Diagnosis and management of fibromuscular dysplasia: an expert consensus

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Introduction

The prevalence of symptomatic renal fibromuscular dysplasia (FMD) in the general population is estimated to about 4/1000 and cervico-cephalic FMD is probably half as common as renal FMD. Renal FMD can lead to hypertension (HTN) and progressive renal atrophy [1]. Cervico-cephalic FMD can result in ischaemic or haemorrhagic stroke, cervical artery dissection and may be associated with intracerebral aneurysms, with risk of subarachnoid haemorrhage [2]. In some patients, the diagnosis of FMD can lead to invasive procedures such as percutaneous angioplasty, reconstructive surgery or intracranial aneurysm clipping. Thus, both the disease and its treatment can lead to significant morbidity [1].

Unfortunately, there are no specific guidelines for the diagnosis and treatment of FMD, which is at least partly explained by the absence of randomised clinical trials and, until recently [3], of systematic reviews or meta-analyses dealing with this condition, most of the evidence being derived from small and old cohorts and expert opinions.

This article is a summary of a recent ‘formalised expert consensus’ (extended version: see Data S1), developed by French and Belgian experts upon request of the French ‘Haute Autorité de la Santé’ (http://www.has-sante.fr). It includes recommendations for the definition, classification, diagnosis and management of FMD in adult patients (≥ 18 years) with symptomatic FMD of the renal arteries, supra-aortic trunks and digestive and peripheral arteries. The rationale underlying each recommendation is discussed, and the, usually low, grade of evidence [4] is indicated in square brackets.

Definition and classification

The medical subject headings (MeSH) definition of FMD is ‘an idiopathic, segmental, nonatheromatous disease of the musculature of arterial walls, leading to stenosis of small and medium-sized arteries. There is true proliferation of smooth muscle cells and fibrous tissue’.

Three main types of renal FMD have been identified according to the arterial wall layer that is mostly affected [5,6]:

1 Intimal FMD (about 10% of renal artery FMD cases) is characterised by irregularly distributed mesenchymal cells within a loose matrix of subendothelial connective tissue and a fragmented internal elastic lamina.
2 Medial FMD (80–90% of renal artery FMD) consists of homogeneous deposits of elastic tissue leading to multiple stenoses interspersed with aneurysmal segments, with a preserved, sometimes fragmented, internal elastic lamina.
3 Adventitial FMD (< 5% of adult renal artery FMD cases) involves hypertrophy of the connective tissue at the junction of the media and adventitia.

However, these categories are not mutually exclusive, as involvement of more than one layer in the same diseased artery is not uncommon [7]. Although these different subtypes were initially described in patients with renal FMD, similar lesions have been observed in patients with cervical or intracranial FMD [2].

Later on, Kincaid et al. [5] proposed an angiographic classification, based on the pathological–angiographic correlations found in 60 patients who underwent angiography and from whom pathological renal artery FMD specimens were obtained. Three angiographic types of renal artery FMD have been described: multifocal (‘string-of-beads’ appearance), unifocal (solitary stenosis < 1 cm in length) and tubular (stenosis at least 1 cm in length) (Fig. 1). As
the two last categories only differ by the length of the diseased segment, it was proposed to group them under the generic term unifocal [1].

The ‘string-of-beads’ aspect accounts for over 80% of cases, and its histological substrate is medial FMD [5]. It affects mainly women between 30 and 50 years old [1,8]. The lesions commonly involve the medium or distal thirds of the main renal artery, and there is often extension into the proximal portion of the first-level branches. Lesions are bilateral in 60% of cases [1]. Although the ‘string-of-beads’ appearance is almost pathognomonic of multifocal (medial) FMD, aspects of multifocal stenosis have been described following intoxication by sympathomimetic agents and ergotamine derivatives. Congenital aortic hypoplasia may also be associated with RAS, especially in children [9] and histological lesions similar to those of medial FMD may be observed on examination of renal arteries or even the aorta [10].

Unifocal FMD can be found at the ostium, the trunk or the bifurcation of the renal arteries. As this feature lacks specificity, the diagnosis can be established in young (usually < 40 year old) patients with no atherosclerosis or other less frequent diseases. The differential diagnosis of unifocal FMD includes compression of the proximal renal artery by the median arcuate ligament, Takayasu arteritis and other rare diseases (type 1 neurofibromatosis, vascular Ehlers–Danlos syndrome, Alagille syndrome, Williams syndrome, etc) [1].

As FMD-related RAS is now usually treated by percutaneous transluminal angioplasty (PTA) rather than surgery, histological verification is seldom available, and the angiographic classification has progressively replaced the histological classification.

The angiographic features of carotid and vertebral artery FMD are very similar to those described in renal FMD. However, atypical forms of FMD exist, with diaphragmatic stenoses because of intimal dysplasia at the origin of the internal carotid artery [2] (Fig. 2).

The diagnosis of multifocal FMD can be established when a ‘string-of-beads’ appearance is observed on a medium-sized artery, in the absence of aortic involvement or exposure to vasoconstrictor agents. This angiographic aspect is strongly correlated with medial FMD lesions on histological examination. The diagnosis of unifocal FMD can be established in young patients (usually < 40 years) in the absence of atherosclerotic plaque, multiple vascular risk factors, inflammatory syndrome or vascular thickening and familial or syndromic disease [11].

Screening and diagnosis

Screening

Renal artery FMD. The most common presentation of renal artery FMD is renovascular HTN. In the general population, the prevalence of this presentation is estimated to roughly 4/1000 [1]. The majority of patients are women between 15 and 50 years of age [8]. The AHA/ACC has proposed the following indications of RAS screening [4]:

Screening for FMD-related RAS is recommended in the following cases of HTN: occurrence at age < 30 years, accelerated, malignant, grade 3 (≥ 180/110 mmHg), refractory (blood pressure target not achieved despite tritherapy including a diuretic) or associated with a small kidney [IC].

However, these practice guidelines are only derived from an expert consensus and are not specific to FMD. In subjects aged

Figure 1 Angiographic classification of renal artery fibromuscular dysplasia (FMD). From left to right, ’string-of-beads’ appearance of multifocal FMD, unifocal FMD and tubular FMD (adapted from Plouin et al. [1]).
< 50 years, screening for FMD may also be considered in milder HTN cases.

**FMD of the cervico-cephalic arteries.** The frequency of symptomatic FMD of cervico-cephalic arteries is lower than that of renal FMD. The mean age at diagnosis in most series of patients with cervical FMD was over 50 years [2].

The presence of underlying FMD of the cervico-cephalic arteries should be considered in case of retinal or cerebral ischaemic events, intracranial aneurysms, subarachnoid haemorrhage, cervical or intracranial dissections, asymptomatic cervical bruit or pulsatile tinnitus [IC].

However, it should be kept in mind that none of these symptoms is specific of FMD. In particular, the existence of intracranial aneurysms is not sufficient to establish the diagnosis of FMD.

**FMD of other vascular territories.** Finally, FMD stenotic lesions of the mesenteric territory may cause nausea, digestive pain and weight loss. Several clinical cases describing severe forms have been reported [10,11]. Some cases of claudication of the upper or lower limbs have been associated with FMD in the subclavian or iliac arteries.

**Diagnosis**

**Renal artery FMD.**

*Echo-Doppler:* Echo-Doppler is inferior to MRI- and CT angiography for atherosclerotic [4,8] and FMD-related [8] lesions. Nevertheless, it allows detecting stenoses and measuring kidney height, is less expensive than CT-, MRI- or conventional angiography and is therefore a reasonable first-line screening technique.

When there is a clinical suspicion of RAS, echo-Doppler is recommended as the first-line screening test to detect renal artery stenosis or renal asymmetry. However, the results have to be confirmed by another imaging technique: (i) in the case of positive findings; (ii) in the case of negative results despite a high clinical suspicion [IIC].

*CT- and MRI angiography:* CT- and MRI angiography display a good specificity in detecting renal artery FMD [12,13], especially of the multifocal subtype [14], and are thus the recommended imaging techniques to confirm the diagnosis. They can also be considered as the first screening test when the results of echo-Doppler are expected to be suboptimal (obese patients, apnoea difficult or impossible), especially when the clinical suspicion is high (Fig. 3). However, they do not allow accurate quantification of the degree of stenosis. As a result of its higher spatial resolution, CT angiography is probably superior to MRI angiography, especially for the detection of FMD lesions limited to distal renal branches and/or segmental renal arteries and may thus be preferred. Nevertheless, systematic studies assessing the diagnostic performance of CT- or MRI angiography in multifocal FMD have yet to be conducted.
CT- and MRI angiography are the recommended imaging techniques to confirm the diagnosis of renal artery FMD. These techniques show good specificity in establishing the diagnosis, particularly for the ‘string-of-beads’ appearance, which is typical of the multifocal subtype. Nevertheless, they do not allow the degree of stenosis to be accurately estimated [IB].

Conventional angiography: As FMD is associated with spontaneous dissections [2], the per-procedure risk of dissection might be increased. However, as FMD lesions are usually distal, they are probably unaffected by diagnostic arteriography. Thus, in patients with FMD, the risk of the procedure is probably very low, at least in the absence of associated atherosclerotic lesions. Nevertheless, it is recommended to reserve arteriography for patients in whom performing a simultaneous revascularisation procedure is medically justified. Arteriography is also advised in the case of a high clinical suspicion of FMD-related stenosis, when the diagnosis remains uncertain after performing the noninvasive tests [1C].

FMD of the cervico-cephalic arteries. To the best of our knowledge, no study compared the performance of noninvasive tests with conventional angiography for the diagnosis of cervico-cephalic FMD. Echo-Doppler may reveal an irregular stenosis compatible with the diagnosis. However, CT- and MRI angiography are likely to perform better, especially because FMD usually affects the middle and distal portions of the carotid and vertebral arteries, which are less accessible to Echo-Doppler [8]. Moreover, CT and MRI have the advantage to allow the detection of associated intracranial aneurysms.

CT- and/or MRI angiography are the recommended techniques to establish the diagnosis of FMD of the cervico-cephalic arteries and to detect associated intracranial aneurysms [IIIC].

FMD of other vascular territories. In patients with mesenteric or limb ischaemia symptoms, involvement of mesenteric or limb arteries must be screened for using CT angiography or ultrasound [15]. Although this strategy was recommended for detecting atherosclerotic stenoses, it can logically be applied to the rarer cases in which dysplasia-induced stenosis is detected. In rare cases of FMD with limb ischaemia where the affected artery is superficial, echo-Doppler is the first-line imaging technique.

Diagnosis of significant stenosis

Renal artery FMD. Usually, revascularisation of FMD lesions is only considered if there are arguments in favour of a significant stenosis, i.e. a stenosis responsible for downstream ischaemia, stimulation of the renin angiotensin system and renovascular HTN. Although of the utmost practical importance, the diagnosis of significant renal artery stenosis in humans remains elusive.

The threshold proposed by the AHA to confirm the existence of a RAS is 60% [16] of diameter reduction, which corresponds to an 80% reduction in the luminal surface area. This applies to both atherosclerotic RAS and unifocal FMD-induced RAS, which are generally unifocal. By contrast, in multifocal FMD, assessment of luminal diameter reduction is imprecise because of the frequent absence of a healthy reference segment and the difficulty in visualising precisely and quantifying diaphrag-
matic stenoses. Furthermore, given a similar reduction in the luminal diameter, the haemodynamic obstacle may be aggravated by the length of the lesions and the presence of multiple diaphragms. The quantification of multifocal RAS is therefore notoriously difficult [5,8].

Several studies suggest that echo-Doppler velocimetric indexes, particularly acceleration time, may reliably predict the existence of a significant stenosis [17,18]. However, these studies included only few patients with FMD.

Renal scintigraphy and/or assessment of renin activity in renal veins before and after captopril are no more recommended in the assessment of RAS, in view of their poor performance in bilateral RAS [4], which is often the case for FMD [1]. Trans-stenotic gradient measurements may help to localise the haemodynamic obstacle. However, the significance of such measures is unclear owing to intrarenal resistances [19], which also depend on the duration of HTN and renal function. Indirect signs such as total lesion length, number of diaphragms or pseudo-aneurysms, the presence of collateral circulation or jet image, or small downstream kidney, may all be taken into account. However, these criteria are poorly defined and not based on consensus.

FMD of the cervico-cephalic arteries. A cervico-cephalic stenosis can be considered haemodynamically significant if it leads to downstream consequences. For atherosclerosis, a threshold of 70% is generally accepted [20]. As in atherosclerosis, techniques assessing cerebral perfusion, such as transcranial Doppler, MRI angiography or cerebral scintigraphy can be used. However, the prognostic value of potential abnormalities in the context of FMD has not been established.

Screening for FMD lesions of other territories

Fibromuscular dysplasia lesions most commonly involve the renal arteries and the extracranial portion of the cervico-cephalic arteries. Involvement of the mesenteric, axillary, iliac, hepatic, intracranial and, in a few cases, coronary arteries has also been reported. The frequency of lesions of different vascular beds in an old series from Zürich [21] and more recent series from Paris (P.-F. Plouin, personal communication) and Brussels [22] is indicated in Fig. 4. In these series, the prevalence of FMD lesions affecting two or more vascular beds was in the range of 16–28%. However, these figures are likely underestimated as exploration was not systematic in all vascular beds. As expected, the most frequent association was that of renal and cervico-cephalic FMD [21,22].

In addition to the usual angiographic features of supra-aortic FMD, patients with renal artery FMD often show abnormal echographic patterns at the common carotid artery, a site that is usually not affected by macroscopic FMD lesions [1,23]. This observation, made using high-resolution echotracking, suggests that arterial abnormalities without concomitant clinical or angiographic manifestations are common during the course of FMD.

In view of these elements, it appears appropriate to screen for cervico-cephalic FMD in patients with renal FMD and vice-versa, provided there are arguments that identification of lesions in the second vascular bed could modify management. In particular, in patients with renal artery FMD, screening for asymptomatic cervico-cephalic lesions may help to establish the diagnosis of FMD and may have practical implications in cases of intracranial aneurysm (see infra) or for the management of blood pressure in cases of severe stenotic cervico-cephalic lesions. Conversely, screening for renal FMD in hypertensive patients with cervico-cephalic FMD may lead to revascularisation of a significant FMD-related RAS.

In patients with renal artery FMD, it is recommended to screen for asymptomatic cervico-cephalic lesions, if there are arguments indicating that identification of lesions could modify management [IIC].

Patients with cervico-cephalic FMD who have HTN should be screened for renal FMD [IC].

Screening for intracranial aneurysms

Renal artery aneurysms were identified in four of 716 (0.6%) potential kidney donors, all four presenting with lesions suggestive of FMD; furthermore, 12 of 125 (9.6%) patients with symptomatic renal artery FMD also had renal artery aneurysms.
[1]. Similarly, the prevalence of intracranial aneurysms in patients with cervico-cephalic FMD was estimated to 5%–9.5% [24], i.e. higher than in the general population. An association between renal artery FMD and cerebral aneurysm was also documented [25]. However, there are no data on the prevalence of this association.

Algorithms for the treatment of unruptured intracranial aneurysms have been proposed, taking into account factors such as the size of the aneurysm and its location, as well as the patient’s preferences [26]. However, no study has been specifically devoted to the management of FMD-related aneurysms. The AHA guidelines nevertheless recommend that patients with cervico-cephalic FMD should be screened for intracranial aneurysms [4].

Patients with cervico-cephalic FMD should be screened for intracranial aneurysm if there are arguments indicating that the identification of intracranial aneurysm could modify management [IIC].

Screening for FMD in first-degree relatives
A retrospective analysis of 104 patients with renal artery FMD revealed that 11% had familial FMD, as documented by the detection of renal artery FMD lesions by arteriography in at least one other first-degree family member [27]. In cases of hereditary FMD, renal artery lesions were usually multifocal and more often bilateral compared with sporadic FMD cases. Conducting FMD screening among asymptomatic parents of a patient with established FMD remains a research topic. However, if the parent is symptomatic, i.e. if he/she presents precocious HTN or unexplained neurological symptoms, the notion of FMD within the family may provide an aetiological clue.

It is recommended to question a patient with FMD about precocious HTN, history of dissection, aneurysm or cerebral haemorrhage among his/her first-degree relatives. If there is a positive answer to at least one of these questions, the patient may inform the respective relative(s) about the possibility of hereditary FMD [IIC].

Treatment
To our knowledge, there are no published controlled studies comparing revascularisation to medical treatment only or revascularisation by PTA to surgical revascularisation in patients with FMD. Usually, revascularisation is only considered in cases of symptomatic FMD (renovascular HTN or documented renal atrophy for renal FMD, ischaemic symptoms for FMD of other vascular beds). In the absence of evidence-based recommendations, the best therapeutic option should be discussed within a multidisciplinary team including clinicians, interventional radiologists or cardiologists and vascular surgeons with considerable experience of FMD.

Revascularisation of FMD-related lesions is recommended only in cases of symptomatic FMD. The therapeutic decision should take into account the symptomatology, the nature and localisation of the lesions, the experience of the centre, as well as the age and preferences of the patient. It should be made by a multidisciplinary team with an extensive experience of the disease [IIC].

Renal artery FMD
By contrast with atherosclerotic RAS, recovery of HTN is fairly common following revascularisation of FMD-induced RAS (30–50% according to the definition of HTN) [3]. In addition, patients with FMD-induced RAS do not require any cardiovascular or renal prevention once the HTN has been cured. As shown by a recent meta-analysis [3], recovery rates are higher in younger subjects (Fig. 5), those with more recent onset of HTN and in unifocal FMD compared with multifocal FMD. Thus, in hypertensive patients with FMD-related RAS, revascularisation is usually proposed, especially if HTN is recent and in case of treatment failure. By contrast, in FMD without HTN and with normal renal function, the value of revascularisation has not been established [1,28]. However, if there is a downstream reduction in renal size exceeding 1 cm during two successive examinations (excluding a congenital asymmetry in kidney size), revascularisation may be justified [28].

In hypertensive patients with FMD-induced significant RAS, revascularisation is recommended if HTN is recent and in cases of treatment failure (drug resistance or intolerance). Even in the absence of HTN, revascularisation may also be considered if there is a downstream reduction in kidney size or deterioration in renal function [IC].

It is impossible to reliably compare the results of PTA and surgery because they are not performed in patients with simi-
lar characteristics. Furthermore, surgical revascularisation has been performed for a longer time than PTA revascularisation, and the assessment methods therefore also differ in series using PTA or surgery. PTA is proposed as a first-line therapy for patients with uni- or multifocal truncal FMD lesions, whereas surgery is proposed as the primary approach for patients with complex lesions of arterial bifurcation or branches, stenoses associated with aneurysms, or following PTA failure [4,8,29]. A second PTA may be attempted following PTA failure, but a third PTA is not recommended so as to prevent arterial trauma that could jeopardise surgical results [30].

In patients with significant RAS, the first-line revascularisation technique is PTA, whereas surgery is recommended only for patients with complex lesions of arterial bifurcation or branches, stenoses associated with aneurysms or in case of technical failure of PTA. In cases of restenosis following a first PTA procedure, a second dilatation is recommended. However, in cases of repeated PTA failure for the same lesion, surgical revascularisation should be preferred [IC].

**FMD of the cervico-cephalic arteries**
Fibromuscular dysplasia of the cervico-cephalic arteries has a good long-term prognosis and should thus not be considered as an indication of prophylactic surgery. The situation is more complex for symptomatic lesions. The risk of recurrence with medical treatment alone is probably low. Furthermore, the causal role of carotid FMD in the development of symptoms is difficult to establish in patients with embolic cardiopathy or concomitant atherosclerosis. However, certain symptoms, which are not threatening but debilitating, such as pulsatile tinnitus, may be considered as an indication of revascularisation. In conclusion, surgical indications are mainly based on individual decisions [2].

**It is recommended to revascularise only symptomatic carotid FMD lesions. The indication should take into account the symptoms, the lesions, the experience of each centre and the patient’s preferences [IC].**

**FMD of other territories**
Fibromuscular dysplasia lesions of other sites are rarely symptomatic. For symptomatic stenoses of digestive or limb arteries, the first-line treatment is usually PTA.

**Follow-up**

**In the absence of revascularisation**

**Renal artery FMD.** If revascularisation is not considered, because the stenosis is not deemed significant, the patient declines intervention or for other reasons, the duration of clinical (monthly BP measurements until target BP values are reached, then every 3 months) and biological (annual monitoring of creatinaemia) follow-up is indefinite, as for any HTN with renal involvement [31]. Slovut and Olin [8] also recommend annual ultrasound monitoring of kidney height. This may be especially useful in cases of bilateral or nonmedial FMD, which are more likely to progress [32,33]. In the latter, indefinite ultrasound monitoring is probably useful. Failing that, an annual surveillance over 2 years, reconverted in cases of BP or creatinine elevation, is acceptable.

If revascularisation does not seem justified in renal artery FMD patients with HTN, clinical (monthly BP measurements until target BP values are reached, then every 3 months) and biological (annual assessment of creatinaemia) monitoring is recommended [IC].
FMD of the cervico-cephalic arteries. In asymptomatic cervical and intracranial forms, an annual check of cervical and intracranial vessels (MRI angiography and echo-Doppler, followed by CT angiography if necessary) is recommended. In the absence of lesion progression, monitoring visits may be less frequent.

In the forms diagnosed after an ischaemic accident:

- a new arterial check is usually necessary approximately 3 months after diagnosis in cases of acute dissection;
- a new arterial check is indicated after 6 months, in the absence of acute dissection, and then annually;
- in the absence of lesion progression, monitoring visits may occur less frequently.

In symptomatic forms revealed by meningeal haemorrhage, no specific recommendations exist. Aneurysm follow-up options depend on the specific primary treatment implemented. Other FMD lesions are checked on an annual basis. In the absence of progression, monitoring visits may occur less frequently.

After revascularisation

Renal artery FMD. An early assessment at 1 month allows antihypertensive treatment to be adjusted, often by reducing doses or discontinuing treatment. As restenoses mostly occur within the first 6 months [34], an imaging assessment is performed within this time period, consisting of echo-Doppler in cases of trunk lesions and CT- or MRI angiography in cases of distal lesions. This check is performed before 6 months in cases of BP or plasma creatinine elevation. If the 6-month follow-up is satisfactory, subsequent monitoring is similar to that of FMD without significant stenosis.

Before and after revascularisation of FMD-related RAS, it is recommended to measure blood pressure and glomerular filtration rate at 1 month and to check renal imaging at 6 months, or earlier in case of BP or plasma creatinine elevation [IC].

Perspectives

The major aims of current research are to unravel the pathophysiological mechanisms of FMD. This includes seeking genes that predispose to this condition, more accurate assessments of the risk of disease progression in focal or multifocal FMD and in FMD affecting renal or extrarenal arteries, and improvements in the detection and quantification of renal artery stenosis [1]. Several projects exploring these topics are currently under way. Accordingly, an update of this consensus will be considered within 3–5 years. Leaflets for patients derived from these recommendations are also under preparation.

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Conflicts of interest

All authors provided a detailed conflict of interest statement to the French ‘Haute Autorité de la Santé’. However, none of them was related to the current topic.

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References


### Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Data S1.** Extended version of the expert consensus.

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