The signal-averaged electrocardiogram in diabetic children

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Abstract

A signal averaged ECG is a useful tool for detecting low-amplitude, high frequency electrical potentials in the terminal portion of QRS. There is a close association between abnormal signal averaged ECG and coronary heart disease. In this study we evaluated late potentials and total QRS duration determined by this technique in diabetic children with and without good glycemic control. The signal averaged ECG of 20 children with diabetes mellitus and nine healthy age-matched controls were compared. The total QRS duration was longer in diabetic children than in controls (104.6 and 97.9 ms vs. 82.7 ms, P < 0.0005). Late potentials were not observed in the patient and control groups. The RMS voltage of the QRS complex in the last 40 ms was significantly lower in the diabetic group compared to the control group. There was no significant difference in the signal averaged ECG indexes between the two diabetic groups determined by the glycemic control state. These findings suggested that the children with diabetes mellitus frequently have intraventricular conduction disturbance regardless of glycemic control condition.

Key words: Signal-averaged; Late potentials; Intraventricular conduction disturbance; Diabetes mellitus; Children

1. Introduction

Signal-averaged electrocardiography has been demonstrated to be a useful tool for detecting low-amplitude, high-frequency electrical potentials in the terminal portion of QRS. These are commonly termed late potentials. Much investigative attention has been focused on the association of the late potentials with ventricular tachycardia [1]. A close association between late potentials and left ventricular dysfunction has also been indicated in coronary heart disease and in cardiomyopathy [1,2].

There has long been thought to be a relationship between diabetes mellitus and impairment of the cardiovascular system. Increasing clinical and experimental evidence indicates that the prevalence of atherosclerosis and heart failure in diabetics is higher than in normal subjects [3–5]. The pathologic basis for cardiovascular lesions in these patients are still controversial, but micro-
angiopathy is thought to be important in their etiology [3,4]. Children with diabetes mellitus can have several derangements involving the cardiovascular system [6]. No studies have yet been performed assessing the association between late potentials with glycemic control in children with diabetes mellitus. This study was conducted to evaluate the late potentials and QRS duration in these children to determine whether they suffered from silent intraventricular conduction impairment and ventricular electro-instability, which can not be shown with the standard ECG.

Materials and methods

2.1. Patients and controls

Twenty diabetic children participated in this study. They were divided into two groups according to laboratory findings of good glycemic control: Group I (n = 12), patients without; and Group II (n = 8), with laboratory findings of good glycemic control. The average characteristics of Group I patients were as follows: age, 13 ± 4 years (range, 8–23 years); Hba1c, 13.3 ± 2 g/dl (range, 10–17 g/dl); microalbumine levels, 63.4 ± 25.8 μg/min per 1.73 m² (range, 30–110); and duration of diabetes, 3.2 ± 1.2 years (range, 2–6 years). The average characteristics of Group II patients were as follows: age, 12.5 ± 3.5 years (range, 9–19 years); Hba1c, 8.2 ± 0.5 g/dl (range, 7.5–9 g/dl); microalbumine levels, 34 ± 6 μg/min per 1.73 m² (range, 23–39.8); and duration of diabetes, 4.1 ± 2 years (range, 3–10 years). All diabetic children have been managed with conventional subcutaneous insulin.

Control group (Group III) involves nine healthy children. All of them had a normal medical history and physical examination, had no evidence or history of chronic disease, and were not on any medications. Their average age was 10 ± 2 years (range, 8–14 years).

2.2. Signal-averaged electrocardiograms

Signal-averaged ECG measurements were performed on all subjects using the technique described before [1]. The ECG recording technique was performed by placing seven silver/silver chloride electrodes in the following locations: five leads were placed in a horizontal plane about the torso at the level of the fifth intercostal space, one on the head (back of the neck or forehead) and one on the left leg. Signals were recorded and processed using a microprocessor-augmented Marquette Mac 12. The signal-averaged ECGs were recorded during sinus rhythm from standard bipolar X, Y, and Z leads.

In all patients, 500 beats were averaged and the data were processed by amplifying the signal by 1000 mm/mV. The trigger point was based on the earliest onset of QRS activity. The paper speed was set at 2000 mm/s. The signals were averaged, amplified, and filtered with a bidirectional filter at a frequency between 25 and 250 Hz. A vector magnitude was calculated as $V = X^2 + Y^2 + Z^2$ by combining the filtered signals from the three leads.

The indices of the signal-averaged ECG recordings were: (1) the RMS voltage of the QRS complex in the last 40 ms, (2) the duration of late potentials identified as signals of under 40 μV during the last portion of the QRS complex (HFLA), (3) the total duration of the QRS complex.

2.3. Autonomic function tests

All subjects underwent several autonomic function tests the detailed methods of which were described before [7]. The tests included the following: heart rate response to deep breathing, to standing (30:15 ratio), to Valsalva Maneuver, to carotid massage, and blood pressure response to standing. Patients were scored from 0 to 5 based on the number of abnormal tests.

2.4. Two-dimensional echocardiography

Two-dimensional echocardiograms were obtained with an SSH-60A (Toshiba Corp., Tokyo, Japan). Left ventricle ejection fraction and shortening fraction were determined according to previous protocols using M-mode echocardiographic measurements.

2.5. Statistical analysis

Data are presented as means ± standard deviations and differences between the groups were
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Clinical data of the groups

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<td>HbA1C (g/dl)</td>
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tested with the analysis of variance (ANOVA) and were considered significant at P < 0.05.

3. Results

Age, and duration of diabetes in the two groups with diabetes mellitus and in the control group were not significantly different (P > 0.05). Glycosylated hemoglobin (HbA1C) and urine microalbumin levels in diabetic children with poor glycemic control (Group 1) were significantly higher than other diabetic children (P < 0.001, and P < 0.005 (Table 1). Autonomic function tests in all diabetic children were normal according to the formerly described protocol. All children with diabetes mellitus had normal left ventricular systolic function which was determined by M-mode echocardiography.

Results displayed in Table 2 represent the analysis of signal-averaged ECG in 29 children which enrolled in the study. Control group (Group III) had significantly lower filtered QRS duration than diabetic children without and with good glycemic control (Group I and Group II) by signal-averaged ECG analysis (82.7 ± 8.6 vs. 97.9 ± 11.3 and 104.6 ± 9.9 ms, P < 0.0005). RMS values were significantly higher in Group III than Group I and II (223 ± 123 vs. 97 ± 49, and 101 ± 57 ms, P < 0.005). HFLA measurements were not different between three groups (P > 0.05).

4. Discussion

Previous studies of cardiovascular function in children with long standing diabetes mellitus have considered the cardiovascular system may be affected by this disease [7,8]. Clinical evidence of heart disease is seldom apparent in diabetics during the first 20 years of life. So it is important to detect subclinical abnormalities in patients with

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HFLA, high-frequency late potentials; RMS, root-square mean signals.

*Group 3 vs. groups 1 and 2.
diabetes mellitus as early as possible. The most commonly measured indices are cardiovascular autonomic function, systolic and diastolic function of left ventricle [5,7,9]. The current study demonstrated that the signal-averaged ECG measurements were abnormal in children with diabetes mellitus regardless of their glycemic control state.

The main findings in this study were as follows: (1) late potentials were not demonstrated in patient and control groups. (2) The intraventricular conduction time was significantly longer in the diabetic group than in the control group, that was detected by prolonged total QRS duration. (3) The terminal portion of the QRS complex tended to be decreased in the diabetic group. These results indicated that the patients with diabetes mellitus have silent intraventricular conduction disturbances.

Late potentials have been thought to signify delayed electrical activity in ischemic zones or regions of old myocardial infarction. They have been shown to be closely related to reentrant ventricular tachycardia both in experimental animals and in humans [1]. There are a few studies concerning the signal-averaged ECG analysis in children with muscular dystrophy [10] and children who underwent ventriculotomy for repair of their congenital heart disease [11,12]. In normal children, the incidence of late potentials in the signal-averaged ECG is not known, but in normal adults, they are reported to be zero [1]. In this study no patients had late potentials, but several indices were significantly different from healthy controls. Silent impairment of the heart in children with diabetes mellitus is a serious problem, as has been emphasized by the others.

Yang et al. [13] showed the late potentials and prolonged QRS duration by signal-averaged ECG technique in adult patients with non-insulin diabetes mellitus. They indicated diabetes mellitus may cause intraventricular conduction disturbance detected by signal-averaged ECG measurements. Our results are comparable with this study and showed the prolonged total QRS duration and low RMS measurements in diabetic children regardless of glycemic control state.

In conclusion, signal-averaged ECG analysis may be used to assess the subclinical cardiac impairment in diabetic children. So, this method may be useful for follow-up of these patients. But, it remains to be determined whether changes in management result in meaningful change in these parameters of signal-averaged ECG.

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