Electrocardiographic Findings Predict Short-term Cardiac Morbidity After Transient Ischemic Attack

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Background: Current guidelines recommend the use of electrocardiography (ECG) in the evaluation of transient ischemic attack (TIA), but the data supporting its value in acute management are sparse.

Objective: To determine whether ECG findings are useful as independent predictors of short-term cardiac or neurologic complications after TIA.

Methods: We included patients who presented to 1 of 16 emergency departments of a health maintenance organization in northern California and received a diagnosis of TIA from March 1, 1997, through February 28, 1998, for a 90-day follow-up. A cardiac event was defined as a hospitalization or a death due to myocardial infarction, ventricular arrhythmia, heart failure, or unstable angina.

Results: Among the 1327 patients with TIA for whom ECG findings were available for diagnostic coding, cardiac events occurred in 2.9%, strokes in 10.9%, recurrent TIAs in 13.7%, and deaths in 2.6% during 90-day follow-up. The ECG findings disclosed a new diagnosis of atrial fibrillation in 28 (2.3%) of the 1200 patients with no history of this condition. The 90-day risk for a cardiac event was greater in those who had any abnormal ECG findings (4.2% vs 0.6%; \( P \leq 0.001 \)). This association remained significant after adjustment for medical history and examination findings (odds ratio, 6.9; 95% confidence interval, 1.6-29.5; \( P = .009 \)). Left ventricular hypertrophy, atrial fibrillation, and atrioventricular conduction abnormalities were each independently associated with more than doubling of the risk. The ECG abnormalities were not associated with risk for stroke or death.

Conclusions: Short-term cardiac morbidity is substantial after TIA. Electrocardiographic findings disclose new atrial fibrillation in a significant portion of patients with TIA and can identify a group of patients at a substantially higher risk for short-term cardiac events.

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Transient Ischemic attacks (TIAs) are common and entail a substantial short-term risk for stroke and other adverse events. Based on estimates of stroke incidence, approximately 300,000 TIAs occur in the United States each year.\(^1,2\) Within 90 days of a TIA, approximately 10.5% of patients have a stroke, and 2.5% are hospitalized for cardiac events.\(^3\) During long-term follow-up, cardiac disease is the most common cause of death in these patients.\(^4,5\) Despite the frequency and morbidity of TIA, clinical management varies substantially.\(^6\) Consensus guidelines currently recommend the standard 12-lead electrocardiography (ECG) as an initial diagnostic study in the evaluation of TIA.\(^10,12\) Some benefits of screening ECG in TIA are self-evident; ie, abnormal ECG findings may indicate a direct cardiac cause of the patient’s symptoms or may identify a condition, such as atrial fibrillation, that would alter treatment in the secondary prevention of stroke. However, certain ECG findings may also be relevant to the assessment of short-term cardiac or stroke risk in patients with TIA. The overall utility of ECG in this context has not been formally evaluated, and its full implications for clinical management are uncertain.

Previous studies of the relationship between initial ECG findings and TIA outcome have not focused on short-term risk.\(^4,13-15\) For example, in the largest previous study of the role of ECG in TIA, patients were enrolled up to 3 months after the index TIA, and more than 50% were enrolled after 1 month.\(^15,16\) Although several ECG findings have been associated with an increased probability of stroke and cardiac events in patients with TIA,\(^3,14,15\) it is not known whether their short-term risk is sufficient to prompt urgent intervention or further testing. To assess the
ability of ECG findings to predict short-term stroke and cardiac events in patients with TIA, we studied a cohort of patients with a diagnosis of TIA in the emergency departments of a large health maintenance organization.

**SUBJECTS AND METHODS**

This study was based on a cohort of patients with a diagnosis of TIA in the 16 hospitals within Kaiser Permanente of Northern California. Details of the cohort definition and predictors of stroke risk were described previously and are only briefly reviewed herein. Kaiser Permanente of Northern California is a large health maintenance organization providing medical care for 2.9 million enrollees with a demographic distribution similar to that of the regional population. All patients were included in the study if they received a diagnosis of TIA in the emergency department from March 1, 1997, through February 28, 1998. Patients were excluded if they did not have emergency department records, were not members of the health care plan, or had a previous TIA treated in the emergency department during the study period. Using emergency department records, investigators extracted information about demographic characteristics, medical history, baseline medications, TIA symptom details, examination findings attributed to TIA, and treatment plans according to predefined criteria. A neurologist (S.C.J.) masked to follow-up events reviewed the medical records of all patients in whom the diagnosis of TIA was uncertain. Emergency department physicians ordered all cardiac diagnostic tests at their discretion. The ECG results were abstracted from the official reports of hospital cardiologists. Abnormal ECG findings included any of the following diagnoses in the ECG report: acute myocardial infarction, previous myocardial infarction, ST-T wave changes, left ventricular hypertrophy, atrial fibrillation, atrioventricular block (first through third degrees), and bundle branch block.

Patients were followed up for 90 days after presentation with TIA. Incident stroke, recurrent TIA, death, and hospitalization for cardiac events were identified from computerized databases and review of medical records. Hospitalizations outside the Kaiser Permanente system were recorded in a separate database, which enabled complete follow-up of the cohort. Deaths occurring during the 90-day follow-up were identified from medical records, enrollment files, and the California Automated Mortality Linkage System. Stroke was defined as a rapidly developed clinical sign of focal or global disturbance of cerebral function lasting more than 24 hours or until death without an apparent nonvascular cause. Strokes had to be distinguishable from the initial TIA event. Stroke diagnosis required independent confirmation by 2 neurologists. Diagnosis of recurrent TIA required confirmation by a reviewing neurologist and a written diagnosis in the medical record. A cardiac event was defined as a hospitalization or death due to myocardial infarction, ventricular arrhythmia, heart failure, or unstable angina. To estimate the cardiac event rate in a geographically similar and age-matched population, we used codes from the International Classification of Diseases, Ninth Revision, to identify all cardiac-related hospitalizations and deaths in patients 30 years and older in Kaiser Permanente of Northern California for 1997. We then matched the patient population by age using 5-year increments to calculate an adjusted cardiac event rate for comparison with our cohort.

The risks for stroke, recurrent TIA, and cardiac events were determined as the proportion of patients with these events during the 90 days after the resolution of TIA symptoms. For patients without documentation of symptom resolution, follow-up began at the time of emergency department discharge. For univariate analysis of dichotomous outcomes, we used the Fisher exact test when any cell in a $2 \times 2$ table was 5 or less; otherwise, we used the $\chi^2$ test. We entered all variables that were associated with the specified outcome (at $P<.20$) in univariate analysis into multivariable logistic regression models by removing variables that were no longer associated with the outcome (at $P>.10$) with a backward stepwise elimination approach. Continuous variables were dichotomized at prespecified cut points (eg, heart rate of 80 beats/min; systolic blood pressure of 140 mm Hg) to simplify the models. Kaplan-Meier life-table analysis was used to illustrate the timing of follow-up events. All statistical analyses were performed with the Stata statistical package (Version 6.0; Stata Corp, College Station, Tex).

**RESULTS**

Among the 1797 patients with a diagnosis of TIA during the study period, 1707 met the inclusion criteria. Electrocardiography was performed in 1365 (80.0%). Those undergoing ECG were more likely to be male and to have a medical history of hypertension and atrial fibrillation (Table 1). Symptoms of weakness, dizziness, and gait disturbance were also associated with a greater likelihood of undergoing ECG. The 90-day risk for cardiac events (2.9% vs 2.9%; $P=.99$), stroke (10.8% vs 9.7%; $P=.54$), and death (2.6% vs 2.9%; $P=.71$) were not significantly different between the patients with TIA who underwent ECG and those who did not.

The ECG findings from 1327 patients were available for diagnostic coding. Of these, findings in 474 (35.7%) were normal. The most common abnormality was ST-T wave changes (n=467 (Table 2). A new diagnosis of atrial fibrillation was made in 28 patients (2.3%) who underwent ECG. An acute myocardial infarction was identified in 3.

During the 90-day follow-up, 145 strokes (10.9%), 182 recurrent TIAAs (13.7%), 39 cardiac events (2.9%), and 34 deaths due to all causes (2.6%) occurred. By comparison, the 90-day cardiac event rate in age-matched control subjects was 0.39%. Cardiac events included 11 myocardial infarctions, 21 hospitalizations or deaths due to heart failure, 4 cases of ventricular arrhythmias, and 3 cases of unstable angina. Nineteen cardiac events (49%) occurred within the first 30 days of follow-up (Figure). Fifteen cardiac events (38%) occurred in patients without a medical history of coronary artery disease or heart failure. Three (8%) of the 39 cardiac events were deaths. Seven patients (18%) with cardiac events died within 90 days.

The prognostic value of ECG findings for adverse events was evaluated in multivariable models. The ECG findings at the time of TIA were not independent predictors of stroke, recurrent TIA, or death within 90 days ($P>.10$). The risk for any adverse cardiac event during the 90-day follow-up was higher in patients with any abnormal ECG finding (4.2% vs 0.6%; $P<.001$). This association remained significant after adjustment for medical history and clinical presentation (odds ratio [OR], 6.9; 95% confidence interval [CI], 1.6-29.5; $P=.009$). The ECG findings of left ventricular hypertrophy (OR, 4.4; 95% CI, 2.0-10.1; $P<.001$), atrial fibrillation (OR, 7.2; 95% CI, 3.0-17.0; $P<.001$), and atrioventricular block (OR, 3.3; 95% CI, 1.2-9.3; $P=.02$) were all independent risk factors for cardiac events. However, the most common
ECCG abnormalities, ST-T wave changes and previous myocardial infarction, were not independent predictors of cardiac events (P=.27 and P=.95, respectively). Abnormal ECG findings had a sensitivity of 92% and a specificity of 36% for predicting short-term cardiac events. Their positive predictive value for cardiac events was 4%, whereas their negative predictive value was 99%. Aside from abnormal ECG findings, other findings from the history or examination that predicted cardiac events were a history of coronary artery disease or hypertension, a heart rate of greater than 80 beats/min, or a systolic blood pressure of less than 140 mm Hg at presentation (Table 3).

At discharge from the emergency department, 898 patients (67.7%) were treated with aspirin; 192 (14.5%),
with heparin sodium or warfarin sodium; and 157 (11.8%), with ticlopidine hydrochloride. Compared with patients with normal ECG findings, patients with abnormal ECG findings were more likely to receive warfarin (14.8% vs 5.7%; P < .001) and less likely to receive aspirin (64.6% vs 73.2%; P < .001). No medical treatments, however, were independently associated with cardiac events (P = .67, P = .13, and P = .27 for aspirin, ticlopidine, and anticoagulants, respectively). Abnormal ECG findings predicted hospitalization and death related to heart failure (P < .001), but their association with more rare cardiac events (eg, ventricular arrhythmias [P = .17]) was not statistically significant. When heart failure events were considered exclusively as the outcome of interest, the ECG findings of atrial fibrillation (OR, 7.3; 95% CI, 2.9-18.3; P < .001) and left ventricular hypertrophy (OR, 4.7; 95% CI, 1.9-11.3; P < .001) but not atrioventricular block (OR, 3.8; 95% CI, 0.3-50.1; P = .11) remained significantly associated in multivariable models. A systolic blood pressure of less than 140 mm Hg was also more closely associated with heart failure events than with cardiac events in general.

Although abnormal resting ECG findings have been associated with an increased incidence of cardiac morbidity in some studies,20-22 they generally have lacked sufficient sensitivity and specificity to be useful as prognostic screening tests.23 Although our cohort consisted of patients with TIA due to all causes, the cardiac event rate during the 90-day follow-up was high, nearly 7 times the rate of age-matched controls. Furthermore, abnormal resting ECG findings in our cohort were strong independent risk factors for short-term cardiac morbidity and had a negative predictive value of 99% for cardiac events. Our definition of TIA was based on the clinical impression of emergency department physicians and not on results of specialized testing or expert review. Although certain subgroups of patients with TIA may differ with respect to cardiac risk, our findings offer practical guidance for the management of TIA in the acute care setting, where clinical findings frequently do not allow for risk stratification based on underlying pathophysiology. Events diagnosed as TIA likely include some instances of syncope or presyncope with cardiac causes, but it may not be possible to differentiate these causes, even with neurologist review.24,25

Electrocardiographic findings do not merely confirm information that is available from the medical history; 38% of the patients in our cohort who had cardiac events had no medical history of coronary disease or heart failure. Furthermore, the pathological changes detected by means of ECG appear to be better predictors of early cardiac events than medical history alone. For example, in our cohort and in previous studies, left ventricular hypertrophy on ECG findings was a significant predictor of cardiac events, whereas a history of hypertension alone was not.4,14,15 Previous studies have shown an association of ECG findings with only a long-term risk for cardiac events after TIA.14,15 In a study with a mean follow-up of 31 months, the ECG findings of old anterior infarction, T-wave inversion, and left ventricular hypertrophy were each independently associated with cardiac events in multivariable models.15 Their longer follow-up compared with ours may account for the differences; some ECG findings may entail a more acute risk, whereas others act as long-term risk factors or markers for underlying vascular disease.

The results of our study are limited by the nonrandom selection of patients to undergo ECG. Symptoms and examination findings such as dizziness and gait abnormality were associated with undergoing ECG. This association may have selected a group whose TIA symptoms were more likely to be cardiac related. In most patients, however, ECG was performed, and the cardiac event rates were nearly identical in patients who underwent ECG and those who did not. Therefore, the selection of patients for ECG did not appear to be related to prognosis overall and is unlikely to significantly influence the generalizability of our findings.

We found a strong association between abnormal ECG findings and cardiac events in aggregate. However, in the subgroup analysis of specific types of cardiac events, only heart failure events remained significantly associated with ECG abnormalities. Cardiac events related to heart failure were the most common subtype in our cohort and likely account for the association between cardiac events and low systolic blood pressure.20 Previous investigators have not included hospitalizations related to heart failure in their assessment of cardiac events after TIA.4,14,15 Although exacerbations of heart failure may be largely reversible, they can be triggered by cardiac ischemia and are associated with high rates of mortality.25 Three (14%) of 21 patients who had cardiac events related to heart failure died within the 90-day follow-up. Furthermore, as only hospitalizations and death were included, all heart failure events entailed significant resource consumption and morbidity. The relatively low short-term rates of myocardial infarction, ventricular arrhythmia, and unstable angina made it difficult to detect possible associations between these end points and ECG findings.

This study confirms the utility of the routine use of ECG in the acute evaluation of TIA. In addition to the detection of new-onset atrial fibrillation and myocardial ischemia, the ECG identifies a group of patients with TIA who are at a substantially higher risk for short-term cardiac morbidity. Given the high risk for cardiac events after TIA, more extensive medical evaluation may be indicated in certain subgroups of patients with abnormal ECG findings, such as those with left ventricular hypertrophy, atrial fibrillation, or atrioventricular conduction abnormalities. Additional research studies are needed to assess the incremental effectiveness of timely cardiac diagnostic or therapeutic interventions in these subgroups.

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