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ORIGINAL ARTICLE

Evaluation of characteristics, associations and clinical course of isolated spontaneous renal artery dissection

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ABSTRACT

Background. Spontaneous renal artery dissection (SRAD) is a rare entity of unknown etiology. We aimed to study the clinical course and outcomes and compare the characteristics of patients with SRAD with those of the general population.

Methods. All cases of isolated renal artery dissection diagnosed at the University of Michigan Hospitals between January 2000 and July 2012 were identified by the ICD-9 code. Cases were matched by age, gender and race with individuals from the 2009–2010 National Health and Nutrition Examination Survey (NHANES). Characteristics and awareness of comorbid conditions were compared. Information about the clinical course after diagnosis was retrieved from the case group to ascertain their outcomes.

Results. Overall, 17 patients with SRAD with a mean age of 38.6 years (SD = 8.3) were identified. Eleven patients were male and 14 were white. The most common presenting symptom was excruciating sudden-onset flank pain ipsilateral to the site of dissection. Fibromuscular dysplasia, Ehlers–Danlos and polyarteritis nodosa were present in 4, 4 and 1 patients, respectively. After adjusting in a multivariable model, the case group was more likely to report history of hypertension, cancer and connective tissue disorders ($P < 0.001$), and less likely to have obesity (BMI $\geq$30 kg/m^2) compared with the general population. Supportive medical treatment, endovascular intervention and surgery were required in 8, 5 and 4 cases, respectively. After discharge from the hospital, hypertension was adequately controlled in all the patients but one.

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Conclusion. SRAD may be part of a syndrome having multi-organ involvement. With appropriate medical or surgical management, long-term clinical outcome appears favorable.

INTRODUCTION

The first case of spontaneous renal artery dissection (SRAD) was reported in 1944 [1]. For several decades after the first reported case, the literature remained limited to case reports and small case series describing this rare entity. The roles of different therapeutic options including supportive medical management, endovascular angioplasty and surgical operations were also described in some of these reports. No study to date has examined the clinical characteristics of these patients in a systematic manner and compared these with those of the general population or a standard control group. In order to determine the clinical characteristics of patients with SRAD, we aimed to compare the characteristics of the patients with the radiologic diagnosis of SRAD in our medical center with age, gender and race-matched individuals from the general population. In continuum, we illustrate the clinical course and compare the renal outcomes and control of blood pressure by treatment strategies in this group of patients.

ORIGINAL ARTICLE

METHODS

This is a Health Insurance Portability and Account Act (HIPAA)-compliant, retrospective, case–control study. Patients with the diagnosis of 'renal artery dissection' (RAD) using the International Classification of Diseases (ICD)-9 443.23 code were identified by searching all inpatient and outpatient medical records at the University of Michigan from 1 January 2000 to 31 July 2012. Institutional review board approval was obtained for conduct of this study.

A diagnosis of RAD was established by conventional angiography, CT angiogram or both in all the patients. The radiologic criteria for diagnosis included luminal irregularity associated with aneurysmal dilatation or secular dissection with segmental stenosis, extension of dissection distal to the first renal artery bifurcation, 'cuffing' at branch points and variable degrees of reversibility documented by subsequent arteriographic images [2]. All the images were reviewed by two of the authors (F.A. and B.S.) and the diagnoses were verified. The inclusion criteria in the case group were age older than 18 and RAD with or without kidney infarction. The exclusion criteria included the following: blunt or deceleration traumatic injury or severe stretching of the renal artery, iatrogenic dissection of renal arteries by surgical or catheter manipulation and extension of an aortic dissection into the renal arteries.

Demographic data, comorbid conditions and other relevant clinical information were abstracted for each patient by review of medical records. Blood pressure and serum creatinine at the time of presentation and at the last follow-up were recorded. Connective tissue disorders included patients exhibiting fibromuscular dysplasia (FMD), Ehler–Danlos syndrome, polyarteritis nodosa, gout or arthritis. The control group was composed of individuals from the general population matched by age, sex and gender, selected from the 2009–2010 National Health and Nutrition Examination Survey (NHANES) publically available datasets. Comparable information including awareness of comorbid conditions was obtained for the control group. Definitions of comorbidities and the variables obtained from the NHANES dataset are summarized in Appendix 1.

Statistical analysis

The 2003–2004 guidelines for analysis of NHANES datasets set forth by the National Center for Health Statistics, Centers for Disease Control and Prevention based the weighing methodology applied in the analysis [3]. For descriptive purposes, counts and percentages are used to compare categorical variables. Mean ± standard deviation is applied for presentation of normally distributed variables. To test categorical variables in the two groups, the chi-square test and to compare continuous variables the *t*-test is used, respectively. The two-sided Fisher exact test was applied when the expected frequency in at least 25% of the cells in the contingency tables is less than five. Ordinal regression analysis is used to identify the comorbidities independently associated with SRAD. IBM SPSS Statistics version 20 (Chicago, IL) was used for the analysis.

RESULTS

Seventeen patients with SRAD were identified. The demographic characteristics of the patients are shown in Table 1. Accordingly, the mean (SD) of age was 38.6 (8.3) years. There were 11 male (64.7%). Fourteen patients (82.4%) were white and the others were black or multiracial. The distribution of smoking status, weight and height was not significantly different in patients compared with age-, gender- and race-matched individuals from the general population. Patients with SRAD had significantly higher mean serum creatinine, systolic and diastolic blood pressure at presentation ($P \leq 0.01$). BMI in SRAD patients was slightly lower ($P = 0.046$). Among the comorbid conditions, the distribution of awareness from diabetes, coronary artery disease, stroke, chronic pulmonary diseases, liver diseases, cancer, leukemia, lymphoma, and positive HIV) was not significantly different from that in matched individuals in general population. History of hypertension, CHF and connective tissue disorders was more common in SRAD patients compared with the general population ($P \leq 0.011$). After adjusting for other comorbidities, hypertension, connective tissue disorders and cancer were more likely to be present in association with SRAD. Similarly, risk of SRAD was higher in normal-range BMI (20–24 kg/m^2) as well as overweight (25–29 kg/m^2) compared with the obese category (≥30 kg/m^2) (Table 2).

The individualized characteristics, clinical course and outcomes of each patient were revealing (Table 3). The most frequently observed presenting symptom was pain (flank pain in 10 cases and abdominal pain in 2 cases). One patient presented with CHF exacerbation and flank pain, one with headache and two were asymptomatic. The two SRAD patients

Table 1. Distribution of general characteristics and chronic comorbidities in patients with isolated dissection of renal arteries compared with age- and gender-matched individuals from the 2009–2010 NHANES. Values are mean ± SD or percentages

Variable	Case	Control	P value
n	17	27760610	
Age (year)	38.6 ± 8.3	37.5 ± 9.5	0.635
Male gender (%)	64.7%	64.6%	0.991
Race			0.950
White (%)	82.4%	84.6%	
Black (%)	5.9%	5.9%	
Others (%)	11.8%	9.5%	
Smoking			0.309
Never smoked (%)	41.2%	59.2%	
Ex-smoker (%)	23.5%	17.7%	
Current smoker (%)	35.3%	23.2%	
Weight (kg)	82.7 ± 14.7	85.3 ± 20.7	0.624
Height (kg)	1.74 ± 0.09	1.72 ± 0.10	0.395
BMI (kg/m^2)	26.8 ± 3.5	28.7 ± 6.3	0.046
BMI category			0.253
<20 kg/m^2	0	4.2%	
20–24 kg/m^2	33.3%	24.8%	
25–29 kg/m^2	53.3%	36.9%	
≥30 kg/m^2	13.3%	34.1%	
Systolic BP (mmHg)	150.5 ± 22.1	116.8 ± 13.1	<0.001
Diastolic BP (mmHg)	86.7 ± 12.6	71.1 ± 11.6	<0.001
Baseline creatinine (mg/dL)	1.16 ± 0.43	0.87 ± 0.19	0.013
Baseline eGFR (mL/min)	77.0 ± 26.0	100.0 ± 20.0	<0.001
Comorbidities			
Hypertension (%)[a]	88.2%	20.8%	<0.001
Diabetes (%)[a]	0%	5.7%	0.621
CAD (%)[a]	0%	2.1%	1.0
CHF (%)[a]	5.9%	0.1%	0.01
Stroke (%)[a]	0%	0.9%	1.0
Pulmonary (%)[a]	5.9%	15.3%	0.498
Liver disease (%)[a]	5.9%	4.1%	0.510
Arthritis, gout, connective tissue dis. (%)[a]	35.3%	12.0%	0.011
Cancer (%)[a]	11.8%	2.6%	0.073
Leukemia (%)[a]	0%	0.3%	1.0
Lymphoma (%)[a]	0%	0.3%	1.0
HIV positive (%)[a]	0%	0.4%	1.0

SD, standard deviation; BMI, body mass index; BP, blood pressure; CAD, coronary artery disease; CHF, congestive heart failure; HIV, human immunodeficiency virus.
[a]Fisher exact test applied.

Table 2. Multivariable analysis of the factors independently associated with spontaneous dissection of renal arteries

Variables	Coefficient	Standard error	95% CI	P value
Hypertension	6.5	1.5	3.5 to 9.5	<0.001
Cancer	5.5	1.4	2.8 to 8.1	<0.001
Connective tissue dis.	3.5	0.7	2.0 to 4.9	<0.001
BMI < 20 kg/m^2	−13.5	1440.3	−2836 to 2809	0.999
BMI 20–24 kg/m^2	5.4	1.4	2.7 to 8.1	<0.001
BMI 25–29 kg/m^{2a}	3.8	1.1	1.6 to 6.1	0.001

CI, confidence interval; BMI, body mass index.
[a]BMI ≥ 30 kg/m^2 is reference category in BMI subgroups.

who presented with headache also had coexisting dissection of vertebral arteries. The pain was spontaneous sudden and severe in 12 patients (70.6%). In one patient the pain started after weight lifting, and in two patients it was associated with gross hematuria. Connective tissue disorders were observed in nine patients including FMD in four patients, Ehlers–Danlos syndrome in four patients and polyarteritis nodosa in one patient. Poland syndrome was observed in one patient. One patient with FMD also had nail patella syndrome. Seven patients had radiographic features of renal artery aneurysm (Figures 1–3), including all four patients with Ehlers–Danlos, two patients with FMD and the patient with Poland syndrome syndrome. One patient with FMD and the patient with Poland syndrome had simultaneous dissection of vertebral arteries. Two patients with FMD also had malignant melanoma. Two patients including one with Ehlers–Danlos syndrome had recurrent bilateral dissection within a 7-year period.

Supportive medical management including analgesics, antihypertensive medications and anticoagulation was administered to eight of the SRAD patients. Endovascular procedures were performed in five patients. One patient with radiographic evidence of total occlusion of left renal artery due to formation of thrombosis underwent thrombolytic therapy followed by systematic heparinization as a bridge to subsequent oral anticoagulation with warfarin. Three patients with Ehlers–Danlos syndrome who had a leak from dissection of renal artery aneurysm underwent selective arterial embolization by interventional radiology service with immediate stabilization. Four cases underwent surgical operation with aortorenal arterial bypass surgery. Of the four bypass procedures, one required unilateral nephrectomy at the site of RAD due to extension of dissection to hilum of the kidney making the arterial reconstruction impossible (Figure 4). All the patients were stabilized and discharged after recovery from acute presentation.

The blood pressure and serum creatinine in the patients subjected to different modalities of therapy are listed in Table 4. Median follow-up was 16, 32 and 4 months in medical, endovascular and surgical methods of therapy, respectively. Accordingly, systolic blood pressure decreased with follow-up, but has not reached statistical significance in any of the subgroups compared with their baseline. One patient in the subgroup of radiographic endovascular treatment developed acute kidney injury, which progressed to end-stage kidney disease, and underwent kidney transplantation after 5 years. Serum creatinine with follow-up has not been different clinically from baseline in medical or surgical treatment subgroups. Blood pressure was eventually controlled with follow-up in all patients except in one (case 14). One patient with Ehlers–Danlos syndrome (case 14) died after 40 months because of cerebral hemorrhage.

DISCUSSION

This is a large case series of patients with SRAD and the first study that systematically compares the characteristics of patients with spontaneous RAD with those of matched controls from the general population. In this study, SRAD is associated with middle-age, a history of hypertension and flank pain, elevated creatinine and uncontrolled blood pressure at presentation. In patients with SRAD CHF, cancer and connective tissue may also be present at a significantly higher rate as expected in this age-group.

The etiology of SRAD is unclear. In addition to its association with connective tissue disorders such as FMD, Ehlers–Danlos syndrome and Marfan's syndrome in a few case reports, SRAD is also reported in association with malignant hypertension, atherosclerosis, blunt trauma and strenuous exercise in several other case reports and small series [4–18]. Cocaine abuse and extracorporeal shock wave lithotripsy were reported in rare cases [19, 20]. Arterial dysplasia and abnormalities involving vasa vasorum have been viewed as predisposing factors for spontaneous peripheral arterial dissections [21]. Arterial dysplasia is further classified to intimal fibroplasia (5%), medial hyperplasia (1%), medial fibroplasia (84%) and perimedial dysplasia [22]. Rupture of vaso vasorum may result in hemorrhage with subsequent intramural hematoma, which may lead to medial ischemia and a further compromise in vessel wall integrity. In a study of 316 dissected vessels from 196 patients with arterial fibrodysplasia, medial dysplasia was

Table 3. Presenting symptoms, associated diseases and clinical course in patients with RAD

#	Age (year)	gender	Chief complaint	Characteristics of the pain and other symptoms	Site	Associated diseases/ findings	Intervention, clinical course, outcome
1	38	M	R flank pain	Spontaneous sudden onset, severe	R	–	Supportive medical therapy, stabilized, alive at 119 Mo
2	38	F	L flank pain	Spontaneous sudden onset, severe	L	HTN	L aortorenal arterial bypass, stabilized, alive at 39 Mo
3	26	F	Increase in creatinine	Asymptomatic	R	HTN, FMD	R aortorenal arterial bypass, stabilized, alive at 117 Mo
4	49	M	R flank pain	Spontaneous sudden onset, severe	R	HTN, history of spontaneous L RAD 7 years earlier.	R aortorenal arterial bypass, stabilized, alive at 13 Mo
5	40	M	CHF exacerbation	Spontaneous sudden onset, severe	L	HTN, CHF, Poland syndrome, aneurismal dissection of vertebral artery	Supportive medical therapy, stabilized, alive at 23 Mo
6	30	M	L flank pain	Spontaneous sudden onset, severe, recurrent epistaxis	L	HTN, FMD, Nail Patella, renal artery aneurysm	Supportive medical therapy, stabilized, alive at 17 Mo
7	42	M	R flank pain	Spontaneous sudden onset, severe	R	–	Supportive medical therapy, stabilized, alive at 18 Mo
8	47	F	LLQ pain (abdominal)	Spontaneous sudden onset, severe	L	HTN, cryptogenic liver cirrhosis, status post orthotopic liver transplantation	Thrombolysis and supportive care, stabilized, alive at 33 Mo
9	51	M	L flank pain	Spontaneous sudden onset, severe with gross hematuria	L	HTN, Ehlers–Danlos, renal artery aneurysm, gout	Supportive medical therapy, stabilized, alive at 19 Mo
10	45	M	R flank pain	Sudden onset severe pain and hematuria post weight lifting	R	HTN, FMD	Supportive medical therapy, stabilized, alive at 73 Mo
11	27	M	R flank pain	Spontaneous sudden onset, severe	R	HTN, Ehlers–Danlos, leak from renal artery aneurysm	Embolization of R accessory renal artery, stabilized, alive at 48 Mo
12	41	F	Headache	Headache, blurry vision	L	HTN, FMD, renal artery aneurysm, carotids & L vertebral artery dissection	Intensive care, stabilized, alive at 41 Mo

Continued

Table 3. Continued

#	Age (year)	gender	Chief complaint	Characteristics of the pain and other symptoms	Site	Associated diseases/findings	Intervention, clinical course, outcome
13	26	F	Uncontrolled hypertension	Asymptomatic	R	HTN, complicated by renal artery stenosis	R nephrectomy, alive at 38 Mo
14	33	F	Harrington rod placement	Developed L flank pain on post-operative day 12	R	HTN, Ehlers–Danlos, leak from renal artery aneurysm	Embolization and coiling, died at 40 Mo with cerebral hemorrhage
15	46	M	R flank pain	Spontaneous sudden onset, severe	R	HTN, polyarteritis nodosum	Embolization, progressed to ESRD, transplanted in 5 years
16	32	M	Abdominal pain	Spontaneous sudden onset, severe	R,L	HTN, Ehlers–Danlos, renal artery aneurysm	Embolization and coiling, recurrent dissection in 3 and 7 years
17	45	M	L flank pain	Spontaneous sudden onset, severe	L	HTN	Supportive medical therapy

M, male; F, female; R, right; L, left; Mo, month; HTN, hypertension; FMD, fibromuscular dysplasia; CHF, congestive heart failure; LLQ, left lower quadrant.

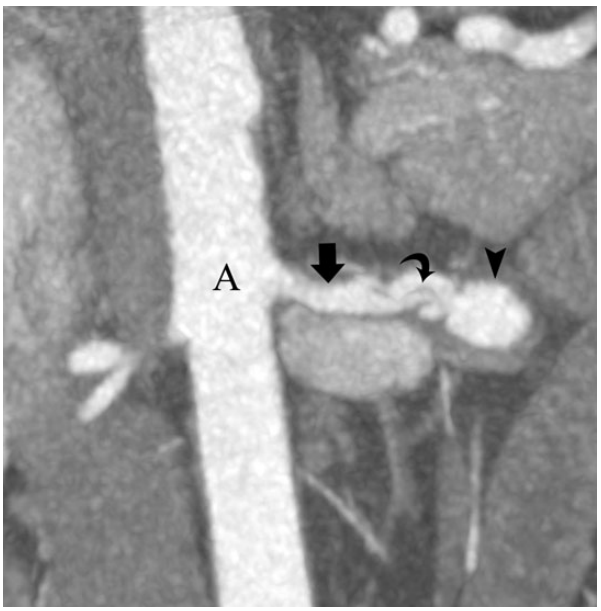

FIGURE 1: (Case#5) A 40-year-old male with congestive heart failure and Poland syndrome. Coronal maximum intensity projection image from a CT angiography of the abdominal aorta (A) shows dissection flap (curved arrow) and aneurysmal dilatation (arrow head) of the left renal artery (arrow).

observed in up to 85% of cases, but only two were associated with RADs, suggesting rarity of SRAD in arterial fibrodysplasia [23]. Unusual physical stress can lead to traction of renal arteries and abnormalities in the integrity of connective tissue may present predisposing factors that can result in rapture of vasa vasorum and subsequent cascade of events such as intramural hematoma and SRAD.

In the present study, SRADs were observed in two different categories. One is an isolated form without any other significant comorbidity and the other one is being part of a syndrome with multisystem involvement including association with Ehlers–Danlos syndrome in four patients, FMD in four patients, Poland syndrome, polyarteritis nodosa and nail–patella syndrome each in one patient suggesting possibility of disorders in connective tissue. Although the two groups are distinct by the above-mentioned comorbidities, the underlying etiologic factors may be identical, including genetic predisposition and interactions with environmental factors. As Ehlers–Danlos syndrome and FMD are rare diseases in the general population, their clustering in our patients strongly suggests that they are risk factors for development of SRAD.

In an earlier observation from 1960 to 1976, two of four patients with SRAD exhibited with renal artery FMD and other two had arteriosclerosis of the renal arteries [24]. Two of the patients with FMD also were diagnosed with malignant melanoma. An association of FMD with neoplastic disorders such neurofibromatosis, carotid body tumor, cardiac fibroelastoma, renal cell carcinoma, pheochromocytoma and spinal hemangioma has been the subject of a few case reports [25–30]. Larger studies are needed to identify possible associations of connective disorders and cancer with SRAD.

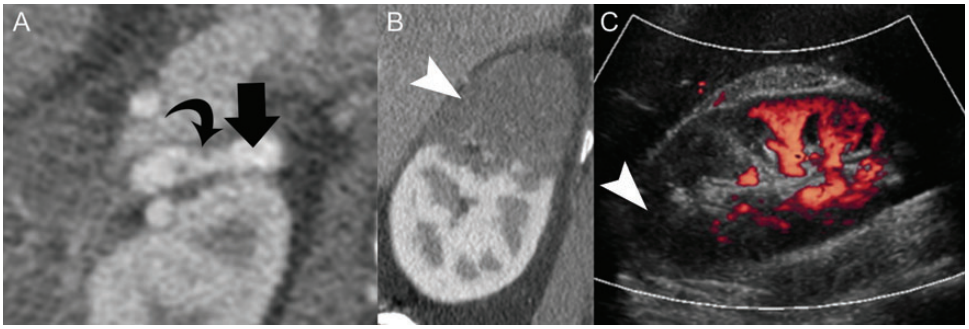

FIGURE 2: (Case #7) A 42-year-old male with no significant past medical history. Magnified axial image (**A**) from an intravenous contrast-enhanced CT renal angiography shows subtle internal luminal strands (curved arrow) indicating a branch artery (arrow) dissection at the right renal hilum. Sagittal reformatted image (**B**) of the right kidney shows geographic low attenuation of the upper pole (arrow head). Power Doppler evaluation (**C**) of the right kidney also shows absent perfusion (arrow head) of the upper pole with preservation blood flow in the lower pole.

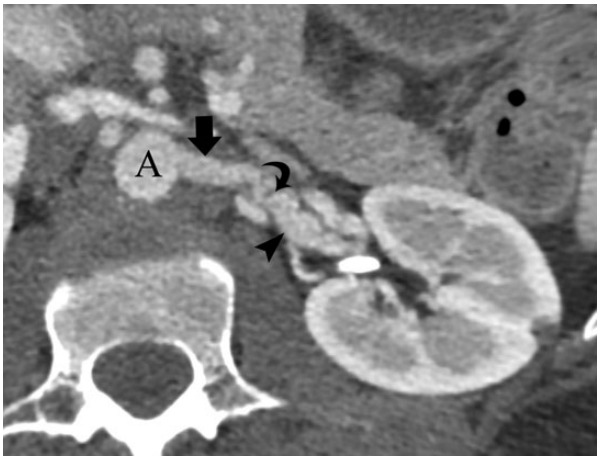

FIGURE 3: (Case #12) A 41-year-old female with fibromuscular dysplasia. Axial image from a CT angiography of the abdominal aorta (A) shows dissection flap (curved arrow) and aneurysmal dilatation (arrow head) of the left renal artery (arrow).

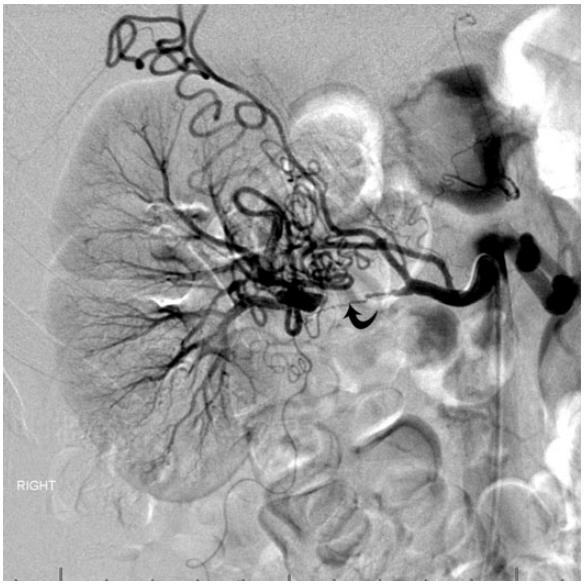

FIGURE 4: (Case#13) A 26-year-old female with a history of hypertension presented with severe right-sided main RAD. Failed attempt for surgical revascularization required nephrectomy.

Sustained elevated blood pressure may contribute to the development of arterial dissection by potentiating arteriosclerosis and medial degeneration [24], although hypertension itself may be secondary to renal ischemia following the SRAD. Depending on the severity, extent and main artery versus branch involvement, SRAD may cause renal ischemia of varying degree, renin-mediated renovascular hypertension and renal infarction [31–34].

In our study, as compared to obese patients, risk of SRAD was higher in individuals with normal BMI and overweight patients. Although this finding may just be a chance finding, protective effect of obesity may be explained by coexisting sedentary lifestyle imposing less stretch to renal arteries. We also noted bilateral dissection of the renal arteries over a span of 7 years, which suggests that unilateral SRAD may be a risk factor for the subsequent dissection of the contralateral renal artery.

The most frequent presenting features were uncontrolled hypertension and severe spontaneous sudden-onset flank pain ipsilateral to the site of dissection. Other series have reported additional symptoms, including groin and/or testicular pain, headache, nausea, vomiting, fever, dysuria, hematuria and blurry vision [6, 33, 35]. These symptoms are unspecific and may also be present in patients with nephrolithiasis, a very common disease. Among the laboratory findings, increased serum creatinine, leukocytosis and markedly increased level of serum lactate dehydrogenase (LDH) may reflect renal parenchymal cell death [36, 37].

In an exhaustive review of published reports, up to 29% of all cases (42 cases) were diagnosed during autopsy, and the rest were diagnosed based on arteriography or during surgery following an abnormal but non-diagnostic angiography [33]. There is general agreement that the definite diagnosis is most commonly achieved by catheter arteriography. However, recent advances in multi-detector CT and magnetic angiography make renal artery evaluation possible in a robust and reliable way. It is also a relatively more efficient, safe and

Table 4. Follow-up information in patients with RAD by different therapeutic strategies including medical, radiographic endovascular and surgical operation

Treatment strategy	*n*	Duration, median (IQR), months	SBP at presentation, mmHg	SBP at follow-up, mmHg	DBP at presentation, mmHg	DBP at follow-up, mmHg	Creatinine at presentation, mg/dL	Creatinine at follow-up, mg/dL
Medical	8	16.2 (1.3, 50.6)	154 ± 8	122 ± 15	87 ± 11	79 ± 9*	1.1 ± 0.3	1.0 ± 0.2
Endovascular	5	32.0 (25.0, 42.5)	152 ± 28	131 ± 25	84 ± 10	80 ± 13	1.1 ± 0.4	3.1 ± 3.8
Surgical	4	4.4 (0.2, 10.1)	145 ± 37	127 ± 10	91 ± 21	82 ± 6	1.4 ± 0.7	1.4 ± 0.7

IQR, inter-quartile range; SBP, systolic blood pressure; DBP, diastolic blood pressure.
*P = 0.01.

inexpensive procedure than invasive catheter angiography [11, 38, 39]. In our report, duplex ultrasound was applied in four cases in conjunction with definite diagnostic modalities, and could show a non-specific pattern of interruption in segmental blood flow in two cases (Figure 2).

Treatment options for SRAD include supportive medical management, endovascular procedures and open surgical operations [8, 32, 40–43]. Medical management is the preferred method of management, when further invasive procedures can be avoided. This includes pain management, control of hypertension, systemic anticoagulation and management of coexistent symptoms [7, 35, 43]. There is still controversy surrounding the role of anticoagulation. Pellerin *et al.* argue for a beneficial role of thrombosis of the false lumen preventing the risk of occlusion of the true lumen, which may be hampered by systemic anticoagulation [40]. On the other hand, there is general agreement for control of hypertension with a goal of systolic blood pressure <140 mmHg and diastolic blood pressure <90 mmHg. In the absence of acute kidney injury or rise of serum creatinine to <30%, angiotensin-converting enzyme inhibition or angiotensin receptor blockade may be beneficial particularly in the presence of evidence for survival benefit in renovascular atherosclerosis [44].

Endovascular procedures are described in several reports and series [40, 45–48]. In a small series of only three patients with RAD and obstruction of the artery in the setting of trauma, a self-expanding stent was deployed through a guide wire with immediate restoration of blood flow and stable kidney function at 23–30 months of follow-up [45]. In cases of dissection with luminal thrombosis, thrombolysis was performed, followed by stent placement and hemodynamic stabilization [46, 47]. In another series of 16 consecutive patients with SRAD with a mean age of 42 years, all patients underwent endovascular stenting irrespective of severity of dissection [40]. The authors have reported normal blood pressure at 8.6 years of follow-up with normal-level plasma creatinine and no sign of restenosis or occlusion in any of the patients.

In the setting of aneurysm formation of the renal artery and/or rupture or leak from the aneurysm particularly in the presence of renovascular hypertension and in women of childbearing age, renal artery embolization has been successfully employed [49, 50].

Surgical repair as the definitive treatment was reported in few prior studies [8, 9, 32, 42]. Some of the proposed criteria for surgical intervention include presence of correctable dissection which causes hemodynamically significant occlusion of the main or major segmental renal arteries, uncontrolled renovascular hypertension resistant to medical treatment and significantly deteriorating renal function [35]. In a case series of 22 patients with a mean age of 41 years, Lacombe reported 17 repairs in 16 patients along with 8 nephrectomies [8]. Hypertension resolved in 9 patients (41%) and improved in 11 (50%). No death was reported during surgery, but with long-term follow-up one late thrombosis of repaired polar artery and one spontaneous dissection of the contralateral artery were observed. In the remaining eight patients, late angiography revealed hemodynamic stability with long-term follow-

up. In another series of nine treated patients, there were 10 bypass procedures, including 5 complex branch reconstruction performed with 100% immediate patency in reconstructed arteries, adequate blood pressure control and restoration of normal renal function with long-term follow-up [9]. There were two deaths, each due to subarachnoid hemorrhage and septic meningitis. Muller *et al.* reported a series of 25 surgically repaired dissection patients of whom 22 patients had SRAD and the other 3 had after trauma. Hypertension resolved or improved in 86% of patients who did not have kidney injury prior to the operation, while this rate was only 38% in patients with preoperative kidney injury. Preservation of kidney function was noted in 82% of the revascularized kidneys, but in three kidneys late renal artery occlusion developed. Overall, our choice of selecting the surgical approach for management of SRAD is reserved for severe cases where medical management alone was insufficient to treat symptoms or preserve renal function. The renal outcomes and control of blood pressure in our study are similar to those of the other case series which have shown a relative preservation of renal function and control of blood pressure in the long-term. The overall outcome is a function of general comorbid conditions.

This is the first systematic study of RAD comparing its characteristics with those of the general population. In that regard, several novel relationships with the above details are noted. There are several limitations in our study. The sample size in the case group is small and conclusions should be drawn with caution. For this reason, we chose the entry criteria for stepwise inclusion in the structure of the multivariable model to be set at 0.01. The results may not be generalizable to other settings. Since the search for the cases was based on the application of ICD9 codes, the search strategy might have missed some cases of RAD.

In conclusion, SRAD may be seen in association with hypertension, CHF, cancer and rare connective tissue disorders. Therefore, its occurrence should prompt investigation for rare diseases such as Ehlers–Danlos syndrome and FMD. The diagnosis can be established in most cases using high-resolution CT and magnetic angiography. Medical management appears to be a reasonable choice in some patients, but severity and extent of the dissection as the degree of hemodynamic instability in the territory of the dissected artery determine the need for intervention. With appropriate intervention and follow-up, the clinical course of the disease may remain favorable.

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CONFLICT OF INTEREST STATEMENT

None declared.

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