Identifying independent risk factors for stroke in patients with atrial fibrillation is important for 2 main reasons: it sheds light on stroke pathogenesis associated with this common cardiac dysrhythmia, and it allows stratification of stroke risk for individual patients. Both are keys to prevention of the unduly large cardioembolic brain infarcts that complicate atrial fibrillation. Among nonvalvular atrial fibrillation patients, the absolute risk of stroke averages 3% to 4% per year, but it varies 20-fold depending on patient age and other clinical features.1,2 Hence, stroke risk stratification allows the absolute benefits of prophylactic antithrombotic therapy to be estimated for individual patients.

Since the initial analysis of the pooled control groups of 5 randomized clinical trials in 1994,3 several studies analyzing stroke risk factors in nonvalvular atrial fibrillation patients using multivariate analysis have yielded 4 consistent predictors: increasing age, hypertension/systolic blood pressure, diabetes, and prior embolism (Table 1).1 Prior stroke/TIA is the most powerful risk factor and is associated with high rates of stroke (>5% per year, averaging 10% per year) warranting anticoagulation, even in atrial fibrillation patients without other risk factors.1 Female sex has been less consistently linked to stroke risk, although independently predictive in 3 studies.1 Unexpectedly, heart failure has not been an independent predictor of stroke in atrial fibrillation patients. Further, a recurrent paroxysmal pattern (as opposed to persistent or permanent atrial fibrillation) in elderly patients was not independently predictive of reduced stroke risk in any of 4 studies in which it was assessed.

What are the pathogenetic implications? The 4 most consistent risk factors for stroke in atrial fibrillation patients (ie, prior stroke/TIA, advancing age, hypertension, and diabetes) are also risk factors for stroke among persons without atrial fibrillation. However, the absolute stroke rates associated with these risk factors are several times higher among atrial fibrillation patients compared with risk factor–specific age-adjusted rates in patients without atrial fibrillation. Hypertension is associated with stasis of flow and thrombus in the left atrial appendage and with cardioembolic strokes in atrial fibrillation patients (Figure).9–11 Left atrial appendage flow velocities, strongly and inversely associated with appendage thrombi, decrease with advancing age.11 Diabetes may be a marker of a prothrombotic state favoring left atrial thrombus formation.12 The large relative risk reduction of ischemic strokes by anticoagulation over aspirin in atrial fibrillation patients compared with risk factor–specific age-adjusted rates in patients without atrial fibrillation suggests that anticoagulation is associated with reduced flow stagnation and thrombus formation in the left atrial appendage.

Table 1. Independent Risk Factors for Stroke in Atrial Fibrillation Patients: Summary of Studies Using Multivariate Analysis

<table>
<thead>
<tr>
<th>Feature</th>
<th>No. of Positive Studies/Total No. of Studies Analyzing</th>
<th>Pooled Relative Risk Estimate* (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior stroke or TIA</td>
<td>5 of 5</td>
<td>2.5 (1.9–3.3)</td>
</tr>
<tr>
<td>Increasing age per decade</td>
<td>6 of 6</td>
<td>1.4 (1.3–1.6)</td>
</tr>
<tr>
<td>History of hypertension</td>
<td>4 of 5</td>
<td>1.9 (1.5–2.4)</td>
</tr>
<tr>
<td>Systolic blood pressure ≥160†</td>
<td>3 of 3</td>
<td>1.4 (1.2–1.6)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>4 of 6</td>
<td>1.7 (1.5–2.1)</td>
</tr>
<tr>
<td>Female sex</td>
<td>3 of 6</td>
<td>NC</td>
</tr>
<tr>
<td>Left ventricular dysfunction by echocardiography</td>
<td>1 of 3</td>
<td>NC</td>
</tr>
<tr>
<td>Heart failure</td>
<td>0 of 4‡</td>
<td>NC</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>0 of 5</td>
<td>NC</td>
</tr>
<tr>
<td>Paroxysmal vs permanent pattern</td>
<td>0 of 4</td>
<td>NC</td>
</tr>
</tbody>
</table>

TIA indicates transient ischemic attack; NC, not calculated. *Adapted from the Stroke Risk in Atrial Fibrillation Working Group1 with addition of data from Healey et al4; studies of anticoagulated patients were excluded. Pooled relative risks derived from maximum likelihood methods. Other independent risk factors that were statistically significant in at least 1 multivariate analysis include hormone replacement therapy6 and left atrial thrombus detected by transesophageal echocardiography.1 A recent multivariate analysis of 8932 patients receiving placebo, aspirin, or warfarin in 12 randomized trials was confirmatory.6

†Relative risk estimate for a 30-mm Hg difference in 2 trials combined15,16; estimate for systolic blood pressure is ≥160 mm Hg.

‡Significant (RR=1.7, p=0.03) in 1 subgroup analysis of patients undergoing echocardiography.7

© 2009 American Heart Association, Inc.

Stroke is available at http://stroke.ahajournals.org DOI: 10.1161/STROKEAHA.109.549428
patients with these risk factors except diabetes\textsuperscript{13,14} sharply differs from the lack of superiority of warfarin over aspirin in patients with noncardioembolic cerebrovascular diseases,\textsuperscript{15–17} indirectly supporting a cardioembolic etiology in atrial fibrillation patients. A smaller reduction by warfarin over aspirin has been reported in diabetics,\textsuperscript{13} suggesting that diabetes may be associated with noncardioembolic strokes from which elderly atrial fibrillation patients are not spared.

Heart failure alters left atrial dynamics and should logically be a predictor of left atrial thrombus formation and, consequently, of embolic stroke. Even recent heart failure (ie, within 3 months of study entry) failed to emerge from multivariate models as independently predictive of stroke.\textsuperscript{5} Heart failure can be difficult to accurately diagnose in elderly people with multiple comorbidities, potentially blunting its predictive power, yet it was diagnosed by cardiology specialists in several studies.\textsuperscript{4–6} Heart failure was significantly predictive of stroke in a pooled analysis of 3 trials, but its independent predictive value was not significant when left ventricular function by echocardiography was added to the prediction model.\textsuperscript{7} Left ventricular systolic dysfunction by echocardiography might have the advantage of being a current assessment of ventricular function over a clinical diagnosis of a history of heart failure.\textsuperscript{7} Ventricular diastolic dysfunction is less readily assessed by echocardiography and may have more influence on left atrial dynamics.

**Stroke Risk Stratification Schemes**

More than a dozen published stroke risk stratification schemes have resulted in widely varying treatment recommendations, confusion among clinicians, and nonuniform treatment.\textsuperscript{3} Currently there is an emerging consensus based on 3 prominent schemes (Table 2)\textsuperscript{18–20} that apply to both patients with paroxysmal and permanent atrial fibrillation.\textsuperscript{21,22} The popular CHADS\textsuperscript{2} scheme uses a point system with 1 point given for each of Congestive heart failure, Hypertension, Age > 75 years, Diabetes, and Stroke/TIA - 2 points. The ACC/AHA/ESC Guidelines (2006)\textsuperscript{19} and ACCP Practice Guidelines (2008)\textsuperscript{20} provide similar risk stratifications with slight differences in point allocation and risk categorization.

**Table 2. Stroke Risk Stratification in Atrial Fibrillation: Three Prominent Schemes**

<table>
<thead>
<tr>
<th>CHADS\textsuperscript{2}</th>
<th>ACC/AHA/ESC Guidelines (2006)\textsuperscript{19}</th>
<th>ACCP Practice Guidelines (2008)\textsuperscript{20}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congestive heart failure*–1 point</td>
<td>High risk</td>
<td>High risk</td>
</tr>
<tr>
<td>Hypertension†–1 point</td>
<td>Prior thromboembolism‡</td>
<td>Prior thromboembolism‡</td>
</tr>
<tr>
<td>Age &gt; 75 yrs–1 point</td>
<td>≥2 moderate risk features</td>
<td>≥2 moderate risk features</td>
</tr>
<tr>
<td>Diabetes–1 point</td>
<td>Moderate risk</td>
<td>Intermediate risk</td>
</tr>
<tr>
<td>Stroke/TIA - 2 points</td>
<td>Age &gt; 75 years</td>
<td>Age &gt; 75 years</td>
</tr>
<tr>
<td>Low risk = 0 points</td>
<td>Heart failure**</td>
<td>History of hypertension†</td>
</tr>
<tr>
<td>Moderate risk = 1 point</td>
<td>Diabetes</td>
<td>Diabetes</td>
</tr>
<tr>
<td>High risk ≥2 points</td>
<td>Left ventricular ejection fraction ≤35% or fractional shortening &lt;25%</td>
<td>Moderately to severely impaired left ventricular systolic function¶</td>
</tr>
<tr>
<td>Low risk §</td>
<td>No moderate- or high-risk features</td>
<td>No intermediate or high-risk features</td>
</tr>
</tbody>
</table>

ACC/AHA/ESC indicates American College of Cardiology/American Heart Association/European Society of Cardiology; ACCP, American College of Chest Physicians.

*Recent heart failure exacerbation was used in the original stratification, but subsequently any prior or current heart failure has supplanted.
†A history of hypertension, not specifically defined.
‡Prior stroke, TIA, or systemic embolism.
§“Less well-validated” risk factors were female sex, coronary artery disease, and age 65 to 74 years. Unclear whether patients with ≥1 should be categorized as moderate risk; antithrombotic therapy with either vitamin K antagonists or aspirin is reasonable depending on bleeding risks, ability to safely sustain anticoagulation, and patient preferences.
¶Echocardiographic parameters not specifically defined.
*In previous studies, moderate risk was typically defined as CHADS\textsuperscript{2} scores of 1 or 2.\textsuperscript{5} The current definition makes the 3 schemes very similar.
**Not clear whether history of heart failure, recent heart failure, or current heart failure.
Overall stroke rates were low, and there is a paucity of data tested in a large administrative outpatient database in which unresolved. These schemes did not perform optimally when other 2 (very similar) schemes (Table 3).

Data from 7 studies support that a CHADS2 score of 1 carries by many) from those with higher or lower risks. Aggregate stroke risk (ie, considered to be moderate or intermediate risk accurately discriminate patients with an approximately 2%/yr risk that would alter antithrombotic prophylaxis: their ability to

Discrimination of these schemes is dependent on the threshold stroke rates for prior Stroke/TIA. If CHADS2 score of 1 is defined as moderate or intermediate risk, the 3 schemes are very similar, the remaining 2 guidelines using CHADS2 variables with the addition of echocardiographic assessment of left ventricular systolic dysfunction. The addition of left ventricular systolic dysfunction by echocardiography to the CHADS2 scheme shifts classification of about 5% of atrial fibrillation patients to a higher strata. A representative cohort of atrial fibrillation patients would be categorized as 20% low risk, 34% intermediate risk, and 46% high risk. The clinical value of these schemes is dependent on the threshold stroke rates that would alter antithrombotic prophylaxis: their ability to accurately discriminate patients with an approximately 2%/yr risk (ie, considered to be moderate or intermediate risk by many) from those with higher or lower risks. Aggregate data from 7 studies support that a CHADS2 score of 1 carries an ischemic stroke risk of about 2%/yr, with no data for the other 2 (very similar) schemes (Table 3).

Despite the emerging consensus, many important issues are unresolved. These schemes did not perform optimally when tested in a large administrative outpatient database in which overall stroke rates were low, and there is a paucity of data about the absolute stroke rates associated with classification as high risk. It is also unclear whether and how heart failure, not an independent predictor of stroke in atrial fibrillation patients as discussed above, contributes to risk stratification. Current schemes do not take into account the duration, severity, or treatment of the key predictors. Does well-treated hypertension carry the same risk as untreated hypertension in atrial fibrillation patients? Probably not. Markers of a prothrombotic state contributing to left atrial appendage thrombus formation have been explored in many studies, but their contribution to risk stratification is ill-defined. Much work remains to improve stroke risk stratification for the millions with nonvalvular atrial fibrillation.

Disclosures

None.

References


Key Words: atrial fibrillation • stroke • risk factors • clinical prediction rules • risk stratification
Current Status of Stroke Risk Stratification in Patients With Atrial Fibrillation
Robert G. Hart and Lesly A. Pearce

*Stroke*. 2009;40:2607-2610; originally published online May 21, 2009; doi: 10.1161/STROKEAHA.109.549428

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2009 American Heart Association, Inc. All rights reserved.
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/40/7/2607

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Stroke* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to *Stroke* is online at:
http://stroke.ahajournals.org/subscriptions/