Electrocardiographic Abnormalities in Individuals With Long-Duration Type 1 Diabetes

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Individuals with diabetes are more likely to experience cardiovascular morbidity and mortality than those without diabetes (1–4). We sought to investigate prevalence relationships of electrocardiogram (ECG) abnormalities and risk indicators that might be intervened upon in people with long-duration type 1 diabetes.

RESEARCH DESIGN AND METHODS

— The study was population based. It consisted of survivors of a cohort (identified in 1979–1980) who were diagnosed with diabetes before 30 years of age, taking insulin, and receiving care in 11 counties in Wisconsin (5). The institutional review board approved the study, which conformed to the principles of the Declaration of Helsinki. Informed consent was obtained. Participants have been seen every 4–6 years for examinations (6) and are contacted annually. At the 2000–2001 examination, the following measures were added: waist and hip circumference; sitting (7), standing, and supine blood pressures; peak expiratory flow rate (PEFR) (8); and ECG. Standard fundus photographs were omitted from the 2000–2001 examination. Blood was obtained for measurement of LDL (9) and HDL (10) cholesterol and serum triglycerides (11), fasting blood glucose (12), and GHb (13). A standard medical history was obtained at all examinations. ECGs were analyzed at EPICARE Center, Wake Forest University (14). Data analyses included multiple linear and logistic regressions in which age and sex were incorporated in every model.

RESULTS

— The mean ± SD age of the 565 participants was 45.5 ± 10.1 years, duration of diabetes 31.2 ± 8.0 years, GHb 7.9 ± 1.5%, sitting systolic blood pressure 128 ± 18 mmHg, and sitting diastolic blood pressure 76 ± 11 mmHg. A total of 51% were men. Those who had died before this examination were older, had higher blood pressure, were more likely to be smokers, had proteinuria, and had higher GHb.

Twenty-one (3.2%) subjects had evidence of an old myocardial infarction, 17 (3.0%) had isolated ST segment abnormalities, and 7 (1.2%) had major T-wave abnormalities in ECGs. In total, 66 major (not mutually exclusive) ECG abnormalities occurred in 56 subjects, and 1 or more minor abnormalities occurred in 121 subjects. Means ± SDs of the quantitative traits of cardiac autonomic neuropathy (CAN) were: QT Index (QTI) 99 ± 5%, square root of the mean of squared differences (RMSSD) of successive RR intervals 16 ± 22 ms, and SD of successive RR intervals (SDNN) 16 ± 19 ms. RMSSD and SDNN, both measures of heart rate variability, were highly correlated with each other ($r = 0.93$) and were inversely correlated with heart rate (-0.39 and -0.35, respectively). They were both negatively correlated with QTI, an index of prolonged QT interval adjusted for heart rate ($r = -0.16$ and -0.19, respectively).

Multivariable analyses found that age, sex (women), GHb, fibrinogen, triglycerides, and end-stage renal disease (ESRD) were associated with (longer) QTI and that age, sex (women), triglycerides (higher), GHb (higher), hypertension, and ESRD were associated with decreased RMSSD and SDNN. Age, sex, fibrinogen level, sedentary lifestyle, PEFR, and ESRD were significantly associated with a major ECG abnormality; however, GHb, serum lipids, and blood pressures were not. The quantitative CAN traits were associated with many other complications of diabetes (Table 1).

CONCLUSIONS

— The quantitative CAN traits were distributed in ways that were typical of persons with diabetes and differed from published data from participants in the Atherosclerosis Risk in Communities Study (15), a general population study. As such, the QTI was prolonged, and measures of heart rate variability (RMSSD and SDNN) were decreased. These findings may be related to the poor cardiovascular experience of those with diabetes, as they may be predisposed to fatal arrhythmias (16–22) and to end diastolic dysfunction (23). Major and minor ECG abnormalities were associated with PEFR. It is possible that diminished pulmonary function precedes the ECG abnormalities. It is also possible that they are comorbid results of long-term diabetes.

The relationships of several complications of diabetes in our study, some related to autonomic dysfunction including quantitative traits of CAN, are displayed

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Abbreviations: CAN, cardiac autonomic neuropathy; ECG, electrocardiogram; ESRD, end-stage renal disease; PEFR, peak expiratory flow rate; QTI, QT index; RMSSD, square root of the mean of squared successive differences; SDNN, SD of successive RR intervals.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

Table 1—*Mean values of quantitative ECG traits for specific complications of diabetes*

Variable categories	QTI	*P*	RMSD	*P*	SDNN	*P*
Ankle/brachial index						
<0.9	102	0.09	9	0.10	10	0.06
0.9–1.3	100		19		19	
>1.3	99		12		13	
Postural blood pressure						
>20-mmHg decrease	102	<0.001	10	<0.001	10	<0.001
≤20-mmHg decrease	99		18		18	
PEFR (l/min)						
30–430	102	<0.001	13	0.004	12	<0.001
440–500	100		17		17	
510–580	100		15		16	
590–760	98		21		21	
Sensory neuropathy index						
0,1	99	0.003	19	<0.001	19	<0.001
2,3	101		9		9	
Erectile dysfunction						
No	98	<0.001	19	0.12	20	0.06
Yes	100		13		13	
Ulcers on feet						
No	99	0.02	18	<0.001	18	<0.001
Yes	101		9		10	
Lower extremity amputation						
No	99	0.07	17	<0.001	17	<0.001
Yes	101		7		7	
Diabetic retinopathy*						
None to minimal	99	0.007	23	<0.001	23	<0.001
Moderate	98		17		18	
Proliferative	100		9		9	
CVD						
No	99	<0.001	17	0.002	18	<0.001
Yes	103		12		11	
Hypertension						
No	99	0.22	20	<0.001	20	<0.001
Yes	100		12		13	
ESRD (dialysis or renal transplant)						
No	99	0.007	18	<0.001	18	<0.001
Yes	101		7		7	

*As graded at examination phase 4 (1995–1996). CVD, cardiovascular disease, including myocardial infarction, coronary bypass surgery, coronary angioplasty, transient ischemic attack, carotid endarterectomy, congestive heart failure, use of nitroglycerine or anticoagulants, or angina or stroke.

in Table 1. Zeigler (24) adds exercise intolerance, intraoperative blood pressure, lability, gastric distress, intermittent diarrhea, constipation, bladder dysfunction, and sudomotor abnormalities to the list. It is possible that better control of glycemia, hypertension, and triglycerides, factors we found related to CAN, might ameliorate some of these problems.

The study is limited in that the population was first identified in 1979–1982, but ECGs were not obtained until 2000–2001. Thus, we are not certain when any of these abnormalities were first manifested, and we cannot be certain of the temporal relationships of risk indicators to them. Many of the original study participants died before the 2000–2001 examinations. This may have caused a decrease in the estimated frequency of ECG abnormalities because many may have been associated with death. Further, many correlates of ECG abnormalities may not be obvious now due to both lower sample size and to altered levels of risk factors that may have accompanied long-duration type 1 diabetes. Nevertheless, the data we present are likely to be representative of such individuals and they may suggest possible areas of interventions that might ultimately impact ECG abnormalities in them.

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