Eponyms in medicine revisited

Moyamoya disease

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Summary

Moyamoya disease is a rare cerebrovascular condition of uncertain aetiology commonly affecting young persons. The disease is mainly seen in Japanese patients. We report two cases of moyamoya disease in Caucasian women and review the postulated aetiological factors and associated conditions as well as the spectrum of invasive and non-invasive imaging modalities useful in the diagnosis and follow-up of the disease, with particular reference to the developing role of magnetic resonance imaging and angiography.

Keywords: moyamoya disease, cerebrovascular disease, magnetic resonance

Moyamoya disease

Clinical features in children

- cerebral ischaemia
- recurrent transient ischaemic attacks
- sensorimotor paralysis
- convulsions

Clinical features in adults

- intracranial haemorrhage
- cerebral infarction

Associated features

- head and neck infection
- tonsillitis, sinusitis, basal meningitis
- tuberculous meningitis
- neurofibromatosis
- tuberous sclerosis
- circle of Willis aneurysms

Box 1

Moyamoya disease: diagnostic tests

- digital subtraction angiography
- CT (including spiral CT)
- MRI
- MRA and 3D time-of-flight MRA

Box 2

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Moyamoya disease is a rare disease first described in the 1960s.¹ It is seen mainly in Japan and has rarely been reported in Caucasians, though clinical experience would indicate that it is probably more common than the literature suggests. It has a peak incidence in childhood and early adolescence, females being more commonly affected than males. In paediatric cases the most common presentation is recurrent episodes of cerebral ischaemia manifesting clinically as hemiplegia, monoplegia, paraesthesia, involuntary movements and convulsions. Symptoms are usually preceded by transient ischaemic attacks which are occasionally provoked by hyperventilation. Mental retardation may also be present and is usually a consequence of the disease rather than a true association. In adults, the presenting features are usually those of intracranial haemorrhage, and occasionally cerebral infarction without evidence of haemorrhage.³ Although in one of the original reviews by Suzuki *et al*,² subarachnoid haemorrhage was described as the main site of bleeding, computed tomography (CT) has now revealed that haemorrhage is primarily intracerebral with secondary intraventricular extension.

Aetiology

The aetiology of moyamoya disease is unknown, although the disease has been associated with a history of tonsillitis, sinusitis, otitis media or basal meningitis, including tuberculous and leptospiral meningitis.⁴ The association of moyamoya phenomena with bacterial infection of the head and neck has been extensively investigated and it is thought that inflammation involving the extensive sympathetic innervation around the internal carotid artery induces the pathological angiogenesis which results in the characteristic angiographical features seen. Appearances similar to moyamoya have been described in radiation-induced cerebral vasculopathy.⁵ Anecdotal reports describing the association of moyamoya with concurrent renovascular disease, circle-of-Willis aneurysms and cerebral arteriovenous malformations are also present in the literature. Other associations include neurofibromatosis, peri-arteritis nodosa, atherosclerosis, sickle cell disease, Down's syndrome, tuberous sclerosis and Fanconi's anaemia.⁴ A genetic basis for the disease with a familial occurrence of 7% has been described and the condition has also been reported in identical twins.⁶ Most of these associations are, however, anecdotal and the vast majority of cases are sporadic and there are no associations normally. It has been proposed that the term *moyamoya disease* should be reserved for idiopathic cases and *moyamoya syndrome* where the underlying condition is known.⁷

Diagnosis

ARTERIOGRAPHY

Arteriography has traditionally been regarded as essential for a definite diagnosis of moyamoya disease. The findings include narrowing or occlusion of the supraclinoid portion of the internal carotid artery as well as the stems of the anterior cerebral arteries and middle cerebral arteries. Involvement is usually bilateral. Chronic ischaemia leads to the development of extensive collateral vessels, resulting in the characteristic *moyamoya* (literally Japanese for 'puff of smoke') appearance at the base of the brain. These collaterals involve the thalamoperforate, anterior and posterior choroidal, lenticulostriate arteries and transdural external to internal carotid anastomoses from the middle meningeal, internal maxillary and other branches of the external carotid artery.²

It is now considered that the main feature of the disease is the progressive occlusion of the intracranial internal carotid arteries and to a lesser degree the proximal anterior and middle cerebral arteries. The formation of the characteristic moyamoya 'leash' of vessels is a secondary process, induced by the chronic ischaemia.

Arteriography is not without risk and carries an appreciable morbidity and mortality, particularly when performed on acutely ill patients. The search for

safer, less invasive modalities of investigation has led to the evaluation of the usefulness of CT and more recently, magnetic resonance imaging (MRI) in the diagnosis of moyamoya.

COMPUTED TOMOGRAPHY

The CT appearances of moyamoya disease are nonspecific and include the presence of cerebral cortical atrophy, most commonly of the frontal lobes, multiple infarcts, and intracranial haemorrhage. The abnormal parenchymal collateral vessels are visible as multiple serpiginous low attenuation areas in the basal ganglia which enhance after injection of intravenous contrast medium. The appearances are very suggestive, but do not provide conclusive evidence of moyamoya disease.^{3,8}

Helical (spiral) CT techniques permit rapid sequential scanning of the neck vessels, circle of Willis and proximal intracranial branches to be performed during a timed bolus injection of intravenous contrast, providing maximum vascular delineation. Using these techniques attempts have been made to demonstrate moyamoya changes in the intracranial vessels. Although CT detail is less than that for conventional angiography, it has been claimed that sufficient information can be obtained with this less invasive technique to enable a firm diagnosis to be made.⁹ Although striking 3D images of the circle of Willis and proximal intracranial cerebral branches can be produced using spiral CT techniques, this entails a significant amount of ionising radiation to the brain, particularly the orbits, and with the availability of MRI, CT should not be used as the primary investigative modality.

MAGNETIC RESONANCE IMAGING

MRI combines the advantages of a noninvasive and non-radiation-dependent imaging modality with excellent grey/white matter differentiation and, with the increase in its availability, it has often become the first-line imaging modality in neurological disease.

The utility of magnetic resonance in the diagnosis and follow-up of moyamoya disease has only been recently investigated.¹⁰ Hasuo *et al*¹¹ commented that most of the angiographic features of the disease, including the narrowing and occlusion of the internal carotid artery, dilated pericallosal collaterals and the parenchymal changes secondary to the arterial occlusion were all visible using standard spin-echo techniques. Imaging in the coronal plane is especially useful for showing the basal ganglia collateral vessels.¹²

An additional advantage over CT is the ability of MRI to demonstrate neck and intracranial vessels without the need of potentially toxic intravenous contrast medium.

In a study that did not include magnetic resonance angiography (MRA), Fujisawa *et al*¹⁰ concluded that, when MRI is compared to conventional

Case report 1

A 52-year-old previously fit Caucasian woman was admitted with acute onset of severe bitemporal headache followed by a left hemiplegia. CT revealed large bilateral intraventricular haemorrhages (figure 1). There was no visible intracerebral extension of the haemorrhage. Cerebral angiography showed narrowing of the terminal portions of the right and left internal carotid artery and the left vertebral artery, with formation of extensive abnormal collateral vessels in the base of the brain (figure 2). The remaining intracranial vessels were normal. A diagnosis of moyamoya disease was made. The patient was treated conservatively with gradual clinical improvement

Figure 1 Axial unenhanced CT scan of brain showing large bilateral fresh intraventricular haemorrhages. Note absence of mass effect or midline shift and no intracerebral haematoma

Figure 2 Selective intra-arterial digital subtraction angiogram (lateral projection) of the right internal carotid artery showing replacement of the supraclinoid portion with extensive collateral moyamoya vessels resulting in the characteristic 'puff of smoke' appearance. Note the large collaterals anteriorly (arrow)

Case report 2

A 17-year-old Caucasian woman presented with recurrent cerebral ischaemic episodes over a two-year period. MRI revealed numerous infarcts in the right parietal and occipital cortex and smaller lacunes in the frontal white matter bilaterally. Coronal images showed low intensity serpiginous areas in both basal ganglia, characteristic of extensive moyamoya collaterals (figure 3). Time-of-flight MRA confirmed the presence of abnormal collateral vessels in the basal ganglia and the absence of significant flow in either right or left middle cerebral artery or the anterior cerebral artery (figures 4, 5), enabling a diagnosis of moyamoya to be made. Conventional angiography confirmed the replacement of both left and right middle and anterior cerebral arteries with the characteristic 'rete' of abnormal collaterals

Figure 3 Coronal T1-weighted MRI (TR/TE 600/15) showing multiple serpiginous low signal areas in the right basal ganglia due to the extensive moyamoya collaterals (arrow)

Figure 4 3D Time-of-flight MRA source image demonstrating flow within the basal ganglia collaterals (arrow). Note the poor flow within the terminal branches of the middle cerebral artery

Figure 5 3D Time-of-flight MRA projection image showing the absence of normal flow in the middle cerebral arteries and anterior cerebral arteries. There is a clear demonstration of abnormal flow within the basal ganglia collaterals, the moyamoya 'puff of smoke' appearance

arteriography, the diagnosis of moyamoya can be made on MRI in all the angiographically definite cases, while useful information can be inferred in angiographically probable cases. MRI has been proposed as the first-line investigation in cases of suspected moyamoya disease,¹⁰ thus obviating the use of invasive cerebral angiography which is associated with a high frequency of potentially serious complications.^{12,13}

Yamada *et al*¹⁴ assessed the utility of 3D time-of-flight MRA in 12 moyamoya cases and demonstrated occlusion or stenosis of the supraclinoid portion of the internal carotid artery and the proximal anterior cerebral arteries and middle cerebral arteries in all cases. Correlation of up to 80% with angiographic findings was possible in these major arteries and delineation of moyamoya vessels in the basal ganglia occurred in 75% of cases. In a similar study, Houkin *et al*¹⁵ conclude that MRI and MRA provide sufficient diagnostic information for a firm diagnosis to be made of moyamoya disease during screening of relatives with the disease, with results comparable to conventional invasive diagnostic techniques. In both studies, the authors stress that interpretation of the MRA findings has to be made with caution, however, particularly in early and late stages of the disease, because of the possibility of errors of overestimation of the disease severity on the MRA images. Current MR techniques are not capable of duplicating all the information available on conventional angiography. The use of intravenous MR contrast enhancement improves visualisation of smaller, more peripheral vessels. MRI is, however, capable of providing more information than CT. The brain parenchymal changes visible on CT are detectable at an earlier stage using MRI, even without the use of MRA. MRI is more sensitive than CT in demonstrating the moyamoya vessels in the basal ganglia and the deeper parts of the cerebral hemispheres.¹¹

Noninvasive MRI and MRA techniques are particularly well suited as a first-line management diagnostic modality in children. Several studies^{15,16} have shown that both modalities show primary abnormalities in the distal carotid vessels and around the circle of Willis, as well as the presence of moyamoya vessels, in most of the patients observed.

Treatment – mainly surgical

- only of clinical benefit in paediatric cases
- superficial temporal to middle cerebral artery anastomosis
- encephaloduroarteriosynangiosis
- encephalomyosynangiosis

Box 3

Prognosis

- significantly higher mortality for adults (10% *vs* 4.3%)
- death usually due to haemorrhage
- 50–60% have gradual deterioration of cognitive function

Box 4

Treatment

Various surgical revascularisation options have been described in the management of moyamoya disease.¹⁷ These are primarily of use in paediatric moyamoya disease since the principal feature is that of cerebral ischaemia. Surgery is of unproven benefit in adults, although the prevention of recurrent haemorrhage by delaying the development of the delicate moyamoya vessels with early revascularization techniques is theoretically advantageous.

The natural history of moyamoya disease is not fully established but adult presentation generally carries a better prognosis (box 4).¹⁸ Most symptoms are transient and remission generally occurs. Patients usually succumb to the disease due to intracranial haemorrhage.

Conclusion

MRI is a safe, noninvasive imaging modality, suitable for both diagnosis and follow-up of moyamoya disease, particularly in paediatric cases. The addition of 3D time-of-flight MRA further enhances the value of MR imaging. The combined use of MRI and MRA should suffice as the only investigations necessary to establish a diagnosis of moyamoya disease in most cases without the need for more invasive and potentially hazardous conventional arteriography. The latter should be reserved for patients in whom more detail of the intracranial vascular anatomy is required, prior to revascularisation surgery.

- 1 Nishimoto A, Takeuchi S. Abnormal cerebrovascular network related to internal carotid artery disease. *J Neurosurg* 1968; **29**: 223–30.
- 2 Suzuki J, Takaku A. Cerebrovascular 'moyamoya' disease. *Arch Neurol* 1969; **20**: 288–99.
- 3 Takahashi M, Miyauchi T, Kowada M. Computed tomography of moyamoya disease: demonstration of occluded arteries and collateral vessels as important diagnostic signs. *Radiology* 1980; **134**: 671–6.
- 4 Chaudari KB, Edwards R. Adult moyamoya disease. *BMJ* 1993; **307**: 852–4.
- 5 Bitzer M, Topke H. Progressive cerebral occlusive disease after radiation therapy. *Stroke* 1995; **26**: 131–6.
- 6 Kitihare T, Ariya N, Yamaura A, Makine H, Maki Y. Familial occurrence of moyamoya disease: report of three Japanese families. *J Neurol Neurosurg Psychiatry* 1979; **42**: 208–14.
- 7 Houkin K, Tanaka N, Takahashi A, *et al.* Familial occurrence of moyamoya disease. Magnetic resonance angiography as a screening test for high risk subjects. *Child Nerv Syst* 1994; **10**: 421–5.
- 8 Asari S, Sota T, Sakurai M, *et al.* The advantage of coronal scanning in cerebral computed angiography for diagnosis of moyamoya disease. *Radiology* 1982; **145**: 709–11.
- 9 Tsuchiya K, Makita K, Furui S. Moyamoya disease: diagnosis with 3D CT angiography. *Neuroradiology* 1994; **36**: 432–4.
- 10 Fujisawa I, Asato R, Nishimura K, *et al.* Moyamoya disease: MR imaging. *Radiology* 1987; **164**: 103–5.
- 11 Hasuo K, Yasumori K, Yoshida K, *et al.* Magnetic resonance imaging compared with computed tomography and angiography in Moyamoya disease. *Acta Radiol* 1990; **31**: 191–5.
- 12 Waugh JR, Sachasias N. Arteriography complications in the DSA era. *Radiology* 1992; **182**: 243–6.
- 13 Leow K, Murie JA. Cerebral angiography for cerebrovascular disease – the risks. *Br J Surg* 1988; **75**: 428–30.
- 14 Yamada I, Matsushima Y, Suzuki S. Moyamoya disease: diagnosis with three dimensional time-of-flight MR angiography. *Radiology* 1992; **184**: 773–8.
- 15 Makiyama Y, Nishimoto H, Aikara T, Tsubokawa T. Magnetic resonance angiography in the management of childhood moyamoya disease: first choice for neurovascular scrutiny. *Surg Neurol* 1994; **42**: 32–40.
- 16 Takanashi J, Sugita K, Ishii M, *et al.* Moyamoya syndrome in young children. MR comparison with adult onset. *AJNR* 1993; **14**: 1139–43.
- 17 Ueki K, Meyer FB, Mellinger JF. Moyamoya disease: The disorder and surgical treatment. *Mayo Clin Proc* 1994; **69**: 749–57.
- 18 Houlston RS, Saadek IK, Barker S, *et al.* Cerebral infarction due to moyamoya disease in an 18 year old female. *Postgrad Med J* 1993; **69**: 932–3.