The Electrocardiogram in Stroke: Relationship to Pathophysiological Type and Comparison with Prior Tracings

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SUMMARY **The author reviewed electrocardiographic records of 150 patients with acute stroke and 150 age- and sex-matched controls, to assess the relative frequencies of ECG abnormalities among the pathophysiologic categories of stroke, and to distinguish new abnormalities at the time of the stroke from those noted on prior tracings. Of the 150 patients with stroke, 138 (92%) showed ECG abnormalities. The most common abnormalities were also changes from prior tracings: QT prolongation (68 patients, 45%), ischemic changes (59, 35%), U waves (42, 28%), tachycardia (42, 28%), and arrhythmias (41, 27%). Patients with cerebral embolus had a significantly increased frequency of atrial fibrillation (9 patients, 47%); and with subarachnoid hemorrhage an increased frequency of QT prolongation (20, 71%) and sinus arrhythmia (5, 18%). The frequencies of QT prolongation and ischemic changes related strongly to admission systolic pressure but not to mortality. Stroke patients had an increased frequency of pathologic Q waves (30 patients, 20%) and left ventricular hypertrophy (39, 26%), but these were not new findings at the time of the stroke.**

The results are consistent with an interaction of underlying hypertensive or atherosclerotic cardiovascular disease, sympathetic hyperactivity, and possibly myocardial necrosis, in producing ECG changes.

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PHYSICIANS HAVE KNOWN for centuries that primary cardiac disorders can lead to stroke,[1] but the realization that strokes may produce cardiac abnormalities is much more recent. In 1947, Byer, Ashman, and Toth[2] described a patient with intracerebral hemorrhage whose electrocardiogram (ECG) showed marked QT prolongation with large T and U waves. In 1954, Burch, Myers, and Abildskov[3] reported a pattern of QT prolongation, abnormal T waves, and U waves which they considered distinctive of acute stroke.

Although many subsequent reports have described ECG abnormalities in stroke — especially subarachnoid hemorrhage — none has included adequate numbers of patients to assess statistically the relative frequencies of these abnormalities among the pathophysiologic categories of stroke.[4-11] Further, despite the likelihood of underlying hypertensive or atherosclerotic cardiovascular disease, no previous studies have included detailed examinations of prior ECG's to distinguish abnormalities specifically associated with acute stroke.

The current study retrospectively reviewed the charts of 150 patients with stroke and the ECG files of 150 age- and sex-matched control inpatients, in order to describe the frequency, character, specificity, and prognostic significance of ECG abnormalities associated with acute stroke.

Methods

The author reviewed the charts at four Seattle hospitals (University of Washington Hospital, Harborview Medical Center, Seattle Veterans Administration Hospital, and Ballard Community Hospital) of patients admitted with acute cerebrovascular accidents between January, 1975, and November, 1977, using computer-generated chart lists arranged according to ICDA (*International Classification of Diseases, Applied to the United States*)[12] coding for cerebral thrombosis, cerebral embolus, subarachnoid hemorrhage, and acute cerebrovascular accident, etiology undetermined. All patients with strokes were included, unless: 1) a legible copy of the patient's ECG, done within 24 hours of the onset of neurological symptoms, was unavailable; 2) head trauma occurred within 1 week prior to the stroke; 3) there was a documented history of subdural hematoma; 4) the stroke occurred in the setting of dissecting aortic aneurysm; 5) the patient had a functioning artificial pacemaker; or 6) alternative diagnoses were not excluded.

Each patient was assigned to 1 of 5 pathophysiologic diagnostic categories according to the following criteria. *Cerebral thrombosis* was diagnosed if the patient suffered the gradually progressive onset of a focal neurologic deficit *and* had one of the following: 1) a history of transient ischemic attacks in the same vascular distribution as the subsequent stroke; 2) previously documented carotid occlusive disease or a carotid bruit on the same side as the cerebral infarction; 3) documented hypotension just prior to the onset of symptoms; or 4) autopsy-proven cerebral infarction without evidence for cerebral embolization. *Cerebral embolus* was diagnosed if the patient had the abrupt onset of a focal neurologic deficit, *and* had one of the following: 1) systemic embolization; 2) simultaneous multiple neurologic defects in different vascular distributions; 3) intracardiac clot, endocarditis, rheumatic vegetations, or tumor; 4) a prosthetic heart valve with recent discontinuation of oral anticoagulation; 5) recent electric cardioversion; or 6) diagnostic autopsy findings. *Subarachnoid hemorrhage* was diagnosed if 1) the patient suffered the sudden onset of headache and stiff neck without lateralizing neurologic signs, and had grossly bloody

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cerebrospinal fluid; or 2) angiography or autopsy findings were diagnostic. *Intracerebral hemorrhage* was diagnosed if 1) the patient suffered the sudden onset of headache with progressive lateralizing signs, progressive loss of consciousness, and bloody cerebrospinal fluid in the setting of chronic hypertension; or 2) angiography, computerized tomography, or autopsy findings were diagnostic. *Stroke of indeterminate etiology* was diagnosed if the patient did not fall into one of the above categories. This includes patients suffering the abrupt onset of a focal neurologic deficit without autopsy proof of cerebral thrombosis and without satisfying the other diagnostic criteria for cerebral embolus.

In analyzing the ECGs, the author considered U waves as significant if they were visible in more than 2 leads, and defined sinus arrhythmia as a variation of R-R interval-derived heart rate of more than 30 beats per minute, based on the admission 12-lead ECG. QT intervals were corrected for age, sex, and heart rate according to the tables of Ashman and Hull.[13] Estes' scoring system was used to determine left ventricular hypertrophy.[14] Q waves were considered significant (unless confined to lead III) if they were greater than 0.04 seconds in duration or more than ¼ the height of the R wave for that lead.

The author also analyzed the admission ECGs of 150 age- and sex-matched inpatients without acute stroke, myocardial infarction, or a functioning artificial pacemaker. These ECG's were randomly selected from ECG record room files. The most recent previous ECG for each patient also was analyzed if available.

Statistical testing of the data was performed using Yates-corrected chi-square analyses.[15]

Results

Of 585 charts reviewed, 435 (74%) were excluded according to the criteria listed above. The study, therefore, included 150 stroke patients: 49 with cerebral thrombosis, 38 with stroke of indeterminate etiology, 28 with subarachnoid hemorrhage, 19 with cerebral embolus, and 16 with intracerebral hemorrhage. The average patient age was 66.4 years, ranging from 21 to 92, with 72 males and 78 females.

Overview

Of the 150 stroke patients, 138 (92%) had an abnormal admission ECG, compared with 97 (65%) of the controls ($\chi^2 = 33.01$, $p < 0.001$). Table 1 lists the types and frequencies of ECG findings among patients with stroke and controls. The most common ECG abnormalities associated with stroke were prolonged QT (45% of patients), T wave inversion (29%), U waves (28%), tachycardia greater than 90

TABLE 1 *ECG Findings in 150 Acute Stroke Patients and 150 Age- and Sex-Matched Controls*

Finding	Cerebral thrombosis	Stroke, indeterminate etiology	Subarachnoid hemorrhage	Cerebral embolus	Intracerebral hemorrhage	Stroke, overall	Controls
Normal	7 (14%)	4 (11%)	0 (0%)	0 (0%)	1 (6%)	12 (8%)	53 (35%)
Abnormal	42 (86%)	34 (89%)	28 (100%)	19 (100%)	15 (94%)	138 (92%)	97 (65%)†††
Prolonged QT	18 (37%)	15 (39%)	20 (71%)**	7 (37%)	8 (50%)	68 (45%)	18 (12%)†††
T wave inversion	12 (24%)	14 (37%)	7 (25%)	4 (21%)	6 (38%)	43 (29%)	32 (21%)
U waves	13 (27%)	9 (24%)	9 (32%)	4 (21%)	7 (44%)	42 (28%)	14 (9%)†††
Increased HR	7 (14%)	10 (26%)	10 (36%)	8 (42%)	7 (44%)	42 (28%)	12 (8%)†††
ST depression	12 (24%)	12 (32%)	8 (11%)	5 (26%)	4 (25%)	41 (27%)	15 (10%)†††
LVH	12 (24%)	10 (26%)	7 (25%)	3 (16%)	7 (44%)	39 (26%)	18 (12%)††
Q waves	11 (22%)	6 (16%)	6 (21%)	4 (21%)	3 (19%)	30 (20%)	14 (9%)††
Atrial fib.	0 (0%)	8 (21%)	3 (11%)	9 (47%)***	1 (6%)	21 (14%)	6 (4%)††
Axis deviation	7 (14%)	9 (24%)	3 (11%)	1 (5%)	1 (6%)	21 (14%)	20 (13%)
PVCs	8 (16%)	6 (16%)	2 (7%)	1 (5%)	1 (6%)	18 (12%)	8 (5%)†
1° heart block	3 (6%)	4 (11%)	3 (11%)	1 (5%)	1 (6%)	12 (9%)	4 (3%)
Decreased HR	4 (8%)	3 (8%)	0 (0%)	2 (11%)	3 (19%)	12 (8%)	6 (4%)
Sinus arrhythmia	3 (6%)	1 (3%)	5 (18%)*	0 (0%)	1 (6%)	10 (7%)	0 (0%)††
Other arrhythmia	1 (2%)	2 (5%)	4 (14%)	1 (5%)	2 (13%)	10 (7%)	4 (3%)
PACs	4 (8%)	1 (3%)	3 (11%)	0 (0%)	2 (13%)	10 (7%)	7 (5%)
RBBB	5 (10%)	2 (5%)	2 (7%)	0 (0%)	1 (6%)	10 (7%)	8 (5%)
ST elevation	2 (4%)	4 (11%)	3 (11%)	0 (0%)	0 (0%)	9 (6%)	2 (1%)
LAE	1 (2%)	3 (8%)	2 (7%)	1 (5%)	1 (6%)	8 (5%)	3 (2%)
LBBB	0 (0%)	2 (5%)	1 (4%)	0 (0%)	0 (0%)	3 (2%)	4 (3%)
Other	1 (2%)	1 (3%)	1 (4%)	1 (5%)	0 (0%)	4 (3%)	0 (0%)

*$p < 0.05$ difference from all other stroke groups combined.
**$p < 0.01$ difference from all other stroke groups combined.
***$p < 0.001$ difference from all other stroke groups combined.
†$p < 0.05$ difference from stroke groups combined.
††$p < 0.01$ difference from stroke groups combined.
†††$p < 0.001$ difference from stroke groups combined.

beats per minute (28%), ST depression (27%), and left ventricular hypertrophy (26%). Arrhythmias of any type occurred in 27% of patients.

Few ECG findings characterized particular types of stroke. Atrial fibrillation occurred in 9 out of 19 (47%) patients with cerebral embolus, compared with 12/131 (9%) patients with all other types of stroke (χ^2 = 15.80, $p < 0.001$), and compared with 0/49 patients with cerebral thrombosis ($\chi^2 = 21.43, p < 0.001$). QT prolongation occurred more frequently in patients with subarachnoid hemorrhage (20/28, 71%) than in other types of stroke (28/122, 39%; $\chi^2 = 9.46, p < 0.01$), as did sinus arrhythmia (5/28, 18% vs 5/122, 4%; $\chi^2 = 4.30, p < 0.05$). Combined QT prolongation and U waves occurred more frequently in patients with intracranial bleeding (subarachnoid hemorrhage or intracerebral hemorrhage: 11/44, 25%) than without (8/106, 8%; $\chi^2 = 7.28, p < 0.01$).

Fifty-three of the patients with stroke (35%) and 63 of the controls (42%) had prior available ECGs. The median intervals between tracings were 4 months for the patients with stroke and 3 months for hhe controls, with ranges of 1 day to 7 years and 1 day to 5 years, respectively. Prior ECGs were abnormal in 48/53 (91%) of the patients with stroke and 45/63 (71%) of the controls ($\chi^2 = 6.64, p < 0.01$). *New* abnormalities appeared on the current ECGs of 39 (74%) of the patients with stroke and 9 (14%) of the controls (χ^2 = 41.71, $p < 0.001$). Table 2 illustrates that patients with stroke showed significantly greater frequencies of new QT prolongation (32% vs 2%), arrhythmias of any type (25% vs 3%), ischemic changes, i.e., ST depression or T wave inversion (21% vs 3%), U waves (13% vs 0%), and atrial fibrillation (9% vs 0%) than control patients.

TABLE 2 *New ECG Abnormalities in Stroke and Control Patients with Prior, Available ECGs*

Finding	Stroke	Control	Chi-square
Prolonged QT	17 (32%)	1 (2%)	18.40***
T wave inversion	8 (15%)	0 (0%)	7.12**
U waves	7 (13%)	0 (0%)	6.78**
ST depression	7 (13%)	1 (2%)	4.47*
Arrhythmia	13 (25%)	2 (3%)	10.01**
Sinus	2 (4%)	0 (0%)	N.S.
Atrial fib.	5 (9%)	0 (0%)	4.25*
Ventricular	4 (8%)	1 (2%)	N.S.
Other	2 (4%)	1 (2%)	N.S.
PACs	3 (6%)	0 (0%)	N.S.
PVCs	3 (6%)	0 (0%)	N.S.
Either ST depression or T inversion	11 (21%)	2 (3%)	7.40**
Bradycardia	4 (8%)	0 (0%)	N.S.
Tachycardia	1 (2%)	2 (3%)	N.S.
Overall number changed	39 (74%)	9 (14%)	41.71***

*$p < 0.05$ difference between stroke and control groups
**$p < 0.01$ difference between stroke and control groups
***$p < 0.001$ difference between stroke and control groups
N.S. = no significant difference.

Specific ECG Abnormalities

QT Prolongation

Corrected QT intervals were prolonged in 45% of the patients with stroke, constituting the most frequent single ECG abnormality and the most common *new* ECG abnormality in stroke. QT prolongation occurred significantly more frequently in subarachnoid hemorrhage (71%) than other types of stroke (39%), and in intracranial hemorrhage (28/44, 64%) than in strokes without intracranial hemorrhage (40/106, 38%; $\chi^2 = 8.42, p < 0.01$).

The frequency of QT prolongation related strongly to admission systolic blood pressure. QT prolongation was present in 15/54 (30%) of patients with pressures between 100 and 159 mm Hg, 19/46 (51%) with pressures between 160 and 199, and 27/35 (77%) with pressures greater than or equal to 200 ($\chi^2 = 19.10, p < 0.001$). When patients with chronic hypertension (LVH on a prior ECG, history of documented hypertension and anti-hypertensive medication, or hypertensive retinopathy) were excluded, the frequency of QT prolongation still correlated with admission systolic pressure. Patients admitted with *hypo*tension (less than 100 mm Hg) had an increased frequency of QT prolongation (5/9, 56%) compared with patients admitted with normal pressures (120 to 159 mm Hg; 17/53, 32%), but the difference was not statistically significant.

Ischemic Changes

ST depression or T wave inversion occurred in 59/150 (39%) of patients with acute stroke, and *new* ischemic changes occurred in 11/53 (21%) of patients who had prior available tracings. There was no relationship between the frequency of ischemic changes and type of stroke. Of patients with ischemic changes, 25/59 (42%) had a history of myocardial ischemia (myocardial infarction, angina pectoris, or prior ischemic ECG changes), while among patients without ischemic changes, 16/91 (18%) had a positive history ($\chi^2 = 11.07, p < 0.001$). Eighteen patients with available prior tracings had CPK (creatine phosphokinase) measured; 5 of these (28%) showed new ischemic changes, and 3 (60%) had elevated CPK. Of the 13 patients without new ischemic changes, 5 (38%) had elevated CPK. This difference was not statistically significant.

As with QT prolongation, the frequency of ischemic changes related significantly to admission systolic pressure. Ischemic changes occurred in 8/63 (13%) patients with pressures less than 160 mm Hg; 10/46 (22%) with pressures between 160 and 199; and 13/35 (37%) with pressures greater than or equal to 200 (χ^2 = 14.60, $p < 0.001$). The relationship held after patients with a positive ischemic history were excluded. Patients without a prior ischemic history admitted with *hypo*tension had a significantly increased frequency of ischemic changes (4/7, 57%) compared with patients admitted with normal blood pressure (4/39, 10%; $\chi^2 = 5.09, p < 0.05$).

U Waves

U waves occurred in 42/150 (28%) patients with acute stroke, and new U waves in 7/53 (13%) patients who had prior available tracings. No relationship was obtained between the frequency of U waves and type of stroke. Serum potassium levels were measured on admission in 32 (76%) patients with U waves, with a mean level of 3.77, and in 76 (70%) patients without U waves, with a mean level of 4.00 — a non-significant difference. Twenty-five of 32 (78%) patients with U waves had potassium levels greater than 3.5, suggesting in these cases that the U waves were not due to hypokalemia.

Arrhythmias

Arrhythmias of any type occurred in 41/150 (27%) patients with acute stroke, and new arrhythmias occurred in 13/53 (25%) patients who had prior available tracings.

Atrial fibrillation was the most common arrhythmia, occurring in 21/150 (14%) patients. Nine of 19 (47%) patients with cerebral embolus had atrial fibrillation, compared with 0/49 with cerebral thrombosis. Atrial fibrillation also occurred significantly more frequently in patients with strokes of indeterminate origin (8/38, 21%) than with cerebral thrombosis ($\chi^2 = 9.07$, $p < 0.01$). Of 13 patients with cerebral embolus who had prior available tracings, 8 (62%) showed atrial fibrillation on the current ECG, and in 4 of these (50%), atrial fibrillation was a new finding. No significant association appeared between atrial fibrillation and history of mitral or rheumatic heart disease.

Sinus arrhythmia occurred in 10/150 (7%) patients with acute stroke and was a new finding in 2/53 (4%) patients with prior available tracings. Patients with subarachnoid hemorrhage had a significantly greater frequency of sinus arrhythmia than patients with other types of stroke.

Ventricular arrhythmias occurred in 7/150 (5%) patients of acute stroke, and in those patients with prior available tracings, ventricular arrhythmias were always new but uncommon (4/53, 8%) findings. Mortality among patients with ventricular tachycardia, ventricular fibrillation, or asystole (4/5, 80%) was significantly greater than that of patients without these abnormalities (25%; $\chi^2 = 4.82$, $p < 0.05$).

Other arrhythmias — paroxysmal atrial tachycardia, atrial bigeminy, junctional, atrial flutter, and wandering atrial pacemaker — occurred uncommonly.

"Classic" or Bizarre Changes

The combination of QT prolongation, U waves, and T wave changes (inverted or wide, large, and upright) occurred in 12/150 (8%) patients with acute stroke and in 1/150 (1%) controls ($\chi^2 = 8.16$, $p < 0.01$), as well as in 0/53 prior tracings of patients who subsequently suffered strokes. The single control patient with this combination had severe hypokalemia. Of the 12 stroke patients with this pattern, 7 had intracranial bleeding. There was no relationship between the occurrence of this pattern and systolic pressure or mortality.

The combination of QT prolongation and U waves occurred in 19/150 (13%) stroke patients and 1/150 (1%) controls ($\chi^2 = 17.36$, $p < 0.001$). This combination related significantly to intracranial bleeding and to severe systolic hypertension (10/35 = 29% of patients with pressure greater than or equal to 200, vs 8/109 = 7% of patients with pressure less than 200, $\chi^2 = 9.08$, $p < 0.02$), but not to mortality.

Mortality

Overall mortality during the current hospitalization was 37/150 (25%) in patients with acute stroke. As shown in table 3, mortality varied significantly with level of consciousness, type of stroke, level of CPK, hypotension on admission, and the occurrence of malignant ventricular arrhythmias. Mortality did *not* relate significantly with any other ECG abnormality, history of hypertension or ischemic heart disease, extreme hypertension — even if new — or radiographic evidence of cardiomegaly or pulmonary congestion.

Myocardial Infarction

ECG ST Elevations and Q Waves

Nine of 150 (6%) patients with acute stroke showed ECG ST elevations, compared with 2/150 (2%) controls, a non-significant difference; and 30/150 (20%) showed Q waves, compared with 14/150 (9%) controls ($\chi^2 = 6.82$, $p < 0.01$). These ECG changes did not

TABLE 3 *Factors Related to Mortality in Patients with Stroke*

Factor	Mortality	Chi-square
Level of consciousness		
Alert	3/81 (4%)	
Lethargic	5/24 (21%)	
Stuporous	8/17 (47%)	
Comatose	21/28 (75%)	57.05***
Type of stroke		
Cerebral thrombosis	4/49 (8%)	
Indeterminate	3/38 (8%)	
Cerebral embolus	6/19 (32%)	
Subarachnoid hemorrhage	15/28 (54%)	
Intracerebral hemorrhage	9/16 (56%)	30.40***
Level of CPK		
Less than 100	0/13 (0%)	
101–499	4/14 (29%)	
500 or more	6/9 (67%)	8.63**
Admission systolic pressure		
Less than 100 mm Hg	6/9 (67%)	
More than 100 mm Hg	30/135 (22%)	6.09**
Ventricular arrhythmias		
Tachycardia, fibrillation, or asystole	4/5 (80%)	
None	33/145 (23%)	4.82*

*$p < 0.05$
**$p < 0.02$
***$p < 0.001$

relate to type of stroke or mortality. None of the patients with prior available tracings showed new ST elevations or new Q waves on their current ECGs. With serial ECGs, none of the patients with ST elevations showed changes consistent with evolving myocardial infarction, and this group did not have a higher frequency of CPK elevation than patients without ST elevations.

Cardiac Enzymes

Thirty-eight patients with stroke (25%) had CPK levels measured during their hospitalization, including 5 patients whose strokes occurred while being hospitalized for myocardial infarction. Of the 33 patients with stroke without recently diagnosed myocardial infarction, 20 (61%) had CPK levels above 100 and 9 (27%) had levels above 500. Lactic dehydrogenase (LDH) levels were elevated in 29/97 (29%). All 11 of the patients with intracranial bleeding whose CPK levels were measured showed elevations, compared with 9/22 (41%) patients without intracranial bleeding ($\chi^2 = 8.89, p < 0.01$). As discussed above, the frequency and severity of CPK elevations correlated with mortality.

Of 10 patients without recent myocardial infarctions who had CPK isozymes assayed, 4 (40%) had positive CPK cardiac isozyme fractions. Of 21 patients who had LDH isozymes assayed, 4 (19%) had reversals of LDH isozymes 1 and 2. Three of the 4 patients with positive cardiac CPK isozymes had intracranial bleeding.

Stroke in the Setting of Myocardial Infarction

Five patients (3%) suffered strokes in the setting of recent myocardial infarction. All the strokes occurred within 3 days of the infarcts; 3 were embolic, 1 thrombotic, and 1 of indeterminate etiology. At the time of their strokes, none of the patients showed new Q waves, 3 showed ischemic changes, and 2 showed no ECG signs of ischemia or injury. Three patients showed QT prolongation, and 2 of the 3 showed *new* QT prolongation compared with their admission tracings. One patient died during the hospitalization.

Autopsy Data

Eight patients without clinical evidence of myocardial infarction but with elevated CPK died and were autopsied. All 8 had died from intracranial hemorrhage. Three had ischemic ECG changes without ST elevations or Q waves. At autopsy, none of the patients showed gross or microscopic evidence of acute myocardial infarction. One patient showed old, healed infarcts, another left ventricular hypertrophy, and 2 others pulmonary congestion. One patient showed diffuse myofibrillar loss, and another, who had received cardiopulmonary resuscitation, intramyocardial hemorrhage. Four had microscopically normal myocardia. One patient, with normal cardiac isozymes, no clinical evidence of acute myocardial infarction, and with anterior ST elevations in the setting of subarachnoid hemorrhage, died, and at autopsy showed focal areas of myocardial necrosis, cytoplasmic banding, loss of nuclear staining, and increased cytoplasmic eosinophilia.

Discussion

The patient with signs of a stroke and with an abnormal ECG represents a common diagnostic challenge to the clinician. Cardiac diseases such as myxoma, mural thrombus, endocarditis, and atrial septal defect with deep venous thrombosis, may eventuate in cerebral emboli; arrhythmias, heart block, and myocardial infarction associated with decreased cardiac output may precipitate cerebral ischemia. In addition, patients often have simultaneous coronary and cerebral atherosclerosis, or have hypertension, leading to ECG abnormalities and to stroke independently. To this complexity can be added the results of the numerous reports[2-11] demonstrating that primary neurologic abnormalities may produce ECG changes, with or without myocardial lesions.

Despite the extensive literature on the subject, however, few studies actually have assessed the overall frequencies of these abnormalities in the population of patients with acute stroke. None has included adequate numbers of patients to assess statistically the relative frequencies of these abnormalities among the pathophysiologic categories of stroke. No previous studies have included detailed comparisons with prior ECGs to document which changes associated with stroke actually were new. In the present study, 91% of patients with stroke with prior available ECGs showed some ECG abnormality *before* the stroke, making this deficiency in the literature particularly glaring.

In the current study, the most common abnormalities were also the most common changes from prior tracings: QT prolongation (45%), ischemic changes (39%), arrhythmias (27%), tachycardia (28%), and U waves (28%). Except for potentially lethal arrhythmias such as ventricular tachycardia, these abnormalities were unrelated to mortality.

The frequency of QT prolongation and sinus arrhythmia was especially high in patients with subarachnoid hemorrhage, and patients with intracranial bleeding (subarachnoid or intracerebral hemorrhage) showed an increased frequency or combined QT prolongation and U waves. A strong association occurred between atrial fibrillation and cerebral embolus: 47% of patients with cerebral emboli were in atrial fibrillation, in contrast with none of 49 patients with cerebral thrombosis. On the basis of this finding, one might predict that a high proportion of strokes of indeterminate etiology in patients with atrial fibrillation are in fact due to cerebral embolization.

In contrast with the lack of association between ECG abnormalities and mortality in patients with acute stroke, mortality was strongly related to level of consciousness, type of stroke, CPK levels, hypotension on admission, and potentially lethal arrhythmias.

A combination of ECG abnormalities thought to be characteristic of acute stroke[3, 16, 17] — QT prolonga-

tion, U waves, and T wave changes — was uncommon, occurring in 8% of patients. However, only 1 of the 150 control patients (a patient with profound hypokalemia) showed this combination, and none of the 53 patients with stroke with prior available tracings showed this combination on the prior tracings. The combination of QT prolongation, U waves, and T wave changes may be relatively specific for acute stroke, especially if hypokalemia is absent.

None of the patients with acute strokes, including those with autopsy findings of myocytolysis, developed new pathologic Q waves. A review of the medical literature revealed only 2 cases in which acute strokes produced Q waves without autopsy evidence of infarction. New pathologic Q waves, in contrast to ischemic changes, occur rarely in stroke.

CPK and LDH levels were often elevated in patients with acute stroke, thereby limiting their differential diagnostic value in excluding associated myocardial infarction or necrosis. CPK was elevated in 61% of the 33 patients in whom it was measured, and in all of the 11 patients with intracranial bleeding in whom it was measured. Four of the 10 patients who had CPK isozymes assayed showed positive cardiac isozyme fractions, and 26% of the 23 patients who had LDH isozymes assayed showed reversal of fractions 1 and 2. Since these isozyme assays are the most specific currently available tests for myocardial necrosis,[18] it seems reasonable to conclude that a proportion of patients with acute stroke — especially with intracranial bleeding — suffer some degree of myocardial necrosis. Direct autopsy evidence for such was obtained in 2 patients with subarachnoid hemorrhage.

Recent experimental evidence in humans with stroke suggests that increased sympathetic nervous system activity accounts in part for the ECG abnormalities associated with stroke. Cruickshank and Dwyer[19] reported ECG changes and elevated catecholamine levels in patients with subarachnoid hemorrhage; propranolol modified most of the changes. Feibel, Campbell, and Joynt[20] noted a relationship between catecholamine secretion and severity of ECG changes in patients with subarachnoid hemorrhage of cerebral infarction. Lack of statistical testing limits inferences from these studies.

Increased sympathetic activity may explain the striking relationships obtained in the current study between extreme hypo- or hypertension on admission and the frequency of QT prolongation and new ischemic changes. On the basis of the cited studies and the results of the present one, ECG abnormalities associated with stroke may be viewed as due to 3 interacting processes: a) underlying atherosclerotic or hypertensive cardiovascular disease, producing a high frequency of left ventricular ischemic changes, Q waves, arrhythmias, bundle branch blocks, and left ventricular hypertrophy *prior* to the stroke; b) ischemic, arrhythmic, and repolarization changes due to increased sympathetic outflow *during* the stroke; and c) myocardial necrosis, precipitated by (a) or (b) or both.

From a retrospective study by one author, inferences should be made with awareness of the limitations of the research design. In this study there was prior knowledge of the clinical findings when ECG interpretations were made and the author relied on the written records available. The stringent criteria listed in the *Methods* section for categorizing the types of stroke and interpreting ECGs were devised to minimize observer bias.

The use of the Ashman and Hull tables for determining QT prolongation may also be questioned, since 12% of the control patients showed QT prolongation using these tables. Nevertheless, QT prolongation was almost 4 times as common in the patients with stroke, and was a documented new finding in almost 1/3 of the stroke patients who had prior available tracings. It seems reasonable to conclude that QT prolongation is a common new change associated with acute stroke.

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Transient Ischemic Attacks. Retrospective Study of 150 Cases of Ischemic Infarct in the Territory of the Middle Cerebral Artery

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SUMMARY **Transient ischemic attacks (TIA) are episodes of abrupt beginning, consisting of subjective or objective neurological dysfunction of short duration, with complete recovery of neurological function in the course of 24 hours. With this definition, the authors carried out a retrospective study of 150 patients suffering from ischemic infarct in the brain in the territory of the middle cerebral artery. Thirty-eight percent of the patients had had TIAs before their cerebral infarct. The symptoms, in order of frequency, were motor, sensory deficits, alterations of speech and vision. Most of the patients had a definite cerebral infarct, occurring one month after the last TIA; the symptoms of both processes were remarkably similar.**

The authors studied the angiographic characteristics, pharmacological and toxic antecedents, and associated diseases in these patients. The study indicates that TIA may be the first manifestation of cerebral vascular disease.

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A TRANSIENT ISCHEMIC ATTACK (TIA) is an episode of abrupt onset consisting of subjective or objective neurological dysfunction of short duration, and with complete recovery of altered neurological function, usually in the course of 24 hours or less. A characteristic feature of these episodes is their tendency to recur with repetition of the same clinical phenomena.

A TIA is believed to be the clinical expression of transient cerebral ischemia, which appears in those parts of the brain supplied by the carotid arteries or the vertebrobasilar arteries. TIAs have clinical importance as warnings of possible stroke and their presence may allow the application of effective therapeutic prevention treatment.[1-3]

Retrospective studies indicate that a percentage of patients, after having had a TIA, have a cerebral infarct.[4-9] The percentages vary from 9% to 75%. In prospective studies the percentages vary from 2% to 62% (table 1). The period of observation of these studies was between 11 months and 8 years.[6, 10-19]

We carried out a retrospective study of patients with TIA and subsequent ischemic infarcts in the part of the brain supplied by the middle cerebral artery.

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Methods

One hundred and fifty patients, suffering from ischemic cerebral infarct in the portion of the brain supplied by the middle cerebral artery, who had been admitted to the neurology service of the Hospital de la Santa Cruz y San Pablo, were studied. None of these patients had previously suffered a cerebral infarct.

Diagnosis of the ischemic infarct in the territory of the middle cerebral artery was established from the clinical history, neurological examination, and data supplied by the skull x-ray, EEG and cerebral arteriography. The diagnostic criteria for cerebral infarction are those of the Joint Committee for Stroke Resources.

Results

One hundred men and 50 women were studied. The age range was 25–89 with an average age of 63.7 years (table 2). Of the 150 patients with infarct in the territory of the middle cerebral artery, 58 (38.6%) had a TIA prior to the infarct. The age distribution of patients with TIA is shown in table 3. Patients between 50 and 59-years-old had, proportionally, the greater number of TIAs. The frequency distribution of TIA is shown in table 4. Of the 58 patients 42 (72.4%) had only one episode of TIA.

The duration of the TIAs and the area of brain