Diagn Interv Radiol 2017; 23:371–378

INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Percutaneous renal artery revascularization after prolonged ischemia secondary to blunt trauma: pooled cohort analysis

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PURPOSE
We aimed to identify factors related to technical and clinical success of percutaneous revascularization for blunt renal arterial trauma.

METHODS
All cases of percutaneous revascularization for blunt renal arterial trauma were searched in the available literature. We included a case of iatrogenic renal artery occlusion at our institution treated by percutaneous stenting 20 hours after injury. A pooled cohort analysis of percutaneous revascularization for blunt renal artery injury was then performed to analyze factors related to technical and clinical success. Clinical failure was defined as development of new hypertension, serum creatinine rise, or significant asymmetry in split renal function.

RESULTS
A total of 53 cases have been reported, and 54 cases were analyzed including our case. Median follow-up was 6 months. Technical success was 88.9% and clinical success was 75%. Of 12 treatment failures (25%), 66.7% occurred during the first postprocedure month. Time from injury to revascularization was not a predictor of clinical success (OR=1.00, $P = 0.681$). Renal artery occlusion was significantly associated with clinical failure (OR=7.50, $P = 0.017$) and postintervention antiplatelet therapy was significantly associated with treatment success (OR=0.16, $P = 0.043$). At 37-month follow-up, the stented renal artery in our case remained patent and the patient was normotensive with preserved glomerular filtration rate.

CONCLUSION
Percutaneous revascularization for blunt renal arterial injury resulted in relatively high technical and clinical success. Time-to-revascularization was independent of successful outcomes. Clinical success was significantly associated with a patent renal artery at the time of intervention and with postprocedure antiplatelet therapy.

Acute traumatic kidney injury may result in sequelae spanning a spectrum from complete recovery to renal insufficiency and kidney failure (1). Despite the broad differential of inciting factors, the mechanism of injury is felt to be related to loss of organ perfusion with irreversible ischemic changes occurring within the first 24 hours. As such, urgent intervention is essential to prevent renal compromise. While conservative therapy may be sufficient in mild cases, more severe traumatic arterial injury may require intervention. Depending on the nature of the injury, treatment options include open surgical intervention and endovascular intervention. Although surgery is the standard of care for bilateral renal artery injury, it is generally less effective in cases of unilateral injury (1). In light of these findings, percutaneous endovascular stenting has become a potential alternative treatment (2, 3). Although results vary greatly, ranging from complete renal recovery to nephrectomy, reported outcomes may be improved over open surgical techniques and warrant further exploration.

The high degree of variability in outcomes in these patients remains a limiting factor in establishing accurate treatment guidelines (4). In this report, we present a pooled data analysis of all patients in the available literature with blunt renal vascular injury who have been treated with percutaneous techniques. We include a case of successful unilateral renal

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Received 17 January 2017; revision requested 20 February 2017; last revision received 16 May 2017; accepted 31 May 2017.

DOI 10.5152/dir.2017.16415

You may cite this article as: Jahangiri Y, Ashwell Z, Farsad K. Percutaneous renal artery revascularization after prolonged ischemia secondary to blunt trauma: pooled cohort analysis. Diagn Interv Radiol 2017; 23:371–378.

artery revascularization with percutaneous endovascular stenting at our institution despite prolonged ischemia time in a young patient.

Methods

Pooled cohort analysis

We explored PubMed and CINAHL databases using the keywords ("renal artery" AND ["injury" OR "trauma"] AND [percutaneous OR stent OR angioplasty OR transluminal]). Thirty-six relevant publications with at least one case of blunt renal artery trauma treated by stenting, angioplasty, or both were identified. Of these, 31 were case reports and five were studies with a retrospective analysis of data. Data for individual cases were extracted from these manuscripts for further analysis. Clinical failure was defined as development of new hypertension, serum creatinine rise or significant asymmetry in split renal function (i.e., less than 25% of the total activity in the affected kidney) (5) on the last reported follow-up visit. All available case reports were included based on the Joanna Briggs Institute (JBI) critical appraisal checklist for case reports and case series, as appropriate (6).

Statistical analysis

We included our case in all analyses, for a total of 54 cases. Numerical variables were reported as median (minimum-maximum) and categorical variables were reported as frequency (percentage). Risk factors of renal loss after percutaneous intervention were evaluated by univariate binary logistic regression models with post-stenting clinical failure (defined above) as the dependent outcome variable. We included age, gender, hematuria, and renal artery occlusion on presentation, time to intervention, and postprocedure heparin or antiplatelet use as independent exposure variables. Odds ratios (ORs) were calculated as the ratio of odds of developing post-stenting clinical failure in a given independent exposure variable relative to its reference category (e.g., male versus female for gender). The statistical software STATA IC for Windows version 14.1 was used to analyze the data, and P values less than 0.05 were considered significant. Institutional Review Board approval was waived for the single case review from our institution.

Main points

- Percutaneous revascularization for blunt renal arterial injury resulted in relatively high technical and clinical success.
- Time-to-revascularization was independent of successful outcomes.
- Clinical success was significantly associated with a patent renal artery at the time of intervention and with postprocedure antiplatelet therapy.

Results

A total of 53 cases were described in 36 publications (2, 3, 7–40). The publications are summarized in Table 1. A case from our institution was included in analysis, for a total of 54 cases. The first case was reported in 1995 (7). Table 2 demonstrates a summary of the reported subjects' characteristics. In the total study population, median age was 21 years, with 62% being males (male-to-female ratio ≈ 2:1). The right renal artery was the injured artery in most of the cases (right-to-left ratio ≈ 2:1), and subjects had a median of two other associated injuries. Median time of follow-up was 6 months (range, 0–48.7 months) after intervention. Two cases reported injury of a solitary kidney. Case reports presented almost 50% fewer failures than retrospective data analyses (OR=0.48, $P=0.327$).

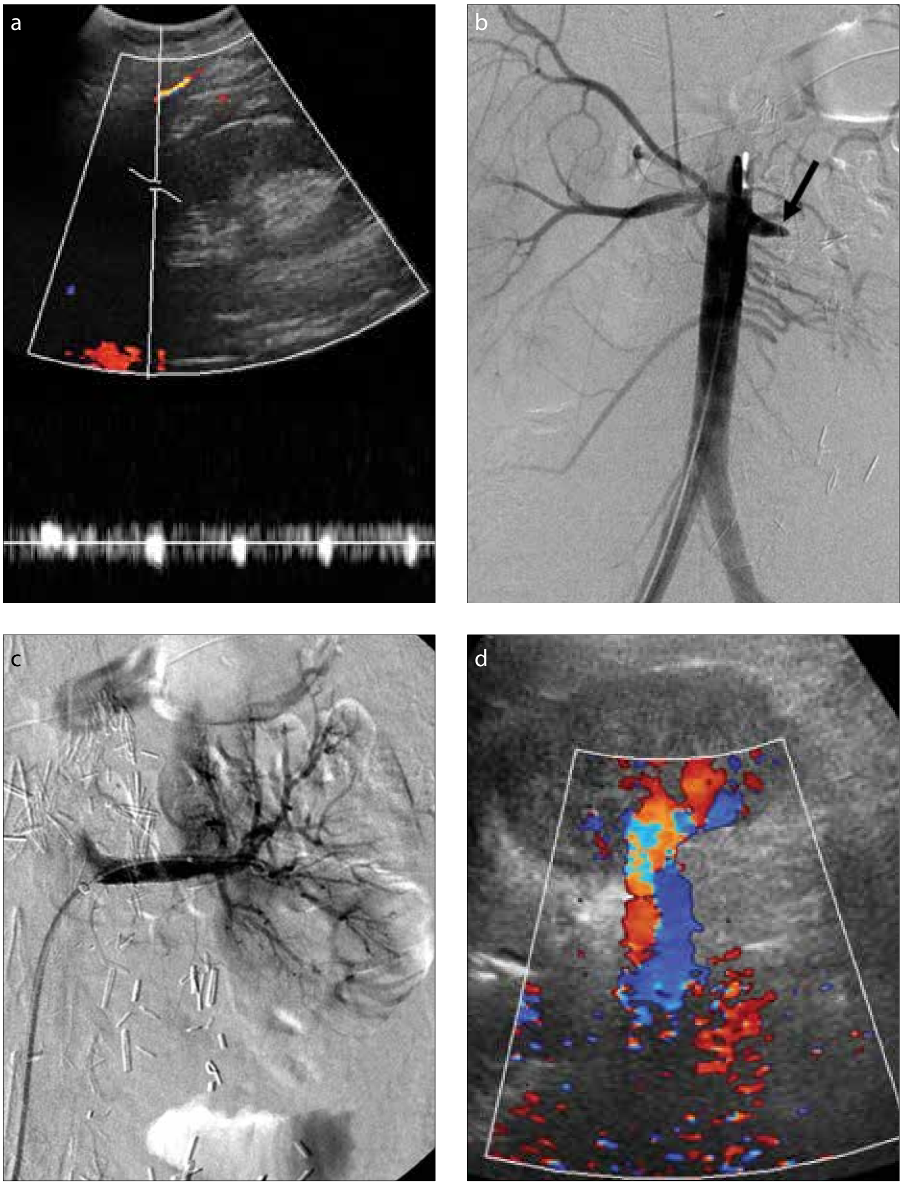

Figure 1. a–d. Duplex ultrasonography **(a)** shows absence of blood flow to the left kidney and the following aortogram **(b)** demonstrates occlusion of the left renal artery just beyond the origin *(arrow)*. After stenting of the dissected artery, blood flow is re-established **(c)**; postprocedure Duplex ultrasonography **(d)** shows good flow in the renal artery.

Table 1. Studies in the literature that reported at least one case of blunt renal artery injury treated with percutaneous transarterial angioplasty, stenting, or both[a]

				Case description				Intervention				Follow-up	
	Author, year, country	Report type	No. of cases	Age, sex	Type of RA stenosis	Affected kidney	Primary dx test	Intervention method	Time-to-intervention	Post-intervention abnormalities/ complications	Antiplatelet use	Duration of follow-up	Occurrence of renal event[b]
1	Whigham 1995, USA (7)	C	1	28 M	NO	Rt.	Angio	BES	24 hrs	-	+	11 days	-
2	Goodman 1998, Canada (8)	C	1	23 M	NO	Lt.	CT	BES	>12 hrs	-	-	9 mo	-
3	Paul 1999, France (9)	C	1	15 F	NO	Rt.	U/S	BES	2 days	-	-	14 mo	-
4	Villas 1999, USA (10)	C	1	37 F	NO	Rt.	Angio	SES	ND	+	ND	ND	-
5	Merrot 2000, France (12)	C	2	6 M 15 F	O NO	Rt. Rt.	U/S IVU	Stent BES	>24 hrs >48 hrs	+ -	+ +	6 mo 20 mo	+ -
6	Lutkevich 2000, USA (11)	C	1	19 F	O	Lt.	CT	PTA	>8 hrs	-	ND	2 mo	+
7	Mutze 2000, Germany (13)	C	1	16 F	NO	Lt.	CT	BES	ND	-	ND	ND	-
8	Bruce 2001, USA (14)	R	1	ND	NO	Lt.	CT	Stent	ND	-	ND	4 mo	-
9	Dobrilovic 2001, USA (15)	C	2	25 M 40 F	NO NO	Lt. Lt.	CT CT	BES BES	ND ND	-	- ND	18 mo 11 mo	-
10	Delarue 2002, France (16)	R	1	9, gender ND	ND	ND	ND	Stent	48 hrs	ND	ND	ND	+
11	Lee 2002, USA (17)	C	1	22 M	90%	Rt.	CT	2 BESs	~24 hrs	-	-	ND	-
12	Saidi 2003, France (18)	C	1	50 F	100%	Rt.	CT	BES	2 hrs	-	-	1 mo	-
13	Long 2004, France (20)	R	5	1 case 14 M others ND	100%, ND	Rt. ND	CT in all cases	Stent	8 hrs and 50 min	-	ND	8.8 days	3+[c], 2-
14	Inoue 2004, Japan (19)	C	1	21 F	90%	Lt.	Angio	SES	~24 hrs	-	+	15 days	-
15	Flugsrud 2005, Norway (21)	C	1	40 M	100%	Lt.	CT	BES	3 hrs	+	ND	6 mo	+
16	Lupattelli 2005, Italy (22)	C	1	18 M	100%	Rt.	U/S	SES	ND	-	+	6 mo	-
17	Memon 2005, New Zealand (23)	C	1	20 M	95%	Rt.	CT	BES	9 hrs	-	+	4 yrs	-
18	Hsu 2006, USA (24)	C	1	2 F	100%	Rt.	CT	PTA+BES,	~12 hrs	-	-	2 mo	+
19	Rha 2006, South Korea (25)	C	1	20 M	100%	Rt. Inferior polar artery	CT, scinti	TS + 2 overlapping BESs	ND	-	+	6 mo	-
20	Sotelo 2006, USA (26)	C	1	17 F	90%	Lt.	CT	BES	18 hrs	-	ND	3 yrs	-
21	Dowling 2007, USA (2)	C	1	42 F	100%	Lt. (solitary kidney)	CT	BES	2.5 hrs	-	ND	4 mo	-
22	Guillén 2007, Spain (27)	R	1	ND, mean age of all reported subjects: 10 years	ND	ND	CT	Stent	ND	ND	ND	6 mo	+
23	Civy 2008, France (29)	C	1	17 M	99%	Both	CT	Stent	4 days	-	+	6 mo	+
24	Breyer 2008, USA (28)	C	1	43 F	100%	Rt.	CT	2 overlapping BESs	6 hrs	-	-	1 mo	+
25	Schwartz 2008, USA (30)	C	1	23 F	ND	Rt.	Angio	SESG	ND	-	+	1 yrs	-
26	Bala 2009, Israel (31)	C	1	20 M	ND	Rt.	CT	BES	3 hrs	-	+	10 mo	-
27	Trottier 2009, Canada (32)	C	1	21 M	Avulsion of the Rt. polar artery	Rt. Side of a horseshoe kidney	CT	SESG	ND	+	+	20 days	-
28	Charbot 2010, France (33)	C	3	17 M 21 M 48 M	99%, 100% 100%	Lt. Rt. Rt.	CT CT CT	BES SES BES	6 hrs 3.5 hrs ND	+ - +	+ - +	23 mo 26 mo 30 mo	- - -
29	Kushimoto 2011, Japan (34)	C	1	34 M	100%	Rt.	CT	Stent	10 hrs	-	-	6 mo	+
30	Lopera 2011, USA (3)[d]	R	8	19.3 M 26.3 F	100% in 5 cases and 90% in one case	3 Rt. 1 Lt. 4 ND	CT in 1 case ND in 7 cases	3 BESG 2 BES 1 SES 2 failed recanalization	5 hrs (range, 2–8 hrs)	ND	1+ 7 ND	8.5 mo (range, 4 days to 2 yrs)	4+, 4-

Table 1. (cont'd) Studies in the literature that reported at least one case of blunt renal artery injury treated with percutaneous transarterial angioplasty, stenting or both[a]

				Case description				Intervention				Follow-up	
	Author, year, country	Report type	No. of cases	Age, sex	Type of RA stenosis	Affected kidney	Primary dx test	Intervention method	Time-to-intervention	Post-intervention abnormalities/ complications	Antiplatelet use	Duration of follow-up	Occurrence of renal event[b]
31	Springer 2011, Germany (36)	C	1	46 M	90%	Rt.	CT	PTA, BES	25 days	-	+	3 mo	-
32	Simeone 2011, USA (35)	C	1	44 M	95%	Rt.	CT	BES	2 hrs	ND	ND	12 days	-
33	Vidal 2011, Italy (37)	C	1	15 M	95%	Lt.	CT	BESG	6 days	-	+	2 yrs	-
34	Hatzinger 2012, Germany (38)	C	1	46 M	100%	Rt.	CT	TL	Days after injury	-	ND	2 wks	-
35	Abu-Gazala 2013, Israel (39)	C	3	24 M 4.5 M 19 M	75% 100% 100%	Rt. Rt. Rt.	CT CT CT	1 BES 1 PTA 1 PTA+BES	Mean time= 153.7 min	- + -	+ - +	23 mo 14 mo 4 mo	- + -
36	Judd 2013, USA (40)	C	1	21 M	80%	Lt.	CT	Stent graft	10 days	-	ND	3 yrs	-
37	Our case 2014, USA	C	1	25 M	100%	Lt.	U/S	BES	24 hrs	+	+	37 mo	-

[a]Joanna Briggs Institute (JBI) critical appraisal checklist was used to assess the case reports and case series.
[b]Renal event was defined as the occurrence of any hypertension, serum creatinine rise, or less than 25% split renal function in the affected kidney reported by the last follow-up visit.
[c]Technical failures were not included in data analyses for clinical efficacy.
[d]Two other subjects of this study, which had initial technical failure and were treated by renal artery embolization were not included.
C, case report; M, male; NO, non-occlusive; Rt., right; angio, angiography; BES, balloon-expandable stent; hrs, hours; Lt., left; CT, computed tomography scan; mo, months; F, female; U/S, Doppler ultrasonography; SES, self-expandable stent; ND, not disclosed; O, occlusive; IVU, intravenous urography; PTA, percutaneous trans-arterial angioplasty; R, retrospective data analysis study; scinti, scintigraphy; TS, thrombosuction; SESG, self-expandable stent graft; BESG, balloon-expandable stent graft; TL, thrombolysis; wks, weeks.

Table 2. Patient characteristics

		All patients (n=54)	Patients with technical success (n=48)
Age (years)		21 (2–50)	21 (2–50)
Sex, n (%)	Male	31 (57.4)	28 (58.4)
	Female	19 (35.2)	16 (33.3)
	N/A	4 (7.4)	4 (8.3)
Hematuria on presentation, n (%)	Yes	15 (27.8)	15 (31.3)
	No	4 (7.4)	4 (8.3)
	N/A	35 (64.8)	29 (60.4)
Type of renal artery stenosis, n (%)	Occlusion	26 (48.2)	24 (50.0)
	No occlusion	24 (44.4)	23 (47.9)
	N/A	4 (7.4)	1 (2.1)
Time to intervention (hours)		8 (1.83–600)	8 (1.83–240)
Postprocedure heparin use, n (%)	Yes	20 (37.1)	17 (35.4)
	No	18 (33.3)	17 (35.4)
	N/A	16 (29.6)	14 (29.2)
Postprocedure antiplatelet use, n (%)	Yes	19 (35.2)	18 (37.5)
	No	16 (29.6)	16 (33.3)
	N/A	19 (35.2)	14 (29.2)
Follow-up time (months)		6 (0–48.7)	6 (0–48.7)
Loss of renal function on follow-up, n (%)	Yes	17 (31.5)	12 (25.0)
	No	37 (68.5)	36 (75.0)

Numerical measures are presented as median (min–max) and categorical variables are shown as frequency (percentage).
N/A, not available.

Renal artery injury was initially diagnosed by contrast-enhanced abdominal CT scan in 37 patients (68.5%). Median reported time to revascularization was 8 hours (range, 1.83 hours to 25 days). Forty-nine cases (90.7%) were treated by primary stent placement, two cases were treated by balloon angioplasty without stenting, and one case was treated by thrombolysis. Two patients underwent metallic coil and Amplatzer plug embolization after failed recanalization. Of the deployed stents, 30 (61.2%) were balloon-expandable, 7 (14.3%) were self-expandable, and 12 (24.5%) were of unknown type. Stent grafts were deployed in 7 cases. Postintervention warfarin was administered in 2 subjects. Twenty cases were given heparin for 48 hours postintervention and antiplatelet therapy was administered in 19 cases (35.2%). Follow-up diagnostic imaging included renal scintigraphy (46.2%), duplex ultrasonography (40.4%) and contrast-enhanced CT (38.5%).

After excluding subjects with technical failure (n=6, Table 3), kidney function loss occurred in 12 of 48 cases (25%) during the follow-up period, 8 (66.7%) of which occurred during the first month. Clinical failure cases are described in Table 4. Stent restenosis or occlusion was reported in four cases (7.4%), two of whom underwent re-stenting. Three patients developed hy-

Table 3. Reported technical failures

	Author, year	Age (years), sex	Cause of the procedure failure	Secondary treatment method	Outcome
1	Long, 2004 (20)	14 M	Failed recanalization of a superior polar branch	None	Nonfunctioning kidney on day 7
2	Long, 2004 (20)	Not mentioned	Inability to introduce the guide into the renal artery	Surgical revascularization by vein grafting	7% of total renal activity in the injured kidney on scintigraphy at 3-month follow-up
3	Long, 2004 (20)	Not mentioned	"Persistent notch" between two stents	None	Nonfunctioning kidney on day 11
4	Lopera, 2011 (3)	46 F	Failed recanalization	Amplatzer plug	Atrophic kidney and normotensive at 2-month follow-up
5	Lopera, 2011 (3)	36 M	Failed recanalization	Metallic coils embolization	Atrophic kidney and normotensive at 11-month follow-up
6	Springer, 2011 (36)	46 M	Failed guidewire passage	Developed sudden onset hypertension with blood pressures up to 200/100 mmHg 25 days after the primary trauma which was treated with angioplasty and stenting	Renovascular hypertension was normalized within days after the intervention; patent stent and delayed perfusion and elimination of contrast media in the affected kidney on contrast-enhanced CT scan at 3-month follow-up

pertension, two of whom also had a documented rise in serum creatinine level at 4 weeks follow-up. Seven subjects had less than 25% split renal function in the affected kidney on follow-up scintigraphy. Three patients in the total pool ultimately underwent nephrectomy, one of whom had documented < 25% activity on split renal function. Two patients died at follow-up, neither from renal causes. One case of renal artery dissection that could not be stented went on to develop symptomatic hypertension with headaches, rise in serum creatinine, and minimal function in the affected kidney on split renal function testing. This patient then underwent a second procedure with successful stenting of the dissected renal artery 25 days after the injury. Hypertension promptly resolved after stenting; however, there was a persistent rise in serum creatinine level with only minimal increase in split renal function at 4-week follow-up.

Univariate logistic regression analysis was performed to identify predictors of renal function loss after intervention (Table 5). Occlusion of the affected renal artery at the time of intervention was associated with clinical failure (OR=8.46, P = 0.012). Postprocedure antiplatelet therapy (aspirin, clopidogrel, or both) was associated with clinical success (OR=0.16, P = 0.043). The time interval between renal artery injury and revascularization was independent of clinical success (OR=1.00, P = 0.681).

The following case from our institution was also included in the analysis: a 25-year-old male with extragonadal germ cell tumor and residual postchemotherapy lymphadenopathy who underwent combined resection of an anterior mediastinal mass and extensive retroperitoneal lymph node dissection. Palpable renal arterial pulses were noted after the lymph node dissection prior to closing the abdomen. Through that evening, the patient developed increasing creatinine to 1.77, up from his preprocedure baseline of 0.86 (baseline estimated glomerular filtration rate [eGFR], 121 mL/min/1.73m^2). Renal duplex ultrasound performed the following day demonstrated absent blood flow to the left kidney (Fig. 1a). The patient was subsequently taken to the interventional radiology suite, approximately 20–24 hours after his surgery, for attempted renal artery revascularization. An abdominal aortogram at that time demonstrated occlusion of the left renal artery just beyond the origin (Fig. 1b). The occlusion was successfully crossed, demonstrating severe intimal injury to the proximal left renal artery with associated thrombus. Primary stenting of the proximal left renal artery was performed using an 8 mm × 29 mm balloon-expandable bare metal stent (Palmaz Genesis, Cordis), successfully re-establishing flow to the left kidney (Fig. 1c). Of note, no significant excretion of contrast from the left kidney was noted during the procedure, indicative of acute renal injury. Postprocedure, the patient had normal vital signs and good left renal arterial flow by duplex ultrasound imaging (Fig. 1d). He was discharged home on oral clopidogrel (75 mg daily) and aspirin (81 mg daily).

Follow-up duplex ultrasound imaging at 3 months demonstrated a patent left renal artery stent with mild interval loss of left renal parenchymal volume. Resistive indices of the left kidney were normal at 0.5, similar to the right kidney. A CT scan performed during this time also demonstrated mild interval atrophy of the left kidney to approximately 75% of its baseline size compared with the CT scan prior to his lymph node dissection (Fig. 2a). Atrophy was primarily seen in the anterior cortex with intact perfusion to the posterior kidney. The left renal artery stent was patent, and the nephrograms comparing the viable portions of the left kidney with the right kidney were symmetric. Additional follow-up renal duplex ultrasound examinations over the following year again confirmed patency of the left renal artery stent with good waveforms and peak systolic velocities. He was taking prazosin and valproic acid for psychiatric management, but was otherwise not on any antihypertensive medication. At 20 months postprocedure, duplex US examination demonstrated a patent left renal artery with brisk upstroke and normal parenchymal resistive indices (Fig. 2b). A MAG-3 renal scin-

Table 4. Reported clinical failures during follow-up period

	Author, year	Age (years), sex	Renal artery injury	Intervention	Outcome
1	Lutkevich, 2000 (11)	19 F	Occlusion of the left renal artery	PTA 8 hours after the accident	Irregular and mottled kidney on nephrogram despite open renal artery on angiography at 1-month follow-up; Nephrectomy done 2 months after procedure
2	Merrot, 2000 (12)	6 M	Complete dissection of the right renal artery	Stenting ~24 hours after injury	Hypoactivity of the affected kidney (9% of total renal function) on scintigraphy at 6 months
3	Delarue, 2002 (16)	Age <15.5	Partial occlusion of the renal artery	Stenting on the second day after injury	Complete kidney atrophy but the patient not nephrectomized (follow-up time was not mentioned)
4	Flugsrud, 2005 (21)	40 M	Total occlusion of the left renal artery	Stenting 3 hours after injury	HTN (150/90 mmHg) and affected kidney hypoactivity (14% total renal function) on scintigraphy despite patent stent at 6-month follow-up
5	Hsu, 2006 (24)	2 F	Complete occlusion of the main right renal artery	PTA and stenting ~12 hours after injury	In-stent restenosis, kidney size reduction and HTN (150–160/90–120 mmHg); laparoscopic nephrectomy at ~2 months after the procedure
6	Guillén, 2007 (27)	A pediatric patient (2–17 yrs)	Intimal lesion and complete devascularization of the kidney (side not mentioned)	Stenting (time not mentioned)	5% of total renal function on DMSA scan at 1 week and 14% at 6-month follow-up
7	Breyer, 2008 (28)	43 F	Occlusion of the right renal artery	Stenting with two overlapping stents ~6 hours after injury	Serum creatinine doubling and absence of flow in the right renal artery on ultrasonography at postop day 3; patchy contrast uptake and 5% relative function on CT scan and Lasix MAG-3 scan at 1-month follow-up
8	Civy, 2008 (29)	17 M	Bilateral renal artery dissection; more severe on the left side with subtotal occlusion	Two stents were deployed in the left renal artery and one stent in the right renal artery ~96 hours after injury	Patient was still anuric and under chronic hemodialysis 6 months after the procedure.
9	Kushimoto, 2011 (34)	34 M	Total occlusion of the right renal artery	Stenting, thrombosuction and thrombolysis 10 hours after injury	11% relative activity on scintigraphy at 4-month follow-up and severe atrophy of the right kidney and limited contrast enhancement of its lower pole on CT scan at 6-month follow-up
10	Lopera, 2011 (3)	21 F	Renal artery occlusion (side not mentioned)	Coil embolization of a small parenchymal extravasation and then stenting 8 hours after injury	HTN, low renal activity (19.1%) on scintigraphy and nephrectomy 1 month after the intervention
11	Lopera, 2011 (3)	23 F	Renal artery occlusion (side not mentioned)	Stenting 8 hours after injury	Atrophic kidney with occluded renal artery on CT scan despite normal blood pressure and serum creatinine 2 months after intervention
12	Abu-Gazala , 2013 (39)	4.5 M	Occlusion of the right renal artery	PTA 110 minutes after admission	19% relative uptake in the right kidney despite normal development, blood pressure and serum creatinine levels 14 months after injury

F, female; M, male; PTA, percutaneous transluminal angioplasty; HTN, hypertension; DMSA, dimercaptosuccinic acid; CT, computed tomography; MAG-3, mercaptoacetyltriglycine.

tigraphy study demonstrated a 2:1 split renal function, with 67% on the right and 33% on the left (Fig. 2c). At 24 months from renal artery stenting, duplex renal US demonstrated stent patency, normal resistive indices, patent renal veins, and stable left renal size at 9.4 cm (Fig. 2d). Furthermore, his blood pressure was 113/60 mmHg, and his renal function was preserved with a serum creatinine of 0.96 mg/dL, giving a normal eGFR of >60 mL/min/1.73m^2. At the time of his most recent follow-up, approximate-

Table 5. Predictors of clinical success after percutaneous revascularization for blunt renal artery trauma

Variable	OR (95% CI)	*P*
Age (years)	0.94 (0.88–1.01)	0.107
Gender (female vs. male)	2.09 (0.50–8.76)	0.313
Hematuria (vs. no hematuria) on presentation	1.09 (0.09–13.78)	0.946
Occluded (vs. nonoccluded) renal artery on presentation	8.46 (1.60–44.76)	0.012*
Time to intervention (hours)	1.00 (0.98–1.01)	0.681
Postprocedure heparin use (vs. no heparin use)	0.60 (0.12–3.05)	0.538
Postprocedure antiplatelet use (vs. no antiplatelet use)	0.16 (0.03–0.94)	0.043*

OR, odds ratio; CI, confidence interval.
*Statistically significant associations.

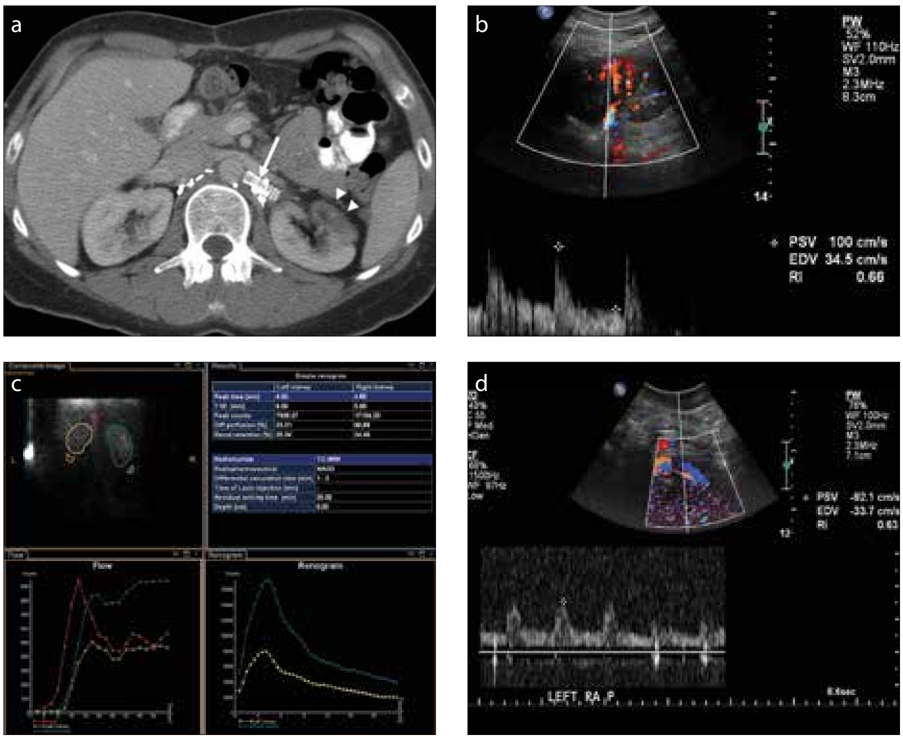

Figure 2. a–d. Contrast-enhanced abdominal CT scan at 3-month follow-up **(a)** shows patent stent *(arrow)* with an intact perfusion to the posterior kidney; mild atrophy could be seen involving the anterior cortex *(arrowheads)*. At 20-month postprocedure Duplex US examination **(b)** demonstrates a patent left renal artery with brisk upstroke and normal parenchymal resistive indices and a MAG3 renal scintigraphy study **(c)** shows a 2:1 split renal function, with 67% on the right and 33% on the left. Duplex renal ultrasonography 24-months postprocedure **(d)** shows stent patency, normal resistive indices, patent renal vein, and stable left renal size at 9.4 cm.

ly 37 months after intervention, duplex US demonstrated a patent left renal artery stent with normal parenchymal resistive indices and preserved eGFR.

Discussion

Renal artery injury from blunt trauma is relatively rare, occurring in approximately 0.08% of cases (14). Prolonged ischemia after renal artery occlusion secondary to blunt trauma may result in sequelae including hypertension, impairment of renal function, and kidney failure (3, 7). As such, an important aspect in guiding therapy is the identification of maximal ischemic time beyond which irreversible injury occurs. Data regarding renal ischemic tolerance from the surgical literature in patients undergoing partial nephrectomy suggest a limited window for revascularization before irreversible kidney injury is sustained. One study evaluating 362 patients with a solitary kidney who underwent partial nephrectomy with follow-up obtained at 3 and 12 months identified a renal artery cross clamp time of 25 minutes beyond which there was a four-fold greater risk of developing new onset renal compromise. This same study also reported increased odds of developing renal failure of approximately 5% for every minute beyond the 25-minute threshold (41). While the above findings support the notion that time to intervention remains an essential consideration in treatment, the suggested duration may not apply to all patients. Published case reports and case series for traumatic renal arterial injury have used longer times to reperfusion as guidelines, generally on the order of 4–12 hours, and some up to 24 hours (3, 7). The illustrative case from our institution demonstrates successful renal artery revascularization after a prolonged ischemia time of approximately 20–24 hours with preservation of renal function at over 37 months follow-up. Serial US examinations demonstrated persistent patency of the renal stent and mild atrophy of the affected kidney, with approximately 20% loss of renal function estimated based on the split renal function. Overall renal function was preserved, with a normal eGFR. The partial atrophy noted on CT imaging was segmental in location, localized primarily to the anterior region with good perfusion to the posterior cortex. It is unclear whether this may have been a result of the original injury or a result of distal emboli after stenting, as has been recently shown (34). This case features a relatively accurate time to reperfusion based on the operative report, compared with the variability in timing in many blunt trauma settings.

Our pooled cohort analysis demonstrated no association between time-to-revascularization and outcome success at 6 months follow-up. In support of this, a retrospective analysis from 6 university trauma centers found that elapsed time to operative renal revascularization after major renovascular trauma was not correlated with renal outcome (5). While an occluded renal artery at the time of intervention was significantly associated with treatment failure in our analysis, our case demonstrated successful recanalization and renal preservation despite occlusion of the renal artery. Antiplatelet therapy after renal artery stenting was significantly associated with treatment success. In a previous study of renal artery stenting for hypertension, no difference was seen in acute or late occlusion between patients treated with anticoagulation and aspirin compared with aspirin alone at 6 months follow-up (42), supporting the role of antiplatelet therapy in stent patency.

Limitations of this study include the retrospective nature of the analysis and possible publication bias as described above. As such, the true denominator of patients with blunt renal arterial trauma who are managed with endovascular procedures remains unknown. Also, univariate regression analysis with a limited number of published cases might not be a strong strategy for the given conclusions. However, currently this is the strongest method given sparsity of the publications on blunt trauma of renal artery.

In conclusion, we present a pooled cohort analysis of endovascular treatment of blunt renal arterial injury in the available literature. Our findings suggest prolonged ischemia time should not necessarily dissuade attempted percutaneous revascularization, and that postprocedural antiplatelet therapy is likely important for treatment success. We report a case of renal artery injury managed with percutaneous stenting after prolonged ischemia of over 20 hours, with preserved renal function after 3 years of follow-up. These findings may help design future guidelines in the management of blunt renal artery injury.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Haas CA, Dinchman KH, Nasrallah PF, Spirnak JP. Traumatic renal artery occlusion: a 15-year review. J Trauma 1998; 45:557–561. [CrossRef]
2. Dowling JM, Lube MW, Smith CP, Andriole J. Traumatic renal artery occlusion in a patient with a solitary kidney: case report of treatment with endovascular stent and review of the literature. Am Surg 2007; 73:351–353.
3. Lopera JE, Suri R, Kroma G, Gadani S, Dolmatch B. Traumatic occlusion and dissection of the main renal artery: endovascular treatment. J Vasc Interv Radiol 2011; 22:1570–1574. [CrossRef]
4. Sangthong B, Demetriades D, Martin M, et al. Management and hospital outcomes of blunt renal artery injuries: analysis of 517 patients from the National Trauma Data Bank. J Am Coll Surg 2006; 203:612–617. [CrossRef]
5. Knudson MM, Harrison PB, Hoyt DB, et al. Outcome after major renovascular injuries: a Western trauma association multicenter report. J Trauma 2000; 49:1116–1122. [CrossRef]
6. The Joanna Briggs Institute. Joanna Briggs Institute Reviewers' Manual: 2016 edition. Australia: The Joanna Briggs Institute; 2016.
7. Whigham CJ, Jr., Bodenhamer JR, Miller JK. Use of the Palmaz stent in primary treatment of renal artery intimal injury secondary to blunt trauma. J Vasc Interv Radiol 1995; 6:175–178. [CrossRef]
8. Goodman DN, Saibil EA, Kodama RT. Traumatic intimal tear of the renal artery treated by insertion of a Palmaz stent. Cardiovasc Intervent Radiol 1998; 21:69–72. [CrossRef]
9. Paul JL, Otal P, Perreault P, et al. Treatment of posttraumatic dissection of the renal artery with endoprosthesis in a 15-year-old girl. J Trauma 1999; 47:169–172. [CrossRef]
10. Villas PA, Cohen G, Putnam SG, 3rd, Goldberg A, Ball D. Wallstent placement in a renal artery after blunt abdominal trauma. J Trauma 1999; 46:1137–1139. [CrossRef]
11. Lutkevich C, Hall JR, Lewis JV, Testerman GM, Westerfield L, Reeves WW. Percutaneous transluminal angioplasty of an acute traumatic renal artery occlusion. Tenn Med 2000; 93:140–141.
12. Merrot T, Portier F, Galinier P, et al. Trauma of the renal pedicle in children. Report of 2 cases of late revascularization with endovascular prosthesis. Prog Urol 2000; 10:277–281.
13. Mutze S, Laun R. Posttraumatic dissection of the renal artery--imaging diagnosis and interventional therapy. Rofo 2000; 172:717–718. [CrossRef]
14. Bruce LM, Croce MA, Santaniello JM, Miller PR, Lyden SP, Fabian TC. Blunt renal artery injury: incidence, diagnosis, and management. Am Surg 2001; 67:550–556.
15. Dobrilovic N, Bennett S, Smith C, Edwards J, Luchette FA. Traumatic renal artery dissection identified with dynamic helical computed tomography. J Vasc Surg 2001; 34:562–564. [CrossRef]
16. Delarue A, Merrot T, Fahkro A, Alessandrini P, Guys JM. Major renal injuries in children: the real incidence of kidney loss. J Pediatr Surg 2002; 37:1446–1450. [CrossRef]
17. Lee JT, White RA. Endovascular management of blunt traumatic renal artery dissection. J Endovasc Ther 2002; 9:354–358. [CrossRef]
18. Saidi A, Bocqueraz F, Sengel C, Descotes JL, Boillot B, Rambeaud JJ. Early revascularization by stent in renal pedicle trauma. Prog Urol 2003; 13:123–127.
19. Inoue S, Koizumi J, Iino M, Seki T, Inokuchi S. Self-expanding metallic stent placement for renal artery dissection due to blunt trauma. J Urol 2004; 171:347–348. [CrossRef]
20. Long JA, Manel A, Penillon S, et al. Traumatic dissection of the renal pedicle. Modalities of management in adults and children. Prog Urol 2004; 14:302–309.
21. Flugsrud GB, Brekke M, Roise O. Endovascular stent in the acute treatment of blunt renal arterial injury. J Trauma 2005; 59:243–245. [CrossRef]
22. Lupattelli T, Basile A, Iozzelli A, et al. Thrombolytic therapy followed by stenting for renal artery dissection secondary to blunt trauma. Emerg Radiol 2005; 11:164–166. [CrossRef]
23. Memon S, Cheung BY. Long-term results of blunt traumatic renal artery dissection treated by endovascular stenting. Cardiovasc Intervent Radiol 2005; 28:668–669. [CrossRef]
24. Hsu W, Mitchell SE, Kim HS. Renal artery stenting for intimal flap injury in a 2-year-old child after blunt abdominal trauma. South Med J 2006; 99:884–887. [CrossRef]
25. Rha SW, Wani SP, Suh SY, et al. Images in cardiovascular medicine. Successful percutaneous renal intervention in a patient with acute traumatic renal artery thrombosis. Circulation 2006; 114:e583–585. [CrossRef]
26. Sotelo T, Hairston J. Successful endovascular salvage for traumatic renovascular injury after eighteen hours. Internet J Urol 2006; 4.
27. Guillen G, Asensio M, Piro C, Martin JA, Perez M. Five years of renal trauma in a paediatric trauma center: new tools in the diagnostic and therapeutic process. Cir Pediatr 2007; 20:209–214.
28. Breyer BN, Master VA, Marder SR, McAninch JW. Endovascular management of trauma related renal artery thrombosis. J Trauma 2008; 64:1123–1125. [CrossRef]
29. Civy AM, Seguin P, Frouget T, Tanguy M, Heautot JF, Malledant Y. Bilateral traumatic dissection of the renal arteries. Ann Fr Anesth Reanim 2008; 27:727–730. [CrossRef]
30. Schwartz JH, Malhotra A, Lang E, Sclafani SJ. One-year followup of renal artery stent graft for blunt trauma. J Urol 2008; 180:1507. [CrossRef]
31. Bala M, Bloom AI, Appelbaum L, Levensart P, Rivkind AI. Early diagnosis of blunt renal artery injury and endovascular treatment. Isr Med Assoc J 2009; 11:571–572.
32. Trottier V, Lortie MA, Gouin E, Trottier F. Renal artery avulsion from blunt abdominal trauma in a horseshoe kidney: endovascular management and an unexpected complication. Can J Surg 2009; 52:e291–292.
33. Chabrot P, Cassagnes L, Alfidja A, et al. Revascularization of traumatic renal artery dissection by endoluminal stenting: three cases. Acta Radiol 2010; 51:21–26. [CrossRef]
34. Kushimoto S, Shiraishi S, Miyauchi M, et al. Traumatic renal artery occlusion treated with an endovascular stent--the limitations of surgical revascularization: report of a case. Surg Today 2011; 41:1020–1023. [CrossRef]
35. Simeone A, Demlow T, Karmy-Jones R. Endovascular repair of a traumatic renal artery injury. J Trauma 2011; 70:1300. [CrossRef]
36. Springer F, Schmehl J, Heller S, Claussen CD, Brechtel K. Delayed endovascular treatment of renal artery dissection and reno-vascular hypertension after blunt abdominal trauma. Cardiovasc Intervent Radiol 2011; 34:1094–1097. [CrossRef]
37. Vidal E, Marrone G, Gasparini D, Pecile P. Radiological treatment of renal artery occlusion after blunt abdominal trauma in a pediatric patient: is it never too late? Urology 2011; 77:1220–1222. [CrossRef]
38. Hatzinger M, Stastny M, Wirsam K, Sohn M. A bowling ball as the cause of a renal artery embolism. Aktuelle Urol 2012; 43:180–182.
39. Abu-Gazala M, Shussman N, Abu-Gazala S, et al. Endovascular management of blunt renal artery trauma. Isr Med Assoc J 2013; 15:210–215.
40. Judd E, Lockhart ME, Rizk DV. Renovascular hypertension associated with pseudoaneurysm following blunt trauma. Am J Kidney Dis 2013; 62:839–843. [CrossRef]
41. Thompson RH, Lane BR, Lohse CM, et al. Every minute counts when the renal hilum is clamped during partial nephrectomy. Eur Urol 2010; 58:340–345. [CrossRef]
42. Hennequin LM, Joffre FG, Rousseau HP, et al. Renal artery stent placement: long-term results with the Wallstent endoprosthesis. Radiology 1994; 191:713–719. [CrossRef]