Supraventricular Tachycardia in Patients With Right Hemisphere Strokes

Richard D. Lane, MD; Jan D. Wallace, MD; Patricia P. Petrosky, MD; Gary E. Schwartz, PhD; and Alan H. Gradman, MD

Background and Purpose: The physiological basis for the arrhythmias commonly observed after a stroke is not well understood. Based on evidence that the right and left cerebral hemispheres influence cardiac function in different ways, we sought to determine whether the nature and severity of cardiac arrhythmias in the context of an acute stroke vary in relation to whether the stroke is located in the left or the right hemisphere.

Methods: Data were obtained from the medical records of nineteen patients with left hemisphere strokes and nineteen patients with right hemisphere strokes who had also had 24-hour electrocardiographic (Holter) recordings within 2 weeks of admission to a stroke unit. Written Holter monitor reports already on file were used for the data analysis.

Results: All four patients with supraventricular tachycardia had right hemisphere strokes (p=0.05). There was a nonsignificant trend for left hemisphere stroke patients to have more severe ventricular arrhythmias.

Conclusions: These data provide partial support for the hypothesis that the two cerebral hemispheres have a differential influence on the nature and severity of arrhythmias following an acute stroke. We speculate that parasympathetic tone was diminished ipsilateral to the affected hemisphere associated with a reciprocal rise in sympathetic tone on that side and recommend that a prospective study be undertaken to test this hypothesis more definitively. (Stroke 1992;23:362–366)

KEY WORDS • cardiovascular diseases • cerebrovascular disorders • tachycardia

Changes in the electrocardiogram have been observed in association with pathological changes in the central nervous system for over forty years.1–3 Most studies in this area of research1–8 have examined changes in the 12-lead electrocardiogram. A smaller number of reports using continuous cardiac monitoring have shown a high incidence of arrhythmias among stroke patients9,10 which exceeds that among control subjects.11 To date, the mechanisms that could account for these changes have not been well understood, but a primary focus has been on increased sympathetic tone,12–16 perhaps through disinhibition of hypothalamic or other autonomic regulatory centers.16 The purpose of this study was to determine whether lesions located in the right or left hemisphere influence the nature and severity of cardiac arrhythmias in a differential manner.

Several studies in animals17 and patients18 show that the sinoatrial node is under right autonomic control, and that stimulation or inhibition of the right medulla,19 hypothalamus,20 and cerebral hemisphere21–24 have a greater influence on heart rate than do comparable changes on the left. These studies suggest that asymmetries in brain function influence the heart through ipsilateral pathways. Other studies demonstrate that an imbalance in sympathetic tone favoring the left side lowers ventricular fibrillation threshold more than an imbalance favoring the right.25,26 Consistent with the greater ventricular distribution of left-sided sympathetics and the greater supraventricular distribution of right-sided sympathetics,17 stimulation of the right-sided sympathetics is associated with supraventricular arrhythmias.27

Based on the evidence suggesting that the brain may influence the heart through ipsilateral pathways and that arrhythmias after stroke are primarily due to increased sympathetic tone, we predicted that strokes on a given side would be associated with cardiac arrhythmias characteristic of ipsilateral sympathetic stimulation. We therefore predicted an association between 1) right-hemisphere strokes and tachyarrhythmias of supraventricular origin and 2) left-hemisphere strokes and arrhythmias of ventricular origin.

Subjects and Methods

The records of all patients who were admitted to the Stroke Unit of the West Haven, Conn., Veterans Affairs Medical Center over a 4½-year period were reviewed for the purposes of this study. There were 723 admissions. Patients diagnosed with strokes (ischemic or
hemorrhagic infarcts of the brain resulting in persistent neurological deficits) localized to either the right or left hemisphere were identified. Localization was accomplished primarily on the basis of neurological examination, although data such as findings on computed tomography were used as well when available. The final diagnosis used was that noted in the database maintained by the director of the stroke unit. Only patients whose lesions could be localized to the right or left hemisphere with certainty were included. Patients with acute onset of bilateral neurological deficits, lesions in the brain stem, transient ischemic attacks, ischemic neurological deficits that resolved before 24-hour electrocardiographic (Holter) monitoring, or lesions with uncertain location were excluded.

This list of patients with lateralized strokes was then cross-referenced with the records of all West Haven Veterans Affairs Medical Center patients who had ever undergone 24-hour electrocardiographic (Holter) monitoring. Approximately 20% of the patients admitted to the stroke unit had undergone Holter monitoring during their hospitalization. Patients who had undergone Holter monitoring within 2 weeks after their admission to the stroke unit and who met the other exclusion criteria listed above were identified. Nineteen patients with right-hemisphere strokes and 19 patients with left-hemisphere strokes met these criteria. The percentage of patients with right- and left-hemisphere strokes who had had Holter monitor recordings was virtually identical. The written Holter monitor reports already on file were used for the data analysis.

Charts that could be located were reviewed to determine age, race, and handedness, as well as the presence of diabetes mellitus, hypertension, previous myocardial infarction or coronary artery disease, chronic obstructive pulmonary disease, prior structural central nervous system lesions, carotid artery disease, indication for obtaining the Holter recording, and antiarrhythmic medications on admission. In addition, the accuracy of the localization of the stroke was verified.

Results

The charts of 18 of 19 right-hemisphere stroke patients and 17 of 19 left-hemisphere stroke patients were located and reviewed. All patients were male except for one female left-hemisphere stroke patient. The mean age of right-hemisphere stroke patients was 68.2 (SD=13.1) years compared with a mean age of 63.8 (SD=11.1) years for left-hemisphere stroke patients (t 33=1.06, NS). Except for two right-hemisphere stroke patients who were black, all patients were white. The number of patients in each of the two groups who were left-handed as well as the number of patients in each group who had diabetes mellitus, hypertension, coronary artery disease including prior MI, COPD, and prior lateralized strokes is indicated in Table I.

These charts were also reviewed to determine whether patients were receiving medication(s) at the time of admission that might alter the propensity for cardiac arrhythmias. Among the 18 patients with right-hemisphere strokes, five were receiving β-blockers alone (for hypertension or angina), three were receiving digoxin alone, one was receiving quinidine alone, and one was receiving digoxin and quinidine. Among the 17 patients with left-hemisphere strokes, two were receiving digoxin alone, two were receiving digoxin plus propranolol, and one was receiving digoxin plus quinidine. The remainder of the patients were receiving medications that did not have antiarrhythmic effects.

Charts were also reviewed to determine the indication for obtaining the Holter monitor recording. In over one third of cases the recording was obtained without specific indication as part of a broad search for a possible etiology of the stroke ("rule-out arrhythmia"). The indications and their frequency are listed in Table 2.

An independent set of records was also reviewed to determine whether ultrasound studies of the internal carotid arteries had been done within 6 months after patient admission to the stroke unit. Six of 19 patients with right-hemisphere strokes and eight of 19 patients with left-hemisphere strokes had had such studies done. Among the patients with right-hemisphere strokes, three had equivalent degrees of disease on the two sides, two had more severe disease on the left that was not hemodynamically significant, and one had more severe disease on the right that was hemodynamically significant. Among the patients with left-hemisphere strokes, four

<table>
<thead>
<tr>
<th>Clinical characteristic</th>
<th>Right (n = 18)</th>
<th>Left (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left-handed</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definite</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Possible</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Essential</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Labile or borderline</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(including myocardial infarction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definite</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Possible</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary diseases</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Prior lateralized strokes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Right</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Antiarrhythmic medications</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

patients with left-hemisphere strokes, two were receiving digoxin alone, two were receiving digoxin plus propranolol, and one was receiving digoxin plus quinidine. The remainder of the patients were receiving medications that did not have antiarrhythmic effects.

Charts were also reviewed to determine the indication for obtaining the Holter monitor recording. In over one third of cases the recording was obtained without specific indication as part of a broad search for a possible etiology of the stroke ("rule-out arrhythmia"). The indications and their frequency are listed in Table 2.

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<table>
<thead>
<tr>
<th>Indication</th>
<th>Right (n = 18)</th>
<th>Left (n = 15*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule-out arrhythmia</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Bradycardia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>History of atrial arrhythmia</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>History of ventricular arrhythmia</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Frequent premature ventricular contractions</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rule-out demand pacemaker malfunction</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Syncope</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Angina, recent myocardial infarction</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

*Two charts reviewed originally could not be located for reanalysis.
had equivalent degrees of disease on the two sides, three had greater disease on the left that was not hemodynamically significant, and one had greater disease on the right that was hemodynamically significant.

One right-hemisphere and one left-hemisphere stroke patient were in atrial fibrillation. The remaining patients were classified according to the severity of supraventricular arrhythmias manifested. Premature atrial contractions were categorized as follows: no (none), rare (1–2/min), occasional (3–4/min), or frequent (5–6/min). Supraventricular tachycardia (SVT) was defined as three or more consecutive supraventricular beats at an average rate of ≥100 beats per minute. Each patient was classified in the category of greatest severity.

The results are shown in Table 3. In general, patients with right-hemisphere strokes had more severe supraventricular arrhythmias. The difference between the two groups in number of patients with SVT was statistically significant.

Ventricular arrhythmias were classified according to a modification of the Lown grading system. The categories included no premature ventricular contractions (PVCs), uniform PVCs, multiform PVCs, couplets, and ventricular tachycardia. No distinction was made between <30 or >30 PVCs per hour, nor was the presence or absence of R on T included because these distinctions were not always addressed by the original reader. Ventricular tachycardia was defined as three or more consecutive beats of ventricular origin at an average rate ≥100 beats per minute. Each patient was classified in the category of greatest severity.

The results are shown in Table 4. There were no statistically significant differences in any of the categories. However, there was a nonsignificant trend (p = 0.16 by Fisher’s exact test) for patients with left-hemisphere strokes to have more severe ventricular arrhythmias, illustrated by collapsing the first two categories (no premature atrial contractions and rare premature atrial contractions) into a “less severe” group and the last three categories into a “more severe” group.

**Discussion**

These data provide partial support for the hypothesis that right- and left-hemispheric lesions are associated with different types of cardiac arrhythmias. The finding that SVT was found only in patients with right-sided strokes is consistent with the literature showing that hemispheric modulation of cardiac function is predominantly ipsilateral. This finding is also consistent with a case report describing a patient with a tumor in the right frontal lobe who experienced repeated bouts of SVT until the tumor was excised, after which time SVT did not recur.

The two groups of stroke patients were comparable in terms of handedness, diabetes, chronic obstructive pulmonary disease, prior arrhythmia history, and coronary artery disease, including past myocardial infarction. Although more right-sided stroke patients were hypertensive, taking β-blockers, and had prior structural lesions of the central nervous system on the contralateral side, these differences (none were statistically significant) cannot explain the association between SVT and right-sided strokes: none of the four patients with SVT had a history of SVT before the index admission, and only one of the four patients with SVT had had a prior lateralized stroke. Because β-blockers are an effective treatment for most cases of SVT, the greater use of β-blockers in patients with right-sided strokes may have masked an even larger association with SVT.

Supraventricular tachycardia is a heterogeneous phenomenon, the subtype of which can be elucidated in most cases by special leads and bedside maneuvers. Unfortunately, such special techniques were not used in this study. However, it is known that SVT is initiated by one of three general mechanisms: reentry, enhanced automaticity, and triggered automaticity. All three mechanisms can be activated by an increase in sympathetic tone. Reentry is the cause in over two thirds of cases, and triggered automaticity is least common. Asymmetry in sympathetic tone is well accepted as a source of reentry.

The findings of Yokoyama and colleagues, who demonstrated that patients with right-hemisphere strokes manifested impairment in a parasympathetically mediated heart-rate response, make it possible to hypothesize how right-sided strokes can induce SVT. The parasympathetic innervation of the heart follows a general mechanism: reentry, enhanced automaticity, and triggered automaticity. Although a decrease in parasympathetic tone would be associated with an increase in atrial refractoriness, the probable reciprocal rise in sympathetic tone could enhance automaticity, increase the dispersion of refractory periods (and the propensity for reentry), or increase the likelihood of triggered automaticity.

The finding of a nonsignificant trend linking left-sided strokes with ventricular arrhythmias can be understood in several different ways. 1) Only the right hemisphere has a direct influence on cardiac function. Although only patients with right-hemisphere impair-

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**Table 3. Number of Patients With Right- and Left-Hemisphere Strokes With Supraventricular Arrhythmias of Varying Severity**

<table>
<thead>
<tr>
<th>Categories</th>
<th>Right (n=18)</th>
<th>Left (n=18)</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No PACs</td>
<td>4</td>
<td>4</td>
<td>0.65</td>
</tr>
<tr>
<td>Rare PACs</td>
<td>8</td>
<td>10</td>
<td>0.37</td>
</tr>
<tr>
<td>Occasional PACs</td>
<td>0</td>
<td>3</td>
<td>0.11</td>
</tr>
<tr>
<td>Frequent PACs</td>
<td>2</td>
<td>1</td>
<td>0.50</td>
</tr>
<tr>
<td>Supraventricular tachycardia</td>
<td>4</td>
<td>0</td>
<td>0.05</td>
</tr>
</tbody>
</table>

PAC, premature atrial contraction.

*For each category, a 2×2 table (right-left, present-absent) was created and the probability of that result calculated. Probabilities shown reflect one-tailed tests. A probability value of ≤0.05 was considered statistically significant.

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**Table 4. Number of Patients With Right Hemisphere and Left Hemisphere Strokes With Ventricular Arrhythmias of Varying Severity**

<table>
<thead>
<tr>
<th>Categories</th>
<th>Right (n=19)</th>
<th>Left (n=19)</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No PVCs</td>
<td>3</td>
<td>1</td>
<td>0.30</td>
</tr>
<tr>
<td>Rare PVCs</td>
<td>6</td>
<td>4</td>
<td>0.36</td>
</tr>
<tr>
<td>Multiform PVCs</td>
<td>4</td>
<td>6</td>
<td>0.36</td>
</tr>
<tr>
<td>Couplets</td>
<td>4</td>
<td>5</td>
<td>0.50</td>
</tr>
<tr>
<td>Ventricular tachycardia</td>
<td>2</td>
<td>3</td>
<td>0.50</td>
</tr>
</tbody>
</table>

PVC, premature ventricular contraction.

*For each category, a 2×2 table (right-left, present-absent) was created and the probability of that result calculated. Probabilities shown reflect one-tailed tests. A probability value of ≤0.05 was considered statistically significant.
ment have been shown to manifest attenuated autonomic arousal,\textsuperscript{22,23,38–40} no previous study, to our knowledge, has been specifically designed to look at the relation between left-hemisphere function and left-sided autonomic influences on the heart. 2) A weaker relation with unilateral stroke would be expected with ventricular beats, compared to supraventricular beats, insofar as the extent to which the effects of unilateral stroke are primarily mediated through parasympathetic mechanisms: the latter are dominant in the atria, whereas sympathetic mechanisms are dominant in the ventricles. 3) The greater proportion of old contralateral central nervous system lesions in the right-sided stroke patients weakened a larger true difference between the groups. The opposing view that a greater use of $\beta$-blockers in the right-sided stroke group should have increased this difference is not likely, in that three of these five patients were classified in the more severe ventricular arrhythmia group.

Lane and Schwartz\textsuperscript{41} hypothesized that emotion may trigger ventricular arrhythmias and sudden death through lateralized hemispheric activation, which may get channeled downstream to induce a lateralized imbalance in sympathetic input to the heart. Our findings are consistent with this hypothesis in that right-hemispheric lesions appeared to influence cardiac rhythm through ipsilateral autonomic mechanisms. It may be necessary to induce hemispheric asymmetry through activation rather than inhibition (as in this study) to adequately test the applicability of this model to ventricular arrhythmias.

In conclusion, these data provide partial support for the hypothesis that the right and left hemispheres influence the nature and severity of cardiac arrhythmias in a differential manner. A prospective study is now needed in which Holter monitor recordings are obtained on consecutively admitted stroke patients. Such a study could also include greater control of variables such as type of lesion (e.g., ischemic versus hemorrhagic infarct), exact location of the lesion, time interval from onset of symptoms to Holter recording, handedness, and prior structural central nervous system lesions, as well as more precise quantification of other relevant conditions such as diabetes, hypertension, chronic obstructive pulmonary disease, coronary artery disease, prior arrhythmias, medications that decrease or increase the propensity for certain types of arrhythmias, and electrolyte abnormalities. In addition, once arrhythmias are detected, new cardiological techniques\textsuperscript{33} could be used to further elucidate the likely proximal electrophysiological mechanisms involved.

Acknowledgments

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