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The emerging role of multidetector row CT angiography in the diagnosis of cervical arterial dissection: preliminary study

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Abstract *Introduction:* Cervical artery dissection is an important cause of ischemic stroke, particularly in young patients. The diagnosis can be made with invasive catheter angiography or non-invasive imaging, either with MRI in conjunction with MR angiography (MRA) or CT angiography (CTA). Both modalities have been shown to have a high specificity and sensitivity. New developments such as multi-slice CTA (MSCTA) are emerging as an alternative methods for imaging the cervical and intracranial arteries. However, the contribution of modern MSCTA to carotid artery dissection has not been reported. *Methods:* We present a retrospective series of seven patients in whom both MSCTA and cervical axial T1 MRI and MRA were performed in the acute to subacute setting of internal carotid artery dissection. *Results:* Carotid artery dissection was identified in all seven patients by MSCTA. The combination of MRI and MRA identified dissection in five of the seven patients. Additionally, a pseudoaneurysm was identified by MSCTA that was missed by MRI and MRA. *Conclusion:* Our findings confirm that MSCTA is a complementary technique in comparison to cervical axial T1 MRI and cervical MRA for diagnosing carotid artery dissection, and at times may provide additional information that can impact patient management.

Keywords Carotid dissection · CT angiography · MR angiography

Introduction

Cervical artery dissection is a less common cause of ischemic stroke, representing approximately 2% of all cases [1]. In young patients with no or minimal risk factors for cerebrovascular atherosclerotic disease, dissections may account for up to 10–25% of ischemic strokes [2]. They can occur spontaneously, as a result of trauma or secondary to diseases of the arterial vasculature, such as Marfan syndrome and fibromuscular dysplasia (FMD) [1]. The natural history of cervical artery dissection in the majority of patients is benign [3], but persistent headache, pulsatile tinnitus, and devastating strokes are all well-recognized complications [4, 5]. The optimal non-invasive radiologic method for diagnosis of cervical artery dissection remains an important unresolved question. Cervical axial T1 MRI and cervical TOF MRA have shown high sensitivity and specificity, allowing clinicians to almost completely forego invasive conventional angiography [6]. A previous study of patients evaluated with helical CT without multidetectors showed very high specificity and sensitivity for making this diagnosis in the carotid artery [7]. With the development and the increasing application of modern multidetector CT techniques, the diagnostic potential of CTA has increased considerably. Multidetector row or multislice CT, and in particular, 16-detector row CT allows CT angiography of the carotid arteries to be performed with an increased coverage from the aortic arch to the circle of Willis, improved spatial resolution of less than 1 mm section thickness, shorter acquisition times of less than 15 s, and lower doses of contrast material [8]. Multislice CT angiography (MSCTA) is described now as a

good alternative method for peripheral vessels. However, there have been no previous reports of its accuracy in cases of carotid artery dissection and only one report of vertebral artery dissection [9].

We present here a retrospective series of patients with carotid artery dissection in which cervical MRA and cervical axial T1 MRI and MSCTA had been performed in the acute to subacute setting, to evaluate the findings each technique is able to demonstrate, and to determine if one technique is optimal.

Methods

We reviewed seven patients with a diagnosis of internal carotid artery (ICA) dissection who had both cervical TOF MRA/cervical axial T1 MRI and MSCTA performed as part of their evaluation. Intracranial MRI was performed on a 1.5-T magnet (Siemens Medical Solutions) utilizing T1, T2, FLAIR and diffusion-weighted sequences. Cervical TOF MRA was performed utilizing 2-D and 3-D TOF sequences, covering from just above the thoracic inlet to the skull base. The MIP (maximum intensity projection) reformatted images were directed to the carotid bifurcation. Both the axial source data and MIP reformations were reviewed. Axial fat-saturated (FS) T1-weighted images were also obtained. MSCTA was performed on a 16-slice CT scanner (Siemens Medical Solutions). A contrast agent bolus at a high injection rate (3.5–4.0 cm^3/s) was used. The scans were performed at a slice thickness of 1 mm at 0.7-mm intervals from the aortic arch to the circle of Willis and then reconstructed as 5-mm slices. The axial images as well as the MIP reformations were reviewed.

The images were reviewed by two independent examiners. They evaluated mural thickening, intimal flap, and intraluminal abnormalities. Mural thickening was noted on MRA when a semilunar hyperintensity on the FS T1-weighted images, consistent with a mural hematoma, was seen in conjunction with luminal narrowing [10]. On MSCTA, mural thickening included mural hematoma and eccentric luminal narrowing [7]. An intimal flap was defined as a band of abnormal signal traversing the vessel lumen, present on either MSCTA or MRI/MRA. Intraluminal signs included stenosis, aneurysm, or occlusion.

Approval for this study was obtained from the Institutional Review Board. The patients did not require informed consent as the studies represented part of their clinical evaluation and a retrospective waiver of consent was obtained for review of the images and charts. The entire study was HIPAA-compliant.

Results

In all seven patients ICA dissection was diagnosed on MSCTA. On MRI/TOF MRA, ICA dissection was diagnosed in five patients. The findings are summarized in Table 1. There were two patients in whom dissection was not diagnosed on MRI/MRA, but was diagnosed on MSCTA. One of those was patient 3 who had a left ICA occlusion (Fig. 1). Dissection was diagnosed on MSCTA by the presence of a tapered occlusion in a segment atypical for atherosclerosis, approximately 3 cm above the carotid bifurcation. The occlusion was seen on MR, but it appeared to be a short segment. In addition, a T1 hyperintense mural hematoma was not seen in the vessel wall and may have been obscured by the T1 hyperintensity of the occluded

Table 1 Clinical and imaging characteristics of the patients

Patient no.	Age (years)/ sex	Presenting symptoms	Intimal flap		Mural hematoma		Eccentric narrowing		Atypical segment		Occlusion		Time between studies
			MSCTA	MRI/ MRA	MSCTA	MRI/ MRA	MSCTA	MRI/ MRA	MSCTA	MRI/ MRA	MSCTA	MRI/ MRA	
1	49/M	Dysarthria	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	18 hours
2	58/M	Left Horner syndrome	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	36 hours[a]
3	38/M	Headache, transient dysarthria	No	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	3 hours
4	20/F	Left-sided weakness	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	14 hours
5	49/F	Left hand numbness	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	24 hours
6	66/M	Altered mental status	Yes	No	No	No	No	No	No	No	No	No	72 hours
7	35/M	Right neck pain	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	4 days

[a]Patient 2 is the only one to have had MSCTA before MRI/MRA

lumen. The second was patient 6 who had a history of surgery and radiation therapy for squamous cell carcinoma of the larynx. A left common carotid artery stent had been previously placed for presumed radiation stenosis. On MSCTA, an intimal flap was seen in the right common carotid artery compatible with dissection (Fig. 2). The intimal flap was not seen on the TOF MRA. Otherwise, there was no evidence of mural thickening/hematoma or eccentric narrowing on either MSCTA or TOF MRA.

MSCTA detected associated findings that were not readily apparent with the combination of cervical T1 MRI or TOF MRA. In patient 2, MSCTA detected a left ICA dissection with pseudoaneurysm (Fig. 3). The dissection was seen on cervical T1 MRI and TOF MRA, but the pseudoaneurysm was not seen. In patient 1, cervical T1 MRI and TOF MRA diagnosed right ICA occlusion whereas MSCTA demonstrated stenosis (Fig. 4). Right ICA dissection with stenosis, not occlusion, was confirmed on catheter angiography. Both of these additional findings seen on MSCTA had implications on the management of these patients.

Discussion

Our study demonstrates the complementary contribution of MSCTA to the diagnosis of carotid artery dissection, especially when associated findings were not readily apparent on cervical T1 MRI and TOF MRA. Cervical artery dissection is usually suspected on clinical grounds, but when attempting to make a radiologic diagnosis, there are important practical considerations in choosing an imaging modality. Catheter digital subtraction angiography (DSA) is widely regarded as the gold standard in the diagnosis of cerebrovascular disease. But this technique is invasive, limiting its use in clinical practice. Non-invasive techniques such as cervical T1 MRI and cervical TOF MRA or CTA have been suggested as an alternative to conventional angiography with similar sensitivity and specificity. The single-section helical CT appearance of cervical artery dissection has been reported previously [6, 7, 11], but to our knowledge the usefulness of MSCTA for the diagnosis of carotid artery dissection has not been previously reported. The recently developed multidetector row CT scanners allow performance of CT angiography of the carotid arteries with increased coverage from the aortic arch to the circle of Willis, improved spatial resolution, and shorter acquisition times. In addition, this makes MSCTA much less sensitive to motion artifact. MSCTA also has the important practical advantage of wider availability, particularly in the emergency setting.

Mural thickening/hematoma

Regardless of the technique employed, identifying mural thickening with an irregular and/or stenotic lumen is essential. In cervical artery dissection, arterial luminal irregularities are the features most commonly identified with CTA [7, 10, 12]. Even though hematoma detection is highly accessible when MRA includes a cervical axial fat-saturation sequence [13], MR findings may be nonspecific or absent and this is a situation in which MSCTA may be superior. Visualization of the mural hematoma can be problematic in certain circumstances that cause T1 hyperintensity within the vessel. Complete hyperintense signal in the artery can lead to confusion between the mural hematoma and thrombus in the true arterial lumen, making it more difficult to separate hematoma from hyperintense vessel occlusion. Moreover, if the diagnosis is suspected at a very early stage, within the first few days after the clinical onset, helical CT might theoretically be superior to MRI,

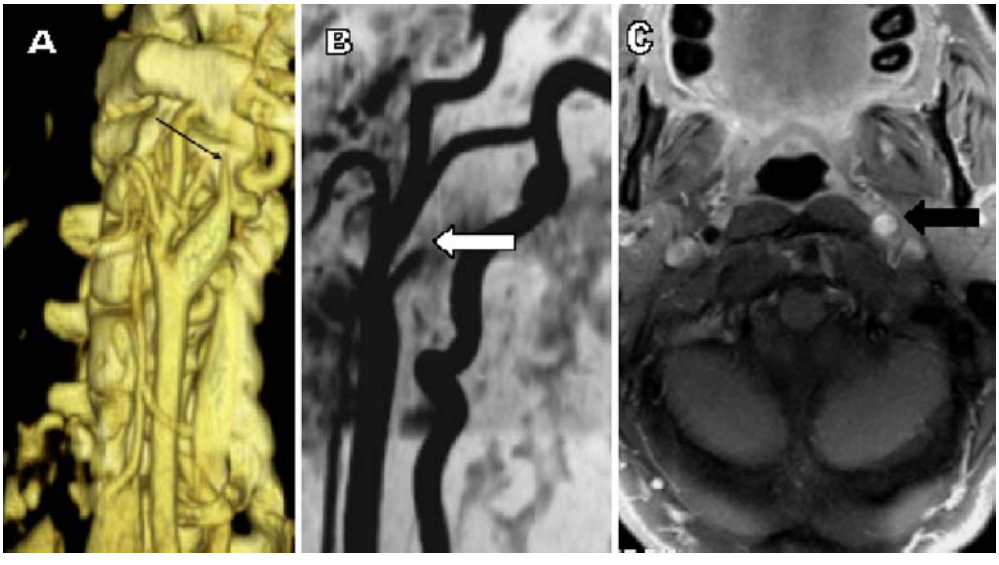

Fig. 1 **a** 3-D reformatted MSCTA image from patient 3 demonstrates a long tapered occlusion of the left ICA (*arrow*) suggesting dissection. **b** MIP MRA image shows abrupt occlusion of the left ICA (*arrow*). **c** Axial T1 fat-saturated image demonstrates complete occlusion with T1 hyperintensity of the left ICA involving both the lumen and the vessel wall (*arrow*)

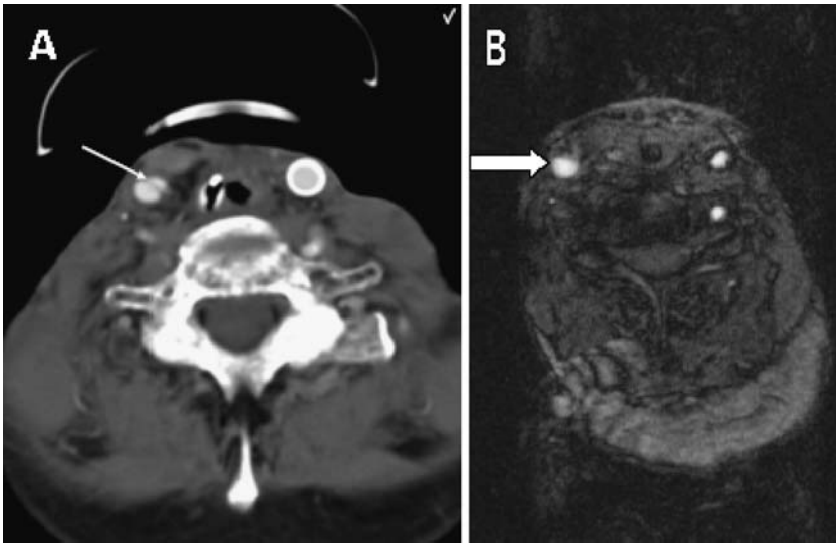

Fig. 2 **a** Axial MSCTA image from patient 6 demonstrates an intimal flap in the right ICA consistent with dissection (*arrow*). **b** The intimal flap is not seen on the axial TOF MRA image at the same level (*arrow*). The right vertebral artery is poorly visualized for two reasons. It is congenitally small and it is being visualized at the point when it is horizontal to the axial plane as it swings into the transverse foramen. Thus, it is above or below the plane of section

since a fresh hematoma appears isointense or slightly hyperintense on MRI. Two such examples of difficulty in accurately identifying the mural hematoma were present in our series. The first was in the setting of vessel occlusion. In this case, T1 hyperintensity secondary to intraluminal occlusion obscured visualization of the mural hematoma which is most often seen as T1 hyperintensity in the vessel wall (Fig. 1). Direct MR imaging of the vessel wall represents a promising advance in the identification of the mural hematoma. This technique has been applied to accurately characterize the components of carotid atherosclerotic plaques [14]. However, it would also be subject to the same difficulties in arteries that are completely occluded as the signal from the lumen and hematoma may be indistinguishable, particularly if dissection extends through the vessel wall and the hematoma is on the endothelial surface of the vessel. The second example of difficulty with hematoma detection was related to the flow-related changes in tortuous vessels causing a false hyperintense signal along the vessel wall [15]. This is known to occur commonly in the carotid siphon, as is demonstrated in the right ICA in patient 2. The MRI (see Fig. 5) had a flow-related hyperintensity in the right carotid siphon that is similar in appearance to the mural hematoma in the left ICA. The axial MSCTA image demonstrated definite mural thickening on the left with eccentric luminal narrowing compatible with dissection. The right carotid artery was normal on MSCTA without evidence of dissection. In these circumstances, MSCTA can be particularly useful; recent evidence suggests that MSCTA may be superior to DSA in diagnosing dissection, possibly due to its better visualization of the blood vessel wall [11, 16]. However, mural thickening is not specific and can be observed in non-dissected vessels, in patients with physical inactivity, abdominal adiposity, abnormal glucose metabolism, or atherosclerotic disease. The search for associated

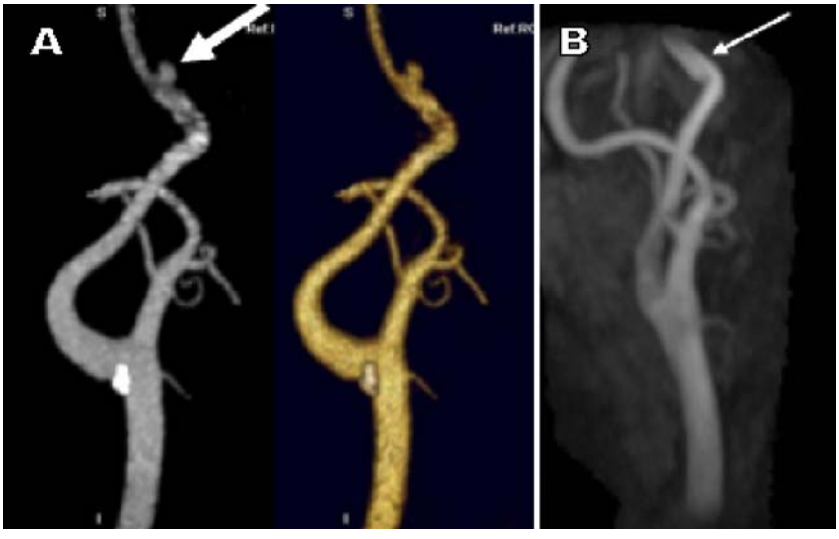

Fig. 3 **a** 3-D reformatted MSCTA image from patient 2 demonstrates pseudoaneurysm in the left ICA (*arrow*). **b** The pseudoaneurysm is not seen on the MIP image from the TOF MRA (*arrow*)

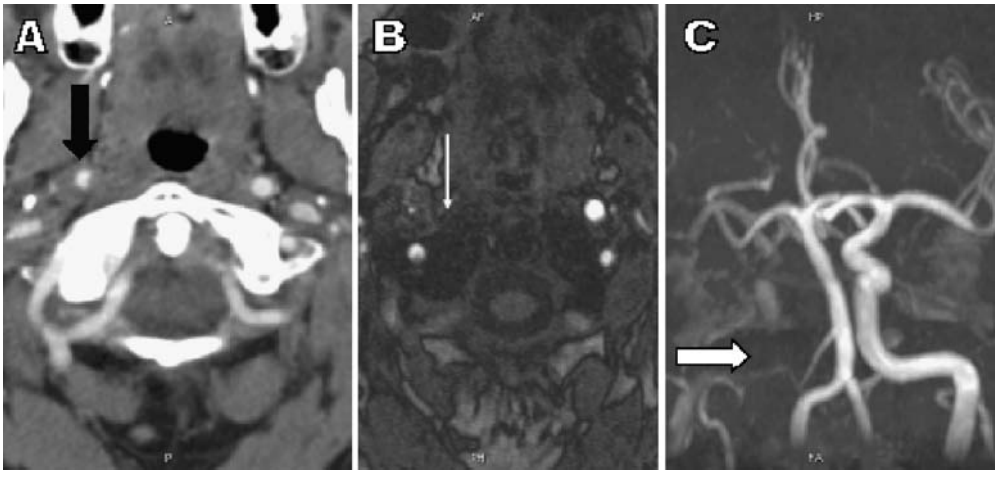

Fig. 4 **a** In patient 1, axial MSCTA image demonstrates mural hematoma and an eccentrically narrowed but patent lumen (*arrow*). **b**, **c** Axial (**b**) and MIP (**c**) TOF MRA images show absence of signal in the right ICA (*small and large arrows*, respectively), indicating an advantage of MSCTA over TOF MRA

signs such as an intimal flap and intraluminal abnormalities is important.

Intraluminal stenosis/occlusion and pseudoaneurysm

Different intraluminal appearances can be seen in cervical artery dissection. In the acute phase, tapered long stenosis is seen in 50% of patients. The alternating segments of stenosis followed by dilated segments and the formation of pseudoaneurysms is encountered in 30% of patients [17]. Occlusive lesions are observed in 20% of patients with a fusiform appearance. Near complete occlusions and pseudoaneurysms, both of which are typified by slow arterial flow, are more optimally demonstrated by MSCTA than TOF MRA. The flow-dependent limitation of TOF MRA has been well described in studies of carotid stenosis [18] in which it may not be sensitive to slow flow in stenotic segments. One might expect that this limitation applies to cervical artery dissection as either an overestimation of stenosis as complete occlusion (patient 1) or by not demonstrating a pseudoaneurysm (patient 2). Both of these findings have clinical relevance. If a pseudoaneurysm is identified and the patient is persistently symptomatic, endovascular intervention may be indicated. The presence of occlusion rather than luminal stenosis may dissuade a clinician from anticoagulation therapy, which is the typical medical therapy for cervical artery dissection. The basic imaging principles of the techniques are the primary reason why different information is obtained via the two methods. MSCTA uses intravascular contrast material making it a true angiographic study. TOF MRA images are dependent on the flow of ferromagnetic particles through the vasculature [19]. In contrast to TOF sequences, gadolinium-enhanced MRA (as an adjunct to MRI) is akin to MSCTA, and preliminary studies in vertebral dissection support its use in the follow-up these patients who often have slow/turbulent flow lesions with intraluminal stenosis [20]. However, it is important to remember that the isolated visualization of these intraluminal signs is not specific for dissection and may be observed in other circumstances.

Intimal flap

The less common but pathognomonic intimal flap or double arterial lumen is demonstrated in only approxi-

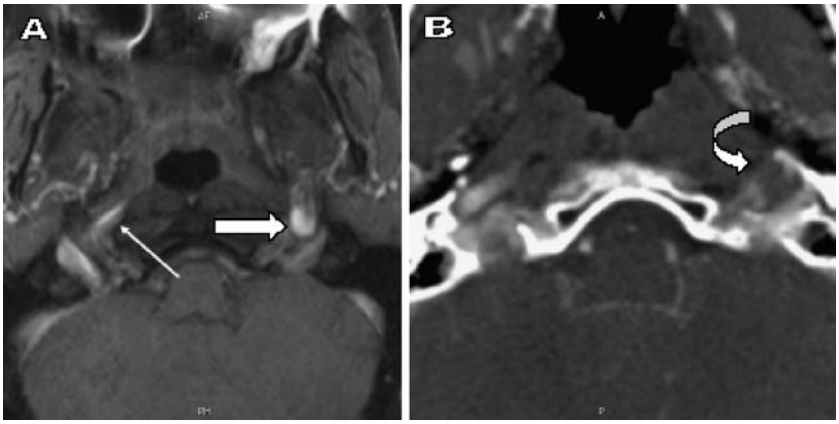

Fig. 5 **a** Axial fat-saturated T1-weighted image demonstrates a hyperintense mural hematoma in the left ICA (*large arrow*). However there is also T1 hyperintensity in the right ICA (*small arrow*), which may be related to flow or hematoma. **b** Axial image from MSCTA demonstrates mural hematoma and eccentric luminal narrowing in the left ICA (*curved arrow*)

mately 10% of conventional angiograms in patients with cervical arterial dissection [1]. Studies of aortic dissection with MSCTA reliably identify the pathognomonic intimal flap/membrane [21], and this modality has been suggested as the new gold standard examination in the place of DSA—in part because of its superior visualization of the vessel wall [22]. Additionally, the visualization of a dissected membrane in the vessel wall distinguishes a dissection from an intramural hematoma adjacent to a ruptured atherosclerotic plaque or from any other process that may make the vessel appear thicker than normal. The presence of a flap may be the only demonstrable evidence of dissection. In patient 6 (see Table 1), the diagnosis of dissection was made by demonstrating an intimal flap on MSCTA, as no other intravascular or mural abnormalities were identified with either modality. The advantage of 16-detector row examinations compared to cervical T1 MRI in concert with cervical TOF MRA in identifying this subtle finding is likely related to both the faster acquisition time and higher spatial resolution of the images translating into a minimal motion artifact [23]. MSCTA is also likely to outperform contrast-enhanced MRA in identifying small intimal flaps because MRA has a very wide field of view (with lower spatial resolution) and its acquisition is in the sagittal plane.

We recognize that there is an inherent bias in retrospectively reviewing this series of cases from our institution in which both studies were performed. The fact that both studies were performed indicates that these were somewhat complicated or problematic cases. This does not prove that MSCTA would perform better prospectively in routine cases. These cases do demonstrate that MSCTA and MRI in conjunction with TOF MRA are not interchangeable with regard to the information they provide despite their independently reported high specificity and sensitivity in diagnosing cervical artery dissection. Moreover, it is not always possible to obtain both of these tests, as MSCTA is relatively contraindicated in patients with contrast agent allergy and renal insufficiency, and MRI has relative and absolute contraindications such as the presence of a pacemaker.

In conclusion, our study suggests that MSCTA plays a complementary role in the diagnosis of cervical artery dissection, and in some instances provides clinically significant information not obtained by cervical TI MRI and TOF MRA. This is due in large part to its true angiographic nature. Additionally, MSCTA appears better suited for the diagnosis of carotid artery dissection in patients with an intimal flap associated with intraluminal abnormalities. A prospective comparison of cervical T1 MRI and MRA with gadolinium or MSCTA is necessary to determine the optimal modality for the radiologic diagnosis of cervical artery dissection.

Conflict of interest statement We declare that we have no conflict of interest.

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