Clinical Sciences

Epidemiology of Moyamoya Disease in Taiwan
A Nationwide Population-Based Study

Pei-Chun Chen, PhD*; Shih-Hung Yang, MD, PhD*; Kuo-Liong Chien, MD, PhD; I-Ju Tsai, MS; Meng-Fai Kuo, MD, PhD

Background and Purpose—Previous studies have shown regional and temporal variations in epidemiological features of moyamoya disease, but population-based studies in regions other than Japan are limited. We investigated the incidence and patient characteristics of moyamoya disease during 12 years in Taiwan using claims databases of a universal health insurance system.

Methods—From the inpatient databases of the Taiwan National Health Insurance program, we identified subjects who had an initial hospitalization with moyamoya disease and had been underwent cerebral angiography as incidence cases during 2000 to 2011. The incidence and the patient characteristics were described by age and time periods of the hospitalization.

Results—During the 12-year period, 422 patients were identified, representing an annual incidence of 0.15 per 100,000 person-years. Adults exhibited an upward trend in incidence with an incidence rate ratio of 1.74 (95% confidence interval [1.17–2.58]) in years 2010 to 2011 comparing with years 2000 to 2001. However, children had a decreased incidence except a slightly increase in the last 2 years. Compared with patients hospitalized during 2000 to 2005, patients identified during 2006 to 2011 had greater women-to-men ratio (1.7 versus 1.1, P=0.048). Children were more likely to have comorbid epilepsy than were adult patients (25.0% versus 3.4%, P=0.002). Hemorrhagic stroke was rare among pediatric patients but presented more frequently in adults. However, ischemic stroke was more prevalent in both groups.

Conclusions—The incidence of moyamoya disease has increased in adults but not in children from 2000 to 2011 in Taiwan. Sex ratio and comorbid conditions differed by age and study period. (Stroke. 2014;45:1258-1263.)

Key Words: epidemiology ■ incidence ■ moyamoya disease

Moyamoya disease is a rare cerebrovascular disorder of unknown pathogenesis. It is characterized by progressive occlusion of large intracranial vessels around the bifurcation of internal carotid artery, and development of collateral circulation from superficial scalp arteries, meningeal arteries, and deep perforating arteries. Patients with moyamoya disease often have transient ischemic attacks and stroke, and may have debilitating neurological sequelae or cognitive impairment.

Epidemiological features of moyamoya disease have been reported in various regions during the past 3 decades. The observations have shown regional and ethnic differences in incidence, prevalence, and patient characteristics. Furthermore, temporal variations in characteristics of moyamoya disease have been observed in nationwide surveys in Japan. Compared with surveys in 1990s, the prevalence and incidence rate in 2000s has doubled, and the onset age was older. Studies depicting characteristics of a disease and its temporal trends in a given population would aid in generating hypothesis for pathogenetic studies, healthcare resource allocations, and evaluation and improvements in healthcare practices. Several studies have reported moyamoya disease in Asia, particularly in Japan, South Korea, and China, where the incidence and prevalence were recognized high. However, most of these studies, except those from Japan, were performed a decade ago or in a single center or selected hospitals, and may be vulnerable to selection bias.

Taiwan is a Southeast Asian country where people are predominantly ethnic Chinese. The National Health Insurance (NHI) program of Taiwan provides universal health coverage to the population since its inception in 1995. The size and representativeness of the research database of NHI allows for study of rare diseases and population-based observations on temporal changes in epidemiological features. Using the database, we documented the incidence and characteristics of

Received November 14, 2013; accepted February 21, 2014.
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The online-only Data Supplement is available with this article at http://stroke.ahajournals.orglookup/suppl/doi:10.1161/STROKEAHA.113.004160/DIC1.

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Stroke is available at http://stroke.ahajournals.org

DOI: 10.1161/STROKEAHA.113.004160

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patients with moyamoya disease and observed their changes during 12 years in Taiwan.

Methods

Data Source
We used multiple data sets distributed by the National Health Research Institute, which has collaborated with the NHI Administration to construct the NHI research database. The data sets of inpatient expenditures contain inpatient claims of the 23 million NHI beneficiaries that represent >99% of the population. Information included were date of admission, date of discharge, diagnostic codes (up to 5), and procedures (up to 5) for all hospital admissions. The files of inpatient orders contain claims for inpatient services, and registry for beneficiaries contains limited demographics such as sex, date of birth, and date of enrollment in and withdrawal from NHI. All data sets can be linked by using a unique individual identification number, which were scrambled before the release of data sets to protect patient privacy. The Institutional Review Board of the National Taiwan University Hospital approved this study.

Study Subjects
Within inpatient claim data sets from 1996 to 2011, we identified 627 patients with an initial hospital admission with moyamoya disease between 2000 and 2011, based on a discharge diagnosis coded with International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code 437.5. In an attempt to reduce the possibility of including prevalent cases, we used a wash-out period of ≥4 years. Patients were excluded if they had a hospital admission with moyamoya disease before their hospitalization during 2000 to 2011, identified by retrospectively searching claims back to 1996. Patients also were excluded if they had been diagnosed with conditions associated with moyamoya syndrome (n=13), including neurofibromatosis type 1 (ICD-9-CM 237.71), Down syndrome (ICD-9-CM v15.3), cranial irradiation (ICD-9-CM 758.0), and sickle cell anemia (ICD-9-CM 282.6), or if they did not undergo conventional cerebral angiographic study (n=192).

Demographics and Comorbid Conditions
The inpatient data sets were searched for records with discharge diagnosis of conditions presented during or within 3 years before the hospitalization with moyamoya disease, including ischemic stroke (ICD-9-CM 430.xx-437.xx), hemorrhagic stroke (ICD-9-CM 430.xx-432.xx), and epilepsy (ICD-9-CM 345.xx, 780.3, 779.0). To observe the use of surgical treatments, claims records of extracranial-intracranial revascularization were also searched (ICD-9-CM procedures code 39.28, 39.29, 39.31).

Statistical Analysis
We calculated the annual incidence rate with the first hospital admissions with moyamoya disease divided by the number of subjects insured in the NHI program in each year during 2000 to 2011. Age standardization was performed using the direct method to the population insured in year 2000 in age bands of 5 years. The incidence was also estimated by age of the hospitalization with moyamoya disease (age of diagnosis), to compare whether there are differences in incidence trends between children (<18 years) and adults (≥18 years). The confidence intervals (CI) of incidence were estimated by assuming Poisson distribution, and incidence rate ratios and 95% CIs were estimated using Poisson regression with the incidence of years 2000 to 2005 (Figure 1A). However, adults exhibited an upward trend in incidence for the years 2000 through 2011, but the rates fluctuated among pediatric population. Using the incidence of years 2000 to 2001 as the reference, the incidence rate ratios of years 2010 to 2011 were 1.16 (95% CI [0.66–2.04]) for subjects <18 years and 1.74 (95% CI [1.17–2.58]) for those aged ≥18 years. We calculated the prevalence of moyamoya disease in 2011. Among 422 patients with moyamoya disease, 384 subjects who were alive and remained enrolled in NHI by December 31, 2011, were the prevalent cases as of the end of 2011. Prevalence was calculated by dividing the number of prevalent cases in 2011 by number of subjects insured by NHI in the same year. The resulting estimate was 1.61 per 100,000.

Results

Incidence, the Trend, and Prevalence
From 2000 to 2011, we identified 422 subjects as incidence cases of moyamoya disease from the initial hospitalization; the annual average incidence rate was 0.15 (95% CI [0.14–0.17]). The age-standardized incidence rate increased from 2000 through 2011 by 44% in all subjects (annual incidence per 100,000, 0.14–0.20), 40% in women (0.18–0.25), and 48% in men (0.10–0.15; Figure 1). The overall incidence rate was higher in pediatric population than in adult population (Table 1). However, adults exhibited an upward trend in incidence for the years 2000 through 2011, but the rates fluctuated among pediatric population. Using the incidence of years 2000 to 2001 as the reference, the incidence rate ratios of years 2010 to 2011 were 1.16 (95% CI [0.66–2.04]) for subjects <18 years and 1.74 (95% CI [1.17–2.58]) for those aged ≥18 years.

We calculated the prevalence of moyamoya disease in 2011. Among 422 patients with moyamoya disease, 384 subjects who were alive and remained enrolled in NHI by December 31, 2011, were the prevalent cases as of the end of 2011. Prevalence was calculated by dividing the number of prevalent cases in 2011 by number of subjects insured by NHI in the same year. The resulting estimate was 1.61 per 100,000.

Age Distribution
The incidence rates differed by age, with the highest peak at 5 to 9 years in men and 10 to 14 years in women and the second peak at ages 40 to 44 years in both sexes (Figure 2A). When the study duration was split into 2, the highest peak at 5 to 9 years of age was observed for both men and women who had their first hospitalization with moyamoya disease between 2000 and 2005 (Figure 2B). In the time period of 2006 to 2011, the highest peak was observed at 5 to 9 years in men. In women, the incidence fluctuated with age, with the highest incidence appeared at 10 to 14 years (Figure 2C).

Figure 1. Trends in age-standardized incidence rate (per 100,000 persons) of moyamoya disease, Taiwan, 2000 to 2011.
Demographics and Comorbid Conditions Across Age Groups and Time Periods

Of all patients, women accounted for 58.8% (sex ratio, 1.4; Table 2). The mortality rate at discharge was 3.6%. Ischemic stroke and hemorrhagic stroke had been diagnosed in 46.7% and 26.5% patients, respectively. Extracranial-intracranial revascularization was performed in 37% patients. Compared with patients with hospitalization between 2000 and 2005, women accounted for a higher percentage in the period of 2006 to 2011 (sex ratio 1.1 versus 1.7, \( P = 0.048 \)). Patients of the later period were older (\( P = 0.002 \)) and more likely to have ischemic stroke (\( P = 0.007 \)). Mortality at discharge decreased by half in the period of 2006 to 2011 (5.1% versus 2.4%), but the difference was not statistically significant (\( P = 0.14 \)).

Patients aged \( \leq 18 \) years were 3 times more likely to have epilepsy than were adult patients (\( P = 0.003 \), Table 3). Patients aged 0 to 6 years had the highest extracranial-intracranial revascularization rate (75.7%), followed by patients in the 7- to 12- (68.9%), 13- to 18-year-old group (51.7%), and the lowest in those aged \( \geq 18 \) years (24.5%; \( P < 0.001 \)).

The proportion of presence of ischemic stroke was higher than that of hemorrhagic stroke in both children and adults (Table 3 and Figure 3). Of patients aged <18 years, 24.0% had ischemic stroke and 4.0% had hemorrhagic stroke. The corresponding figures for adults were 56.2% and 36.0%. The proportion of ischemic stroke in adults has increased since 2004. Adults were more likely to have both ischemic stroke and hemorrhagic stroke. Among patients aged \( \geq 18 \) years, 9.4% (28 cases) had both subtypes of stroke; the corresponding figures were 6.5% (2 cases) for patients who were 13 to 18 years old, 0% for those were 7 to 12 years old, and 3% (1 case) for those who were \( \leq 6 \) years old (\( P = 0.053 \), data not shown).

Discussion

Several studies have reported epidemiology of moyamoya disease and shown variations in incidence and characteristics of patients (Table in the online-only Data Supplement).\(^4\)\(^-\)\(^8\),\(^12\)\(^-\)\(^17\) Explanations for the discrepancy may include the differences in survey methods and the studied regions, ethnic groups, and time periods. In general, studies from regions other than Asia yielded lower incidence. However, our observation showed that the incidence of moyamoya disease in Taiwan was far below that of Japan, Korea, and Nanjing, China, although the incidence increased in the last 12 years. The reason is not known, and future studies are needed to address the role of genetic and environmental factors in the pathogenesis of moyamoya disease. The incidence estimated in the present study is 7 to 8 times higher than that (0.02 per 100,000) revealed by a survey across regional medical centers in the late 1990s.\(^14\) Less awareness of moyamoya disease in the
medical profession as well as the society may partly explain
the low incidence in early years.
In line with our observations, previous investigations have shown increased incidence of moyamoya disease over time. In Japan, the incidence (or detection rate) increased from 0.35 per 100,000 in 1994 to 0.54 per 100,000 in 2003 to 1.13 per 100,000 in 2006. An upward trend was also observed in a study in Korea, which revealed an increase of 15% of new cases per year during 2004 to 2008. Kuroda et al have found that radiological findings detected abnormal conditions in asymptomatic patients with moyamoya disease, of which the prevalence may be higher than previously recognized. The increasing incidence may reflect increased detection of the disease resulting from the widespread use of noninvasive diagnostic techniques in adults. Decreased incidence of moyamoya disease in pediatric population has been reported previously, but the reasons remain unclear.

Our analysis showed differences in patient characteristics between patients who had first hospitalization with moyamoya disease in time periods of 2000 to 2005 and 2006 to 2011. The ratio of women to men has been reported in many regions (Table in the online-only Data Supplement), but none of these studies included data on temporal changes in sex ratio within the same population in the same study.

### Table 2. Characteristics of Moyamoya Disease by Year of the First Hospitalization

<table>
<thead>
<tr>
<th></th>
<th>Total (n=422)</th>
<th>2000–2005 (n=175)</th>
<th>2006–2011 (n=247)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women, no. (%)</td>
<td>248 (58.8)</td>
<td>93 (53.1)</td>
<td>155 (62.8)</td>
<td>0.048</td>
</tr>
<tr>
<td>Sex ratio, women to men</td>
<td>1.4</td>
<td>1.1</td>
<td>1.7</td>
<td>...</td>
</tr>
<tr>
<td>Age of hospitalization, no. (%)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>0.002</td>
</tr>
<tr>
<td>&lt;18 y</td>
<td>125 (29.6)</td>
<td>66 (37.7)</td>
<td>59 (23.9)</td>
<td>...</td>
</tr>
<tr>
<td>≥18 y</td>
<td>297 (70.4)</td>
<td>109 (62.3)</td>
<td>188 (76.1)</td>
<td>...</td>
</tr>
<tr>
<td>Deceased at discharge, no. (%)</td>
<td>15 (3.6)</td>
<td>9 (5.1)</td>
<td>6 (2.4)</td>
<td>0.14</td>
</tr>
<tr>
<td>Comorbid conditions*, no. (%)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Ischemic stroke</td>
<td>197 (46.7)</td>
<td>68 (38.9)</td>
<td>129 (52.2)</td>
<td>0.007</td>
</tr>
<tr>
<td>Hemorrhagic stroke</td>
<td>112 (26.5)</td>
<td>45 (25.7)</td>
<td>67 (27.1)</td>
<td>0.74</td>
</tr>
<tr>
<td>Epilepsy</td>
<td>45 (10.7)</td>
<td>20 (11.4)</td>
<td>25 (10.1)</td>
<td>0.67</td>
</tr>
<tr>
<td>EC-IC revascularization†, no. (%)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>0.60</td>
</tr>
<tr>
<td>No operation</td>
<td>266 (63.0)</td>
<td>113 (64.6)</td>
<td>153 (61.9)</td>
<td>...</td>
</tr>
<tr>
<td>1 operation</td>
<td>74 (17.5)</td>
<td>32 (18.3)</td>
<td>42 (17.0)</td>
<td>...</td>
</tr>
<tr>
<td>&gt;1 operations</td>
<td>82 (19.4)</td>
<td>30 (17.1)</td>
<td>52 (21.1)</td>
<td>...</td>
</tr>
</tbody>
</table>

EC-IC indicates extracranial-intracranial.
*Conditions presented in 3 years before or during hospitalization with moyamoya disease.
†Number of operations after hospitalization with moyamoya disease.

### Table 3. Characteristics of Moyamoya Disease by Age of the First Hospitalization

<table>
<thead>
<tr>
<th></th>
<th>0–6 (n=33)</th>
<th>7–12 (n=61)</th>
<th>13–18 (n=31)</th>
<th>≥18 (n=297)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women, no. (%)</td>
<td>23 (69.7)</td>
<td>26 (42.6)</td>
<td>17 (54.8)</td>
<td>182 (61.3)</td>
<td>0.027</td>
</tr>
<tr>
<td>Sex ratio, women to men</td>
<td>2.3</td>
<td>0.7</td>
<td>1.2</td>
<td>1.6</td>
<td>...</td>
</tr>
<tr>
<td>Deceased at discharge, no. (%)</td>
<td>0 (0)</td>
<td>2 (3.3)</td>
<td>1 (3.2)</td>
<td>12 (4.0)</td>
<td>0.36</td>
</tr>
<tr>
<td>Comorbid conditions*, no. (%)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Ischemic stroke</td>
<td>5 (15.2)</td>
<td>12 (19.7)</td>
<td>13 (41.9)</td>
<td>167 (56.2)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hemorrhagic stroke</td>
<td>1 (3)</td>
<td>0 (0)</td>
<td>4 (12.9)</td>
<td>107 (36)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Epilepsy</td>
<td>6 (18.2)</td>
<td>13 (21.3)</td>
<td>5 (16.1)</td>
<td>21 (7.1)</td>
<td>0.003</td>
</tr>
<tr>
<td>EC-IC revascularization†, no. (%)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>No operation</td>
<td>8 (24.2)</td>
<td>19 (31.1)</td>
<td>15 (48.4)</td>
<td>224 (75.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>1 operation</td>
<td>11 (33.3)</td>
<td>15 (24.6)</td>
<td>6 (19.4)</td>
<td>42 (14.1)</td>
<td>...</td>
</tr>
<tr>
<td>&gt;1 operations</td>
<td>14 (42.4)</td>
<td>27 (44.3)</td>
<td>10 (32.3)</td>
<td>31 (10.4)</td>
<td>...</td>
</tr>
</tbody>
</table>

EC-IC indicates extracranial-intracranial.
*Conditions presented in 3 years before or during hospitalization with moyamoya disease.
†Number of operations after hospitalization with moyamoya disease.
The overall women-to-men ratio in our analysis was similar to the observations of an earlier study in Taiwan (1.3)\cite{14} and was much higher in patients hospitalized during 2006 to 2011 (1.7) than during 2000 to 2005 (1.1). Our analysis also revealed increased incidence in ≥10-year-old subjects in the later period, and the highest peak of age distribution increased in women. Baba et al\cite{7} has reported a similar pattern, suggesting that the highest peak of incidence shifted from children to adult, and the higher peak in adults than in children was more pronounced in women. The increase in percentage of adults in the latter period may partly explain the increased prevalence of comorbid ischemic stroke in this period. Additional studies on temporal changes of characteristics may help confirm the observations.

Previous studies have reported differences in clinical presentations between children and adults. The majority of pediatric patients present with ischemic attacks, whereas adults present with both hemorrhagic and ischemic events at almost equal proportion.\cite{1,2,20} The present study showed that both children and adult patients have more ischemic strokes than hemorrhagic events, although the ratio of hemorrhagic stroke to ischemic stroke was greater in adults. We also found that children were more likely to have comorbid epilepsy. Routine use of magnetic resonance angiography as a noninvasive screening tool could help detect moyamoya disease in children <12 years old who had epilepsy. This strategy may improve the detection rate of moyamoya disease in Taiwan.

Comparison on clinical presentations across studies needs to take into account the differences in survey methods. Using Nationwide Inpatient Sample (NIS) database of the United States, Starke et al\cite{21} identified 2280 patients hospitalized for moyamoya disorder between 2002 and 2008. Of these patients, ≈70% did not have a diagnosis of stroke. This is in stark contrast to the result of studies performed using patient registry or case series based on hospital records. Hoshino et al\cite{10} studied 941 Japanese patients with moyamoya disease from the patient registry of Research Committee on Moyamoya Disease, whose clinical presentations were transient ischemic attack in 46%, infarction in 20%, hemorrhage in 21%, headache in 6%, epilepsy in 4%, and asymptomatic in 3%. Scott et al\cite{22} reported 143 patients with moyamoya treated in the Boston Children’s Hospital and found presentation of stroke in 67.8%, transient ischemic attack in 43.4%, hemorrhage in 2.8%, and asymptomatic in 4.2%. These observations revealed that studies based on insurance claims database may underestimate the incidence of stroke because of coding procedures or other methodological issues. In our analysis of the NHI database of Taiwan, 46.7% of moyamoya cases had ischemic stroke 26.5% had hemorrhagic stroke, and 10.7% had epilepsy. Although the proportion of hemorrhagic stroke is similar to that reported in Japanese series, the proportion of ischemic stroke is lower. The latter could be partly because of patients with transient ischemic attack were listed as moyamoya disease alone.

This study has several limitations, primarily because of the use of administrative databases. First, misclassification of the disease may occur because the accuracy of diagnostic codes for identifying patients with moyamoya disease is not yet validated. Although we included only patients who underwent conventional cerebral angiography, the imaging results were not available in the databases for us to confirm the diagnosis of moyamoya disease. In addition, patients may have not been identified, if diagnostic codes of other events such as ischemia or hemorrhage were coded instead of that of moyamoya disease. These could lead to underestimate of the incidence of the disease. Second, our analyses did not include patients whose diagnosis was made solely with magnetic resonance angiography. This may cause underestimation of the incidence. Third, patients with moyamoya disease treated only in outpatient clinics were not included. Lack of outpatient claims can also result in underestimating both the incidence of moyamoya disease and the presence of the comorbid conditions. Fourth, the claims data include healthcare information for subjects with symptoms who seek care. Thus, the incidence in this study is actually the detection rate. Fifth, we were unable to capture hospitalizations earlier than 1996 because the claims database was not available until the year. A patient who had been admitted to hospital before 1996 may have been classified as a new case in the period of 2000 to 2011 if he or she had a recurrent admission. The incidence in the earlier years of our analysis, and the incidence of adults who may have had incident events in their childhood or an early age, may have been overestimated. Finally, in analyses of administrative claims database, it is difficult to identify clinical presenting symptoms or complications accurately because information on clinical symptoms is limited and might be underreported. The inherent limitation of claims database should be taken into account when interpreting results of our analyses and comparing them with those of others.

There are strengths of this study. Our observations were population based and national representative. The large size of
the database allows the relative comparison of epidemiological feature between children and adults and between time periods. This study was consistent with previous studies on several observations on characteristics of moyamoya disease such as dual age peaks and women predominance. The epidemiological patterns observed in this study are believed to be valid.

In conclusion, this study documented the incidence and patient characteristics of moyamoya disease during a 12-year period using a national inpatient database in Taiwan. The incidence rate has increased in adults from 2000 to 2011, but no upward trend was observed in patients <18 years old. Patient characteristics including sex ratio and comorbid conditions differed by age and study period.

Sources of Funding
This study was supported by grants from the National Science Council of the Republic of China, Taiwan (Grant No. NSC 101-2321-B-002-085) to Drs Kuo and Chen.

Disclosures
None.

References
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Stroke. 2014;45:1258-1263; originally published online March 27, 2014;
doi: 10.1161/STROKEAHA.113.004160
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://stroke.ahajournals.org/content/45/5/1258

Data Supplement (unedited) at:
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**SUPPLEMENTAL MATERIAL**

**Supplementary Table.** Incidence of moyamoya disease reported in previous studies and the present study

<table>
<thead>
<tr>
<th>Authors, years</th>
<th>Study region</th>
<th>Year surveyed</th>
<th>Study method</th>
<th>No. of cases*</th>
<th>Incidence† (or detection rate)</th>
<th>Men-to-women ratio</th>
<th>Peaks in age distribution (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yonekawa et al, 1997¹</td>
<td>Europe</td>
<td>1993-1996</td>
<td>Questionnaire surveys in selected hospitals (160 departments of neurology and neurosurgery; response rate, 43%)</td>
<td>168</td>
<td>0.3 per center per year†</td>
<td>1:1.4</td>
<td>0-9; 20-29</td>
</tr>
<tr>
<td>Wakai et al, 1997²</td>
<td>Japan</td>
<td>1994</td>
<td>Questionnaire surveys in randomly selected hospitals (2015 departments of neurology and neurosurgery; response rate, 67%)</td>
<td>126</td>
<td>0.35</td>
<td>1:1.8</td>
<td>Men: 10-14, 45-49; Women: 10-14, 40-45</td>
</tr>
<tr>
<td>Hung et al, 1997³</td>
<td>Taiwan</td>
<td>1978-1995</td>
<td>Chart review of patients collected from 7 major medical centers</td>
<td>92</td>
<td>0.02</td>
<td>1:1.3</td>
<td>31-40</td>
</tr>
<tr>
<td>Wetjen et al, 1998⁴</td>
<td>Iowa, USA</td>
<td>1973-1997</td>
<td>Chart review of patient records selected from stroke database of a university; Medical Records Department database of the region</td>
<td>30⁵</td>
<td>0.05</td>
<td>1:2.8</td>
<td>31-40</td>
</tr>
<tr>
<td>Uchino et al, 2005⁵</td>
<td>California, Washington, USA</td>
<td>1987-1998</td>
<td>Administrative hospital discharge databases from two states (patients identified using diagnosis code of ICD-9-CM)</td>
<td>298</td>
<td>0.09</td>
<td>1:2.1</td>
<td>5-9; 55-59</td>
</tr>
<tr>
<td>Baba et al, 2008⁶</td>
<td>Hokkaido, Japan</td>
<td>2002-2006</td>
<td>All patients diagnosed in the region, collected from certification system of registered intractable diseases</td>
<td>267</td>
<td>0.94</td>
<td>1:2.2</td>
<td>5-9; 45-49</td>
</tr>
<tr>
<td>Kuriyama et al, 2008⁷</td>
<td>Japan</td>
<td>2003</td>
<td>Questionnaire surveys in randomly selected hospitals (3254 departments of neurology, neurosurgery, etc.; response rate, 57%)</td>
<td>112</td>
<td>0.54</td>
<td>1:1.8</td>
<td>Men: 10-14, 35-39, 55-59; Women, 20-24, 50-54</td>
</tr>
<tr>
<td>Study</td>
<td>Location</td>
<td>Date</td>
<td>Methodology</td>
<td>Cases</td>
<td>Incidence</td>
<td>Ratio</td>
<td>Age (years)</td>
</tr>
<tr>
<td>-----------------------</td>
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<tr>
<td>Miao et al, 2010⁸</td>
<td>Nanjing, China</td>
<td>2000-2007</td>
<td>Chart review of patient collected from 15 major hospitals in the region</td>
<td>202</td>
<td>0.43</td>
<td>1:1.1</td>
<td>5-9; 35-45</td>
</tr>
<tr>
<td>Yim et al, 2012⁹</td>
<td>Korea</td>
<td>2004-2008</td>
<td>National Health Insurance Corporation data</td>
<td>466</td>
<td>1 (in 2008)</td>
<td>1:1.9</td>
<td>10-19; 40-49</td>
</tr>
<tr>
<td>The present study</td>
<td>Taiwan</td>
<td>2000-2011</td>
<td>Administrative inpatient databases of the National Health insurance program (patients identified using diagnosis code of ICD-9-CM)</td>
<td>422</td>
<td>0.15</td>
<td>1:1.4</td>
<td>Men: 5-9, 40-44; Women: 10-14, 40-44</td>
</tr>
</tbody>
</table>


⁸The crude incidence calculated on the basis of the number of cases and was expressed as per 100,000 annually unless indicated.
⁹The incidence was estimated to be one-tenth of that in Japan.
²One patient was categorized as akin moyamoya disease (Down’s syndrome).
References