Etiology spectrum and clinical characteristics of renal artery stenosis in a Chinese cohort

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ABSTRACT

OBJECTIVE To analyze the causes of renal artery stenosis (RAS) and compare the clinical characteristics in accordance with the primary disease among patients aged from 30 to 50.

METHODS Patients were grouped by etiologies of RAS. Groups were retrospectively examined and compared regarding demographic data, clinical manifestations, laboratory findings, and imaging findings.

RESULTS A total of 152 patients (74 females, 78 males; mean age: 40.70 ± 6.01 years) were enrolled, including 84 patients (55.3%) with atherosclerosis (AS), 46 patients (30.3%) with Takayasu arteritis (TA), 18 patients (11.8%) with fibromuscular dysplasia (FMD), and four patients (2.6%) with other etiologies. Patients in AS group had greater body mass index, higher prevalence of comorbidities and higher rate of smoking and drinking history. TA patients showed more constitutional symptoms and vascular findings, and higher erythrocyte sedimentation rate. RAS in both AS group and TA group mainly located on ostia and proximal segments, but RAS in FMD group mainly involved middle to distal segment of renal artery. The AS group had significantly lesser stenosis than the other groups. Although renal function evaluated by the estimated glomerular filtration rate did not significantly differ among the groups, the incidence of kidney shrinkage was significantly higher in the TA and FMD groups (39.1% and 50%, respectively) than in the AS group (8.3%). The FMD group had milder cardiac damage than other groups.

CONCLUSIONS AS was the most common cause of RAS in patients aged from 30 to 50, followed by TA and FMD. The etiology of RAS should be carefully distinguished based on clinical manifestations, laboratory findings, and imaging to ensure that proper treatment is provided.

Renal artery stenosis (RAS), a common cause of secondary hypertension, is traditionally considered more frequent to involve geriatric patients.[1] The most common etiology of RAS is atherosclerosis (AS), followed by Takayasu arteritis (TA), and fibromuscular dysplasia (FMD), while rare causes include congenital RAS, Behcet’s disease, and polyarteritis nodosa, et al.[2] Regarding the secondary etiology of hypertension, targeted treatments for primary disease are essential in controlling blood pressure (BP), reducing the incidence of cardiovascular events, and improving the long-term prognosis of RAS. However, RAS is not rare in younger patients, and similar manifestations and numerous confounding factors make accurate etiological diagnosis difficult. A previous study showed that AS induced 82.4% of RAS cases in patients of all ages, while TA and AS were the main cause in patients aged ≤ 40 years and > 40 years, respectively.[3] AS has traditionally been considered an aged-related condition that mainly involved older adults, while TA and FMD were thought to usually occur in young patients.[1–6] However, a growing number of RAS cases in patients aged ≤ 40

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years have been caused by AS in recent years, and TA can also be diagnosed in patients older than 40 years, as there may be a long asymptomatic period.\textsuperscript{2} The etiological spectrum and clinical features of RAS in middle-aged patients may be vastly different with those in the elderly, which has rarely been summarized before. In the present study, we analyzed the causes of RAS in patients aged from 30 to 50 years, as well as the demographic data, clinical manifestations, laboratory findings, and imaging findings in accordance with different primary diseases. This information will be helpful in clinical practice.

METHODS

Study Population

Consecutive RAS patients admitted to Fuwai Hospital from January 2014 to October 2019 were identified. A patient hospitalized more than one time was regarded as a single patient. The inclusion criteria were as follows: (1) age 30–50 years at admission; and (2) diameter in trunk section and/or primary branch of RAS ≥ 50\% confirmed by multidetector row computed tomography angiography (CTA) or selective renal artery arteriography (RAG).\textsuperscript{7}

This study was approved by the Ethics Committee of Fuwai Hospital (No.2020-1321) and informed consent was obtained from all participants.

Data Collection

Demographic data, clinical manifestations, physical examination findings, comorbidities, laboratory findings, and imaging findings were retrospectively collected. BP was evaluated by clinical measurements using an automatic device. Body mass index (BMI) was calculated as the weight in kilograms divided by the square of the height in meters. Urinary protein was semiquantitatively detected by enzyme-coated dipstick testing, with proteinuria and nephritis defined as > 0.5 g and > 3.5 g, respectively.

Renal function was evaluated by the estimated glomerular filtration rate (eGFR) calculated using the Chronic Kidney Disease Epidemiology Collaboration equation (2009).\textsuperscript{8} A diagnosis of renal insufficiency was established when eGFR < 90 mL/min per 1.73 m\textsuperscript{2}.\textsuperscript{9} Kidney shrinkage was defined as a difference between the sizes of the two kidneys of ≥ 1.5 cm on imaging.\textsuperscript{10}

Echocardiographic evaluation was acquired by standard M-mode and two-dimensional images. The left atrial diameter (LAD), left ventricular end diastolic diameter (LVDD), interventricular septum thickness, diastolic posterior wall thickness, and left ventricular ejection fraction were measured and assessed based on the recommendations of the American Society of Echocardiography.\textsuperscript{11}

Criteria of Etiological Diagnosis

RAS was diagnosed on the basis of imaging examinations, including color Doppler flow imaging, CTA, and standard angiography. As histopathology was seldom obtained due to extensive use of endovascular treatment, the etiological diagnosis was established based on clinical features and angiographic imaging (CTA and/or selective RAG). Diagnostic criteria of AS, TA and FMD are summarized (supplemental material, Table 1S). AS was diagnosed depending on risk factors and imaging findings.\textsuperscript{2,6,12} TA was diagnosed in accordance with the American College of Rheumatology’s revised criteria (1990)\textsuperscript{13} or the revised criteria of Sharma and co-workers.\textsuperscript{14} FMD was diagnosed depending on the angiographic appearance of the renal artery after the careful exclusion of other diseases.\textsuperscript{15} Furthermore, one of the included patients with RAS had coexistent congenital anomalies of the kidney, which were considered to share a common genetic background, and was diagnosed with congenital RAS after other secondary causes were excluded.\textsuperscript{16}

Statistical Analysis

Data were analyzed using SPSS 23.0 (SPSS Inc., IBM, Armonk, NY, USA). Continuous variables are expressed as mean ± SD, while categorical variables are expressed as numbers and percentages. As the ‘other’ group consisted of four patients with high heterogeneity, continuous variables were compared among the AS, TA, and FMD groups only (excluding the ‘other’ group) using one-way analysis of variance followed by Bonferroni correction. The Pearson’s chi-squared test or Fisher’s exact test were used to compare categorical variables between
the AS, TA, and FMD groups. All P-value were used to judge the significance of differences between the TA, AS, and FMD groups (excluding the ‘other’ group). A two-sided P-value < 0.05 was considered statistically significant.

RESULTS

Baseline Characteristics

The baseline characteristics are summarized in Table 1. From January 2014 to October 2019, a total of 152 patients (74 females, 78 males; mean age: 40.70 ± 6.01 years) were enrolled. Participants were divided in accordance with the etiologies of RAS into the AS group (n = 84, 55.3%), TA group (n = 46, 30.3%), FMD group (n = 18, 11.8%), and ‘other’ group (n = 4, 2.6%). The ‘other’ group included one patient with congenital RAS, one patient with idiopathic renal artery dissection, and two patients with RAS of undefined etiology. Only one female patient had concurrent TA and AS, and she was included in the TA group. The sex composition differed between the four groups. The percentage of women was highest in the TA group, followed by the FMD and AS groups. The incidences of TA, AS, and FMD in the 74 female patients were 54.1% (n = 40), 31.1% (n = 23), and 14.9% (n = 11), respectively. In the 78 male patients, the respective incidences of AS, FMD, and TA were 79.5% (n = 62), 9.0% (n = 7), and 7.7% (n = 6), respectively. Compared with the other groups, the AS group had a greater BMI and higher incidences of diabetes mellitus, coronary artery disease, history of smoking and drinking than other groups. The TA group had a significantly lower diastolic BP and family history of hypertension than other groups.

Clinical Manifestations and Laboratory Findings

The clinical manifestations and laboratory findings are summarized in Table 2. Compared with the AS and FMD groups, the TA group had more constitutional symptoms and vascular findings indicating involvement of the aortic branches. The clinical symptoms of the AS group varied. Constitutional symptoms, neurological symptoms, and vascular findings are all potential clinical indications of atherosclerotic RAS, although none of the AS group had fever. The RAS in the FMD group and the ‘other’ group mainly manifested as non-specific neurological symptoms. The AS group had significantly

Table 1  Baseline characteristics of the patients grouped by etiology of RAS.

| Variables                  | Atherosclerosis (n = 84) | Takayasu arteritis (n = 46) | Fibromuscular dysplasia (n = 18) | Other (n = 4) | P-value |
|----------------------------|--------------------------|-----------------------------|---------------------------------|--------------|---------|
| Age at diagnosis, yrs      | 42.66 ± 5.35             | 38.63 ± 5.94                | 36.28 ± 5.26                    | 42.59 ± 6.95 | < 0.01  |
| Age at onset, yrs          | 33.35 ± 8.57             | 31.12 ± 9.70                | 36.88 ± 8.94                    | 27.75 ± 4.35 | 0.07    |
| Course of hypertension, yrs| 7.22 ± 6.13              | 7.88 ± 7.91                 | 6.53 ± 6.23                     | 9.00 ± 3.74  | 0.75    |
| Course of RAS, yrs         | 3.31 ± 4.72              | 9.49 ± 9.68                 | 3.78 ± 5.51                     | 3.06 ± 3.76  | < 0.01  |
| Female                     | 22 (26.2%)               | 40 (87.0%)                  | 11 (61.1%)                      | 1 (50.0%)    | < 0.01  |
| BMI, kg/m²                 | 26.63 ± 3.43             | 23.31 ± 2.72                | 22.54 ± 3.57                    | 24.36 ± 4.00 | < 0.01  |
| SBP, mm Hg                 | 154.22 ± 24.35           | 149.35 ± 30.85              | 156.39 ± 20.53                  | 155.75 ± 33.44 | 0.56   |
| DBP, mm Hg                 | 97.17 ± 15.67            | 86.33 ± 22.85               | 102.17 ± 8.9                    | 99.25 ± 19.38 | < 0.01  |
| Hypertension               | 79 (94.0%)               | 36 (78.3%)                  | 18 (100%)                       | 4 (100%)     | < 0.01  |
| Diabetes mellitus          | 13 (15.5%)               | 2 (2.1%)                    | 1 (5.6%)                        | 2 (50.0%)    | 0.11    |
| Coronary artery disease    | 19 (22.6%)               | 0                           | 0                               | 0            | < 0.01  |
| OSAS                       | 43 (51.2%)               | 4 (8.7%)                    | 2 (11.1%)                       | 1 (25.0%)    | < 0.01  |
| Smoking history            | 50 (61.7%)               | 6 (13.6%)                   | 2 (12.5%)                       | 3 (75.0%)    | < 0.01  |
| Drinking history           | 49 (59.0%)               | 6 (13.6%)                   | 5 (27.8%)                       | 3 (75.0%)    | < 0.01  |
| Family history of hypertension | 53 (63.1%)             | 15 (32.6%)                  | 9 (50.0%)                       | 3 (75.0%)    | < 0.01  |

Data are presented as means ± SD or n (%). BMI: body mass index; DBP: diastolic blood pressure; OSAS: obstructive sleep apnea syndrome; RAS: renal artery stenosis; SBP: systolic blood pressure.

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higher high density lipoprotein cholesterol, lower low density lipoprotein cholesterol, higher total cholesterol, and higher triglyceride than other groups. The TA group had lower hemoglobin, higher erythrocyte sedimentation rate, and lower albumin than the AS and FMD groups.

**Imaging Studies**

The RAG and/or renal CTA results are summarized in Table 3. A total of 182 lesions were identified, including 99 lesions in the AS group, 56 lesions in the TA group, 23 lesions in the FMD group, and four lesions in the ‘other’ group. RAS in the AS and TA groups occurred equally on both sides of the renal artery, and the ostia and proximal segment were most commonly involved. More than 90% of the TA lesions and nearly 90% of the AS lesions showed severe RAS (70%–99% stenosis) or renal artery occlusion. In contrast to RAS caused by TA and AS, RAS caused by FMD mainly involved the middle to distal segment of the renal artery, including eight cases (34.8%) of beaded stenosis and six cases (26.1%) of tubular stenosis. The mean degree of stenosis in the AS group was significantly milder than that in the FDM and TA groups. Five aneurysms were identified (three aneurysms loc-
type V was the most common Numano subtypes, in accordance with the differentiation criteria of the common carotid artery and brachiocephalic artery. Branch was the subclavical artery, followed by the main branches; the most commonly involved artery involvement in the TA and AS groups in the TA and AS groups. In the AS, TA, and FMD groups, patients (16.7%), 44 patients (95.7%), and three patients (85.9%) in the AS group had a similar incidence of a thickened wall. In the FMD group, and two aneurysms located in the abdominal aorta. The prevalence of non-calcified plaque and thickened walls was higher in the AS group than in the FDM and TA groups. Figure 1 shows several typical images of RAS caused by different etiologies.

Vessels that might potentially have been affected by TA, AS, or FMD were evaluated by CTA or RAG. Two or more arteries were affected in 73 patients (85.9%), 44 patients (95.7%), and three patients (16.7%) in the AS, TA, and FMD groups, respectively. We compared the incidence of concurrent artery involvement in the TA and AS groups in Figure 2. TA mainly affected the whole aorta and its main branches; the most commonly involved branch was the subclavical artery, followed by the common carotid artery and brachiocephalic artery. In accordance with the differentiation criteria of the Numano subtypes, type V was the most common pattern of artery involvement (n = 39, 84.8%), followed by type IV (n = 6, 13.0%) and type III (n = 1, 2.2%). Although the incidence was less than in the TA group, 63% of patients in the AS group also had concomitant lesions in the abdominal aorta. However, the lesion patterns in the abdominal aorta differed significantly between the TA and AS groups. In the TA group, the most commonly observed abdominal aortic lesions were a thickened wall (n = 28, 60.9%) and stenosis (n = 27, 57.7%), while infrequent manifestations included dilation (n = 4, 8.7%) and calcification (n = 2, 4.3%) of the abdominal aortic wall. Compared with the TA group, the AS group had a similar incidence of a thickened wall (n = 50, 59.5%), significantly higher incidence of calcification (n = 2, 10.7%; P < 0.01), tendency toward less stenosis (n = 2, 2.4%), and no dilation of the abdominal aorta (n = 0, 0%; P < 0.01). Three patients in the FMD group had concurrent lesions, etiologies.

| Variables       | Atherosclerosis | Takayasu arteritis | Fibromuscular dysplasia | Other | P-value |
|-----------------|-----------------|--------------------|-------------------------|-------|---------|
| Lateral<sup>a</sup> |                 |                    |                         |       |         |
| Right           | 31 (36.9%)      | 20 (43.4%)         | 8 (44.4%)               | 1 (25.0%) | 0.78    |
| Left            | 38 (45.2%)      | 16 (34.8%)         | 4 (22.2%)               | 3 (75.0%) | 0.12    |
| Bilateral       | 15 (17.9%)      | 10 (21.7%)         | 6 (33.3%)               | 0     | 0.35    |
| Segment<sup>a</sup> |                |                    |                         |       |         |
| Ostia           | 37 (37.4%)      | 28 (50.0%)         | 1 (4.3%)                | 2 (50.0%) | < 0.01  |
| Proximal        | 55 (55.6%)      | 24 (42.9%)         | 6 (26.1%)               | 1 (25.0%) | 0.03    |
| Mid-to-distal   | 5 (5.1%)        | 4 (7.1%)           | 15 (62.5%)              | 0     | < 0.01  |
| Entire          | 2 (2.0%)        | 1 (1.8%)           | 2 (8.7%)                | 1 (25.0%) | 0.19    |
| Stenosis<sup>a</sup> |             |                    |                         |       |         |
| 50%–70%         | 11 (11.1%)      | 4 (7.1%)           | 1 (4.3%)                | 0     | 0.5     |
| 70%–99%         | 68 (68.7%)      | 35 (62.5%)         | 18 (78.3%)              | 3 (75.0%) | 0.38    |
| 100%            | 3 (3.0%)        | 16 (28.6%)         | 3 (13.0%)               | 1 (25.0%) | < 0.01  |
| Mean,%          | 74.03 ± 14.80   | 87.59 ± 12.21      | 86.09 ± 12.79           | 86.25 ± 11.09 | < 0.01  |
| Aneurysm<sup>a</sup> |               |                    |                         |       |         |
|                  | 0               | 2 (3.6%)           | 3 (13.0%)               | 0     | < 0.01  |
| String-of-beads’ appearance<sup>a</sup> | 0 | 0 | 8 (34.8%) | 0 | < 0.01 |
| Calcified plaque<sup>a</sup> | 3 (3.0%) | 2 (3.5%) | 3 (13.0%) | 0 | 0.18 |
| Non-calcified plaque<sup>a</sup> | 14 (14.1%) | 0 | 0 | 0 | < 0.01 |
| Thickened wall<sup>a</sup> | 27 (27.3%) | 5 (8.9%) | 0 | 0 | < 0.01 |

Data are presented as means ± SD or n (%). *Refers to calculate for comparisons between the atherosclerosis, Takayasu arteritis, and fibromuscular dysplasia groups, excepting the ‘other’ group. #Refers to the numbers of patients in each group used as the cardinal number to calculate the proportions were n = 84 in the atherosclerosis group, n = 46 in the Takayasu arteritis group, n = 18 in the fibromuscular dysplasia group, and n = 4 in the ‘other’ group. *Refers to the numbers of lesions in each group used as the cardinal number to calculate the proportions were n = 99 in the atherosclerosis group, n = 56 in the Takayasu arteritis group, n = 23 in the fibromuscular dysplasia group, and n = 4 in the ‘other’ group.
which were located in the vertebral artery, celiac trunk, and iliac artery. The lesion in the iliac artery presented as a dissecting aneurysm, while the other two lesions were unifocal stenosis.

Organ Damage

Organ damage data are summarized in Table 4. The renal function as evaluated by the eGFR did not significantly differ among groups. However, kidney shrinkage was significantly more common in the TA and FMD groups than the AS group. All included patients underwent 24-h urinary protein (24hUP) testing. The 24hUP level in the whole cohort was $0.48 \pm 1.21$ g (range: 0–7.91 g). The nephritic range was detected in six patients, comprising two patients (4.3%) with TA and four patients (4.8%) with AS. Pathological diagnoses were not acquired. There were also 15 patients with medium 24hUP levels (0.5–3.5 g), comprising three patients (6.5%), nine patients (10.7%), and three patients (16.7%) in the TA, AS, and FMD groups, respectively. Overall, the incidences of proteinuria and the nephritic range were 13.82% and 3.95% in our cohort.

Heart involvement mainly included changes in cardiac structure, valve damage, heart failure (HF), and myocardial infarction. The diameter of the ascending aorta, LAD, LVDD, and diastolic posterior wall thickness were significantly lower in the FMD group than in the AS and TA groups, implying that the FMD group had milder cardiac injury. Severe abnormality of valve activity was not common in our cohort. Twenty-four patients were diagnosed with HF, comprising nine patients (19.6%) with TA, 14 patients (16.7%) with AS, and one patient with congenital RAS. No patients in the FMD group presented with HF. There were no significant differences between groups regarding funduscope findings and neurological complications.

DISCUSSION

Atherosclerotic renal artery disease has gained the most attention as a cause of RAS, with atherosclerotic RAS inducing more than 90% of RAS cases and being regarded as the most common cause of “renovascular hypertension”. Other common etiologies of RAS differ greatly between populations. In the European population, FMD is the second-most common cause of RAS, followed by arteritis; however, in Asian populations, arteritis is more common than FMD. A previous study of Asian populations reported that the three most common causes of RAS are AS (82.4%), TA (11.9%), and FMD (4.3%). In the present study of middle-aged Asian patients, the proportions of different etiologies in middle-aged patients showed less variation. Thus, it is challenging to make an etiological diagnosis of RAS in middle-aged patients, which is a topic that has not yet been investigated.

Previous research reported that < 10% of RAS cases in females < 40 years were caused by AS, but we found that 22.0% and 56.1% of females aged 30–40 years with RAS were diagnosed with AS and TA, respectively. So AS may not actually be a rare cause of RAS in young females. This is consistent with the fact that the age of onset of AS-related RAS is younger than previously reported. In male patients, nearly 80% of RAS cases were related to AS, followed by FMD and TA, which is similar to previ-
The sex ratios of middle-aged patients with AS, TA, and FMD have not been previously reported. In the present study, the ratios of female to male were 1:3, 7:1, and 11:7 in the AS, TA, and FMD groups, respectively.

Hypertension is recognized as the most important clinical feature of RAS. However, 21.7% of patients in the TA group had no hypertension. Furthermore, patients with AS and FMD had a longer course of hypertension than RAS, but TA patients always had a shorter course of hypertension than RAS. This may be because patients with AS and FMD had no constitutional symptoms at the beginning of the disease, which made the onset more insidious, while TA always has an obvious and extensive clinical presentation derived from severe and progressive organ malperfusion. Thus, TA and related RAS are more easily diagnosed before the development of hypertension, but the RAS in AS and FMD tends to be ignored until patients present with uncontrolled hypertension or other severe comorbidities; this theory is supported by the significantly lower diastolic BP in the TA group.

TA and AS are both systemic diseases that tend to involve multiple arteries. In our research, concurrent involvement of an artery other than the renal artery occurred in 95.7% of TA patients and 85.9% of AS patients. Although it is TA that mainly involves the abdominal aorta and its main branches, as showed in our results, 63.0% of AS patients also had abdominal aorta involvement. This may be because the renal arteries are the primary branches of the abdominal aorta. Thickening of the arterial wall was the most common aortic lesion in both the TA and AS groups, followed by calcified plaque. The difference between these groups was that the AS group always had eccentric thickening of the arterial wall and the plaques were often unevenly distributed, while the TA group mostly had annular thickness and calcification involving consecutive segments of the aorta and its main branches. However, TA can also be combined with AS, especially in older adults. Thus, further auxiliary examination such as 18F-fluorodeoxyglucose positron emission tomography may be helpful in identifying the etiology of RAS and detecting active disease.

FMD can also involve multiple vessels (such as the renal artery, cervicocephalic artery, and celiac...
reasons for this. Firstly, the degree of stenosis was the TA and FMD groups. There are two potential significantly lower in the AS group compared with However, the incidence of kidney shrinkage was eGFR, incidence of renal insufficiency, and 24hUP. there were no significant intergroup differences in our cohort.

ated incidence of concurrent artery involvement in tion bias may have contributed to an underestim-

fected artery. However, insufficient systematic and of patients in the FMD group had more than one af-

In the present group of middle-aged patients, 16.7 %

volving more than one vessel ranges from 16 to

and fibromuscular dysplasia groups, excepting the ‘other’ group. *Refers to only in patients with moderate to severe aortic insufficiency and mitral regurgitation. eGFR: estimated glomerular filtration rate.

artery),[18] and the prevalence of FMD lesions in-

volving more than one vessel ranges from 16% to 35% in several cohorts from Europe and America. In the present group of middle-aged patients, 16.7% of patients in the FMD group had more than one affected artery. However, insufficient systematic and standardized investigations of all vessels and selection bias may have contributed to an underestimated incidence of concurrent artery involvement in our cohort.

Although decreased renal function was identified in a large number of patients in all groups, there were no significant intergroup differences in eGFR, incidence of renal insufficiency, and 24hUP. However, the incidence of kidney shrinkage was significantly lower in the AS group compared with the TA and FMD groups. There are two potential reasons for this. Firstly, the degree of stenosis was higher in the TA and FMD groups than in the AS group, indicating poorer renal perfusion in the TA and FMD groups. Secondly, the course of RAS, which was inferred in accordance with clinical manifestations, was shorter in the AS group than in the TA and FMD groups. So renal damage may occur relatively earlier in the AS group than in the TA and FMD groups. Moreover, six patients in our cohort had a 24hUP of > 3.5 g (two patients in the TA group, and four patients in the AS group), indicating concomitant glomerulonephritis. Although no renal biopsies were conducted in our study, several previous reports have confirmed this possibility.[9,22]

Although there were no significant intergroup differences in left ventricular ejection fraction and prevalence of HF, the changes in cardiac structure (evaluated by the LAD, LVDD, and left ventricular systolic time) seemed severer in the AS and TA
groups compared with the FMD group. Abnormal valve activity, coronary artery involvement, and pulmonary stenosis were observed in the AS and TA groups, but not in the FMD group. Although most patients in our cohort had hypertension, there were no discrepancies between groups in the incidence and course of hypertension. The FMD group even had a higher diastolic BP than the AS and TA groups. Thus, we considered valve damage, myocardial ischemia, and pulmonary arterial hypertension as potential mechanisms inducing severe cardiac remodeling in the AS and TA groups. The most common abnormal valve activity was aortic incompetence, which may occur secondarily to dilatation of the ascending aorta and heart cavities and hypertension. TA can also directly involve the aortic valve, as previously reported. Overall, organ damage was not rare in middle-aged patients with RAS. Early diagnosis and targeted therapy for the primary disease will help protect organ function and improve the prognosis.

LIMITATIONS

The present study has several limitations. Firstly, it was a retrospective study, and so some selection bias is inevitable. Secondly, the degree of RAS cannot be exactly estimated based only on imaging. Last but not least, other FMD lesions, especially in the intracranial artery, were not routinely screened for in our study.

CONCLUSIONS

The most common cause of RAS in middle-aged patients is AS, followed by TA and FMD. The involved segment, RAS morphology, concomitant lesions of the renal artery, and involvement of multiple vessels differed significantly among patients with different primary diseases. Organ damage was not rare in our cohort. The etiology of RAS must be carefully distinguished based on medical history, laboratory findings, and imaging to ensure that the appropriate treatment is provided.

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