1. A 23-year-old woman who had suffered a motor-vehicle accident. **A** Axial CT scan after intravenous contrast administration shows no evidence on nephrogram suggesting a renal hilar injury. **B** Selective left renal artery injection demonstrates active extravasation from a ruptured main renal artery (bullet is from a prior injury). **C** Selective arteriogram after coil embolization of the main renal artery shows no further extravasation and no perfusion to the renal parenchyma.

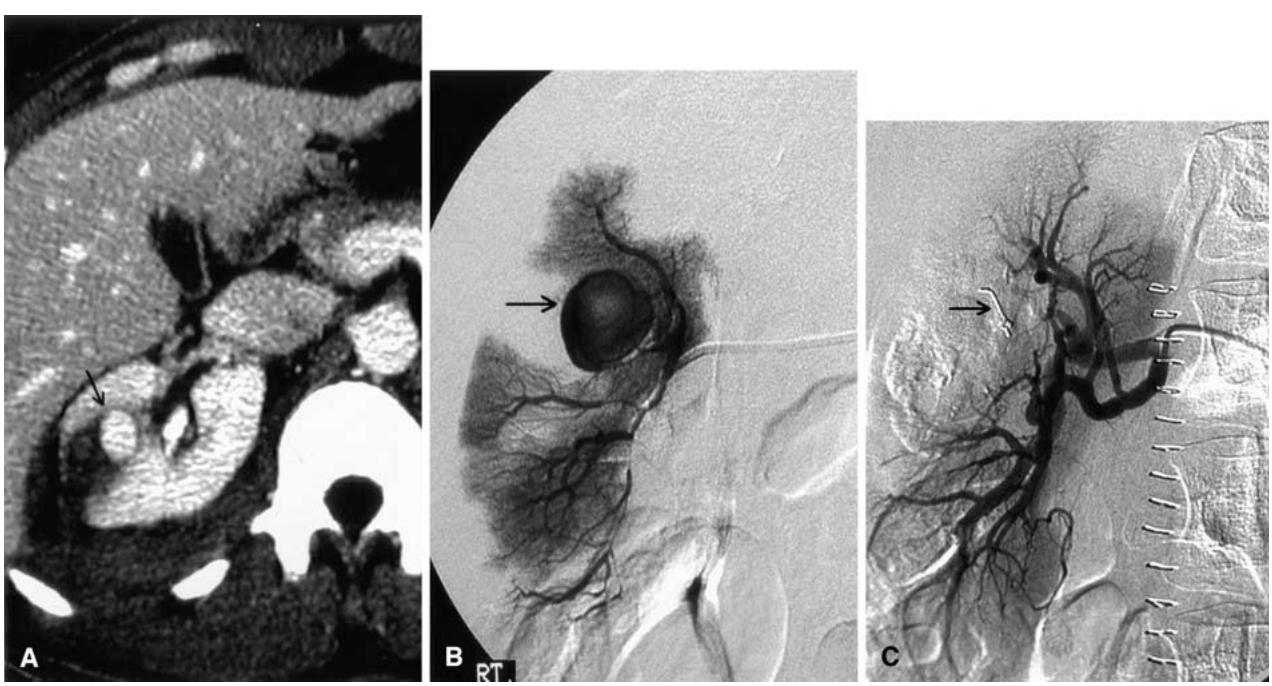

Fig. 2. A 37-year-old man with a stab wound. **A** Axial CT scan shows pooling of contrast in an area of laceration in the right kidney, suggesting traumatic pseudoaneurysm (arrow). **B** Right renal arteriogram shows a large pseudoaneurysm (arrow). **C** After superselective microcoil (arrow) embolization of the branch feeding the pseudoaneurysm, no further filling of the aneurysm is seen and there is excellent preservation of flow to the rest of the organ.

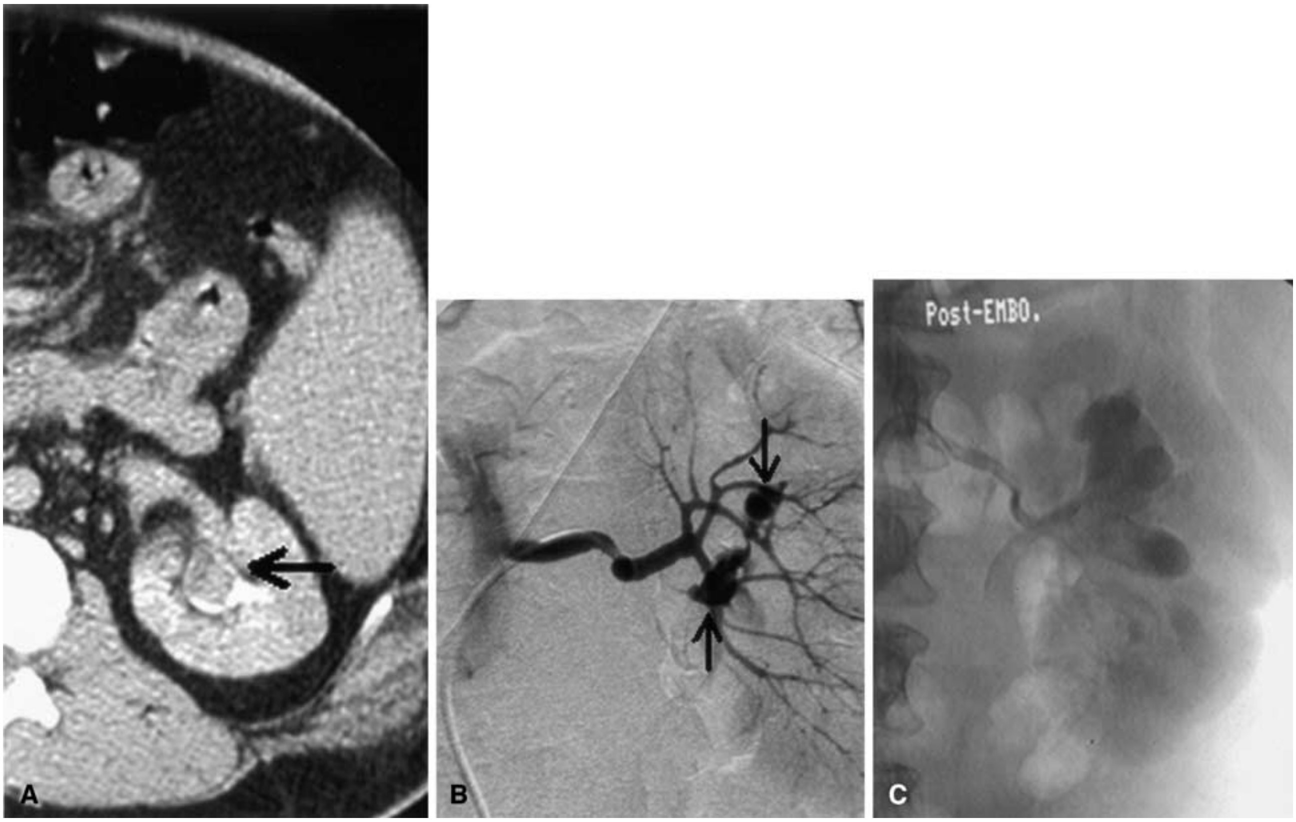

Fig. 3. A 48-year-old man who suffered a motor-vehicle accident. **A** Delayed images from the contrast-enhanced axial CT scan demonstrate a filling defect (arrow) in the left renal collecting system suggestive of blood clot. **B** Selective left renal artery injection exhibiting communication between aneurysmally dilated branches to the collecting system—arteriocalyceal fistula (arrows). **C** Selective left renal artery injection after Gelfoam embolization of branches feeding the arteriocalyceal fistula.

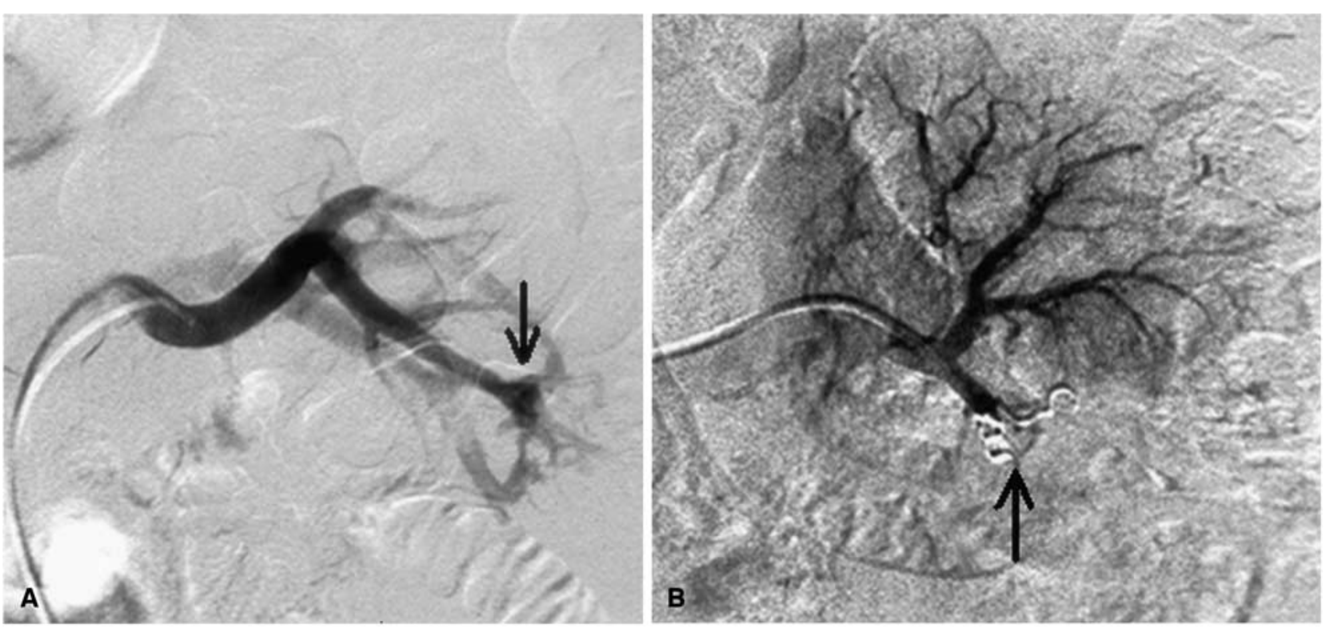

Fig. 4. A 58-year-old man with a stab wound to the abdomen. **A** Left renal arteriogram with early visualization of the renal veins during the arterial phase of the study due to arteriovenous fistula (arrowhead). **B** Arteriography after superselective coil embolization (arrow) of the arterial venous fistula.

subsequent operations for her colonic and spinal injuries. She was discharged and remained in good condition at her latest follow-up 20 months after the embolization (Table 1, patient 4; Fig. 1). One of the patients who suffered main renal artery trauma was treated by coil embolization alone. She had no associated injuries (Table 1, patient 2) and was hemodynamically stable prior to embolization. Her immediate post-embolization clinical course was completely uneventful and she was closely monitored for signs of sepsis or abscess formation. She recovered quickly from her injury and was discharged from the hospital in excellent condition without the need for a nephrectomy. She remained asymptomatic at her latest 30-month follow-up. Non-target embolization was not observed. Complete parenchymal tissue loss was noted in the post-embolization arteriogram in all patients undergoing main renal artery embolization. The mean "estimated parenchymal loss," representing a gross estimate from the post-embolization arteriogram in the remaining 17 patients who underwent selective or superselective branch embolization, was under 30% (27%; Table 1).

Serum creatinine was abnormal in 8 patients at the time of intervention (creatinine > 1.5), as a result of hematuria and some degree of obstructive uropathy. It returned to normal in 4 after resolution of hematuria. One of the patients was already in renal failure at the time of the injury. No patient with an initial normal creatinine developed renal failure after embolization.

Discussion

The treatment of renal vascular injuries depends on the etiology and the clinical course of the disease. In the vast majority of renal trauma the injury is minor and self-limiting [10]. Since these injuries usually heal spontaneously, conservative management has become the preferred approach to most renal injuries in the absence of life-threatening symptoms [10–14]. Persistent or life-threatening bleeding is an indication for surgical or radiological intervention aiming at localization and treatment of the vascular lesion. Hemodynamic instability, avulsion of the renal pelvis and injury of the vascular pedicle are the accepted indications for surgery [12]. In renal trauma patients, the choice between surgical or percutaneous management largely depends on the condition of the patient and the availability of interventional services in the institution. Patients with severe hemodymamic instability, resulting from multiple associated injuries, undergo emergent laparotomy during which the underlying cause of ongoing bleeding including renal vascular injuries is usually addressed. This may necessitate a nephrectomy if the patient is unstable. However, in multiorgan trauma victims, when the associated hemorrhagic injuries are addressed intraoperatively and the patient becomes hemodynamically stable or controlled, the concomitant renal injury can be treated by arteriography and embolization in an attempt to salvage as much renal tissue as possible. Patients who can maintain a relatively stable hemodynamic status while aggressively being resuscitated can also benefit from percutaneous arteriography and embolotherapy [1–8]. In more stable patients the treatment of choice has been percutaneous selective embolization [1–5, 7, 8], which is directed to the site of injury by a previously performed CT examination [9]. In this series 20 patients were referred directly to angiography and embolization, while 2 were initially managed surgically for multiple intra-abdominal and intrathoracic injuries causing hemodynamic instability, then referred to angiography, due to persistent hemorrhage after the operation. Delayed bleeding after surgery or trauma is not an uncommon finding [3, 5]. Angiography has a very high specificity in depicting the bleeding lesion. All reported series have shown that significant bleeding was associated with angiographically identifiable lesions in the majority of the cases [2–5, 7, 8, 11, 15]. In rare instances the traumatized vessel may not be demonstrated by arteriography and close observation and serial blood work is needed to confirm stability. Any clinical signs of bleeding, as well as decreasing levels of hematocrit and hemoglobin, may be indications for a repeat arteriogram. It is important to note that some of the indications mentioned here may not be the norm in other institutions and is a reflection of the aggressive usage of angiography in this institution.

Arterial lacerations and ruptures, pseudoaneurysms, arteriovenous fistulae and arteriocalyceal fistulae are the most common renal vascular injuries [1–8]. In this series pseudoaneurysms were demonstrated in 5 patients in addition to extravasation; in 2 patients arteriovenous fistula (AVF) was seen. It is of note that most pseudoaneurysms and arteriovenous fistulae were the result of stab wounds in this series. Active extravasation from a lobar or interlobar branch was by far the most common type of injury in this series. This reflects the fact that in all our patients arteriography and embolization was undertaken in the setting of acute trauma and in the majority as a lifesaving procedure. The use of coaxial microcatheters greatly facilitated the procedure whenever superselective embolization of an interlobar branch was attempted. This approach, followed in stable and metastable patients, allowed superselective embolization of the injured vessel while preserving the normal renal parenchyma. We agree with others that acute curving of the microcatheter does not impede the delivery of platinum microcoils in the desired location [11]. We did not use the microcatheter for embolization of the proximal renal artery. Technical success (cessation of flow in the lesion) was achieved in all embolized branches, which is consistent with the high technical success rates previously reported [1–8, 11]. False negative arteriography is rare [1–8]. We had 2 cases where a traumatized vessel was not identified in the initial arteriogram. Repeat arteriography should be undertaken when continuous evidence of bleeding persists in the setting of trauma. In our experience repeat arteriography identified the lesion and allowed successful treatment by embolization. Recurrent bleeding from the initially embolized lesion has been the most common reason of discrepancy between clinical and technical success in patients with no additional injuries [1–5]. Non-target embolization was not seen in this series. In early series using superselective embolization for the treatment of renal branch embolization, early failures were reported due to non-target Gelfoam embolization [2] as well as early recanalization of an embolized branch [15].

Non-target embolization of a lumbar artery was also reported after migration of a microcoil deployed initially in a renal branch [8]. Guglielmi detachable coils, although much more expensive than the traditionally used microcoils, offer the safety of controlled deployment and easy retrieval if deployment is unsatisfactory [8], and should be considered in technically challenging lesions.

Complications of interventional embolization are rare [2]. Additional renal arterial trauma as a result of embolization is extremely rare. Dissection has been reported in a small percentage of patients [3]. Post-embolization syndrome, usually seen after complete renal embolization for tumor ablation, has rarely been reported after the use of Gelfoam in trauma patients [2]. Renal infarction along with contrast nephropathy and hemorrhagic-shock-induced acute tubular necrosis are important reasons for renal functional impairment after embolization. Using the superselective technique the extent of a renal infarct can be significantly reduced resulting in excellent preservation of functioning renal tissue [2, 3, 8, 16, 17]. This is confirmed in this study, where the gross estimate regarding average parenchymal tissue loss after lobar and interlobar branch injury was under 30%. Earlier series using larger catheters, which could not catheterize smaller branches selectively, resulted in significantly larger infarcts and parenchymal as well as organ and functional loss [16]. In this series every effort was undertaken to minimize the extent of the post-embolization infarct size by the use of coaxial microcatheters whenever possible.

Follow-up renal CT showed that the extent of renal infarcts decreased over time, and functioning renal parenchyma was present in superselectively and selectively embolized kidneys. This was also reflected in the patients' renal function.

Surgical repair of renal pedicle injury has poor results [12]. In a recent comparison of surgical and non-surgical treatment of serious renal trauma a better outcome was reported for the most conservative approach [18]. In this series nephrectomy was performed in one unstable patient who needed additional embolization to stop the bleeding. Elective nephrectomy was undertaken to prevent infectious complications in 3 multitrauma patients following embolization of the main renal artery. In one patient with main renal artery injury and no associated injuries embolotherapy obviated the need for any additional surgery or intervention. This young patient has been asymptomatic in long-term clinical follow-up.

In our institution post-embolization nephrectomy is performed after main renal artery embolization in multiorgan trauma patients who need multiple operations for associated intra-abdominal injuries. We consider these patients at high risk for sepsis, and after embolization that is performed as a life-saving procedure the completely embolized organ is surgically removed, in order to decrease the risk of abscess formation and further compromise of the overall clinical status of these critically injured victims. Nephrectomy was also performed in a sixth multitrauma patient who did not suffer main artery trauma but underwent prior embolization of multiple interlobar branches with significant parenchymal loss (>50%) and developed a post-embolization renal abscess. This could have been treated conservatively with percutaneous abscess drainage; however, it was felt that it was better for his management to undergo nephrectomy while he was under general anesthesia for surgical repair of associated intestinal injuries.

Nephrectomy after injury of the main renal artery treated by embolization can be avoided in patients who have not suffered multiorgan trauma, as it was seen in a single case in this series. This observation is a key point of this paper and it may lead to further studies in order to evaluate the need for nephrectomy after embolization.

Our study has the limitations of its retrospective nature. Randomization between embolization and conservative management in the setting of a prospective trial would thoroughly evaluate the benefit of this approach in stable patients, but might be impossible in the setting of acute trauma care. This series confirms the conclusion of previous investigations [2, 8] that percutaneous embolization is effective and sufficient in the treatment of renal vascular trauma even in the acute setting, provided that the hemodynamic status of the patient can be controlled. The role of angio-embolization in renovascular trauma is evolving. The larger question of whether embolotherapy affects outcome in renal salvage in comparison with surgery alone or conservative management cannot be definitively addressed by this retrospective observational study. This study can, however, form the basis for considering a future prospective evaluation of outcome in renovascular trauma. Embolotherapy in renovascular trauma requires a multimodality approach with close coordination between the trauma surgeon and the interventional radiologist. Thus, in institutions with appropriately trained interventional radiologists and a supporting trauma service, arteriography and embolization is the treatment of choice.

References

1. Uflacker R, Paolini RM, Lima S (1984) Management of traumatic hematuria by selective renal artery embolization. J Urol 132:662–667
2. Fischer RG, Ben-Menachem Y, Whigham C (1989) Stab wounds of the renal artery branches: Angiographic diagnosis and treatment by embolization. AJR Am J Roentgenol 152:1231–1235
3. Corr P, Hacking G (1991) Embolization in traumatic intrarenal vascular injuries. Clin Radiol 43:262–264

4. Heyns CF, van Vollenhoven P (1992) Increasing role of angiography and segmental artery embolization in the management of renal stab wounds. J Urol 147:1231–1234
5. Eastham JA, Wilson TG, Larsen DW, Ahlering TE (1992) Angiographic embolization of renal stab wounds. J Urol 148:268–270
6. Clark RA, Gallant TE, Alexander ES (1983) Angiographic management of traumatic arterial venous fistulas: Clinical results. Radiology 147:9–13
7. Sclafani SJA, Sahaftan GW, Mitchell WG, Nayaranaswamy TS, McAuley J (1982) Interventional radiology in trauma victims: Analysis of 51 consecutive patients. J Trauma 22:353–360
8. Dinkel H-P, Danuser H, Triller J (2002) Blunt renal trauma: Minimally invasive management with microcatheter embolization—experience in nine patients. Radiology 223:723–730
9. Becker CD, Mentha G, Schmidlin F, Terrier F (1998) Blunt abdominal trauma in adults: Role of CT in the diagnosis and management of visceral injuries. II. Gastrointestinal tract and retroperitoneal organs. Eur Radiol 8:772–780
10. Brandes SB, McAninch JW (1999) Urban free falls and patterns of renal injury: a 20-year experience with 396 cases. J Trauma 47:643–649
11. Huppert PE, Duda SH, Erley CM, Roth M, Lauchart W, Dietz K, Claussen CD (1993) Embolization of renal vascular lesions: Clinical experience with microcoils and Tracker catheters. Cardiovasc Intervent Radiol 16:361–367
12. McAninch JW, Carroll PR, Klosterman PW, Dixon CM, Greenblatt MN (1991) Renal reconstruction after injury. J Urol 145:932–937
13. Carroll PR, Klosterman PW, McAninch JW (1998) Surgical management of renal trauma: Analysis of risk factors, technique, and outcome. J Trauma 28:1071–1077
14. Danuser H, Wille S, Zoscher G, Studer U (2001) How to treat blunt kidney ruptures: Primary open surgery or conservative treatment with deferred surgery when necessary? Eur Urol 39:9–14
15. Fisher RG, Ben-Menachem Y (1985) Embolization procedures in trauma: The abdomen-extraperitoneal. Semin Intervent Radiol 2:148–157
16. Beaujeux R, Saussine C, al Fakir A, et al. (1995) Superselective endovascular treatment of renal vascular lesions. J Urol 153:14–17
17. Dorffner R, Thurnher S, Prokesch R, et al. (1998) Embolization of iatrogenic vascular injuries of renal transplants: Immediate and follow-up results. Cardiovasc Intervent Radiol 21:129–134
18. Altman Al, Haas C, Dinchman KH, Spirnak JP (2000) Selective nonoperative management of blunt grade 5 renal injury. J Urol 164:27–30