Factors Associated with Moyamoya Syndrome in a Kentucky Regional Population

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Objectives: Our study aimed to report both new and previously identified conditions associated with moyamoya syndrome in a Western population and to present our outcomes after surgical treatment with indirect bypass. *Methods:* We performed a retrospective chart review of patients evaluated at our institution from June 2011 to June 2015 who were diagnosed with moyamoya. Data collected include patient demographics, presenting manifestations, vessels involved, comorbid conditions, abnormal laboratory values, treatments administered, and clinical outcomes. *Results:* Thirty-one patients with moyamoya were enrolled (11 male and 20 female), with 84% Caucasian and 16% African-American. The most common comorbidity was hypertension in 61% of the patients. Coexisting autoimmune conditions were present in 26%, with another 13% having coexisting prothrombotic disorders. Diabetes mellitus was not found to correlate with the Suzuki grade of disease at presentation ($P = .30$). When noninvasive imaging was performed before the cerebral angiogram, the computed tomography angiography had a false-negative rate of 59%, and magnetic resonance angiography had a false-negative rate of 33%. Twenty-one patients underwent surgical intervention, 2 underwent intracranial stenting, and 19 underwent indirect bypass with encephaloduroarteriosynangiosis. At an average 28-month follow-up, all 15 patients who had an angiogram after intervention showed evidence of neovascularization. *Conclusions:* Autoimmune and prothrombotic disorders were found to be comorbid in patients with moyamoya at much higher rates than expected in the general population. Diabetes mellitus was not significantly correlated with Suzuki grade. Angiogram remains an important diagnostic modality when noninvasive imaging is negative for vasculopathy. We demonstrate excellent evidence of revascularization within 1 year with intracranial stenting and indirect bypass. **Key Words:** Angiography—artery—stenosis—stroke—moyamoya—bypass.

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Introduction

Moyamoya disease is a progressive occlusive disease of the cerebral vasculature, with particular involvement of the vessels of the circle of Willis.[1] Over time, abnormal collateral networks develop to bypass these stenotic vessels. Although first described as a bilateral phenomenon affecting East Asians,[2] similar angiographic features of moyamoya disease are evident in patients with other medical conditions, such as autoimmune or congenital disorders.[3-6] In these instances, the terms "moyamoya syndrome" or "moyamoya vasculopathy" are often used. Medical management of the disease usually consists of managing complications, such as controlling hypertension and modifying stroke risk factors, as well as antiplatelet therapy. Surgical revascularization techniques can restore cerebral blood flow through forms of direct or indirect bypass.[7]

Numerous associated conditions have been reported in the literature in reference to moyamoya syndrome, but most occur as case reports.[8] Few publications have analyzed the prevalence of such conditions or have given a comprehensive overview of associated conditions within a regional population.[9] Even fewer studies have focused on moyamoya within a Caucasian population, which has different epidemiological and clinical features. The aim of the present study was 2-fold: first, to report both new and previously identified conditions in patients with moyamoya syndrome within a Kentucky regional population treated at the University of Kentucky Medical Center and to compare this to what has been reported in the literature; second, we report clinical and angiographic outcomes in our cohort of patients undergoing surgical intervention. The identification of these coexisting conditions will hopefully serve to allow better conceptualization of the pathophysiology involved in moyamoya syndrome, as well as a more timely and accurate diagnosis of moyamoya syndrome.

Methods

Patient Population

We performed a retrospective chart review of all patients with the International Classification of Diseases, Ninth Revision (ICD-9), and the subsequent International Classification of Diseases, 10th Revision (ICD-10), diagnoses of moyamoya disease who were evaluated at the University of Kentucky Medical Center between June 1, 2011, and June 1, 2015. All were patients under treatment by one of the investigators. Thirty-six total patients were initially identified, but 5 patients were subsequently excluded due to age younger than 18 years or having incomplete hospital records necessary for analysis. Records of all inpatient stroke admissions between 2011 and 2015 were also obtained for epidemiological comparison.

Data Collection

Epidemiological information about patient demographics was obtained, including age at diagnosis, gender, presenting manifestation, and vessels involved. Baseline stroke risk factors, including hypertension, hyperlipidemia, obesity, diabetes, smoking, coronary artery disease, and peripheral vascular disease, were collected. In addition, moyamoya syndrome risk factors, in particular, comorbid autoimmune and prothrombotic disorders, were assessed. Treatments administered were classified as either medical only (antiplatelet or anticoagulation therapy), surgical (indirect bypass or stenting), or both. Patient angiograms were reviewed retrospectively by an independent investigator (S.G.) who had not performed the procedures for Suzuki grade and for angiographic success of bypass procedures. In addition, results of noninvasive imaging modalities like computed tomography angiography (CTA) and magnetic resonance angiography (MRA) before the diagnostic angiogram were reviewed. The results were determined to be diagnostic of moyamoya if the term "moyamoya" was included as part of the radiology report; otherwise, they were considered nondiagnostic for moyamoya. Data storage and analysis were performed using REDCap (Research Electronic Data Capture), a secure online application for building clinical databases hosted at the University of Kentucky. Subsequent statistical analyses were performed using Microsoft Excel. The protocol used obtained institutional review board approval.

Statistical Analysis

Although the majority of the present study was descriptive, statistical analysis was performed to compare the severity of moyamoya disease at the time of diagnosis between patients with and without diabetes, as well as between patients with and without autoimmune disease, as measured by Suzuki grade on angiogram. Because disease burden most likely had laterality, the left and right sides of intracranial arteries were graded separately, and comparisons were performed using both the higher Suzuki grade and the total Suzuki grade for each patient. An unpaired, 1-tailed Student *t*-test was used to compare the severity of the disease in patients without diabetes with that of patients with diabetes. In addition, a 1-tailed Student *t*-test was also used to determine whether a higher glycosylated hemoglobin at diagnosis in diabetics correlated with more severe disease just among diabetic patients. We also compared the Suzuki grade of patients with autoimmune disease with that of patients without autoimmune disease to investigate whether those with comorbid autoimmune disease had a more severe moyamoya presentation.