Readmission and Death After Hospitalization for Acute Ischemic Stroke
5-Year Follow-Up in the Medicare Population

Dawn M. Bravata, MD; Shih-Yieh Ho, PhD; Thomas P. Meehan, MD; Lawrence M. Brass, MD; John Concato, MD

Background and Purpose—Stroke is a leading cause of hospital admission among the elderly. Although studies have examined subsequent vascular outcomes, limited data are available regarding the full burden of hospital readmission after stroke. We sought to determine the rates of hospital readmissions and mortality and the reasons for readmission over a 5-year period after stroke.

Methods—This retrospective observational cohort study included Medicare beneficiaries aged >65 years who survived hospitalization for an acute ischemic stroke (International Classification of Diseases, Ninth Revision, Clinical Modification codes 434 and 436) and who were discharged from Connecticut acute care hospitals in 1995. This population was followed from discharge in 1995 through 2000 using part A Medicare claims and Social Security Administration mortality data. The primary outcome was hospital readmission and mortality and readmission diagnosis.

Results—Among 2603 patients discharged alive, more than half had died or been readmitted at least once during the first year after discharge (1388/2603, 53.3%), and <15% survived admission-free for 5 years (372/2603, 14.3%). The reasons for hospital readmission varied over time, with stroke remaining a leading cause for readmission (3.9 to 6.1% of patients annually). Acute myocardial infarction accounted for a comparable number of readmissions (4.2 to 6.0% of patients annually). The most common diagnostic category associated with readmission, however, was pneumonia or respiratory illnesses, with an annual readmission rate between 8.2% and 9.0% throughout the first 5 years after stroke.

Conclusions—Few stroke patients survive for 5 years without a hospital readmission. Between the acute care setting and readmission to the hospital, a window of opportunity may exist for interventions, beyond prevention of recurrent vascular events alone, to reduce the huge public health burden of poststroke morbidity. (Stroke. 2007;38:1899-1904.)

Key Words: brain ischemia • mortality • patient readmission

Stroke, as the second leading cause of hospital admission among the elderly,1,2 is a major public health problem. Among those who survive, readmission is common,3 with estimates ranging from 20% to 27% in the first year.4,5

The importance of recurrent stroke is widely recognized in terms of both poor clinical outcomes and high health care costs.6 Cardiac events are also common after stroke, and are the leading cause of death after stroke.7,8 These vascular outcomes have been the focus of most clinical trials of prevention after stroke and epidemiological studies of stroke patients, but stroke also increases the risk for stroke-related nonvascular events.9 The risk for stroke-related nonvascular events (eg, pneumonia) is based in part on neurological deficits.

For other forms of vascular disease, such as congestive heart failure, a large portion of hospital readmissions are associated with nonvascular diagnoses.10 Limited data are available on the burden of readmissions after stroke. Existing data were often derived from restricted cohorts, typically from a single or small number of institutions, limited geographic area, restricted patient population (eg, from a clinical trial), short follow-up, or focused on a limited number of outcomes (eg, recurrent stroke or secondary ischemic events).5,11,12 In addition, few studies have been performed within the United States.

To prevent readmissions after stroke, accurate estimates of the absolute rates of hospital readmission, the associated diagnoses, and temporal patterns are needed. This information is needed by clinicians caring for patients, researchers designing clinical trials, and policy makers allocating limited healthcare resources.

Our study was accomplished as part of the ongoing quality improvement efforts of Qualidigm (formerly the Connecticut...
Peer Review Organization). We examined rates and reasons for readmission over a 5-year period in a cohort of patients aged ≥65 years who survived hospitalization for an acute ischemic stroke.

Methods

Study Population
The population for this retrospective cohort study included fee-for-service Medicare beneficiaries aged ≥65 years who had been admitted with an acute ischemic stroke to an acute care hospital in Connecticut during the period January 1, 1995 through December 31, 1995. The index hospitalization was defined as the first or only hospitalization the patient had in 1995 with a principal discharge diagnosis from one of the following International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes: 434.XX (cerebrovascular occlusion) or 436 (acute cerebrovascular disease). These ICD-9-CM codes identify patients with high specificity for acute ischemic stroke.13

The annual part A Medicare claims files for patients who had been hospitalized with an index stroke were linked so that we could follow the cohort forward in time from their index hospitalization in 1995 through December 31, 2000. To examine whether a patient with an index hospitalization in 1995 had a hospitalization before 1995, we linked the 1995 files to 1994 Medicare files. Each record in the Medicare file contains a unique identifier known as the health insurance claim number. This claim number allows claims to be uniquely identified and allows for the linkage of records for individuals over time (eg, for a longitudinal follow-up of hospitalizations). These Medicare data were linked to Social Security files to determine each patient’s mortality status. We used the date of death from the master beneficiary records of the Social Security Administration. Most deaths are reported within 4 months of their occurrence, and <1 in 10 000 is found in error. This death data includes all deaths (eg, inpatient and outpatient mortality).

We examined the primary and secondary ICD-9-CM codes and Current Procedural Terminology procedure codes associated with those 1994 hospitalizations to determine whether patients had a previous diagnosis of stroke, carotid endarterectomy, coronary artery disease, or peripheral vascular disease. This approach has been validated among Medicare patients.14

Inclusion and Exclusion Criteria
Our population did not include Medicare beneficiaries enrolled in health maintenance organizations, nor did it include out-of-state discharges for patients whose primary residence was in Connecticut. We did include patients who were transferred from one Connecticut acute care hospital to another in the cohort. Hospital admissions to VA hospitals were not included.

Outcomes
We examined whether patients died or were re-hospitalized during follow-up; zero-time was defined as the date of discharge of the index hospitalization in 1995. Our outcome categories were: alive and never readmitted; alive and readmitted; dead and never readmitted; dead and (interim) readmission. Because our goal was to identify broad categories of reasons for readmission, we used the primary diagnostic related group (DRG) diagnosis to define the category for hospital readmission. As performed in previous reports, records with similar DRGs were grouped into closely associated subgroups (see Appendix).1,2

Comorbidity Assessment
Comorbidity was determined at the time of the index hospitalization using the Deyo Score.15 The Deyo Score is based on the Charlson Comorbidity Index.16 We also used the Medicare claims data from 1994 to determine the number of previous hospitalizations, within the 12 months before the index (stroke) admission, as well the cause for the previous hospitalization.

Statistical Analysis
We used descriptive statistics (medians and proportions) to summarize the baseline characteristics of the cohort. We also used proportions to describe the rates and causes of hospital readmissions at various time points after the index stroke. Survival analysis with Kaplan-Meier methodology was used to examine the proportion of patients alive without hospital readmission over time.

Results
A total of 2603 acute ischemic stroke patients were discharged alive after their index stroke in 1995. The characteristics of the study cohort are presented in Table 1; the median age was 80 years (range 65 to 103), and the majority was women (1570/2603, 60.3%) and white (2384/2603, 91.6%). More than one-quarter of patients had at least one hospital admission during the year before the index stroke admission (694/2603, 26.7%); 1136/2603 (43%) of those discharged alive went to a skilled care facility.

Death or Readmission Rates
Cumulative rates of hospital readmission and death are shown in Table 2. More than half of the stroke patients had died or been readmitted at least once during the first year after discharge (1388/2603, 53.3%). Less than 15% of stroke patients discharged alive from their index stroke survived admission-free for 5 years (372/2603, 14.3%). The Figure displays the proportion of stroke patients who survived without hospital readmission during the 5-years after hospital discharge for their index stroke.

Readmission Diagnoses
Categories of diagnoses for readmission are shown in Table 3. The reasons for hospital readmission varied somewhat over time, with stroke remaining a leading cause for readmission. Stroke accounted for readmissions in 3.9% to 6.1% of patients annually. Acute myocardial infarction accounted for a comparable number of readmissions (4.2% to 6.0% of patients annually). The most common diagnostic category associated with readmission, however, was pneumonia and respiratory illnesses, with annual readmission rates between 8.2% and 9.0% throughout the 5 years after a stroke.

Discussion
The public health burden of stroke is widely recognized, but critical gaps exist in our knowledge.17 Previous work has shown that by 5 years after a stroke, half of patients are dead.18 This study extends that previous work, showing that among those who survive their stroke, few escape a readmission to the hospital.
Our study is novel in that we examined long-term readmission rates after hospitalization for ischemic stroke in a large geographically based United States cohort. We found that 1388/2603 (53%) of our cohort were either readmitted or died during the first year after stroke; this is higher than results of a study of 326 patients from Connecticut who survived a stroke, where 39.6% were readmitted or died during the first year after stroke.19 Most other stroke outcome studies focus on recurrent stroke and death.20,21 Our results help define the frequency, timing, and causes for hospital readmission, and should inform clinicians, investigators, and policy makers in identifying opportunities for application of targeted preventive strategies after stroke.

Recurrent Stroke
The clinical significance of recurrent stroke is clear; however, recurrent stroke represents only a minority of the rehospitalizations. Therapies to prevent recurrent stroke can reduce the risk of recurrent stroke, but we must move beyond recurrent stroke prevention alone if we are to reduce the public health burden of ischemic stroke.

Myocardial Infarction After Stroke
Our results emphasize the importance of cardiovascular events and extended follow-up in stroke outcome studies.8,21,22 In this study, the number of readmissions for acute myocardial infarction was comparable to that for stroke. The combination of cardiovascular events, including heart failure, coronary artery disease, and other vascular events, exceeded recurrent cerebrovascular events, even when stroke and transient ischemic attack admissions were combined. Unfortunately, clinical trials on this topic have had shorter follow-up periods and enrolled patients who are younger and healthier than community-based cohorts.6

Pneumonia and Respiratory Illness
Because of its association with dysphagia, pneumonia is especially common among patients with stroke.23 Pneumonia is a leading cause of nonvascular death after stroke in both the acute24 and chronic25 care settings. Interventions are available to prevent pneumonia among older patients,12,25 including influenza vaccination,26 pneumovax,27 and improved oral hygiene.28 Emphasizing the prevention of respiratory illness may substantially improve the long-term outcomes of patients with stroke.29

Hospital Admission Before Index Event
Hospital-based programs are important for secondary prevention of vascular disease.3,30 Although one-quarter of our patients had a hospital admission during the year before their stroke, only 5% were hospitalized with a cerebrovascular diagnosis. These results suggest a complimentary role for community-based programs in reducing the public health burden of stroke.

Limitations
Three main limitations require acknowledgement. First, the primary limitation of this study is its use of administrative
data, but our goals were not dependent on detailed clinical information, because our objective was to examine hospital readmissions after a stroke. The interpretation of readmission data are challenging, and hospital admission may be caused by more than one condition or event. Nonetheless, readmission data can provide important insights into the morbidity after ischemic stroke, especially for the more frequently reported diagnoses. For this type of large geographically based study, administrative data can provide information not available from more detailed, but restricted, data sources. Administrative data are not only appropriate for this use but currently represents the only source of data available to examine these patterns across large geographic areas of the United States. The benefit of using the Medicare and Social Security data are that it was possible to assemble a large geographically based population and follow them through a 5-year follow-up period with complete outcome assessment and with no losses to follow-up.

Second, this study only included data from Connecticut. State and regional variations exist for stroke mortality, and similar geographic variations may exist for readmission after stroke. Connecticut has a lower stroke mortality rate than most of the

### TABLE 2. Cumulative Readmission or Death by Patients

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Alive, Never Admitted</th>
<th>Alive, at Least 1 Readmission</th>
<th>Dead, at Least 1 Readmission</th>
<th>Dead, Never Admitted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% N</td>
<td>% N</td>
<td>% N</td>
<td>% N</td>
</tr>
<tr>
<td>30 days</td>
<td>83.1 2162</td>
<td>8.9 231</td>
<td>1.8 47</td>
<td>6.3 163</td>
</tr>
<tr>
<td>3 months</td>
<td>70.3 1831</td>
<td>15.3 398</td>
<td>9.3 139</td>
<td>9.0 235</td>
</tr>
<tr>
<td>6 months</td>
<td>59.4 1547</td>
<td>21.3 554</td>
<td>8.4 218</td>
<td>10.9 284</td>
</tr>
<tr>
<td>1 year</td>
<td>46.7 1215</td>
<td>27.2 709</td>
<td>13.2 343</td>
<td>12.9 336</td>
</tr>
<tr>
<td>2 years</td>
<td>31.1 809</td>
<td>32.3 842</td>
<td>21.3 555</td>
<td>15.3 397</td>
</tr>
<tr>
<td>3 years</td>
<td>22.2 577</td>
<td>32.3 841</td>
<td>28.7 746</td>
<td>16.9 439</td>
</tr>
<tr>
<td>4 years</td>
<td>17.2 447</td>
<td>31.7 825</td>
<td>33.5 971</td>
<td>17.7 460</td>
</tr>
<tr>
<td>5 years</td>
<td>14.3 372</td>
<td>34.3 893</td>
<td>33.7 878</td>
<td>17.7 460</td>
</tr>
</tbody>
</table>

The data included in this Table refer to individual patients. These categories are mutually exclusive (row totals N=2603).

Alive without hospital readmission. Kaplan-Meier curve representing patients who were alive and never readmitted to the hospital. Time-zero is discharge (alive) from index stroke admission (N=2603 at time-zero).
country, and has higher rates of preventive therapies such as the use of warfarin among patients with atrial fibrillation; therefore, our results may underestimate the full burden of readmissions after stroke in other parts of the country.32

Finally, we did not include patients with an index stroke when the patient was not admitted to the hospital or the admission was to a federal hospital (eg, Veterans Affairs hospitals). This population included Medicare beneficiaries aged 65 years enrolled in fee-for-service programs. Therefore, these results may not be applicable to patients who do not seek or require hospitalization for their index stroke, who are admitted to federal facility, who are younger than 65 years, or the elderly who are enrolled in managed care programs.

Despite these limitations, our study included a population with a diverse group of patients who represent the full spectrum of cerebrovascular disease treated at a variety of hospital types (academic and community). Therefore, these findings should have broad generalizability.

**Conclusions**

Our study provides a large geographically based assessment of readmission after stroke among the elderly in the United States. Few elderly stroke patients survive admission-free for 5 years after hospital discharge. Between the acute care for an ischemic stroke and a readmission to the hospital, a window of opportunity exists for interventions to reduce the burden of poststroke morbidity. For example, diagnosis and treatment of coronary artery disease or efforts to reduce hospitalizations for pneumonia (eg, swallowing studies or vaccination) among poststroke patients may reduce the readmission rates for patients after a stroke.7,12,25 Our findings lay the groundwork for further efforts to identify the determinants of poststroke readmission and to initiate preventive strategies.

**Appendix**

The outcome (principal discharge diagnosis) categories were defined as: stroke (DRGs 14 and 16); transient ischemic attack (DRG 15); acute myocardial infarction including cardiac catheterizations and cardiac arrest (DRGs 121, 143, 138, 139, 140, 122, 123, 125, 129, 124); cardiovascular procedures including coronary bypass, pacemaker placement, valve replacement, and other major cardiovascular procedures (DRGs 112, 116, 106, 115, 118, 120, 104, 107, 110); congestive heart failure (DRGs 127, 087); other vascular diagnoses including peripheral vascular disease, amputation for circulatory disorders, atherosclerosis, hypertension, and other vascular procedures (DRGs 113, 114, 130, 131, 132, 134, 144, 478, 479); carotid

### Table 3. Total No. of Any Readmissions* by DRG Diagnosis

<table>
<thead>
<tr>
<th></th>
<th>0–30 Days</th>
<th>1–3 Months</th>
<th>3–6 Months</th>
<th>0–1 Years§</th>
<th>1–2 Years</th>
<th>2–3 Years</th>
<th>3–4 Years</th>
<th>4–5 Years</th>
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<tbody>
<tr>
<td><strong>Cause for Readmission</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Cerebrovascular</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td>32 1.2</td>
<td>41 1.7</td>
<td>41 1.8</td>
<td>159 6.1</td>
<td>98 5.1</td>
<td>74 4.5</td>
<td>56 3.9</td>
<td>49 3.9</td>
</tr>
<tr>
<td>Transient ischemic attack</td>
<td>9 0.3</td>
<td>14 0.6</td>
<td>13 0.6</td>
<td>59 2.3</td>
<td>38 2.0</td>
<td>23 1.4</td>
<td>25 1.8</td>
<td>15 1.2</td>
</tr>
<tr>
<td>Extracranial vascular procedures</td>
<td>7 0.3</td>
<td>8 0.3</td>
<td>7 0.3</td>
<td>24 0.9</td>
<td>6 0.3</td>
<td>5 0.3</td>
<td>4 0.3</td>
<td>2 0.2</td>
</tr>
<tr>
<td><strong>Cardiovascular</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td>18 0.7</td>
<td>26 1.1</td>
<td>48 2.2</td>
<td>155 6.0</td>
<td>85 4.4</td>
<td>87 5.3</td>
<td>64 4.5</td>
<td>53 4.2</td>
</tr>
<tr>
<td>Cardiothoracic procedures</td>
<td>11 0.4</td>
<td>7 0.3</td>
<td>15 0.7</td>
<td>59 2.3</td>
<td>43 2.2</td>
<td>39 2.4</td>
<td>29 2.0</td>
<td>12 0.9</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>15 0.6</td>
<td>21 0.9</td>
<td>20 0.9</td>
<td>108 4.1</td>
<td>91 4.7</td>
<td>67 4.1</td>
<td>63 4.4</td>
<td>41 3.2</td>
</tr>
<tr>
<td>Other vascular diagnoses</td>
<td>13 0.5</td>
<td>23 1.0</td>
<td>22 1.0</td>
<td>96 3.7</td>
<td>75 3.9</td>
<td>55 3.3</td>
<td>42 3.0</td>
<td>31 2.4</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneumonia or respiratory illness</td>
<td>43 1.7</td>
<td>59 2.5</td>
<td>39 1.7</td>
<td>233 9.0</td>
<td>169 8.8</td>
<td>136 8.2</td>
<td>116 8.2</td>
<td>112 8.8</td>
</tr>
<tr>
<td>Hip fracture</td>
<td>1 0.0</td>
<td>1 0.0</td>
<td>1 0.0</td>
<td>4 0.2</td>
<td>8 0.4</td>
<td>6 0.4</td>
<td>1 0.1</td>
<td>3 0.2</td>
</tr>
<tr>
<td>Major medical (gastrointestinal) diagnoses</td>
<td>18 0.7</td>
<td>25 1.0</td>
<td>19 0.9</td>
<td>114 4.4</td>
<td>73 3.8</td>
<td>67 4.1</td>
<td>63 4.4</td>
<td>34 2.7</td>
</tr>
<tr>
<td>Psychiatric disorders</td>
<td>2 0.1</td>
<td>3 0.1</td>
<td>3 0.1</td>
<td>14 0.5</td>
<td>11 0.6</td>
<td>8 0.5</td>
<td>5 0.4</td>
<td>1 0.1</td>
</tr>
<tr>
<td>All other diagnosis</td>
<td>136 5.2</td>
<td>138 5.8</td>
<td>182 8.2</td>
<td>692 26.6</td>
<td>448 23.3</td>
<td>332 20.1</td>
<td>247 17.4</td>
<td>216 17.0</td>
</tr>
<tr>
<td><strong>Total number of readmissions</strong></td>
<td>305</td>
<td>366</td>
<td>410</td>
<td>1717</td>
<td>1145</td>
<td>899</td>
<td>715</td>
<td>569</td>
</tr>
</tbody>
</table>

*The data in this Table include all readmissions. Patients may have had >1 readmission.
†The denominator refers to the number alive at beginning of period.
§This column includes all readmissions in the first year after discharge.
endarterectomy (extracranial vascular procedures) (DRG 05); pneumonia or respiratory illness (DRGs 75, 76, 79, 80, 85, 88, 89, 90, 94, 96, 97, 99, 101, 102, 475, 483); hip fracture (DRGs 236,235); major medical diagnoses including small and large bowel procedures and other GI procedures, hepatobiliary procedures, bladder procedures, urethral procedures, kidney and tract signs and symptoms (DRGs 001, 002, 146, 148, 149, 150, 154, 168, 170, 191,197, 200, 201,211, 308, 310, 311, 315, 323, 325, 331, 341, 356, 365, 493, 494); psychiatric disorders including depression, organic disturbances, and psychoses (DRGs 425, 426, 429, 430, 434); and all other diagnoses.

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Disclosures

None.

References

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