Cross-Sectional Relations of Electrocardiographic QRS Duration to Left Ventricular Dimensions

The Framingham Heart Study

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OBJECTIVES
The goal of this study was to assess the relations of electrocardiographic QRS duration to left ventricular (LV) measurements in individuals without heart failure (HF) or prior myocardial infarction (MI).

BACKGROUND
Increased electrocardiographic QRS duration (≥120 ms) is a marker of ventricular dyssynchrony.

METHODS
We evaluated the relations of maximal electrocardiographic QRS duration to echocardiographic LV dimensions in 4,534 Framingham Heart study participants (mean age 54 years, 57% women) without prior HF or MI. QRS duration was analyzed as a continuous variable and as categories (<100, 100 to 119, and ≥120 ms).

RESULTS
In linear regression models, LV mass, end-diastolic dimension, and septal and posterior wall thicknesses were positively related to log-QRS duration, whereas fractional shortening (FS) was inversely related (p < 0.001). There was a significant trend for increasing LV mass and dimensions, and decreasing FS across categories of QRS duration (p < 0.001). Left bundle branch block was associated with higher LV mass and lower FS compared with a normal QRS duration (p < 0.001).

CONCLUSIONS
In our community-based sample of individuals free of HF and MI, increasing electrocardiographic QRS duration was positively related to LV mass and dimensions, and inversely associated with LV FS. Additional investigations are warranted to elucidate the mechanisms underlying the observed associations. (J Am Coll Cardiol 2005;45:685–9) © 2005 by the American College of Cardiology Foundation

A prolonged electrocardiographic QRS duration (≥120 ms) may be a marker of inter- or intraventricular mechanical dyssynchrony, and has been associated with adverse prognosis in systolic heart failure (HF) (1). Cardiac resynchronization therapy has been demonstrated to favorably influence clinical outcomes in systolic HF patients with QRS duration ≥150 ms (2). Others have reported associations of left bundle branch block (LBBB) (3) and interventricular conduction delay (4) with left ventricular (LV) systolic and diastolic dysfunction in patients without clinical HF.

The aforementioned reports linking increased QRS duration to LV dysfunction are paralleled by reports emphasizing associations of prolonged QRS duration with LV structural changes (5,6). Experimental investigations suggest that asynchronous LV contraction (indicated by prolonged electrocardiographic QRS duration) may promote LV remodeling, manifested by increases in wall thickness of late-activated LV segments (6). We hypothesized that increased electrocardiographic QRS duration is associated with greater LV mass and dimensions, and lower systolic function in people without prior myocardial infarction (MI) or HF.

METHODS
The designs of the Framingham Heart study (7) and the Framingham Offspring study (8) have been described previously. Participants who attended either the 16th (n = 2,351) or the 17th (n = 2,180) biennial examination of the original cohort (1979 to 1984), or the 2nd Offspring study (1979 to 1983) examination (n = 3,867), and who had electrocardiographic and echocardiographic measurements available, were eligible. Observations from two sequential original cohort examinations were used because 1,215 attendees at the 16th examination and 866 individuals at the 17th examination underwent computerized electrocardiography. Attendees underwent complete medical history, physical examination, and assessment of cardiovascular risk factors.

Participants were excluded for the following reasons: prevalent HF (Framingham criteria; n = 51); previous MI (n = 146); digoxin or quinidine use (n = 206); and a history of permanent pacemaker implantation (n = 3). After
**Abbreviations and Acronyms**

- BBB = bundle branch block
- FS = fractional shortening
- HF = heart failure
- IVS = interventricular septum at end-diastole
- LA = left atrial size at end-systole
- LLBB = left bundle branch block
- LV = left ventricle/ventricular
- LVDD = left ventricular internal dimensions at end-diastole
- LVDS = left ventricular internal dimensions at end-systole
- MI = myocardial infarction
- PW = posterior wall
- RBBB = right bundle branch block
- R-wave = R-wave
- RBBB = right bundle branch block
- R-wave = R-wave
- RBBB = right bundle branch block

**RESULTS**

The baseline characteristics of our sample are shown in Table 1. In multivariable models, log-QRS duration was positively related to LV dimensions but inversely related to FS (Table 2; all p < 0.001). These associations noted remained robust after additional adjustment for QRS voltage. Partial $R^2$ associated with QRS duration in men were 0.06 for LV mass (model $R^2 = 0.27$), 0.02 for IVS (model $R^2 = 0.20$), 0.02 for PW (model $R^2 = 0.21$), 0.05 for LVDD (model $R^2 = 0.20$); and in women 0.06 for LV mass (model $R^2 = 0.40$), 0.02 for IVS (model $R^2 = 0.39$), 0.02 for PW (model $R^2 = 0.41$), and 0.05 for LVDD (model $R^2 = 0.20$). The contribution of QRS duration to LV mass noted above was three times the magnitude of contribution due to systolic BP in men (partial $R^2 = 0.02$) and in women (partial $R^2 = 0.02$). There was a statistically significant trend of increasing LV measurements and decreasing FS across QRS interval categories (Table 2). A stronger relation of QRS duration to LV mass was noted in obese men ($p < 0.05$) and in women who were hypertensive ($p < 0.0001$) or were ≥55 years ($p < 0.02$).

In additional analyses relating LV dimensions to the type of BBB, LBBB was associated with higher LV mass and LVDD, and with lower FS compared with the referent...
group in both genders (Table 3). Right bundle branch block was not related to any LV measurement in men, but was positively associated with LV mass, and wall thickness in women. Statistically significant increases in LV mass and wall thicknesses were noted in both genders with indeterminate BBB (Table 3).

**Table 2. Relations of QRS Duration and Echocardiographic Variables**

<table>
<thead>
<tr>
<th>Echocardiographic Variables</th>
<th>Log QRS Duration</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>β*</td>
<td>p</td>
<td>p Value (Category 2 vs. 1)</td>
<td>p for Trend</td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV mass, g</td>
<td>10.4 (1.2)</td>
<td>0.0001</td>
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<tr>
<td>LV diastolic dimension, cm</td>
<td>0.09 (0.01)</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Septal wall thickness, cm</td>
<td>0.02 (0.004)</td>
<td>0.0001</td>
<td>0.05</td>
<td>0.009</td>
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<tr>
<td>Posterior wall thickness, cm</td>
<td>0.02 (0.004)</td>
<td>0.0001</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>Fractional shortening, %</td>
<td>−0.33 (0.10)</td>
<td>0.0001</td>
<td>0.006</td>
<td>0.0008</td>
</tr>
<tr>
<td>Left atrial size, cm</td>
<td>0.03 (0.01)</td>
<td>0.007</td>
<td>0.18</td>
<td>0.09</td>
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</tbody>
</table>

**Women**

<table>
<thead>
<tr>
<th>Echocardiographic Variables</th>
<th>Log QRS Duration</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β*</td>
<td>p</td>
<td>p Value (Category 2 vs. 1)</td>
<td>p for Trend</td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LV mass, g</td>
<td>5.8 (0.6)</td>
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<tr>
<td>LV diastolic dimension, cm</td>
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</tr>
<tr>
<td>Septal wall thickness, cm</td>
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<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Posterior wall thickness, cm</td>
<td>0.01 (0.002)</td>
<td>0.0001</td>
<td>0.03</td>
<td>0.0001</td>
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<td>Fractional shortening, %</td>
<td>−0.43 (0.09)</td>
<td>0.0001</td>
<td>0.02</td>
<td>0.0001</td>
</tr>
<tr>
<td>Left atrial size, cm</td>
<td>0.03 (0.008)</td>
<td>0.0002</td>
<td>0.23</td>
<td>0.03</td>
</tr>
</tbody>
</table>

All values are least square means and standard errors (inside parentheses) adjusted for age, weight, height, systolic and diastolic blood pressure, use of antihypertensive medications, and diabetes mellitus. *Regression coefficient (β) is the increase in echocardiographic variable per SD increment in log QRS duration adjusting for covariates. Standard deviation for log QRS in men = 0.136, and women = 0.120.

LV = left ventricular.

**DISCUSSION**

**Principal findings.** In our study increasing electrocardiographic QRS duration was positively related to LV mass, wall thickness, and LVDD, and inversely associated with FS. These associations were observed across the spectrum of...
QRS duration and were consistent in both genders. The absolute effect sizes were modest—a trend for a 10 to 12 g increment in LV mass across the QRS interval categories. A stronger association of LV mass with QRS duration was seen in obese men, in older women, and in hypertensive women, likely because obesity, age, and blood pressure are key determinants of LV mass.

We had limited statistical power to analyze the relations of BBB type to LV measurements; LBBB was associated with higher LV mass and LVDD, and lower FS in both genders, an observation consistent with the published literature (3). Right BBB was associated with increased LV mass, PW, and IVS in women only. The latter observation is new and intriguing, but needs to be interpreted with caution given our small sample size.

Possible mechanisms underlying the observed associations. Given the cross-sectional design of our study, it is not possible to determine if prolonged QRS duration preceded or followed the increased LV dimensions. We postulate three possible mechanisms to explain our findings. First, it is possible that increased QRS duration and higher LV mass and measurements both may be the result of another disease process, such as hypertension or MI. We do not think this is the case because we excluded individuals with prior MI and adjusted for blood pressure. Second, prolongation of QRS may be the result of LV dilation, with concomitant increases in conduction time of the cardiac impulse (4); LV dilation and fibrosis have been reported to reduce conduction velocity due to alterations in the intra-cellular T-tubular system. Third, it is possible that the prolongation of the QRS complex is a marker of dyssynchronous LV contraction. Such noncoordinated mechanical contraction of the ventricle results in a redistribution of mechanical load and differential hypertrophy of the late-activated segments (6). Prolongation of the QRS complex may result in a lower ejection fraction also because opposing walls do not contract synchronously (14). In our study we did not observe asymmetric hypertrophy of wall thickness (septum vs. PW) in individuals with BBB, which may make dyssynchrony a less likely explanation for the observed associations.

It is important to note that the QRS duration is a crude marker of inter- and intraventricular synchrony. Mechanical dyssynchrony has been reported in individuals with QRS duration <120 ms (15). The true effect of ventricular dyssynchrony on LV remodeling would require more sensitive and specific indicators of dyssynchrony (such as tissue Doppler imaging) and the demonstration of a temporal sequence between presence of dyssynchrony and the development of alterations in LV structure and function via well-designed prospective studies.

Study limitations. Limitations of our investigation include the single occasion assessment of QRS duration and the limited power to analyze relations of BBB type to LV measurements. The predominantly Caucasian sample limits the generalizability of our results.

Conclusions. In our large cross-sectional community-based study of individuals free of prior HF and MI, we observed a positive association between electrocardiographic QRS duration and LV mass, dimensions and wall thickness, and an inverse relation to systolic function. Additional investigations are warranted to confirm our findings.
REFERENCES


