Prognostic Value of Computer Electrocardiography in Veteran Outpatients

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In patient populations with increased cardiovascular risk, is routine screening for electrocardiographic abnormalities worthwhile?

Over the course of its 117-year history, the electrocardiogram (ECG) has proven to be an invaluable diagnostic tool, allowing practitioners to detect such cardiovascular disorders as atypical heart rhythms, inadequate oxygen delivery to the heart muscle, and irregular electrical conduction within the heart. Numerous population-based studies investigating the prevalence of various ECG abnormalities have been published.[1–3] Epidemiologic studies also have correlated certain ECG findings with cardiovascular outcome,[4–7] demonstrating that ECGs can provide useful prognostic information.

While these studies may have included substantial numbers of subjects, most were performed as part of some community cardiovascular screening program. Not surprisingly, analysis of the results revealed a low prevalence of ECG abnormalities in asymptomatic, apparently healthy populations, leading some experts to conclude that it's inappropriate to use the ECG for routine screening of cardiovascular risk.[8]

The suitability of the ECG's use in screening populations in whom cardiovascular disease is prevalent—such as older, diabetic, or symptomatic adults—has not yet been resolved. This issue is further complicated by the fact that the majority of previous epidemiologic studies didn't apply modern computerized ECG analysis but, instead, relied on visual analysis supplemented by coding schema.

In 1986, the VA implemented a standard commercial system to provide computerized ECG analysis within its medical centers—providing researchers with an excellent opportunity to evaluate the ECG's prognostic value in the veteran patient population. One year later, the VA Palo Alto Health Care System (VAPAHCS), Palo Alto, CA began maintaining a database of computerized ECGs, which by 1999 held 47,070 individual patient records.

In this article, we'll detail our analysis of these computerized ECG records and explain how our findings have contributed to a better understanding of the prevalence of cardiovascular abnormalities in both male and female veteran populations as compared to a healthy male and female control group. We'll also discuss which ECG variables were predictive of all-cause mortality, based on survival analysis.

STUDY DESIGN

All ECGs obtained from patients at the VAPAHCS are recorded digi-

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tally and stored in the facility's MUSE computer system (GE Medical Systems, Waukesha, WA). Each ECG is labeled with the patient's social security number. For our analysis, we examined all ECGs recorded between 1987 and 1999. If a patient had more than one ECG record in the database, only the first was considered. Computerized measurements from the ECG, as well as several computerized ECG interpretations, were extracted.

We were able to ascertain each patient's vital status as of December 1999 by cross-referencing our patient population records against the Social Security Death Index. Using the database records, we also determined which patients were medical or surgical inpatients or being treated in the emergency department at the time of their ECG. These patients were excluded from the analysis.

We used standardized computerized ECG criteria, as described by the GE 12-lead ECG analysis program. While these interpretations usually are overread by a cardiologist before being released as confirmed, we included only the computer interpretation in our analysis. ST depression was defined as greater than 0.5 mm in any lead except the right augmented voltage lead (aVR). T waves were considered to be abnormal if isoelectric or lower in any lead except the aVR.

ANALYZING THE DATA

The database was imported into the Number Cruncher Statistical System (NCSS Statistical Software, Kaysville, UT) for analysis. For age comparisons, we established 65 years as the cutoff point between "older" and "younger" patients. We cross-tabulated data to determine the prevalence of each ECG abnormality within the parameters of age and gender, as well as the sensitivity and specificity of each for death. We used descriptive statistics to find mean values for continuous variables.

We found bivariate associations between the groups by using chi-square tests (for categorical data) and *t* tests (for continuous variables). For chi-square testing within our patient population, we used as the denominator the facility's 30,471 outpatients; for the meta-analysis, we used as the denominator the total number of patients included in the specific studies of the various abnormalities.[9] *P* values less than .05 were considered significant. To assess impact on survival, we generated Kaplan-Meier curves for individual variables and calculated hazard ratios with confidence limits. In addition, we performed proportional hazard testing to assess independent predictors of mortality.

HIGHER PREVALENCE OF ABNORMALITIES IN VETS

We included for analysis the ECG data from 26,734 male and 3,737 female veterans (Table). The mean age (in years) of the male patients was 55.8 ± 14.7 (standard deviation); the mean age of the female patients was 57.2 ± 17.2 (standard deviation). Mean height, weight, and body mass index were all approximately 6% higher in men than in women. Mean follow-up for the population was 5.6 years.

The prevalence of ECG abnormalities found in our veteran patient population were compared with that of a composite reference group, obtained from a monograph by Ashley and colleagues detailing the prevalence of ECG abnormalities in most of the epidemiologic screening studies[9] (Figures 1–4). With the exception of left ventricular hypertrophy (LVH) and left bundle branch block (LBBB), the ECG abnormalities were more prevalent in the veteran population ($P < .001$).

More than 5% of both male and female veteran populations had several ECG abnormalities. For men, the most common were abnormal T waves, abnormal ST depression, Q waves, left axis deviation (LAD), and QTc greater than 450 msec (with a prevalence of 23.9%, 12.4%, 11.6%, 9.9%, and 8.1%, respectively). For women, the most common were abnormal T waves, abnormal ST depression, and QTc greater than 450 msec (with a prevalence of 23.8%, 13.2%, and 11.9%, respectively).

GENDER DIFFERENCES

We found several ECG abnormalities to be significantly more prevalent in men than in women ($P <$ .001), including right bundle branch block (RBBB), intraventricular conduction deficit (IVCD), LVH by voltage, LVH with strain, LAD, right axis deviation (RAD), atrial fibrillation (AF), and inferior Q waves. Only QTc greater than 450 msec was notably more prevalent in women than in men.

The prevalence of the other abnormalities, including abnormal T waves and ST depression, was equivalent in both men and women. Markers of myocardial damage were infrequent in both men and women in our study—with the exception of inferior Q waves and RBBB in men, which had a prevalence of 3% and 3.4%, respectively, in our male subjects.

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Table. Survival of patients with specified ECG* findings by gender

ECG finding	Men (%)	Mean age (years)†	One-year survival (%)	Five-year survival (%)	Women (%)	Mean age (years)†	One-year survival (%)	Five-year survival (%)
Right bundle branch block	3.4	68 ± 12	96	88	1.3	70 ± 12	98	88
Left bundle branch block	1.1	69 ± 11	93	80	1.3	74 ± 10	94	92
Intraventricular conduction deficit	3.0	54 ± 15	96	91	0.9	60 ± 13	94	94
Left ventricular hypertrophy	2.5	56 ± 16	96	87	1.0	70 ± 11	97	87
Left ventricular hypertrophy with strain	1.6	66 ± 12	92	78	0.8	74 ± 10	97	84
Right ventricular hypertrophy	0.2	56 ± 13	92	87	0.3	61 ± 19	100	100
Abnormal T waves	23.9	61 ± 14	96	89	23.8	64 ± 16	98	93
Abnormal ST depression	12.4	64 ± 13	95	88	13.2	62 ± 16	98	94
Atrial fibrillation	2.7	71 ± 11	94	83	1.6	75 ± 11	91	78
Q waves	11.6	63 ± 12	96	89	7.7	65 ± 15	98	93
QTc > 450 msec	8.1	62 ± 13	95	86	11.9	61 ± 15	99	94
Left axis deviation	9.9	66 ± 12	96	88	4.4	70 ± 13	98	92
Right axis deviation	2.4	52 ± 16	96	91	1.8	50 ± 20	99	96
Normal	37.6	49 ± 13	100	99	40.2	51 ± 17	99	99

*ECG = electrocardiogram. †Plus or minus standard deviation.

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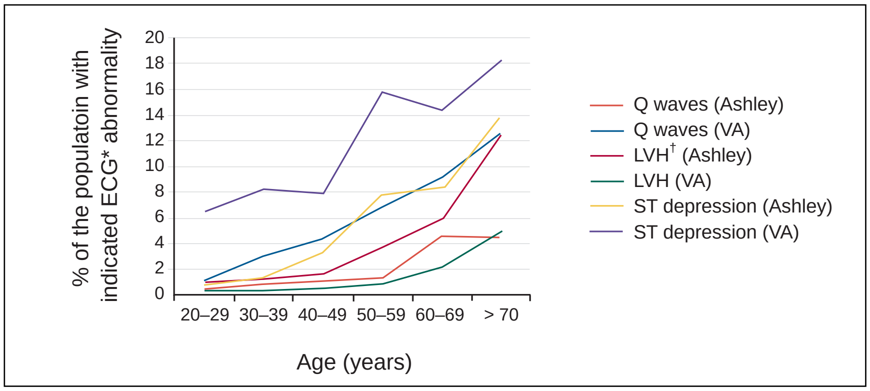

Figure 1. Highly prevalent ECG abnormalities in women from our veteran population compared with a composite reference group of women[9] derived from major epidemiologic screening studies. *ECG = electrocardiogram. †LVH = left ventricular hypertrophy.

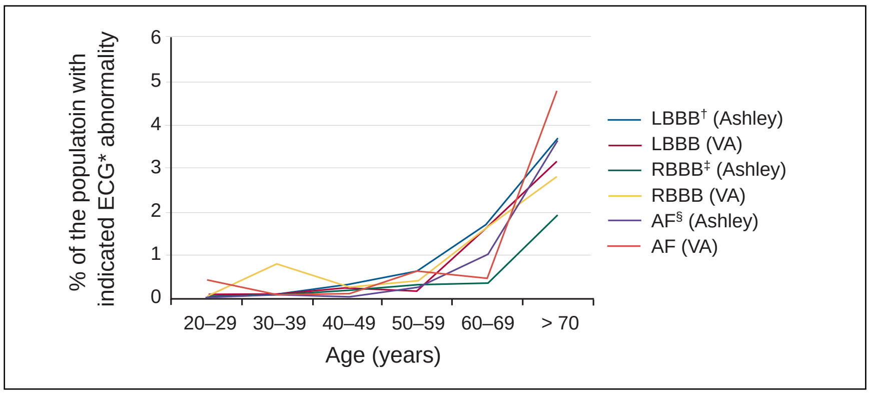

Figure 2. Less prevalent ECG abnormalities in women from our veteran population compared with a composite reference group of women[9] derived from major epidemiologic screening studies. *ECG = electrocardiogram. †LBBB = left bundle branch block. ‡RBBB = right bundle branch block. §AF = atrial fibrillation.

In men and women, most ECG abnormalities became more prevalent with age. With the exception of IVCD and right ventricular hypertrophy (RVH) in both sexes, LVH by voltage in men, and RAD in women, all ECG abnormalities were significantly more prevalent in those older than 65 ($P < .001$). The fact that LVH by voltage in men didn't become more prevalent with age may be attributable to increased aerobic activity and relatively higher levels of testosterone in younger men.

ADJUSTING FOR AGE

Since men develop coronary artery disease an average of 10 years earlier than women—and the presence of ECG abnormalities could relate to the presence of coronary artery disease—we compared the prevalence of ECG abnormalities in men aged 60 through 69 and women aged 70 through 79.

The disparity lessened significantly when age ranges with equivalent rates of coronary artery disease were compared. While men continued to demonstrate a markedly higher prevalence of several abnormalities—including RBBB, IVCD, LAD, and inferior Q waves—other abnormalities were seen with greater frequency in women, causing the overall prevalence of abnormalities to be equivalent between the two groups.

Previous studies also have shown both LAD[5] and RBBB[9] to be more prevalent in men than in women. While the etiology behind this finding is unclear, the higher prevalence of smoking and lung disease in men may be a factor. Prevalence of QT prolongation was higher in women—a finding that's consistent with previous studies, particularly one showing that QT intervals in women are influenced by hormonal levels.[10]

SURVIVAL RATES

The ECG abnormalities associated with the lowest survival rates were LVH with strain, AF, and anterior Q waves in men and AF, LVH by voltage, and LVH with strain in women, though overall death rates were much lower in women than in men ($P < .001$). For men with any ECG abnormality, mortality was greater than 25%, compared with 11% for those with normal ECGs ($P < .001$). Approximately 95% of women with a normal ECG were still living at the end of the follow-up period.

In men younger than 65, the highest hazard ratios were associated with LBBB (3), LVH with strain (2), and RBBB (2). AF, inferior Q waves, anterior Q waves, and abnormal T waves also generated significant hazard ratios, but all were less than 2. In men 65 or older, the highest hazard ratios were associated with LVH with strain (3), anterior Q waves (2), and AF (1.8). Other abnormalities with significant hazard ratios included

IVCD and ST depression, but both were less than 2.

In women younger than 65, the highest hazard ratios were associated with LBBB (3), IVCD (3), inferior Q waves (2), abnormal T waves (2), AF (1.5), and LAD (1.5). In women 65 or older, the highest hazard ratios were associated with LBBB (3), AF (2), and abnormal ST depression (2). Other significant hazard ratios included LAD, prolonged QTc, and abnormal T waves, but all were less than 2.

We produced Kaplan-Meier survival curves of the ECG abnormalities that were most highly associated with all-cause mortality (Figure 5). We compared these with survival curves for patients with abnormal ECGs other than RVH, LBBB, and LVH with strain and with normal ECGs. A normal ECG is associated with extremely good survival.

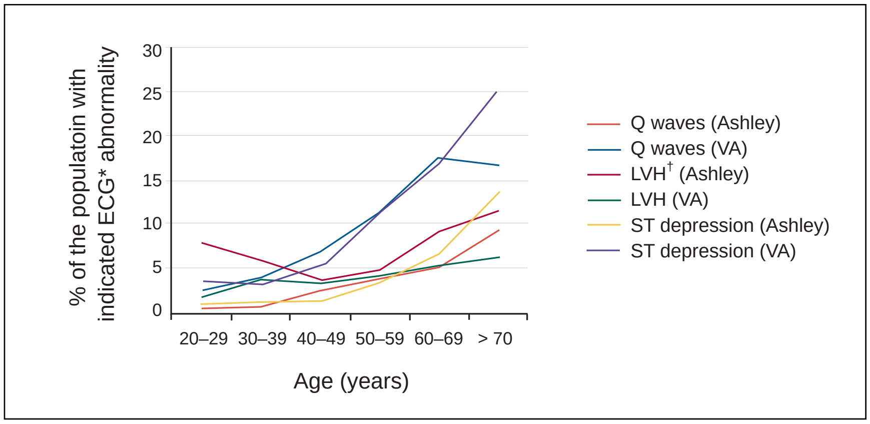

Figure 3. Highly prevalent ECG abnormalities in men from our veteran population compared with a composite reference group of men[9] derived from major epidemiologic screening studies. *ECG = electrocardiogram. †LVH = left ventricular hypertrophy.

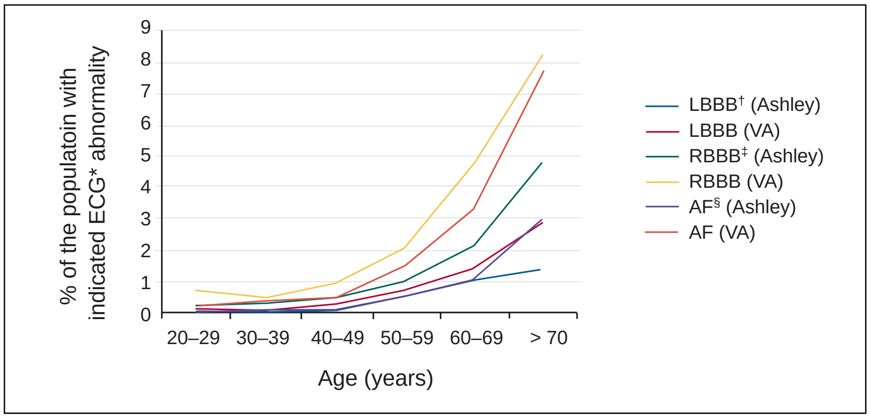

Figure 4. Less prevalent ECG abnormalities in men from our veteran population compared with a composite reference group of men[9] derived from major epidemiologic screening studies *ECG = electrocardiogram. †LBBB = left bundle branch block. ‡RBBB = right bundle branch block. §AF = atrial fibrillation.

PROGNOSTIC IMPLICATIONS

It's difficult to discuss the prognostic implications of LVH by voltage and LVH with strain since there are so many different criteria for this condition, each with variable sensitivity and specificity. The criteria used by our facility's computer program include the Sokolow-Lyon voltage criterion, with the addition of voltage criterion for the left augmented voltage lead. LVH with strain was a separate variable that was constructed using the computerized criteria and the presence of ST depression to duplicate the criteria used in the Framingham study. The hazard ratios associated with LVH by voltage and LVH with strain in the VA database are similar to those in other studies.[9]

In contrast to previous studies, RBBB was a predictor of all-cause mortality in our patient population. Ashley and colleagues had reported all-cause mortality risk ratios for RBBB ranging from 0.5 to 2.[9] Clinical data regarding the patients with RBBB, however, were unavailable, and noncardiac conditions may have contributed to these patient deaths.

We also found LBBB to be associated with significant risk of death. Ashley and colleagues found the risk ratio of LBBB to range from 1.3 to 4.4. Their data, however, came largely from a male population.[9] In the VA population, the risk is particularly profound in women with LBBB.

AF is associated with significant risk in men and women of any age, but it's a particularly powerful predictor of death in young women. Other studies have presented risk ratios ranging from 1.5 to 5[11]; in the

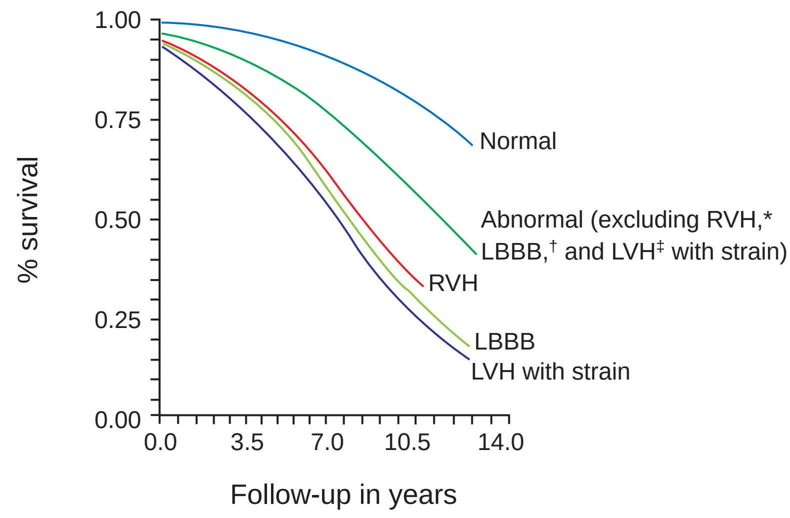

Figure 5. Kaplan-Meier survival curves of the ECG§ abnormalities most highly associated with death and survival curves for patients with normal and abnormal ECGs (excluding RVH, LBBB, and LVH with strain). *RVH = right ventricular hypertrophy. †LBBB = left bundle branch block. ‡LVH = left ventricular hypertrophy. §ECG = electrocardiogram.

VA database, the risk is at the high end of this range.

STUDY LIMITATIONS

The varying criteria for LVH in other studies makes comparison of the prevalence and significance of this abnormality problematic. Limited clinical information was available about the patients in this study, and information regarding lung disease might have been especially revealing.

While this study involves only one commercially available computer interpretive system and provides no comparison to cardiologist interpretations, the system we used is applied widely throughout the world. This analysis demonstrates the performance of the program independent of overreading.

Finally, cardiovascular mortality would be a better endpoint than all-cause mortality for evaluating a cardiovascular test.

TO SCREEN OR NOT TO SCREEN?

In this study of male and female veteran outpatients, the prevalence of ECG abnormalities was substantially higher than in a reference population of healthy individuals—and there were significant differences between men and women in terms of both prevalence and prognostic value of certain ECG abnormalities. While we have no data on cost-effectiveness, the availability and inexpensive nature of the routine ECG along with the prognostic utility demonstrated herein would seem to justify its use as a screening tool in similar populations. Recent studies applying quantitative assessments and scores to the ECG suggest that its prognostic power can be enhanced.[12] Furthermore, a normal ECG had a very high positive predictive value for survival, and should be a reassuring finding. ●

The opinions expressed herein are those of the authors and do not necessarily reflect those of Federal Practitioner, *Quadrant HealthCom Inc., the U.S. government, or any of its agencies. Please review complete prescribing information for specific drugs or drug combinations—including indications, contraindications, warnings, and adverse effects—before administering pharmacologic therapy to patients.*

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