Patients with moyamoya disease presenting with movement disorder

Report of 4 cases

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Moyamoya disease is a rare cerebrovascular disease characterized by idiopathic bilateral stenosis or occlusion of bilateral internal carotid arteries and the development of characteristic leptomeningeal collateral vessels at the base of the brain. Typical presentations include transient ischemic attacks or stroke, and hemorrhage. Presentation with movement disorders is extremely rare, especially in the pediatric population. The authors describe the cases of 4 children with moyamoya disease who presented with movement disorders.

Among 446 patients (118 pediatric) with moyamoya disease surgically treated by the senior author, 4 pediatric patients had presented with movement disorders. The clinical records, imaging studies, surgical details, and postoperative clinical and imaging data were retrospectively reviewed.

The initial presenting symptom was movement disorder in all 4 patients: chorea in 2, hemiballismus in 1, and involuntary limb shaking in 1. All the patients had watershed infarcts involving the frontal subcortical region on MR imaging. Additionally, 1 patient had a ganglionic infarct. Single-photon emission computed tomography studies showed frontoparietal cortical and subcortical hypoperfusion in all patients. Three patients had bilateral disease, whereas 1 had unilateral disease. All the patients underwent superficial temporal arterial–middle cerebral artery bypass. Postoperatively, all 4 patients had complete improvement in their symptoms. The SPECT scans revealed normal perfusion in 3 patients and a small residual perfusion deficit in 1.

Movement disorders are a rare presenting feature of moyamoya disease. Hypoperfusion of the frontal cortical and subcortical region was seen in all patients, and the symptomatology was attributed to ischemic dysfunction and imbalance in the cortical-subcortical-ganglionic-thalamic-cortical circuitry. Combined revascularization with superficial temporal arterial–middle cerebral artery bypass and encephaloduroarteriosynangiosis leads to excellent results. (DOI: 10.3171/2010.9.PEDS10192)

Key Words • moyamoya disease • movement disorder • hypoperfusion • bypass procedure
discussed. In the present report, we describe a series of 4 children with moyamoya disease presenting with movement disorders. We review their clinical presentations, imaging characteristics with an emphasis on MR images and cerebral flow patterns, and the effects of revascularization surgery on their symptomatology.

Methods

A retrospective review of a moyamoya disease database was conducted to look for the clinical presentation of the patients. All patients were surgically treated by the senior author (G.K.S.) between January 1991 and April 2010 at the Department of Neurosurgery, Stanford University Medical Center. Among the 446 patients (118 pediatric) included in the database, 4 pediatric patients had presented with movement disorders. They constituted 0.89% of all patients and 3.4% of all pediatric patients with moyamoya disease in our experience.

All 4 patients were evaluated using MR imaging, cerebral perfusion studies such as an acetazolamide-challenge SPECT, and 6-vessel cerebral angiography, according to the published guidelines. Three of the 4 patients had bilateral moyamoya disease and hence were treated with direct bilateral revascularization using STA-MCA bypass. One patient had unilateral moyamoya disease; therefore, revascularization was performed only on the symptomatic side. The STA was also laid on the cerebral cortex as described in the EDAS procedures. The evolution of the symptomatology, specifically the presenting symptoms, was carefully recorded for each case. Cerebral flow studies with 99mTc-HMPAO SPECT were performed both preoperatively and 6 months to 3 years postoperatively. All patients also underwent MR imaging to detect any new ischemic lesions and cerebral angiography to assess graft patency and collateral vessels postoperatively. All the patients underwent follow-up, which ranged from 3 to 11 years (mean ± SD, 5.25 ± 3.8 years).

Case Reports

Of 446 patients (118 pediatric) with moyamoya disease treated over a 19-year period, 4 patients presented with movement disorders as their primary symptom. A summary of patient demographics and clinical presentations is listed in Table 1.

History and Examination. The patient in Case 1 was an 8-year-old boy who presented with involuntary choreiform movements involving the right upper limb. Movement was intermittent, not present during sleep, and exacerbated by any voluntary movements. The boy also had TIAs with numbness involving the right side of the body along with transient aphasia that came after the onset of the chorea. The patient in Case 2 was an 8-year-old girl who also presented with involuntary movements involving the right side of the body (the upper limb more than the lower limb), as well as transient slurring of her speech. The patient in Case 3 was a 17-year-old girl who presented with involuntary movements involving both sides, although the right side more than the left, over the past year. She had also presented with a left hemispheric infarct 5 months previously, with partial recovery. Her significant medical history included Type 1 GSD. The patient in Case 4 was an 18-year-old man who presented with a 9-month history of flailing movements involving the right arm, which was suggestive of hemiballismus. This disorder was intermittent, without any specific exacerbating or relieving factors. He did not have any TIAs or previous strokes. Two of the patients’ symptoms were partially controlled with clonazepam and trihexyphenidyl. Neurological examination revealed mild weakness involving the right side in the patient in Case 3 and mild clumsiness involving the right hand in the patient in Case 1.

Imaging. Magnetic resonance images of the brain were obtained in all the patients. Imaging in 3 demonstrated small ischemic watershed infarcts involving bilateral frontal subcortical white matter. Images from Case 3 are featured in Fig. 1. None of the patients had a cortical infarct, although 1 patient had a ganglionic infarct in addition to the watershed infaracts. Magnetic resonance imaging results were nondiagnostic in 1 patient. Of note, none of the patients (in the entire moyamoya database) who had basal ganglia hematomas presented with move-

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Presentation</th>
<th>Side</th>
<th>Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8, M</td>
<td>chorea, TIAs lt hemispheric, transient numbness/aphasia</td>
<td>bilat</td>
<td>bilat STA-MCA bypass, EDAS</td>
</tr>
<tr>
<td>2</td>
<td>8, F</td>
<td>rt-sided involuntary limb-shaking, transient slurring of speech</td>
<td>bilat</td>
<td>bilat STA-MCA bypass, EDAS</td>
</tr>
<tr>
<td>3</td>
<td>17, F</td>
<td>chorea, lt hemispheric infarct</td>
<td>bilat</td>
<td>bilat STA-MCA bypass, EDAS</td>
</tr>
<tr>
<td>4</td>
<td>18, M</td>
<td>rt-sided hemiballismus</td>
<td>unilat</td>
<td>It STA-MCA bypass, EDAS</td>
</tr>
</tbody>
</table>
Moyamoya disease presenting with movement disorders. Cerebral flow evaluation was performed using \(^{99m}\text{Tc}-\text{HMPAO SPECT}\) in all patients at baseline and after the Diamox challenge (Fig. 2 and Table 2).

**Operation.** All the patients underwent STA-MCA bypass for direct revascularization. The STA diameter ranged from 0.9 to 1.2 mm, and the M\(_4\) vessel diameter ranged from 1.0 to 1.4 mm. The STA was also laid on the cerebral cortex as an EDAS for indirect revascularization. Three patients (Cases 1–3) underwent bilateral procedures. The symptomatic side (left hemisphere in all cases) was treated first, followed by the right side 1 week later. The patient who presented with hemiballismus had unilateral moyamoya disease (Case 4) and thus underwent left-sided surgery only.

**Postoperative Course.** In 3 patients (Cases 1–3), the movement disorder resolved over 2 days to 1 week. Resolution of the hemiballismus was the most dramatic, which disappeared 2 days after surgery (Case 4). Medications to control movement disorders, such as clonazepam or trihexyphenidyl, were stopped on discharge. In 1 patient with chorea (Case 3), the involuntary movements decreased in frequency, although their complete disap-

![Fig. 2. Case 3. Preoperative SPECT scans showing bilateral cortical and subcortical hypoperfusion.](image)

**TABLE 2: Imaging and cerebral flow characteristics in 4 pediatric patients with moyamoya disease**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>MRI</th>
<th>SPECT</th>
<th>Angiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>bilat frontal &amp; parietal watershed infarcts</td>
<td>diffuse reduction in flow, small focal reduction rt frontotemporal subcortical region</td>
<td>rt supracranial ICA occlusion, lt petrous carotid severe stenosis, moyamoya collaterals</td>
</tr>
<tr>
<td>2</td>
<td>bilat frontal watershed infarcts, lt&gt;rt</td>
<td>lt frontal subcortical hypoperfusion</td>
<td>bilat supracranial ICA occlusion w/ moyamoya vessels</td>
</tr>
<tr>
<td>3</td>
<td>bilat watershed infarcts, bilat frontal subcortical, lt ganglionic infarct</td>
<td>bilat frontal/parietal hypoperfusion, frontal/parietal extensive deficits</td>
<td>bilat supracranial ICA occlusion w/ moyamoya vessels</td>
</tr>
<tr>
<td>4</td>
<td>normal</td>
<td>decreased perfusion bilat parietal, lt&gt;rt</td>
<td>lt ICA occlusion w/ moyamoya vessels, rt ICA/MCA normal</td>
</tr>
</tbody>
</table>
pearance took 6 months; thereafter, the patient did not have any relapse over a follow-up period of 11 years. She remained on clonazepam for 6 months, after which it was stopped. Postoperative brain MR imaging did not reveal fresh ischemic lesions in any patient.

The follow-up ranged from 3 to 11 years (mean $5.25 \pm 3.8$ years). None of the patients experienced any relapse of the movement disorder. Three patients fared well clinically and remained free of TIA and stroke. Cerebral flow studies revealed normal perfusion in all 3 of these patients. Images obtained in the patient in Case 3 are featured in Figs. 1–5. This girl with Type 1 GSD had occasional TIAs for 3 years; thereafter, she was free of symptoms for 8 years. Flow studies in this patient demonstrated bilateral residual perfusion deficits. Follow-up angiography in all of the patients showed widely patent grafts with good revascularization of the MCA territory. Preoperative and postoperative images obtained in the

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**Fig. 3.** Case 3. Postoperative SPECT scans showing normal perfusion.

**Fig. 4.** Case 3. Preoperative angiograms showing bilateral supraclinoid ICA occlusion with moyamoya vessels. LICA = left ICA injection; RICA = right ICA injection.
Moyamoya disease presenting with movement disorders

patients in Cases 2 and 4 are shown in Figs. 6 and 7, respectively, showing excellent postoperative revascularization in both cases.

Discussion

Moyamoya disease is an uncommon cerebrovascular disease characterized by idiopathic bilateral stenosis or occlusion of the supraclinoid ICA with involvement of the proximal anterior cerebral artery and MCA, as well as the formation of collateral vessels resembling a puff of smoke.26 The most common presentation in the pediatric population is with TIAs or stroke,7 although presentation with movement disorders has been reported in both the adult and pediatric populations.

Involuntary movements are generated due to a disruption in the fine balance between excitatory and inhibitory signals connecting basal ganglia and cerebral cortex via direct and indirect pathways.3,5 Ischemic dysfunction of basal ganglia, the thalamus, cerebral cortex, and brainstem have been implicated as causes of simple or complex movement disorders. Previous reports (Table 3) on 13 pediatric patients with moyamoya disease have suggested that ischemia of both the frontal subcortical matter and the basal ganglia are important in the generation of involuntary movements.2,8,11,13,14,16,21,24,25,30–32 In addition, Scott and colleagues22,23 mentioned in their reviews of moyamoya disease 10 pediatric patients presenting with involuntary movements. Eight of these patients had a resolution of symptoms 1 year after revascularization surgery. Baik and Lee1 also reported on 4 patients and reviewed the literature on moyamoya disease presenting with movement disorders. Unfortunately, the results in these 4 patients were not described separately. Im et al.14 documented 6

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\text{Fig. 5. Case 3. Postoperative right (a) and left (b) external carotid artery (ECA) injections showing excellent revascularization.}
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\text{Fig. 6. Case 2. Images obtained in an 8-year-old girl. a: Axial FLAIR MR image showing bilateral watershed infarcts. b and c: Preoperative right and left ICA injection digital subtraction angiograms, lateral projection, showing bilateral supraclinoid ICA occlusion with moyamoya vessels. d and e: Follow-up right and left ECA digital subtraction angiograms, lateral projection, showing excellent revascularization.}
\]
Fig. 7. Case 4. Images obtained in an 18-year-old man. a: Axial MR image showing no evidence of infarction or ischemia. b and c: Preoperative left and right ICA digital subtraction angiograms, anteroposterior projections, showing left supraclinoid ICA occlusion with moyamoya vessels. d and e: Follow-up left ECA injection digital subtraction angiograms, lateral and anteroposterior, projections showing excellent revascularization.

TABLE 3: Literature review of patients with moyamoya disease presenting with movement disorders*

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Pts (type)</th>
<th>Presentation</th>
<th>Surgery</th>
<th>FU</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bakdash et al., 2002</td>
<td>1 (ped)</td>
<td>dystonia, hyperventilation induced paroxysmal hyperkinesia</td>
<td>EDAS</td>
<td>6 wks postop hemiparesis, no dystonia</td>
<td></td>
</tr>
<tr>
<td>Gonzales-Alegre et al., 2003</td>
<td>2 (1 ped)</td>
<td>1, EC-IC bypass</td>
<td>NA</td>
<td>1, no recurrence; 1, (w/o op) had cognitive impairment/hemiparesis, no dyskinesia</td>
<td></td>
</tr>
<tr>
<td>Han et al., 2000</td>
<td>1 (adult)</td>
<td>singing-induced chorea</td>
<td>EDAS</td>
<td>NA</td>
<td>chorea resolved</td>
</tr>
<tr>
<td>Hong et al., 2002</td>
<td>1 (adult)</td>
<td>hemichorea</td>
<td>STA-MCA bypass</td>
<td>4 mos</td>
<td>chorea resolved</td>
</tr>
<tr>
<td>Im et al., 2004</td>
<td>5 (2 ped)</td>
<td>3, chorea; 2, limb shaking</td>
<td>3, EDAS; 2, STA-MCA bypass</td>
<td>3 yrs†</td>
<td>involuntary movements resolved in all pts</td>
</tr>
<tr>
<td>Kamijo et al., 2008</td>
<td>1 (adult)</td>
<td>chorea</td>
<td>EDAS</td>
<td>NA</td>
<td>chorea resolved</td>
</tr>
<tr>
<td>Li et al., 2007</td>
<td>1 (adult)</td>
<td>hemiathetosis, hemidystonia</td>
<td>anti-cholinergics</td>
<td>NA</td>
<td>improved gradually</td>
</tr>
<tr>
<td>Lyoo et al., 2000</td>
<td>1 (adult)</td>
<td>hemichorea, hemichoreoathetosis</td>
<td>none</td>
<td>NA</td>
<td>no FU</td>
</tr>
<tr>
<td>Parmar et al., 2000</td>
<td>1 (ped)</td>
<td>chorea</td>
<td>EDAS</td>
<td>7 mos</td>
<td>chorea resolved</td>
</tr>
<tr>
<td>Pavlakis et al., 1991</td>
<td>1 (ped)</td>
<td>chorea</td>
<td>STA-MCA + EDAS</td>
<td>4 mos</td>
<td>residual chorea</td>
</tr>
<tr>
<td>Shanahan et al., 2001</td>
<td>1 (ped)</td>
<td>hemichorea</td>
<td>anti-cholinergics</td>
<td>NA</td>
<td>chorea improved</td>
</tr>
<tr>
<td>Spengos et al., 2004</td>
<td>1 (adult)</td>
<td>chorea</td>
<td>none</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Takanashi et al., 1993</td>
<td>1 (ped)</td>
<td>chorea</td>
<td>none</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Watanabe et al., 1990</td>
<td>3 (ped)</td>
<td>chorea</td>
<td>1, EDAS; 2, STA-MCA bypass</td>
<td>18 mos</td>
<td>chorea resolved in all</td>
</tr>
<tr>
<td>Yasumoto et al., 1993</td>
<td>1 (ped)</td>
<td>torticollis</td>
<td>EDAS</td>
<td>15 mos</td>
<td>torticollis resolved, hemiparesis</td>
</tr>
<tr>
<td>Zheng et al., 2006</td>
<td>1 (ped)</td>
<td>chorea</td>
<td>STA-MCA + EDAS</td>
<td>2 yrs</td>
<td>chorea resolved</td>
</tr>
<tr>
<td>present series</td>
<td>4 (ped)</td>
<td>2, chorea; 1, hemiballismus; 1, limb shaking</td>
<td>STA-MCA bypass + EDAS</td>
<td>mean 3.5 yrs</td>
<td>involuntary movements resolved in all pts</td>
</tr>
</tbody>
</table>

* EC-IC = extracranial-intracranial; FU = follow-up; NA = not available; ped = pediatric; Pts = patients.
† Median.
patients with an ischemic cause of their movement disorders, which included 5 cases of moyamoya disease and 1 case of radiation-induced MCA stenosis. These authors suggested that the subcortical circuits were more important, and they did not identify any basal ganglionic infarction or ischemia in patients with involuntary movements due to cerebral ischemia. Note, however, that 2 of their patients presented with limb-shaking, which can be a sign of cerebral ischemia. 13 On the other hand, Hong et al., 13 described a patient with moyamoya disease presenting with hemichorea and reversible striatal hypoperfusion on SPECT. In the present series, we observed bilateral subcortical ischemia in most cases. In 1 patient presenting with previous stroke, however, there was evidence of a small ganglionic infarct as well. We hypothesize that any ischemia or lesion that interrupts the cortico-striatal-pallidal-thalamic-cortical pathway and disrupts the fine circuitry causes involuntary movements. However, it remains unclear why movement disorders are such an uncommon presenting feature, especially given that ischemia in this circuit occurs in many cases of moyamoya disease. Quantitative cerebral blood flow measurements with Xe-CT and PET might be useful in establishing the relative ischemia among various cortical, subcortical, and deep structures, as well as their relative importance in the generation of symptomatology.

The surgical treatment of moyamoya disease can be categorized into direct and indirect revascularizations. We have previously published our overall results following 450 revascularization procedures 9 and the outcomes of such interventions in the pediatric population. 6 The morbidity and mortality rates in the procedures were 3.5% and 0.7%, respectively, and 91.8% of the patients presenting with TIAs were free of symptoms at the 1-year follow-up. We prefer direct revascularization of the hemisphere whenever possible, because it immediately increases blood flow to the ischemic territory and because there are reports that STA-MCA bypass combined with encephaloduroarteriomysynangiosis has better results compared with an indirect procedure alone. 15 In the present case series, we did not encounter any significant morbidity. Most of the patients had a dramatic resolution of symptoms, leading us to believe that their involuntary movements were ischemic in origin. One patient (Case 3) with Type 1 GSD had after revascularization occasional involuntary movements for 6 months and TIAs for 3 years despite angiographically proven widely patent grafts. It is possible that the metabolic derangements due to GSD contributed to the persistence of symptoms, although the symptoms did eventually resolve.

Conclusions

Movement disorders can be a rare presentation of moyamoya disease and are likely to be caused by ischemic dysfunction and imbalance in the cortical-subcortical-ganglionic-thalamic-cortical circuitry. Direct revascularization leads to an excellent outcome and lasting relief from symptoms. Quantitative blood flow studies are likely to provide further insights into the generation of the symptomatology of this disease.

Disclosure

This study was supported in part by funding from the Huber Family Moyamoya Fund, Bernard Lacroute, Ronni Lacroute, the William Randolph Hearst Foundation, and Russell and Elizabeth Siegelman (G.K.S.).

Author contributions to the study and manuscript preparation include the following: Conception and design: Steinberg, Pandey. Acquisition of data: all authors. Analysis and interpretation of data: Steinberg, Pandey. Drafting the article: Steinberg, Pandey. Critically revising the article: Steinberg, Pandey. Reviewed final version of the manuscript and approved it for submission: all authors. Administrative/technical/material support: Bell-Stephens.

Acknowledgments

The authors thank Cindy H. Samos for assistance with the manuscript, Beth Hoyte for help with figure preparation, and Margaret Minto for data collection.

References


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