Features on Initial Computed Tomography Scan of Infarcts With a Cardiac Source of Embolism in the NINDS Stroke Data Bank

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Background and Purpose: The lack of valid criteria for the clinical diagnosis of cardiogenic embolism is a major problem in both patient care and research. The aim of this study was to identify features on the initial computed tomogram of the brain that discriminate between patient groups with and without a cardiac source of embolism. To gain insight into the neuroradiological features relevant to the diagnosis of cerebral embolic stroke, we studied the initial computed tomogram of the 1,267 patients with ischemic stroke and such a scan in the National Institute of Neurological Disorders and Stroke (NINDS) Stroke Data Bank.

Methods: We analyzed the initial computed tomographic data from 1,267 patients with ischemic stroke in the NINDS Stroke Data Bank. Based solely on the presence of cardiac sources of embolism, we defined groups with high (n=244), medium (n=165), and low (n=858) risk for cardiogenic embolism and compared the features on the initial computed tomogram among these three groups.

Results: Patients in the high-risk group were significantly more likely (p<0.001) to have infarcts involving one half lobe or larger or infarcts involving both superficial and deep structures than patients in the medium- or low-risk groups. In contrast, deep small infarcts had a negative association (p=0.004) with the presence of a cardiac source of embolism. There was no significant trend across risk groups in the percent with hemorrhagic infarction, regardless of whether patients with anticoagulant use at the time of the stroke were excluded.

Conclusion: Although some features of the initial computed tomogram had highly significant associations with the presence of a cardiac source of embolism, the predictive value of these features for an embolic source was low. (Stroke 1992;23:1748-1751)

KEY WORDS • cerebral ischemia • cerebrovascular disorders • embolism • tomography, emission computed

Computed tomography (CT) of the brain is an important part of the initial evaluation of stroke, primarily to differentiate ischemic from hemorrhagic stroke.1 However, the appearance of the CT scan may also suggest the presence of a cardioembolic stroke mechanism. Prior studies of the CT scan features of cardioembolic stroke have not used comparison groups2,3 or have not focused their analysis on the initial CT scan.4,5 This report is the first to compare features of the initial CT scan among patient groups with high, medium, and low risks of cardiogenic embolism.

Materials and Methods

In the National Institute of Neurological Disorders and Stroke Stroke Data Bank6 1,290 patients with ischemic stroke were studied at Boston University, Columbia University, Michael Reese Hospital, and the University of Maryland. Only the 1,267 patients with a
Almost all patients had a CT scan on admission. Only 613 had repeat scans. The factors responsible for a repeat scan and its timing were unknown and might be differentially distributed across the three patient groups. For this reason, analysis of the initial CT scan was considered to be more valid. All analyses were additionally performed for the last CT scan during hospitalization. However, these results are noted only where they are of particular interest or differ substantially from the results for the initial CT scan.

Several of the CT scan features require further explanation. Edema or mass effect was considered to be present only if it was more than mild in degree. Cortical infarcts in more than one vascular distribution were defined as present if there was bilateral involvement of the frontoparietal lobes or if there was involvement of either frontoparietal lobe and either occipital lobe. For this analysis only, all lesions were considered, both acute and chronic, symptomatic and asymptomatic. For all other analyses, only acute symptomatic lesions were considered. For hemorrhagic infarcts, two analyses were performed. Only patients not on anticoagulant therapy at the time of admission were considered in the first analysis. All patients, regardless of anticoagulant therapy at admission, were included in the second analysis.

The statistical significance ($p<0.05$) of the relation between each CT scan feature and the ordered cardiac source of embolism risk groups was assessed by the Mantel-Haenszel $x^2$ test for trend.

### Results

The median time from stroke onset to the first CT scan differed for the low- (24 hours), medium- (19 hours), and high-risk (13 hours) groups. The median times from stroke onset to the last CT scan were more similar in the low- (72 hours), medium- (75 hours), and high-risk (66 hours) groups.

Table 2 shows the distribution of selected features of the initial CT scan in each cardiac source of embolism risk group. A significant ($p<0.001$) trend for the relation between edema or mass effect and the ordered risk groups was demonstrated. There was also an increased percentage of bilateral anterior circulation cortical infarcts in the high-risk group, although the trend did not achieve significance ($p=0.056$). No association was found between hemorrhagic infarction and the cardiac source of embolism risk groups, regardless of whether patients with anticoagulant use at the time of the stroke were excluded from the analysis.

When features from the last CT scan during hospitalization were used in the analysis, all the findings from the initial CT scan were accentuated. The frequencies of bilateral anterior circulation cortical strokes in the low-, medium-, and high-risk groups were 3.8%, 3.8%, and 5.8%, respectively ($p=0.09$). In the analysis of hemorrhagic infaracts, patients on anticoagulant therapy at the time of admission or during hospitalization were excluded. The rates of hemorrhagic infarction in the low-, medium-, and high-risk groups were 2.5%, 1.0%, and 5.8%, respectively ($p=0.09$). Edema or mass effect in the low-, medium-, and high-risk groups was present in 5%, 7%, and 17% of the patients, respectively.

It was more common for an acute symptomatic lesion to be seen on the initial CT scan in the high-risk group (48%) than in the medium- (38%) or low-risk (41%)
groups, although this trend did not achieve significance ($p=0.09$). Figure 1 shows the distribution of size among acute symptomatic lesions in each cardiac source of embolism risk group for the initial CT scan. Patients in the high-risk group were significantly ($p<0.001$) over-represented among those with lesions involving one half lobe or more and significantly under-represented ($p=0.001$) among those with lesions involving less than 1 cm. When only patients with infarcts involving more than one half lobe were considered, there was an increased percentage with edema in the high-risk group (28%) compared with the medium- (19%) and low-risk (21%) groups, although this trend also did not achieve significance ($p=0.3$).

When the last CT scan during hospitalization was used, acute symptomatic lesions were seen significantly more often ($p=0.001$) in the high-risk group (64%) than in the medium- (54%) or low-risk (51%) groups. The same patterns were seen for each lesion size category, except that differences in the one half to one lobe category were less and did not attain statistical significance while differences in the more than one lobe category were increased (low-risk group, 10%; medium-risk group, 13%; and high-risk group, 25%; $p<0.001$).

Figure 2 shows the distribution of location categories for acute symptomatic lesions for each cardiac source of embolism risk group for the initial CT scan. Patients in the high-risk group were over-represented ($p<0.001$) among those with lesions involving both superficial and deep structures and under-represented ($p=0.004$) among those with deep small infarcts. Lesions involving only superficial structures showed no trend across the cardiac source of embolism risk groups. Deep large infarcts showed a nonsignificant trend ($p=0.13$) toward association with the high-risk group. When the last CT scan was considered in the analysis, trends of the same direction and magnitude were seen.

**Discussion**

Our objective was to study the CT scan features of cardioembolic stroke. Since the CT scans were read by

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**TABLE 2. Distribution of Computed Tomographic Features of Stroke in Relation to Cardiac Source of Embolism Risk Groups**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Low (n=858)</th>
<th>Medium (n=165)</th>
<th>High (n=244)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral anterior circulation cortical infarct*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2.9</td>
<td>2.4</td>
<td>5.7</td>
<td>0.056</td>
</tr>
<tr>
<td>No</td>
<td>97.1</td>
<td>97.6</td>
<td>94.3</td>
<td></td>
</tr>
<tr>
<td>Anterior and posterior circulation cortical infarct*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2.8</td>
<td>3.6</td>
<td>3.7</td>
<td>0.4</td>
</tr>
<tr>
<td>No</td>
<td>97.2</td>
<td>96.4</td>
<td>96.2</td>
<td></td>
</tr>
<tr>
<td>Hemorrhagic infarct†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.6</td>
<td>0</td>
<td>2.7</td>
<td>0.5</td>
</tr>
<tr>
<td>No</td>
<td>98.4</td>
<td>100</td>
<td>97.3</td>
<td></td>
</tr>
<tr>
<td>Edema or mass effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2.9</td>
<td>4.8</td>
<td>9.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No</td>
<td>97.1</td>
<td>95.2</td>
<td>91.0</td>
<td></td>
</tr>
</tbody>
</table>

[Data are %.
*All lesions considered, both symptomatic and nonsymptomatic, acute and old.
†Only patients not on anticoagulant therapy at time of admission considered.]

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**FIGURE 1. Bar graph of distribution of size of acute symptomatic lesions in cardiac source of embolism risk groups. Open bars, low-risk group; shaded bars, medium-risk group; filled bars, high-risk group.**

**FIGURE 2. Bar graph of distribution of location of acute symptomatic lesions in cardiac source of embolism risk groups. Open bars, low-risk group; shaded bars, medium-risk group; solid bars, high-risk group.**
Stroke Data Bank staff, there was the potential for bias in the classification of stroke subtype (cardioembolic versus atherosclerotic, lacunar, other, or unknown cause) or in the description of the CT scan. We sought to minimize bias in the classification of stroke subtype by using the presence of a cardiac source of embolism as proxy for the clinical diagnosis of cardioembolic stroke. There is still the potential for bias in the reading of the CT scans, but we believe that this is unlikely to have accounted for our findings.

The CT scan features found in the high-risk group tend to be associated in that large strokes are more likely to be both superficial and deep and these are the strokes most likely to have edema or a mass effect on a CT scan. These group differences may underestimate the true differences between strokes with and without a cardioembolic source because echocardiograms and Holter monitoring were not performed in every patient. Thus, it is likely that the low-risk group contains some patients with an undetected cardiac source of embolism.

Although our report is the first to examine stroke size per se, Caplan and coworkers reported that patients with a clinical diagnosis of cerebral embolism had a higher frequency of visualized lesions than patients with nonembolic etiologies. Weisberg reported that 13 of 50 patients with a presumptive diagnosis of cerebral embolism had a mass effect on a CT scan performed within 48 hours after admission. Although infarcts involving more than one lobe were highly associated with a cardiac source of embolism, their predictive value for the high-risk group was only 33%.

Our finding that deep small infarcts have a predictive value of 90% for the absence of a major cardiac source of embolism is consistent with recent studies and our earlier analysis of neurological examination features showing that pure motor syndromes were underrepresented among patients in the high-risk group.

Although there was a suggestion that cortical infarcts in more than one vascular distribution (specifically, bilateral anterior circulation infarcts) were more common among patients having a cardiac source of embolism, such infarcts were relatively uncommon and attained statistical significance only when the last CT scan was considered.

Although hemorrhagic infarction was expected on theoretical grounds to be more common in cardioembolic stroke, such infarction was rare in the Stroke Data Bank and did not discriminate between the risk groups even when the last CT scan was considered. Similarly, in the Michael Reese Stroke Registry none of 72 patients with clinically diagnosed cardioembolic stroke had a hemorrhagic infarct on CT. In contrast, in the Lausanne Stroke Registry a hemorrhagic component on the initial CT scan was seen in 7.9% of 305 patients with a potential cardiac source of embolism compared with 4% of 1,006 patients without an embolic source (p < 0.05).

We may have failed to detect hemorrhagic infarction because of the limited resolution of older-generation CT scanners or because the CT scan was performed before hemorrhagic transformation.

Our data show that the initial CT scan in patients admitted for acute stroke contains information that may suggest the presence or absence of an underlying cardiac source of embolism. However, because the predictive value of individual CT scan features is limited, efforts to develop a multivariate predictor based on historical, neurological examination, and CT features are in progress.

Acknowledgment
The authors wish to thank Pat Haworth for her expertise in manuscript preparation.

References
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*Stroke*. 1992;23:1748-1751
doi: 10.1161/01.STR.23.12.1748

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1992 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/23/12/1748

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