Received: 29 October 2018 | Revised: 29 June 2019 | Accepted: 17 August 2019

DOI: 10.1111/eci.13166

ORIGINAL ARTICLE

WILEY

Prevalence and characteristics of renal artery fibromuscular dysplasia in hypertensive women below 50 years old

Silvia Di Monaco[1,2] | **Jean-Philippe Lengelé**[1,3] | **Sheik Heenaye**[1] | **Etienne Danse**[4] | **Frank Hammer**[4] | **Marilucy Lopez-Sublet**[5] | **Laurent Toubiana**[6] | **Franco Rabbia**[2] | **Alexandre Persu**[1,7]

[1]Division of Cardiology, Cliniques Universitaires Saint-Luc, Université catholique de Louvain, Brussels, Belgium

[2]Department of Medical Sciences, Internal Medicine and Hypertension Division, AOU Città della Salute e della Scienza, University of Turin, Turin, Italy

[3]Department of Nephrology, Grand Hôpital De Charleroi, Gilly, Belgium

[4]Division of Radiology, Cliniques Universitaires Saint-Luc, Université Catholique de Louvain, Brussels, Belgium

[5]Department of Internal Medicine, ESH Hypertension Excellence Centre, Hôpital Avicenne, Centre Hospitalier Universitaire, Bobigny, France

[6]Sorbonne Université, Université Paris 13, Sorbonne Paris Cité, INSERM, UMR_S 1142, LIMICS, IRSAN, Paris, France

[7]Pole of Cardiovascular Research, Institut de Recherche Expérimentale et Clinique, Université catholique de Louvain, Brussels, Belgium

Correspondence
Alexandre Persu, Division of Cardiology, Cliniques Universitaires Saint-Luc (UCL), 10 Avenue Hippocrate, 1200, Brussels, Belgium.
Email: alexandre.persu@uclouvain.be

Abstract

Background: Renal fibromuscular dysplasia (FMD) is typically diagnosed in young hypertensive women. The 2014 European FMD Consensus recommended screening in all hypertensive women <30 yo. However, the prevalence of renal FMD in young/middle-aged hypertensive women remains unclear. The aim of this work was to assess the prevalence and characteristics of renal FMD in hypertensive women ≤50 yo.

Methods: We retrospectively included all consecutive women aged ≤50 years referred to our Hypertension Unit from 2014 to 2017 and collected standardized information on patient characteristics and screening modalities.

Results: Of 1083 incident hypertensive patients, 157 patients fitted with inclusion criteria. The prevalence of renal FMD varied between 3.2% in the whole sample and 7.5% in patients explored by CTA and/or MRA (n = 67). In the subgroup of patients ≤30 yo (n = 32), the corresponding figures were 3.1% and 5.6%. The yearly prevalence of FMD tended to increase over time, in parallel with increased use of CTA/MRA as a first-line imaging modality. Out of 5 patients with renal FMD, 2 were revascularized and 1 had extra-renal FMD.

Conclusions: The prevalence of renal FMD in young/middle-aged hypertensive women is probably one order of magnitude higher than previously assumed, in the range of 3%-8%, depending on imaging modalities. While the diagnosis of FMD does not influence short-term management in all patients, it may allow close monitoring and prevention of complications of the disease over time. This analysis provides the *rationale* for a prospective, multicentre study aiming at determining the cost-effectiveness of systematic screening for renal FMD.

KEYWORDS

computed tomographic angiography, fibromuscular dysplasia, hypertension, renal artery stenosis, renal duplex

1 | INTRODUCTION

Fibromuscular dysplasia (FMD) has been defined as an 'idiopathic, segmental, non-atherosclerotic and non-inflammatory disease of the musculature of arterial walls, leading to stenosis of small- and medium-sized arteries',[1,2] occurring frequently in women, with multiple potential clinical presentations.[2,3] Arterial hypertension is one of the most frequent

findings associated with FMD. In the first report of the US registry, 72% of 447 patients with FMD were hypertensive,[4] similar to 77.4% of 469 patients included in the Assessment of Renal and Cervical Artery Dysplasia (ARCADIA) study.[5] Hypertension may be due to FMD of the renal arteries or, alternatively, may coexist as essential hypertension.

Until recently, FMD was considered as a rare disease. The prevalence of symptomatic renal FMD in hypertensive patients, derived from the frequency of FMD among renovascular hypertension cases, has been estimated around 0.04%.[1] In contrast, silent renal FMD lesions have been identified in 3%-6% of potential kidney donors systematically screened with catheter-based angiography or computed tomographic angiography (CTA).[6,7] Moreover, in the Cardiovascular Outcomes in Renal Atherosclerotic Lesions (CORAL) trial, where FMD was an exclusion criteria, 5.8% of 997 patients harboured renal artery lesions suggestive of FMD (8.8% in female subgroup and 2.8% in male patients).[8]

Currently, the diagnosis of FMD is based on vascular imaging and catheter-based angiography is considered the gold standard, because of the possibility to acquire precise anatomic information including the degree and extent of arterial stenosis, in addition to direct quantitative hemodynamic assessment of FMD lesions. However, catheter-based angiography is an invasive procedure, with exposure to ionizing radiation and contrast agents and requiring the availability of an angiographic room; therefore, it is reserved for patients with indication for endovascular treatment.[2,9] Non-invasive CTA and magnetic resonance angiography (MRA) are well-accepted techniques to establish the diagnosis.[2] CTA exposes to radiation and contrast agents and does not provide functional data; however, it is more readily available and quick to perform than catheter-based angiography and provides high spatial resolution images of multiple vascular beds with high level of reproducibility.[9] Non-invasive MRA does not expose to ionizing radiation and can be performed with or without contrast agents. Moreover, the different applications of the MRA allow an indirect hemodynamic assessment.[9] However, MRA is less available, more time-consuming and expensive than CTA, provides images with lower spatial resolution and does not identify accurately calcium deposits, useful in differential diagnosis between focal FMD and atherosclerosis.[10] Finally, renal duplex is a non-invasive, easily available and inexpensive tool for renal artery investigation, but less reproducible compared with the previous ones. Renal duplex has high sensitivity and specificity in the diagnosis of significant renal artery stenosis; however, it does not provide precise morphological information and seldom allows direct visualisation of FMD lesions, in particular the pathognomonic string of beads.[9]

An accurate estimation of the prevalence of renal artery FMD depends on the possibility to screen patients with appropriate vascular imaging. Still, the optimal screening strategy remains to be determined. In the European expert Consensus,[2] screening for renal FMD is recommended in hypertensive patients, aged under 30 years, especially in women. However, in the first report from the US FMD registry, the mean age at diagnosis of FMD was 51.9 years,[4] in the ARCADIA study it was 53 years[5] and in the European/International registry it is currently 45.8 years.[11,12] Along the same lines, the mean age at hypertension diagnosis is 43.1 years in the US registry[4] and 36.5 years in the European/International registry,[11,12] which is substantially higher than the 30 years old cut-off proposed in the European consensus.[2] Secondly, while renal duplex remains the preferred screening modality, CTA or if contraindicated MRA, are recommended as first-line imaging in a number of situations including obesity, expected low echogenicity, high degree of renal FMD suspicion, very young age, malignant or complicated hypertension and/or increased plasma creatinine.[2] This may have led to an increased use of CTA/MRA as initial imaging tests. However, the impact of these changes in detection of renal FMD remains unsubstantiated.

Consequently, the primary aim of this work was to assess the prevalence of renal FMD in young/middle-aged hypertensive women according to age. The second aim was to evaluate temporal trends in prevalence of FMD according to different imaging modalities since the publication of the European FMD consensus in 2014.[2]

2 | MATERIALS AND METHODS

All consecutive women, aged between 18 and 50 years, referred for the first time to the Hypertension Consultation of the Cliniques Universitaires Saint-Luc, Brussels, Belgium, between January 2014 and December 2017 were considered for inclusion in the analysis. Patients with known or previously suspected diagnosis of FMD, referred for hypertensive disorders of pregnancy or for other clinical indications such as known secondary hypertension or orthostatic hypotension, were excluded.

Through the hospital informatic records, we retrospectively collected standardized data about age at first consultation, ethnicity, age at hypertension diagnosis, office blood pressure values, number of antihypertensive drugs classes, smoking habits, oral contraception, estimated glomerular filtration rate (eGFR) according to the Chronic Kidney Disease Epidemiology Collaboration equation (CDK-EPI),[13] body mass index, hypercholesterolaemia and type 2 diabetes mellitus. Finally, we collected data about the type and results of abdominal vascular imaging performed (renal duplex, CTA, MRA and catheter-based angiography of renal arteries). The diagnosis of renal FMD was confirmed based on the results of CTA, MRA and/or catheter-based angiography of renal arteries assessed by a vascular radiologist expert in FMD (FH),

according to the European expert consensus.[2] The diagnosis of multifocal FMD was based on pathognomonic 'string-of-beads' appearance, the alternating sequence, more or less marked, of arterial stenosis and dilation; the diagnosis of focal FMD was based on the presence of an isolated renal artery stenosis in the absence of atherosclerotic plaque, multiple vascular risk factors, inflammatory syndrome or vascular thickening, and familial or syndromic disease..[2] We preferred not to consider patients with focal stenosis localized at the ostia for the diagnosis of focal FMD, as the latter is difficult to differentiate from a localized atherosclerotic stenosis, and atherosclerosis is much more frequent than FMD.

We assessed the prevalence of FMD according to age and type of vascular imaging performed and analysed the main features of patients with and without FMD, as well as the evolution in frequency of different types of vascular imaging over time. Finally, we compared the main features of patients explored using different vascular imaging modalities, or not explored.

For the statistical analysis, we fixed the significance level at 0.05. Continuous variables normally distributed were described as mean and standard deviation and continuous variables non-normally distributed as median and interquartile range, while categorical variables were described as absolute number or fraction and percentage. We compared continuous variables normally distributed in multiple independent subgroups with the one-way ANOVA and continuous variables non-normally distributed with the Kruskal-Wallis test. We used the chi-square test to compare categorical variables. In case of figures <5 in two-dimensional contingency tables, we used Fisher's exact test. Statistical analysis was performed using R software version 3.2.2 (R Foundation for Statistical Computing, Vienna, Austria).

TABLE 1 Main characteristics of the overall population and of patient subgroups according to imaging modalities of renal arteries

	Overall population	No renal imaging	Renal duplex only	CTA/MRA	*P*-value
N°	157	47	43	67	
Age at first visit (years)	39.6 ± 8.6	40.4 ± 8.8	40.9 ± 8.1	38.1 ± 8.7	.71
Ethnic background					
Caucasian (%)	91/122 (74.6)	13/25 (52.0)	25/35 (71.4)	53/62 (85.5)	**.005**
Sub-Saharan Africa (%)	17/122 (14.0)	9/25 (36.0)	6/35 (17.1)	2/62 (3.2)	**.0001**
Maghreb (%)	7/122 (5.7)	3/25 (12.0)	3/35 (8.6)	1/62 (1.6)	.08
Other (%)	7/122 (5.7)	0	1/35 (2.9)	6/62 (9.7)	.22
Body mass index (Kg/m^2)	27.8 ± 6.1	29.7 ± 6.5	26.7 ± 1.7	27.1 ± 6.4	**.04**
Estimated glomerular filtration rate (CKD-EPI, mL/min/1.73m^2)	108.4 ± 40.1	123.1 ± 45.6	93.9 ± 35.7	110.6 ± 38.3	.56
Age at hypertension diagnosis (years)	35.3 ± 9.6	36.8 ± 8.9	37.5 ± 9.5	32.9 ± 9.8	**.02**
Systolic blood pressure (mm Hg)	145.2 ± 23.1	137.1 ± 22.5	146.8 ± 21.4	149.8 ± 23.4	**.005**
Diastolic blood pressure (mm Hg)	92.4 ± 13.5	89.8 ± 12.2	90.8 ± 12.0	95.3 ± 14.8	**.03**
Number of antihypertensive drugs	1 (0-2)	1 (0-2)	1 (0-2)	2 (1-2)	**.004**
Oral contraception					
Current (%)	50 (31.8)	9 (19.2)	13 (30.2)	28 (41.8)	**.04**
Previous (%)	5 (3.2)	1 (2.1)	2 (4.7)	2 (3.0)	.73
Smokers					
Current (%)	27 (17.2)	7 (14.9)	6 (14.0)	14 (20.9)	.57
Former (%)	27 (17.2)	9 (19.2)	9 (20.9)	9 (13.4)	.54
Type 2 diabetes mellitus (%)	8 (5.1)	1 (2.1)	2 (4.7)	5 (7.5)	.48
Hypercholesterolaemia (%)	41 (26.1)	9 (19.2)	15 (34.9)	17 (25.4)	.25

Note: Unless otherwise specified, data were computed on the total number of patients.

Abbreviations: CDK-EPI, Chronic Kidney Disease Epidemiology Collaboration equation[13]; CTA, Computed Tomographic Angiography; MRA, Magnetic Resonance Angiography.

TABLE 2 Use of different modalities of renal vascular imaging from 2014 to 2017

	2014 –2017	2014	2015	2016	2017	*P*-value
N°	110	35	23	26	26	
Type of imaging						
Renal duplex only (%)	43 (39.1)	20 (57.1)	9 (39.1)	10 (38.5)	4 (15.4)	**.01**
CTA and/or MRA ± renal duplex (%)	67 (60.9)	15 (42.9)	14 (60.9)	16 (61.5)	22 (84.6)	**.01**
Patients with newly diagnosed renal FMD (%)	5 (4.5)	0	1 (4.3)	2 (7.7)	2 (7.7)	.36

Note: The *P*-value refers to the comparison between the four years.
Abbreviations: CTA, Computed Tomographic Angiography; FMD, Fibromuscular Dysplasia; MRA, Magnetic Resonance Angiography.

TABLE 3 Prevalence of FMD in different subgroups according to age and imaging of renal arteries

	All hypertensive women	Imaging of renal arteries[a]	Screening by CTA and/or MRA
Age ≤ 50 y	5/157 (3.2)	5/110 (4.5)	5/67 (7.5)
Age ≤ 40 y	2/74 (2.8)	2/53 (3.7)	2/35 (5.7)
Age ≤ 30 y	1/32 (3.1)	1/25 (4.0)	1/18 (5.6)

Note: The percentage corresponding to the fraction is reported in parentheses.
Abbreviations:CTA, Computed Tomography Angiography; FMD, Fibromuscular Dysplasia; MRA, Magnetic Resonance Angiography.
[a]Imaging of renal arteries: renal duplex, Computed Tomography Angiography, Magnetic Resonance Angiography.

The study was approved by the Ethical Review Board of the Cliniques Universitaires Saint-Luc.

3 | RESULTS

One hundred fifty-seven out of 1083 new patients seen during the recruitment period met the inclusion criteria. For more details concerning patients' exclusion, see Figure S1. Seventy-five per cent of patients were Caucasian, and 14% were of sub-Saharan African origin. The mean age at first visit was 39.6 ± 8.6 years and the mean age at hypertension diagnosis 35.3 ± 9.6 years. Mean office blood pressure values were 145/92 ± 23/13 mm Hg, and the median number of antihypertensive drugs was 1 (0-2) (Table 1).

In 43 patients (27.4%), renal arteries were explored only with renal duplex. In 67 patients (42.7%), an abdominal CTA and/or MRA was performed as first-line screening test, alone or in parallel with renal duplex. Finally, renal arteries were not explored in 47 patients (29.9%) (Figure S1). Notably, over the years, the proportion of patients explored only with renal duplex decreased from 57.1% to 15.4% ($P = .01$), while the proportion of hypertensive women explored by CTA and/or MRA as first-line screening test, either alone or associated with renal duplex increased from 42.9% to 84.6% ($P = .01$) (Table 2). The main characteristics of subgroups explored by renal duplex, CTA/MRA or not explored for renal artery lesions are summarized in Table 1. While age at first consultation did not differ among groups, the proportion of patients from sub-Saharan Africa was significantly higher in the subgroup of patients with no renal artery screening compared to patients explored with renal duplex alone or abdominal CTA/MRA (twofold and more than tenfold, respectively). Furthermore, patients explored by CTA/MRA had earlier onset of hypertension, higher office blood pressure values and higher number of antihypertensive drugs in comparison with hypertensive women without renal vascular imaging or only renal duplex screening.

The prevalence of FMD was 3.2% (5/157) in the whole sample and 7.5% in the subgroup of 67 patients explored with at least CTA and/or MRA. The corresponding prevalences were 2.8% and 5.7% in the subgroup of patients aged ≤40 years at first consultation and 3.1% and 5.6% in the subgroup of patients aged ≤30 years, respectively (Table 3). The yearly prevalence of FMD detection tended to increase over time, in parallel with increased use of CTA/MRA as first-line diagnostic test (Table 2).

Overall, five patients were diagnosed with renal FMD. We report the main features of patients with and without FMD in Table S1, show the images of renal artery lesions in Figure 1, and the age at diagnosis of FMD and hypertension in FMD patients is compared with the age distribution of the whole population in Figure S2. P2 and P3 harboured a focal renal FMD: P2 had a pre-occlusive stenosis at 36 mm from the right renal artery ostium, treated with percutaneous transluminal renal angioplasty (PTRA); P3 had a 80% post-ostial stenosis of the right renal artery, also dilated with PTRA. P1, P4 and P5 harboured multifocal FMD: P1 had a mild stenosis of the anterior branch of the right renal artery; P4 had a multifocal FMD of the right main renal artery; P5 had multifocal FMD of the two branches of the right renal artery, more obvious in the inferior branch. While cervico-cephalic arteries were explored by CTA in all five patients, P5 was the only one harbouring extra-renal

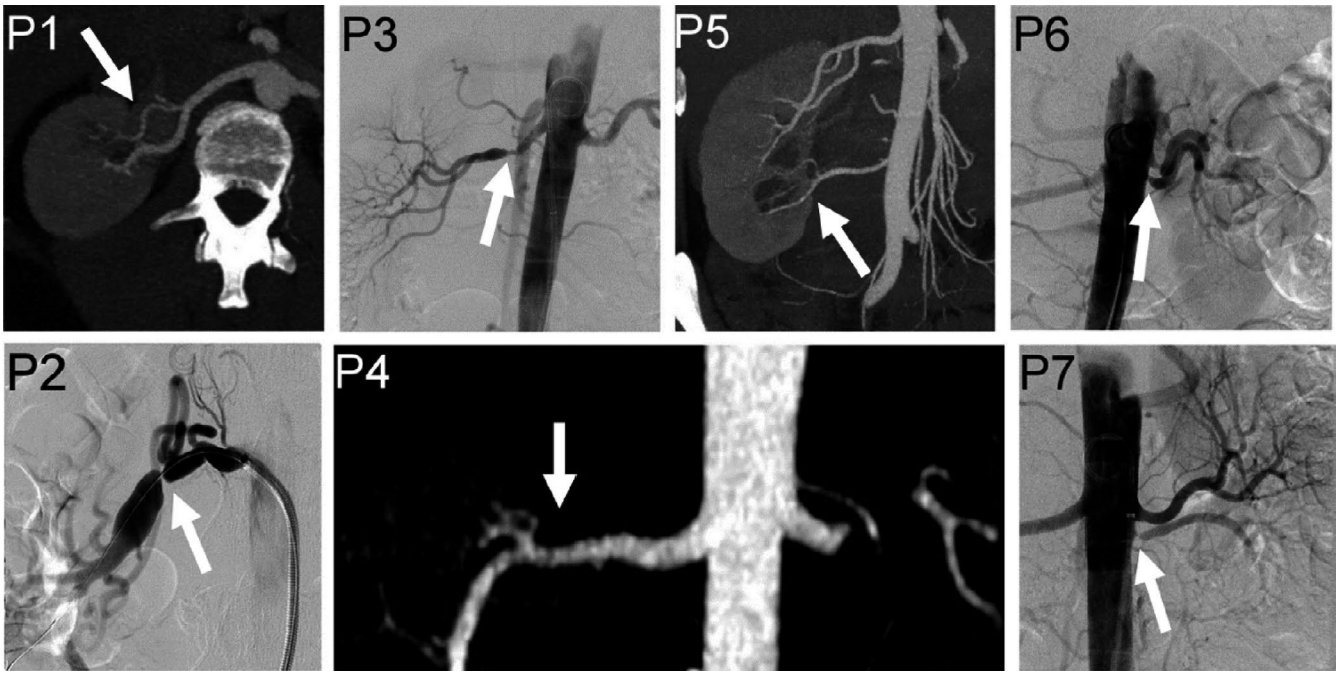
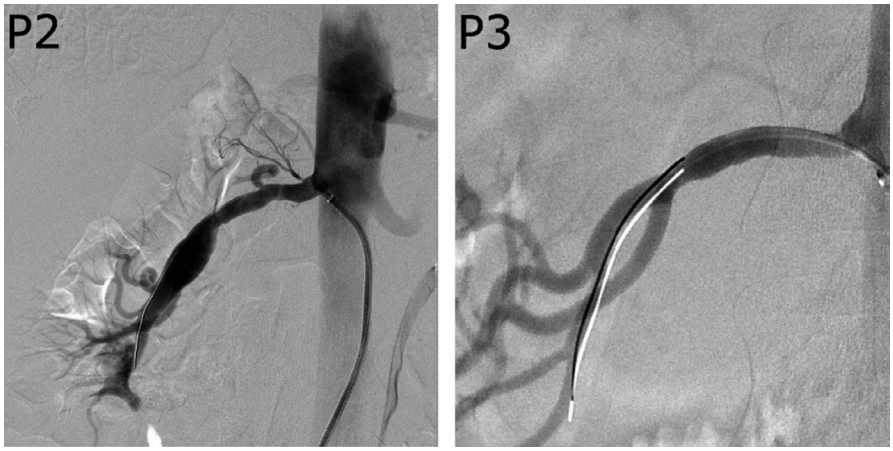


FIGURE 1 Images of renal artery lesions in FMD (P1, P2, P3, P4, P5) and non-FMD patients (P6, P7). Renal artery lesions were documented with Computed Tomographic Angiography (P1, P4, P5) and catheter-based angiography (P2, P3, P6, P7)

FIGURE 2 Arteriographic images of renal arteries of patients with focal FMD stenosis (P2, P3) after percutaneous transluminal renal angioplasty



FMD lesions. She was referred to the Hypertension consultation to optimize blood pressure control after carotid dissection recurrence: the first dissection occurred in 2011 and involved the left internal carotid artery. The patient already suffered from arterial hypertension, but surprisingly FMD had not been suspected. A recurrence involving the right internal carotid artery occurred in 2014.

Two additional patients, harbouring ostial stenosis of renal arteries, P6 and P7, were considered as likely having atherosclerotic renal artery stenosis. Both were diagnosed after 40 years (P7 at 50 years, the upper range of our selection). Both were active smokers at the time of the diagnosis. P7 had severe untreated hypercholesterolaemia. The main features of patients with renal artery lesions are shown in Table S2.

Arteriographic images of renal arteries of patients P2 and P3 after PTRA are shown in Figure 2. The endovascular interventions were not complicated, and eGFR remained stable and in the normal range. The blood pressure values during the follow-up after PTRA are reported in Figure S3. P2 could stop her first antihypertensive drug less than 2 months after PTRA and the second at 3 months. More than 3 years after the intervention, she remains normotensive in the absence of antihypertensive drug. P3 stopped one of her 3 antihypertensive drugs and decreased the dosage of the second within 4 months after PTRA. By the time of redaction of the current work, P3 had not yet completed the first year of follow-up.

4 | DISCUSSION

To our knowledge, this study is the first direct attempt to estimate the prevalence of renal FMD in young hypertensive women: 3.2% in the whole cohort, 4.5% in the subgroup

imaged for renal arteries and 7.5% in patients explored by CTA and/or MRA. Since the publication of the European FMD consensus,[2] the yearly prevalence of FMD increased from 0 to 7.7%, in parallel with a shift from renal duplex to CTA/MRA as first-line screening modality. Despite the limitations and potential biases of this retrospective analysis (academic centre with expertise in FMD and arterial hypertension, monocentric study), we feel that it is likely to provide a reasonable estimation of the prevalence of renal FMD in hypertensive women aged ≤50 years. Indeed, the proportion of grade 3 hypertension was low (12.7%). Furthermore, patients referred for established or suspected renal artery stenosis and/or FMD of any arterial bed (n = 16) were carefully excluded. It is tempting to speculate that the prevalence of FMD in this population is closer to 7.5% than 3.2%, because not all patients were explored for renal artery FMD, and in a substantial proportion, screening was limited to renal duplex, which is highly operator-dependent and has a limited sensitivity, especially for detection of non-hemodynamically relevant or peripheral FMD lesions.[2] On the other side, the choice to use CTA or MRA as first-line screening test, either alone or in parallel with renal duplex has obviously been influenced by the severity and age at onset of hypertension as well as by ethnic origin, Black patients and, to a lesser extent, patients from Maghreb being less often explored by state-of-the-art abdominal imaging. While this attitude may be justified by the high prevalence of low-renin essential hypertension in patients from sub-Saharan Africa,[14] it may also have been influenced by physician and patient preconceptions, socio-economic factors and communication problems. Whether such differential screening strategies are justified remains to be demonstrated, as patients diagnosed with renal FMD did not differ from the whole cohort in terms of age at diagnosis of hypertension or hypertension severity (Table S2), a lower age cut-off was not associated with a higher prevalence of FMD (Table 3), and the prevalence of renal FMD in non-Caucasian patients is not well known.

Overall, our data suggest that the prevalence of renal FMD in young hypertensive women has been substantially underestimated,[1] that limiting screening to patients ≤ 30 years old[2] when the mean age at diagnosis in current series and registries is over 50 years old[3,5,11] will lead to miss a substantial number of cases and finally that renal duplex has not enough sensitivity to detect all cases of renal FMD. In particular, in 2 out of 5 newly diagnosed patients with FMD reported in this study, renal duplex failed to detect FMD-related lesions. Does this mean that current recommendations[2] have to be updated and that all hypertensive women should be aggressively screened for renal FMD, at least up to 50 years? Not necessarily because, outside the context of research, identification of FMD lesions has limited interest if it does not influence the management of affected patients. In other words, a cost-effective screening strategy should aim at identifying in priority younger patients with FMD-related hemodynamically significant renal artery stenosis, who may benefit most from revascularisation[15] and patients with multivessel FMD, associated or not with aneurisms requiring close monitoring or intervention. Notably, in our cohort, only 2 out of 5 patients with FMD were deemed eligible for angioplasty, with subsequent blood pressure improvement and a third one suffered from recurrent carotid dissection before the diagnosis of FMD was made. Hence, while our study is a first step towards determination of the prevalence of renal FMD in hypertensive women ≤ 50 years old, the sample size and particularly the number of newly diagnosed cases of FMD are too low to assess the true benefits and cost-effectiveness of different screening strategies. As such, our study provides the *rationale* for a large, multicentre, prospective screening study including standardized imaging of renal arteries, both with renal duplex performed by experienced, dedicated ultrasonographers and with CTA/MRA. Only an extended follow-up would allow determining which patients eventually benefitted from the diagnosis of renal FMD and subsequently defining a truly evidence-based screening strategy. The development of large scale, highly standardized resources, such as the US[4] and European/International[16] FMD registries, the latter initiated by and predominantly composed of hypertension specialists should make this possible in the next years.

CONFLICT OF INTEREST

None declared.

AUTHORS' CONTRIBUTIONS

Silvia DI MONACO was involved in conception, design and analysis and interpretation of data; and drafting the article; Jean-Philippe LENGELÉ, Franco RABBIA and Marilucy LOPEZ-SUBLET provided intellectual content of critical importance to the work described and revised the article; Sheik HEENAYE and Laurent TOUBIANA were involved in conception, design and analysis and interpretation of data; Etienne DANSE and Frank HAMMER provided intellectual content of critical importance to the work described; Alexandre PERSU was involved in conception and design; analysis and interpretation of data; drafting and revising the article; and final approval of the version to be published.

ORCID

Alexandre Persu https://orcid.org/0000-0002-4007-9695

REFERENCES

1. Plouin P-F, Perdu J, La Batide-Alanore A, Boutouyrie P, Gimenez-Roqueplo A-P. Fibromuscular dysplasia. *Orphanet J Rare Dis*. 2007;2:28.

2. Persu A, Giavarini A, Touzé E, et al. European consensus on the diagnosis and management of fibromuscular dysplasia. *J Hypertens*. 2014;32:1367-1378.
3. Olin JW, Gornik HL, Bacharach JM, et al. Fibromuscular dysplasia: state of the science and critical unanswered questions: a scientific statement from the American Heart Association. *Circulation*. 2014;129:1048-1078.
4. Olin JW, Froehlich J, Gu X, et al. The United States Registry for Fibromuscular Dysplasia: results in the first 447 patients. *Circulation*. 2012;125:3182-3190.
5. Plouin P-F, Baguet J-P, Thony F, et al. High prevalence of multiple arterial bed lesions in patients with fibromuscular dysplasia: The ARCADIA Registry (Assessment of Renal and Cervical Artery Dysplasia). *Hypertens Dallas Tex*. 1979;2017(70):652-658.
6. Cragg AH, Smith TP, Thompson BH, et al. Incidental fibromuscular dysplasia in potential renal donors: long-term clinical follow-up. *Radiology*. 1989;172:145-147.
7. Blondin D, Lanzman R, Schellhammer F, et al. Fibromuscular dysplasia in living renal donors: still a challenge to computed tomographic angiography. *Eur J Radiol*. 2010;75:67-71.
8. Hendricks NJ, Matsumoto AH, Angle JF, et al. Is fibromuscular dysplasia underdiagnosed? A comparison of the prevalence of FMD seen in CORAL trial participants versus a single institution population of renal donor candidates. *Vasc Med*. 2014;19:363-367.
9. Lewis S, Kadian-Dodov D, Bansal A, Lookstein RA. Multimodality imaging of fibromuscular dysplasia. *Abdom Radiol NY*. 2016;41:2048-2060.
10. Bolen MA, Brinza E, Renapurkar RD, Kim E, Gornik HL. Screening CT angiography of the aorta, visceral branch vessels, and pelvic arteries in fibromuscular dysplasia. *JACC Cardiovasc Imaging*. 2017;10:554-561.
11. Di Monaco S, Azizi M, Aparicio LS, et al.ESH-Endorsed European/International Fibromuscular Dysplasia Registry: results of the first 609 patients. 28th European Meeting on Hypertension and Cardiovascular Prevention – European Society of Hypertension; Barcelona, 8th -11th June 2018 (abstract).
12. Van der Niepen P, van Tussenbroek F, Devos H, et al. Visceral fibromuscular dysplasia: from asymptomatic disorder to emergency. *Eur J Clin Invest*. 2018;48:e13023.
13. Levey AS, Stevens LA, Schmid CH, et al. A new equation to estimate glomerular filtration rate. *Ann Intern Med*. 2009;150:604-612.
14. Lemogoum D, Seedat YK, Mabadeje AF, et al. Recommendations for prevention, diagnosis and management of hypertension and cardiovascular risk factors in sub-Saharan Africa. *J Hypertens*. 2003;21:1993-2000.
15. Trinquart L, Mounier-Vehier C, Sapoval M, Gagnon N, Plouin P-F. Efficacy of revascularization for renal artery stenosis caused by fibromuscular dysplasia: a systematic review and a meta-analysis. *Hypertension*. 2010;56:525-532.
16. Persu A, Van der Niepen P, Touzé E, et al. Revisiting fibromuscular dysplasia: rationale of the European fibromuscular dysplasia initiative. *Hypertens Dallas Tex*. 1979;2016(68):832-839.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Di Monaco S, Lengelé J-P, Heenaye S, et al. Prevalence and characteristics of renal artery fibromuscular dysplasia in hypertensive women below 50 years old. *Eur J Clin Invest*. 2019;49:e13166. https://doi.org/10.1111/eci.13166