Comparison of Clinical Characteristics and Functional Outcomes of Ischemic Stroke in Different Vascular Territories

Yee Sien Ng, MD, MRCP; Joel Stein, MD; MingMing Ning, MD*; Randie M. Black-Schaffer, MD, MA*

Background and Purpose—We aim to compare demographics and functional outcomes of patients with stroke in a variety of vascular territories who underwent inpatient rehabilitation. Such comparative data are important in functional prognostication, rehabilitation, and healthcare planning, but literature is scarce and isolated.

Methods—Using data collected prospectively over a 9-year period, we studied 2213 individuals who sustained first-ever ischemic strokes and were admitted to an inpatient stroke rehabilitation program. Strokes were divided into anterior cerebral artery, middle cerebral artery (MCA), posterior cerebral artery, brain stem, cerebellar, small-vessel strokes, and strokes occurring in more than one vascular territory. The main functional outcome measure was the Functional Independence Measure (FIM). Repeated-measures analysis of covariance with post hoc analyses was used to compare functional outcomes of the stroke groups.

Results—The most common stroke groups were MCA stroke (50.8%) and small-vessel stroke (12.8%). After adjustments for age, gender, risk factors, and admission year, the stroke groups can be arranged from most to least severe disability on admission: strokes in more than one vascular territory, MCA, anterior cerebral artery, posterior cerebral artery, brain stem, cerebellar, and small-vessel strokes. The sequence was similar on discharge, except cerebellar strokes had the least disability rather than small-vessel strokes. Hemispheric (more than one vascular territory, MCA, anterior cerebral artery, posterior cerebral artery) strokes collectively have significantly lower admission and discharge total and cognitive FIM scores compared with the other stroke groups. MCA stroke had the lowest FIM efficiency and cerebellar stroke the highest. Regardless, patients with stroke made significant ($P<0.001$) and approximately equal ($P=0.535$) functional gains in all groups. Higher admission motor and cognitive FIM scores, longer rehabilitation stay, younger patients, lower number of medical complications, and a year of admission after 2000 were associated with higher discharge total FIM scores on multiple regression analysis.

Conclusions—Patients with stroke made significant functional gains and should be offered rehabilitation regardless of stroke vascular territory. The initial functional status at admission, rather than the stroke subgroup, better predicts discharge functional outcomes postrehabilitation. (Stroke. 2007;38:2309-2314.)

Key Words: cerebral infarct ■ functional outcomes ■ rehabilitation ■ vascular territory

Advances in stroke care and an aging population result in an increasing prevalence of disabled stroke survivors with subsequent important ramifications for healthcare planning and costs. The important role of rehabilitation in stroke in reducing functional disability has been well established.1 In the stroke rehabilitation literature, functional outcome studies have described disability outcomes from stroke in specific vascular territories,2–4 a brain locality,5,6 or as a result of an impairment such as aphasia or neglect.7 Although these studies provide important information with regard to rehabilitation and prognosis for a certain stroke subtype, they do not address the comparison of functional outcomes across stroke subcategories. Such an overview is important because it provides epidemiologic data in stroke rehabilitation and prognostication as well as providing guidelines in planning limited rehabilitation resources, discharge disposition, and utilization of healthcare funding.8

In this study, we categorized stroke by vascular territory because it is practical and commonly used by clinicians and researchers in stroke care, including neurologists and rehabilitation physicians. The main aim of this prospective stroke database review is to provide baseline and comparative

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demographic, clinical, and functional outcome data of ischemic stroke categorized by different vascular territories. We also aim to evaluate the impact of the vascular territory of stroke on the discharge functional status.

Subjects and Methods

Stroke was defined based on clinical features consistent with a stroke and supported by CT or MRI findings. Admission criteria to our stroke rehabilitation unit include (1) recent hemorrhagic or ischemic stroke, (2) resultant significant impairment and disability that may benefit from inpatient rehabilitation, and (3) sufficient medical stability that allowed for continued care in a stroke rehabilitation setting. The hospital’s nurse liaisons apply these admission criteria and coordinate the transfer of appropriate patients from referring acute hospitals. All patients with stroke admitted to the Spaulding Rehabilitation Hospital (Boston, Mass) Stroke Rehabilitation Unit are prospectively included in the hospital’s Stroke Registry. Data analyses for specific parts of this patient population have been published.6–9 We reviewed the Stroke Registry for the 9-year period from January 1, 1996, to December 31, 2004. The inclusion criterion for this study was a first episode of cerebral infarction. Exclusion criteria were absence of neuroimaging or functional outcome data, death during inpatient rehabilitation stay, hemorrhagic stroke, subarachnoid hemorrhage, border-zone infarcts, recurrent stroke, and a history of admission for stroke rehabilitation. Data collected for all patients included gender, age, cerebrovascular risk factors, vascular territory involved, medical complications, and Functional Independence Measure (FIM) scores collected at admission and discharge, length of stay, and discharge disposition.

For this study, stroke data from eligible patients were extracted, and cases were grouped into 7 lesion location categories based on previously reported criteria in neuroanatomical, neurology, and rehabilitation literature.18–20 These were anterior cerebral artery (ACA), middle cerebral artery (MCA), posterior cerebral artery (PCA), brainstem, cerebellar, small-vessel stroke, and strokes in more than one vascular territory (MVT). All patients had CT and/or MRI scans read by a neuroradiologist and correlated clinically by a neurologist. The arterial territories of ACA, MCA, and PCA have been clearly described and are anatomically10–11. Small-vessel strokes are small deep infarcts in the hemispheres or brain stem that arise from the occlusion of penetrating arteries. These infarcts usually result in well-described lacunar syndromes.12 Brain stem infarcts affecting pons and medulla13 and cerebellar infarcts14 were also separated like in prior neurology and rehabilitation literature. We grouped patients with strokes in MVT for separate comparison, because greater volume of infarcted brain tissue has been correlated to poorer outcomes.9 Only ischemic strokes were included in this study, because hemorrhagic strokes have no equivalent categories and their functional outcomes are different. Only ischemic strokes were included in this study, because hemorrhagic strokes have no equivalent categories and their functional outcomes are different.9

Cerebrovascular risk factors charted included hypertension, diabetes mellitus, cigarette smoking, hypercholesterolemia, connective tissue diseases, arrhythmias, ischemic heart disease, and migraine. Patients with stroke were categorized into having ≥2 risk factors or <2. Medical complications documented were mainly nosocomial infections and included seizures and deep venous thrombosis. We categorized year of admission as year 2000 or later versus before year 2000. Rehabilitation processes have improved and are more efficient in recent years, and year 2000 represents approximately the midpoint of patient recruitment in our 9-year study.14 Age was categorized in 5-year groups for further analysis.

The FIM is the main functional outcome measure in this study. The FIM is the most widely used standardized functional outcome measure in medical rehabilitation. It consists of 13 motor and 5 cognitive items with established content and construct validity, sensitivity, and interrater reliability for the measurement of functional ability in stroke.15–16 Scores range from 1 (totally dependent) to 7 (total independence) for each of the 18 items with a maximum score of 126 indicating total functional independence. The FIM gain is the difference between the discharge and admission FIM scores and indicates functional improvement. The FIM efficiency is the FIM gain divided by the length of stay and measures rate of functional improvement.14 This study was approved by the hospital Institutional Review Board.

Statistical Analysis

For demographic data when groups were compared, the t test and analysis of variance were performed for continuous variables and the χ2 test for categorical ones. For functional outcome data, we used analysis of covariance (ANCOVA) to report adjusted means for FIM scores after correction for differences in age, gender, number of risk factors, and year of admission between the vascular territory groups. Repeated-measures ANCOVA was used to assess for change in within-subjects total FIM scores at admission and discharge and between-subjects categorized by vascular territory. Differences in improvement in FIM scores between the various stroke categories were analyzed with a test of interaction of stroke category and the FIM gain. Within the ANCOVA model, the post hoc Student-Newman-Keuls test was performed to find subsets of stroke categories with similar admission and discharge FIM scores.

Multiple linear regression analysis was performed to identify independent clinical variables associated with the discharge FIM score. Independent variables were chosen based on clinical judgment and prior literature review. The variables consisted of age, gender, year of admission, length of stay, number of cerebrovascular risk factors and medical complications, admission FIM motor scores, admission FIM cognitive scores, and the stroke vascular territory. For the stroke vascular territory, six indicator variables were created to represent the seven stroke vascular territory categories before regression analysis. These variables were then entered simultaneously into the regression model. The principle aim of this regression analysis was to establish if knowledge of the stroke vascular territory was associated significantly with the discharge FIM score above that provided by the rest of the variables. In this model, assessments for violation of assumptions were made, including analyses of normality of the residuals and linearity of the continuous variables. This occurred for admission total motor FIM score as an independent variable in the regression on discharge total FIM scores, in which a quadratic element was added to address this violation. The adjusted R2 was calculated for this model to assess whether the independent variables were good predictors of the discharge FIM score. Only significant associations are reported in the final model. Probability values of <0.05 were considered statistically significant. Analyses were performed with SPSS 11.0 for Windows (SPSS Inc).

Results

General Demographics

A total of 2213 patients met the inclusion criteria. Their mean (SD) age was 68.9 (14.3) years and 1109 (50.1%) patients were male. The male patients were younger than the female patients (mean [SD], 66.9 [13.5] versus 70.8 [14.8]; P<0.001). The mean (SD) length of stay in rehabilitation was 32.9 (23.3) days. The majority of patients (60.5%) were discharged home. The most common risk factor was hypertension (70.6%) followed by diabetes mellitus (19.7%) and 58.7% of patients had 2 or more risk factors.

The mean (SD) unadjusted admission and discharge total FIM scores were 58.28 (24.57) and 80.76 (32.51), respectively, and this improvement in FIM score is highly significant (paired t test, P<0.001). There were also highly significant gains in the motor and cognitive FIM subscores (paired t tests, P<0.001). The distribution of the patient cohort into the various vascular territories is shown in the Figure. The most common stroke subtype was MCA stroke (50.8%) followed by small-vessel stroke (12.8%) and brain stem stroke (11.4%).
TABLE 1. Clinical Demographics of 2213 Patients With Ischemic Stroke in Different Vascular Territories

| Stroke Vascular Territory | ACA (n=120) | MCA (n=1123) | PCA (n=160) | Brain Stem (n=252) | Cerebellar (n=84) | Small Vessel (n=284) | >1 Territory* (n=196) | P
|---------------------------|-------------|-------------|-------------|-------------------|-------------------|---------------------|------------------------|------
| Age, years                | 67.9 (13.2) | 70.2 (14.0) | 70.3 (14.5) | 67.2 (14.5)       | 69.4 (12.1)       | 67.3 (14.4)         | 64.9 (15.5)            | <0.001
| Male sex                  | 63 (52.5)   | 547 (48.7)  | 76 (49.4)   | 128 (50.8)        | 46 (54.8)         | 150 (52.8)          | 99 (50.5)              | 0.832
| Two or more risk factors  | 69 (57.5)   | 638 (56.8)  | 87 (56.5)   | 146 (57.9)        | 53 (63.1)         | 178 (62.7)          | 129 (65.8)             | 0.191
| Length of stay, days      | 31.1 (23.6) | 35.0 (23.9) | 32.4 (25.8) | 31.5 (22.7)       | 24.0 (19.7)       | 27.0 (18.8)         | 36.7 (23.3)            | <0.001
| Home discharge            | 72 (60)     | 63 (56.1)   | 98 (63.6)   | 171 (67.9)        | 59 (70.2)         | 204 (71.8)          | 105 (53.6)             | <0.001

Values are mean (SD) for continuous data, and number (percent) for categorical data.
*Strokes occurring in more than one vascular territory.
†P for analysis of variance for continuous variables or χ² statistic for categorical variables.
TABLE 2. Functional Outcome Measures of Patients With Ischemic Stroke in Different Vascular Territories

<table>
<thead>
<tr>
<th>Stroke Vascular Territory</th>
<th>ACA (n=120)</th>
<th>MCA (n=1123)</th>
<th>PCA (n=154)</th>
<th>Brain Stem (n=252)</th>
<th>Cerebellar (n=84)</th>
<th>Small Vessel (n=284)</th>
<th>&gt;1 Territory (n=196)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIM Scores*</td>
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<tr>
<td>Admission</td>
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<tr>
<td>Total</td>
<td>57.73 (2.13)</td>
<td>53.89 (0.70)</td>
<td>59.19 (1.88)</td>
<td>65.78 (1.47)</td>
<td>69.04 (2.55)</td>
<td>71.26 (1.40)</td>
<td>49.89 (1.69)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Motor</td>
<td>36.91 (1.53)</td>
<td>34.36 (0.50)</td>
<td>38.24 (1.35)</td>
<td>40.12 (1.05)</td>
<td>44.12 (1.83)</td>
<td>45.41 (1.01)</td>
<td>31.36 (1.20)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Cognitive</td>
<td>20.78 (0.81)</td>
<td>19.57 (0.27)</td>
<td>20.95 (0.72)</td>
<td>25.60 (0.56)</td>
<td>24.73 (0.97)</td>
<td>25.83 (0.54)</td>
<td>18.50 (0.64)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Discharge</td>
<td></td>
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<tr>
<td>Total</td>
<td>77.93 (2.84)</td>
<td>76.75 (0.93)</td>
<td>80.62 (2.50)</td>
<td>87.58 (1.96)</td>
<td>93.27 (3.39)</td>
<td>92.71 (1.87)</td>
<td>74.10 (2.23)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Motor</td>
<td>54.42 (2.17)</td>
<td>53.67 (0.71)</td>
<td>56.70 (1.91)</td>
<td>59.99 (1.49)</td>
<td>65.54 (2.59)</td>
<td>64.95 (1.43)</td>
<td>51.05 (1.71)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Cognitive</td>
<td>23.45 (0.83)</td>
<td>23.17 (0.27)</td>
<td>24.00 (0.73)</td>
<td>27.56 (0.57)</td>
<td>27.48 (0.99)</td>
<td>27.74 (0.55)</td>
<td>23.00 (0.65)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>FIM gain</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Total</td>
<td>20.19 (1.90)</td>
<td>22.87 (0.63)</td>
<td>21.45 (1.68)</td>
<td>21.78 (1.31)</td>
<td>24.16 (2.27)</td>
<td>21.45 (1.25)</td>
<td>24.21 (1.50)</td>
<td>0.535‡</td>
</tr>
<tr>
<td>Motor</td>
<td>17.51 (1.50)</td>
<td>19.32 (0.49)</td>
<td>18.46 (1.33)</td>
<td>19.86 (1.04)</td>
<td>21.42 (1.80)</td>
<td>19.54 (0.99)</td>
<td>19.76 (1.18)</td>
<td>0.720‡</td>
</tr>
<tr>
<td>Cognitive</td>
<td>2.68 (0.58)</td>
<td>3.55 (0.19)</td>
<td>3.05 (0.52)</td>
<td>1.95 (0.40)</td>
<td>2.74 (0.70)</td>
<td>1.91 (0.39)</td>
<td>4.46 (0.46)</td>
<td>&lt;0.001‡</td>
</tr>
<tr>
<td>FIM efficiency</td>
<td>1.07 (0.14)</td>
<td>0.90 (0.05)</td>
<td>0.970 (0.13)</td>
<td>0.93 (0.98)</td>
<td>1.37 (0.17)</td>
<td>1.14 (0.09)</td>
<td>0.98 (0.11)</td>
<td>0.083†</td>
</tr>
</tbody>
</table>

>1 territory: strokes occurring in more than one vascular territory.

*All FIM scores are reported as mean (SE) and adjusted for age, gender, number of risk factors, and year of admission.
†Coded as 1: admitted in year 2000 or later; 0: admitted before year 2000.
‡Repeated-measures ANCOVA, test of interaction between magnitude of FIM improvement from admission to discharge and vascular territory group.

Discussion

This large prospective cohort study helps confirm the potential for significant functional recovery during inpatient stroke rehabilitation regardless of the stroke vascular territory. Most of our demographic and functional data agree with previous reports of specific stroke groups, and the data reported here extend clinical knowledge through a comparative overview across all stroke groups.

The mean age of our cohort was similar to other acute stroke hospitals. Incidence of these stroke subtypes found in the acute rehabilitation facility, which more closely reflects the severity of functional disability for each group rather than the true incidence of these stroke subtypes found in the acute hospitals.

TABLE 3. Linear Regression Model for Independent Predictors of Total Discharge FIM Score

<table>
<thead>
<tr>
<th></th>
<th>Unstandardized Coefficient (95% CI)</th>
<th>SE</th>
<th>Standardized Coefficient</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor FIM admission</td>
<td>1.776 (1.533 to 2.018)</td>
<td>0.124</td>
<td>0.952</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Motor FIM admission (squared)</td>
<td>-0.009 (−0.012 to −0.007)</td>
<td>0.001</td>
<td>-0.422</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cognitive FIM admission</td>
<td>1.093 (0.967 to 1.218)</td>
<td>0.064</td>
<td>0.314</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of stay</td>
<td>0.198 (0.155 to 0.240)</td>
<td>0.022</td>
<td>0.141</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age*</td>
<td>-0.964 (−1.294 to −0.633)</td>
<td>0.169</td>
<td>-0.085</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No. of complications</td>
<td>-3.401 (−4.940 to −1.862)</td>
<td>0.785</td>
<td>-0.062</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Year of admission†</td>
<td>2.085 (0.315 to 3.854)</td>
<td>0.902</td>
<td>0.031</td>
<td>0.021</td>
</tr>
</tbody>
</table>

Model-adjusted $R^2=0.621$.

*Age categorized in 5-year age groups (age range, 15–102 years).
†Coded as 1: admitted in year 2000 or later; 0: admitted before year 2000.

Note: Only significant variables associated with the total discharge FIM scores are listed. The stroke vascular territory was not significantly associated with the discharge FIM score (adjusted $R^2$ change=0.001, $P=0.347$).
After adjustments for age, gender, risk factors, and year of admission, the stroke groups can be arranged in order of the most to least severe disability on admission to rehabilitation: strokes in MVT, MCA, ACA, PCA, brain stem, cerebellar, and small-vessel stroke. Strokes in MVT were the most disabled because more vascular territories were involved. MCA, ACA, and PCA infarcts also had severe disability because of the multiple motor, cognitive, and behavioral impairments that are characteristic in these territories.\(^2\)\(^-\)\(^4\) Cerebellar strokes had less motor disability and this is possibly because balance impairments are both less disabling and less well captured by the FIM than strength impairments.\(^6\) Small-vessel strokes had the least disability, because most present with lacunar syndromes with minimal cognitive and/or partial motor impairments.\(^12\)

On discharge from rehabilitation, this hierarchal arrangement of stroke groups with lowest to highest FIM scores is similar with the hemispheric strokes still being the most disabled. Patients with cerebellar stroke, rather than small-vessel stroke, were the least disabled. The mean unadjusted discharge FIM score of approximately 80 for the entire cohort indicates that modified independence or minimal assistance in activities of daily living for a large number of patients with stroke is achievable.

The lower total admission and discharge FIM scores of hemispheric strokes compared with the rest of the stroke groups can be explained partly by the much lower cognitive FIM component of the total FIM score for the hemispheric strokes. Neurocognitive impairments involving attention, memory, and executive functions as well as behavioral issues such as agitation, abulia, and depression are a feature of ACA strokes.\(^3\) MCA and PCA strokes may have further disabling language and visuospatial cognitive impairments as well.\(^2\)\(^,\)\(^4\)

More encouraging is that regardless of the vascular territory of stroke, patients in all groups made clinically significant and approximately equal functional gains on completion of inpatient rehabilitation.\(^20\) The FIM efficiency is lowest for MCA stroke and highest for cerebellar stroke. The lower FIM efficiency for MCA stroke indicates that retraining or learning compensatory techniques may take longer attributable to aphasia and apraxia in left-sided MCA lesions, and neglect and agnosia in right-sided MCA lesions, which can frustrate and hinder learning.\(^4\) The higher FIM efficiency scores for cerebellar strokes suggest that functional disability from ataxia either recovers faster or is overcome more rapidly in rehabilitation.

The lower proportion of patients with MVT and MCA strokes discharged home is likely a result of lower discharge FIM scores and more disability. Patients with ACA strokes had the next lowest proportion of home discharges and this could be attributable to the prominent cognitive and behavioral impairments in this subset, which may be difficult to manage at home.

In the regression on discharge FIM scores, the admission motor and cognitive function were the most important predictors of the discharge functional status, like in previous stroke rehabilitation studies.\(^21\) The quadratic relationship of the admission motor FIM scores with the discharge FIM scores is attributable to well-known ceiling effects in the FIM. The association of longer length of stay with higher discharge FIM scores is complex. The most straightforward interpretation is that the longer they are exposed to an active rehabilitation program, the more patients will improve because of the effect of the program or natural recovery processes. Another explanation is that only patients who are continuing to improve are allowed to stay longer in active rehabilitation. Increasing age was also associated with lower discharge FIM scores, although the absolute impact on the discharge FIM score is small. Most stroke functional outcome studies concur that although older patients have lower admission and discharge FIM scores compared with younger patients, the amount of functional gain is similar, and elderly patients also benefit significantly from stroke rehabilitation.\(^22\)

In recent years, medical rehabilitation interventions have improved tremendously and are more efficient.\(^14\) The better discharge functional outcomes in the half of the stroke cohort that was admitted in the later years agrees with this trend and is most encouraging. Medical complications interrupt or slow rehabilitation recovery and its association with lower discharge functional scores is not surprising.\(^23\) We did not find any association between the number of risk factors and discharge FIM scores. Previous literature has not consistently shown cardiovascular risk factors to be associated with functional outcomes and our sample size may also be too small to detect significant differences.\(^24\) Analysis of the regression model also indicates that specifically for prognostication of the discharge functional status, the initial functional status is the more important consideration rather than the stroke vascular territory.

A major limitation in this study is selection bias. Only patients with stroke selected for inpatient rehabilitation to our hospital were included. This sample therefore does not represent the actual functional disability of each stroke subtype, because those with little disability did not require inpatient rehabilitation and the extremely disabled would have been transferred directly to skilled nursing facilities after acute management. We were also unable to adjust for differences in the acute length of stay before rehabilitation transfer in the ANCOVA model because of incomplete data and this may have affected the baseline FIM scores. A third limitation relates to the well-known ceiling effect and motor performance bias of the FIM as an outcome scale, which may render it more sensitive to the effects of anterior than posterior circulation infarcts.

In summary, our data provide a broad comparative review of functional outcomes of stroke in different vascular territories and put into perspective previous literature reporting these stroke groups separately. In ascending order of functional status at admission to rehabilitation, strokes in MVT had the most severe disability followed by MCA, ACA, PCA, brain stem cerebellar, and small-vessel strokes. This sequential order is similar on discharge from rehabilitation except cerebellar strokes had the least disability instead of small-vessel stroke. However, significant functional improvements are made in rehabilitation by patients after stroke in all vascular territories. This highlights the importance of offering inpatient rehabilitation to appropriate patients regardless of the stroke vascular territory. Finally, in determining the
discharge functional status, the initial functional disability is the more important consideration rather than the stroke vascular territory.

We believe that this stroke functional overview may also help prognosticate disability, set rehabilitation goals, estimate costs of treatment, and facilitate discharge planning for these stroke subtypes. Further research is needed to explore the long-term outcomes of ischemic stroke subtypes and the functional outcomes of recurrent strokes in different territories.

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Disclosures

None.

References

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