The Journal of Tehran University Heart Center

Original Article

Signal-Averaged Electrocardiography in Patients with Advanced Heart Failure: A Better Indicator of Left Ventricular Enlargement Compared with Conventional Electrocardiography

Mohammad Alasti, MD[1*], Majid Haghjoo, MD[2], Abolfath Alizadeh, MD[2], Mohammad Hossein Nikoo, MD[3], Hamid Reza Bonakdar, MD4, Bita Omidvar, MD[5]

[1]*Imam Khomeini Hospital, Jundishapur University of Medical Sciences, Ahvaz, Iran.*
[2]*Rajaie Cardiovascular Medical and Research Center, Tehran University of Medical Sciences, Tehran, Iran.*
[3]*Kosar Hospital, Shiraz, Iran.*
[4]*Heshmat Hospital, Gilan University of Medical Sciences, Rasht, Iran.*
[5]*Golestan Hospital, Jundishapur University of Medical Sciences, Ahvaz, Iran.*

Received 11 August 2010; Accepted 12 January 2011

Abstract

Background: *The signal-averaged electrocardiography is a noninvasive method to evaluate the presence of the potentials generated by tissues activated later than their usual timing in the cardiac cycle. The purpose of this study was to demonstrate the correlation between the filtered QRS duration obtained via the signal-averaged electrocardiography and left ventricular dimensions and volumes and then to compare it with the standard electrocardiography.*

Methods: *We included patients with advanced systolic left ventricular dysfunction (ejection fraction ≤ 35%). All the patients underwent surface twelve-lead electrocardiography, signal-averaged electrocardiography, and echocardiography.*

Results: *The study included 86 patients with a mean age of 54.66 ± 13.23 years. The mean left ventricular ejection fraction was 18.31 ± 5.49%; the mean QRS duration was 0.14 ± 0.02 sec; and 52% of the patients had left bundle branch block. The mean filtered QRS duration was 145.87 ± 24.89 ms. Our data showed a significant linear relation between the filtered QRS duration and left ventricular end-systolic volume, left ventricular end-diastolic volume, left ventricular end-systolic diameter, and left ventricular end-diastolic diameter; the correlation coefficient was, however, not good. There was no significant correlation between the QRS duration and left ventricular diameters and volumes.*

Conclusion: *The filtered QRS duration has a better correlation with left ventricular dimensions and volumes than does the QRS duration in the standard electrocardiography.*

J Teh Univ Heart Ctr 2011;6(2):68-71

This paper should be cited as: Alasti M, Haghjoo M, Alizadeh A, Nikoo MH, Bonakdar HR, Omidvar B. Signal-Averaged Electrocardiography in Patients with Advanced Heart Failure: A Better Indicator of Left Ventricular Enlargement Compared with Conventional Electrocardiography. J Teh Univ Heart Ctr 2011;6(2):68-71.

Keywords: *Heart failure • Echocardiography • Electrocardiography • Heart ventricles*

[*]**Corresponding Author:** ***Mohammad Alasti,*** *Assistant Professor of Cardiology, Jondishpour University of Medical Sciences, Imam Khomeini Hospital, Azadegan Avenue, Ahwaz, Iran. 6193673166. Tel: +98 611 4457205. Fax: +98 611 4457205. E-mail: alastip@gmail.com.*

Introduction

The high resolution electrocardiography (ECG) is designed for the body surface recording of the cardiac signals that are not visible on the standard ECG. Signal averaging is an approach to produce a high resolution electrocardiogram. In this type of electrocardiography, late potentials are generated by tissues activated later than their usual timing in the cardiac cycle.[1] We, therefore, designed an observational study aimed at evaluating the possible correlation between the data obtained by the signal-averaged electrocardiography (SAECG) and left ventricular (LV) dimensions and volumes and compare it with the standard ECG.

Methods

The patients included in the study were selected consecutively among those referred with a diagnosis of heart failure. The inclusion criteria were advanced systolic LV dysfunction (LV ejection fraction [LVEF] ≤ 35%) and underlying cause (idiopathic dilated cardiomyopathy or ischemic heart disease). All the patients signed written informed consent. We excluded patients with non-sinus rhythm, previous pacemaker implantation, a recent myocardial infarction (< 3 months), and severe aortic disease. All the patients underwent standard twelve-lead ECG, SAECG, and two-dimensional echocardiography.

Imaging was done in the left lateral decubitus position, recording the parasternal and apical views (standard long-axis and two- and four-chamber images) with the aid of a commercially available system (Vingmed 7, General Electric, Milwaukee, WI, USA). A 3.5-MHz transducer was used. The LV volumes (end-systolic and end-diastolic) and LVEF were calculated from the conventional apical two- and four-chamber images utilizing the biplane Simpson technique.

The QRS duration was measured on the surface ECG. The ECG was recorded at a speed of 25 mm/sec and a scale of 10 mm/mV. The QRS duration was measured as the widest QRS complex in the precordial leads. QRS durations ≥ 0.12 sec; no q-wave but slurred, broad R waves in leads I, aVL, and V_6; and rS or QS deflections in lead V_1 were considered as the ECG features of left bundle branch block (LBBB). On the other hand, QRS durations ≥ 120 ms, broad and notched R waves in leads V_1 and V_2, and deep S deflections in the left precordial leads and I were noted as the ECG features of right bundle branch block (RBBB). A prolonged QRS not associated with the typical features of bundle branch block was labeled as nonspecific intraventricular conduction delay.

Filtered QRS durations (fQRS) were calculated using the SAECG (Hellige EK 56, Marquette, Freiburg, Germany) with noise level < 0.3 µV and high-pass filtering of 35 Hz. The key hardware elements of the system were an amplifier, a convertor for the digitalization of the signals, a signal processor, and a printer. In this system, a computer algorithm was utilized to identify the QRS onset and offset. Filtering was applied to reduce the residual noise and improve the identification of the low potentials.

The continuous data were expressed as mean ± standard deviation values. Linear regression analysis was the chosen method for evaluating the association between the signal-averaged data and the echocardiographic indices. A p value < 0.05 was considered statistically significant.

Results

The study population consisted of 86 patients: 67 (77.9%) men and 19 (22.1%) women with a mean age of 54.66 ± 13.23 years (range: 18-79). The underlying etiology of heart failure was ischemic in 60% of the patients. Seventy-two (83.8%) patients were in New York Heart Association (NYHA) class III. The baseline characteristics of the study population are summarized in Table 1.

Table 1. Baseline characteristics of study population*

Variable	n=86
Age (y)	54.66±13.23
Male/Female	67 (77.9) / 19 (22.1)
Etiology of heart failure	
Ischemic	52 (60)
Idiopathic	34 (40)
NYHA class	
NYHA class II	12 (14)
NYHA class III	72 (83.8)
NYHA class IV	2 (2.3)
QRS morphology	
Left bundle branch block	45 (52)
Right bundle branch block	6 (7)
Nonspecific intraventricular conduction delay	35 (41)

*Data are presented as mean±SD or n (%)

All the patients had sinus rhythm on the ECG. The mean QRS duration was 0.14 ± 0.03 sec (range: 0.08-0.2 sec), and 45 (52%) patients had LBBB morphology. The mean fQRS duration was 145.87 ± 24.89 ms (range: 86-200 ms).

The mean LVEF was 18.31 ± 5.49% (range: 10-33%), and 15.3% of the patients had severe mitral regurgitation. Detailed echocardiographic characteristics of the patients are presented in Table 2.

The multiple linear regression (stepwise method) demonstrated that while there was a significant correlation between the fQRS duration and LV end-systolic volume (r = 0.37, p value = 0.000) (Figure 1-A), LV end-systolic diameter (r = 0.24, p value = 0.031) (Figure 1-B), LV end-

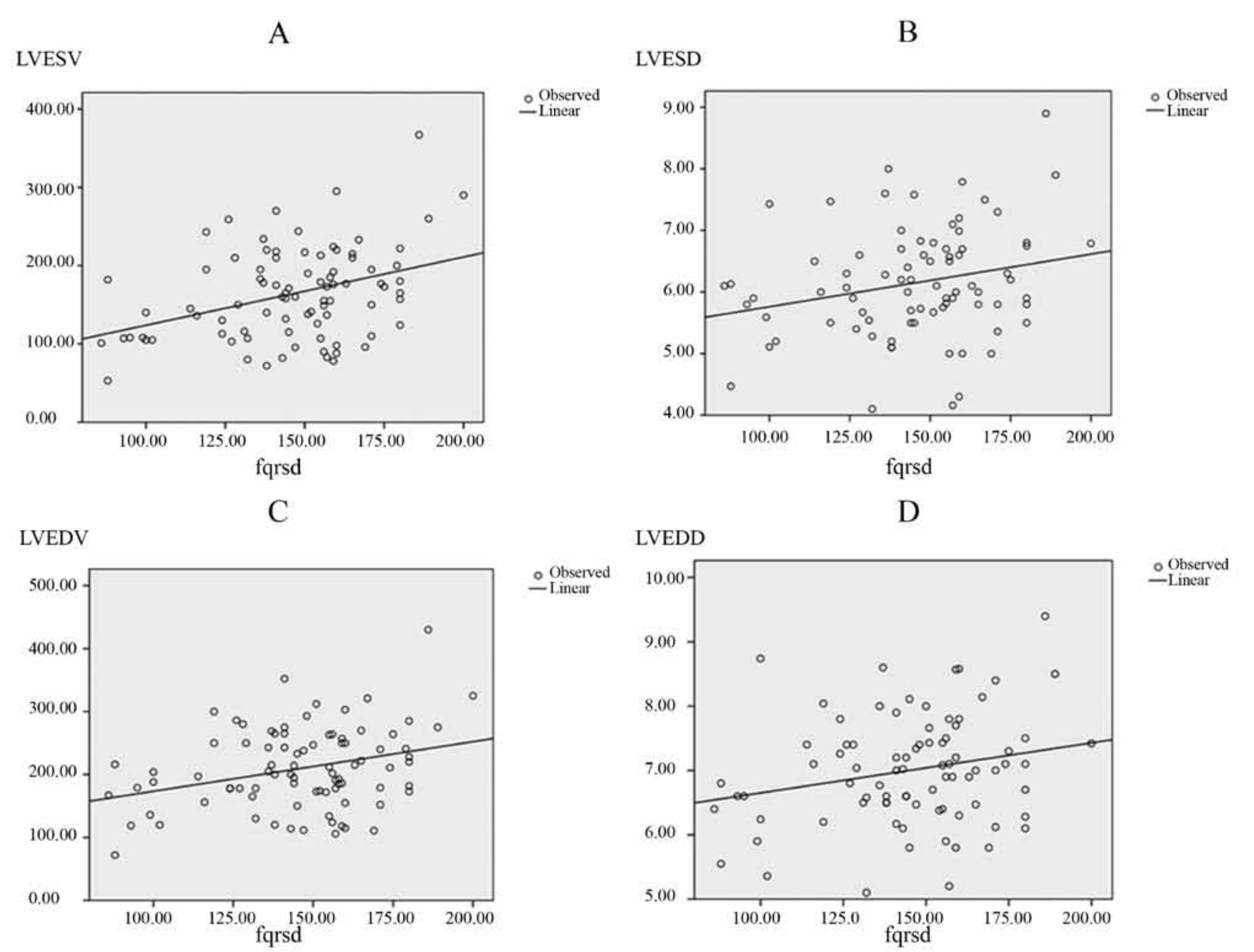

Figure 1. A-Correlation between the left ventricular end-systolic volume (LVESV, ml) and filtered QRS duration (fQRS, ms) (r = 0.37, p value = 0.000). B- Correlation between the left ventricular end-systolic diameter (LVESD, cm) and filtered QRS duration (fQRS, ms) (r = 0.24, p value = 0.031). C- Correlation between the left ventricular end-diastolic volume (LVEDV, ml) and filtered QRS duration (fQRS, ms) (r = 0.31, p value = 0.004). D- Correlation between left ventricular end-diastolic diameter (LVEDD, cm) and filtered QRS duration (fQRS, ms) (r = 0.23, p value = 0.039)

diastolic volume (r = 0.31, p value = 0.004) (Figure 1-C), and LV end-diastolic diameter (r = 0.23, p value = 0.039) (Figure 1-D), there was no significant correlation between the fQRS duration and LVEF. In addition, the relation between age, sex, and underlying disease and the parameters in the model was not significant.

There was no statistically significant relation between the QRS duration and LV dimensions, volumes, and EF (Table 3).

Discussion

QRS prolongation (> 120 ms) occurs in 14% to 47% of patients with heart failure and is a common finding in approximately 30%. LBBB occurs more commonly than does RBBB (25% to 36% vs. 4% to 6%).[2] The prolongation of

Table 2. Echocardiographic characteristics of study population (n=86)*

Left ventricular ejection fraction (%)	18.31±5.49 (10-33)
Left ventricular end-systolic diameter (cm)	6.15±0.90 (4.1-8.9)
Left ventricular end-systolic volume (ml)	163.76±58.34 (53-367)
Left ventricular end-diastolic diameter (cm)	7.00±0.86 (5.1-9.4)
Left ventricular end-diastolic volume (ml)	209.56±64.16 (72-430)

*Data are presented as mean±SD (range)

Table 3. Correlation of QRS duration and left ventricular dimensions and volumes assessed by two-dimensional echocardiography

Variable	Correlation Coefficient	P value
Left ventricular end-systolic diameter	0.13	0.249
Left ventricular end-systolic volume	0.17	0.113
Left ventricular end-diastolic diameter	0.10	0.358
Left ventricular end-diastolic volume	0.11	0.329
Left ventricular ejection fraction	0.04	0.125

QRS is a significant predictor for LV systolic dysfunction in patients with heart failure. One heart failure study indicated that the incidence of QRS prolongation increased from 10% to 32% and 53% when patients moved from NYHA functional class I to class II and III, respectively.[2]

In patients with heart failure, an inverse correlation exists between QRS prolongation and LVEF. In a study, a stepwise increase was found in the prevalence of systolic LV dysfunction as the QRS complex duration increased progressively above 120 ms.[2] As was stated in previous studies, the baseline QRS duration has no correlation with intraventricular dyssynchrony and is not predictive for clinical and echocardiographic responses.[2, 3]

The SAECG is a noninvasive test for the risk stratification of sudden cardiac deaths, especially in the survivors of myocardial infarction. This technique results in the improvement of the signal-to-noise ratio, thus allowing analysis of signals that are too small to be detected by routine measurement.[4]

There are some studies showing a better correlation between the SAECG data and intraventricular dyssynchrony.[5, 6] Our data showed that the fQRS duration in the SAECG had a significant linear correlation with LV diameters and volumes (despite low correlation coefficients) and was a better indicator of LV enlargement than was the QRS duration in the standard twelve-lead ECG. Hence, the SAECG can be more informative than standard ECG in patients with heart failure and may be used more in the future.

This study has some major limitations, first and foremost amongst which is its small size, which requires the evaluation of a larger group of patients to confirm its results. Another limitation is the heterogeneity of the study population insofar as patients with ischemic or idiopathic dilated cardiomyopathies and patients with intraventricular delay or narrow QRS were all included in this study. In addition, the fact that the study patients were selected from those referred to us certainly creates some selection bias.

Conclusions

According to our data, the fQRS duration has a better correlation with LV dimensions and volumes than does the QRS duration in standard ECG. The clinical significance of our findings warrants further investigation.

Acknowledgment

This study was supported by Cardiovascular Research Center of Ahvaz Jundishapur University of Medical Sciences.

References

1. Berbari EJ. High resolution electrocardiography. In: Zipes DP, Jalife J. eds. Cardiac Electrophysiology: from Cell to Bedside. 5th ed. Philadelphia: WB Saunders; 2004. p. 793-802.
2. Kashani A, Barold S. Significance of QRS complex duration in patients with heart failure. J Am Coll Cardiol 2005;46:2183-2192.
3. Mollema SA, Bleeker GB, van der Wall EE, Schalij MJ, Bax JJ. Usefulness of QRS duration to predict response to cardiac resynchronization therapy in patients with end-stage heart failure. Am J Cardiol 2007;100:1665-1670.
4. Turitto G, Abdula R, Benson D, El-sherif N. Signal averaged electrocardiogram. In: Gussak I, Antzelevitch C, eds. Electrical Diseases of the Heart. 1st ed. London: Springer; 2008. p. 353-355.
5. Tahara T, Sogou T, Suezawa C, Matsubara H, Tada N, Tsushima S, Kitawaki T, Shinohata R, Kusachi S. Filtered QRS duration on signal-averaged electrocardiography correlates with ventricular dyssynchrony assessed by tissue Doppler imaging in patients with reduced ventricular ejection fraction. J Electrocardiol 2010;43:48-53.
6. Andrikopoulos GK, Tzeis S, Kolb C, Sakellariou D, Avramides D, Alexopoulos EC, Triantafyllou K, Manolis AS. Correlation of mechanical dyssynchrony with QRS duration measured by signal-averaged electrocardiography. Ann Noninvasive Electro cardiol 2009;14:234-241.