The ECG in Diabetes Mellitus
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**Case Presentation:** A 42-year-old man underwent routine blood tests that revealed a fasting blood glucose value of 105 mg/dL and hemoglobin A1c of 6.2%, resulting in a diagnosis of early type 2 diabetes mellitus. Resting 12-lead ECG showed deep S-wave in L III and R-wave in aVL, indicating early left ventricular hypertrophy; no signs of cardiac autonomic neuropathy (CAN) were found. Stress ECG demonstrated a 2-mm depression of the ST segment. Inasmuch as this finding represents high risk for future cardiovascular disease and mortality, the patient was given strict diet restrictions, and all measures to control cardiac risk factors were advised.

Throughout a 6-year follow-up, the diabetes mellitus remained well controlled, the ECG remained unchanged, and no clinical or ECG signs of neuropathy became apparent.

**Introduction**
The importance of diabetes mellitus, both type 1 and type 2, in the epidemiology of cardiovascular diseases cannot be overemphasized. About one third of acute myocardial infarction patients have diabetes mellitus, the prevalence of which is steadily increasing: In the 1960s, there were 2 million Americans with diabetes mellitus; in the year 2000, their number was 15 million. Statistics have shown that the decrease in cardiac mortality in persons with diabetes mellitus is lagging behind that of the general population. Early diagnosis of diabetes mellitus is crucial.

**ECG Signs in Diabetic Patients**
Fibrotic changes, especially in the basal area of the left ventricle, have frequently been observed in diabetic patients, even when cardiac involvement is clinically not yet evident. An example of the ECG tracing in a diabetic patient with no apparent heart disease is given in Figure 1.

Even in healthy individuals, hyperinsulinemia-induced hypoglycemia can prolong the QTc interval and decrease T-wave area and amplitude. In the Europe and Diabetes (EURODIAB) study on diabetic individuals with a normal QTc at baseline, female sex and higher values of hemoglobin A1c and systolic blood pressure were associated with increased risk of prolonged QTc, whereas physical activity and normal body mass index were protective factors. Correlation was found between the QT duration and the amount of coronary calcium; this association was driven by the QRS and not by JT interval duration.

Okin et al also found that both QTc prolongation and ST depression predicted all-cause mortality in patients with type 2 diabetes mellitus. Genetic variants in previously identified candidate genes may be associated with QT interval duration in individuals with diabetes mellitus. Sawicki et al found QT dispersion to be the most important independent predictor of total mortality and also an independent predictor of cardiac and cerebrovascular mortality; these observations were not confirmed in a later study.

The EURODIAB Insulin-Dependent Diabetes Mellitus Complications Study (EURODIAB IDDM) investigated 3250 type 1 diabetes patients with an average diabetes duration of >30 years; the prevalence of left ventricular hypertrophy was found to be 3 times greater than that reported in the general population of similar age. Okin et al followed up nearly 9000 nondiabetic hypertensive patients. During follow-up, regression or persistent absence of left ventricular hypertrophy on the ECG during antihypertensive treatment was associated with a lower rate of new-onset diabetes mellitus.

**ECG Measures of Cardiac Autonomic Neuropathy**
Baroreflex dysfunction and disturbed heart rate variability are the most commonly used methods to assess CAN. Pop-Busui et al showed the protective effect of intensive therapy on reducing cardiac complications in pa-
tients with type 1 diabetes mellitus. On 24-hour ECG, on both time and frequency domain analyses, day and night recordings were similar, apparently because of the reduced nighttime vagal modulation of the heart rate in these patients. In a general population prospective study, persons with high resting heart rate and low heart rate variability had increased risk for future development of diabetes mellitus.

Ong et al found the QTc to be shorter if patients had signs of neuropathy, although these patients’ heart rate was higher and their circadian patterns seemed to be preserved. Valensi et al found an unchanged QTc in mild neuropathy, although the circadian day/night QTc pattern was reversed. Pappachan et al expressed the view that the QTc interval can be used to diagnose CAN with reasonable sensitivity, specificity, and positive predictive value. Grossmann et al observed a prolonged QTc only in diabetic patients with CAN; late potentials were not recorded in any of these patients with CAN. CAN patients with prolonged variability in QTc, QT, or both had high incidence of sudden death.

Detection of Silent Ischemia in Diabetic Patients

Myocardial ischemia is more often painless in patients with diabetes mellitus. Resting ECG abnormalities as well as cardiac autonomic dysfunction were found to be predictors of silent ischemia in asymptomatic persons with T1D.

In otherwise healthy diabetic men during an average follow-up of 16 years, an abnormal and even an equivocal exercise ECG response was associated with a statistically significant high risk for all-cause and cardiac mortality and morbidity, independently of physical fitness and other traditional risk factors; fit men had a higher survival rate than did unfit men.

In asymptomatic type 2 diabetes patients with a normal resting ECG, exercise testing was the first choice for screening for silent ischemia, whereas thallium scintigraphy with dipyridamole was performed if exercise testing was not possible or was inconclusive; the accuracy of stress ECG was 79%, coronary arteriography being used as gold standard. By combining stress ECG with myocardial scintigraphy, Cosson et al could effectively detect coronary artery lesions in individuals with asymptomatic diabetes mellitus. The use of screening before an exercise training program for patients with asymptomatic type 2 diabetes mellitus “might be justifiable . . . but remains unproven,” as stated in a recent scientific statement by the American Heart Association.

Fetal and Childhood ECG Signs in Diabetes Mellitus

On fetal ECG, ST depression was significantly more prevalent in fetuses of diabetic mothers, as demonstrated by Yli et al. In children with a mean hemoglobin A1c >10%, a reduction in heart rate variability was predictive for onset of symptomatic neuropathy. Shiono et al studied children and adolescents aged 7 to 20 years with poor glycemic control (hemoglobin A1c >10%) with signal-averaged ECG; the authors found a prolonged filtered QRS duration and a significantly low root mean square voltage, demonstrating subclinical cardiac impairment.

Diabetic Cardiomyopathy

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Athy.30 Typical ECG alterations are to diagnose early diabetic cardiomyopathy, and the often subtle structural cardiac abnormalities can be identified at this stage; the early stage of diabetic cardiomyopathy may already be associated with decreased incidence of new-onset diabetes mellitus in hypertensive patients: the Losartan Intervention For Endpoint Reduction in hypertension (LIFE) Study. Hypertension. 2007;50:984–990.

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Disclosures

None.

References


Conclusions

Even early in the course of diabetes mellitus, ECG alterations such as sinus tachycardia, long QTc, QT dispersion, and ventricular hypertrophy may be observed. ECG alterations help evaluate cardiac autonomic neuropathy and detect signs of myocardial ischemia even in asymptomatic patients. Prolonged myocardial fibrosis leads to diabetic cardiomyopathy, with peculiar ECG presentation. Electrocardiographic changes are already present in fetuses, children, and adolescents. The resting ECG, frequently complemented by exercise ECG, assists in demonstrating exercise-induced left ventricular dysfunction, even when the resting cardiac function is still ade- quate.29 The early stage of diabetic cardiomyopathy may already be associated with a range of metabolic abnor- malities and even with abnormalities in diastolic function. Frequently, no structural cardiac abnormalities can be identified at this stage; the often subtle ECG alterations may be our only way to diagnose early diabetic cardiomyopathy.30 Typical ECG alterations are demonstrated in Figure 2.

Table. Cardiovascular Examinations for Diabetic Patients

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Exercise testing

Cardiac autonomic function analysis

Resting heart rate

Altered heart rate variability

24-hour recording is advocated

Baroreflex dysfunction

Length of QTc interval: equivocal

Screening for silent ischemia

Resting ECG

Stress testing

Perfusion imaging

Cardiac autonomic function analysis

Resting heart rate

Altered heart rate variability

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Demonstrating exercise-induced left ventricular dysfunction, even when the resting cardiac function is still ade- quate.29 The early stage of diabetic cardiomyopathy may already be associated with a range of metabolic abnor- malities and even with abnormalities in diastolic function. Frequently, no structural cardiac abnormalities can be identified at this stage; the often subtle ECG alterations may be our only way to diagnose early diabetic cardiomyopathy.30 Typical ECG alterations are demonstrated in Figure 2.


