The Impact of Hospital-Based Cardiac Rehabilitation on Signal Average ECG Parameters of the Heart After Myocardial Infarction

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Background: Cardiac rehabilitation is a combination of integrated programs aimed at improving outcomes in patients recovering from heart events.

Objectives: The present study aimed to evaluate the early benefits of supervised exercise training on electrophysiological function of post-ischemic myocardium. In this regard, signal-averaged electrocardiogram (SAECG) was used.

Patients and Methods: Between May and September 2012, all patients (n = 100) admitted to our center, with the diagnosis of acute Myocardial Infarction (MI), were enrolled in this study. Every other patient was assigned to two groups receiving either inpatient cardiac rehabilitation plus standard post-MI care (cases) or only standard post-MI care (controls). Electrophysiological function was assessed by SAECG in all the patients at baseline and on the day 5. The patients were considered as having late potential if they had abnormalities in at least two SAECG indices.

Results: Cardiac rehabilitation led to significant improvements in QRS duration (P < 0.001), square root of amplitude in the last 40 ms (P < 0.001) and duration of terminal signal with low amplitude (P < 0.001). Cardiac rehabilitation also resulted in amelioration of SAECG parameters; frequency of patients with late potential significantly decreased from 64% to 20% after five days (P < 0.001).

Conclusions: Supervised in-hospital exercise training was associated with improvements in SAECG-measured electrical activity post-MI.

Keywords: Rehabilitation; Myocardial Infarction; Electrocardiogram

1. Background

Several mechanisms contribute to poor prognosis in post Myocardial Infarction (MI) patients, among which ventricular fibrillation and dysfunction, impaired baro-reflex sensitivity and electrophysiological disturbances are associated with marked mortality and morbidity early after the event (1-6). Aside from lethal arrhythmias as a major cause of death early after MI, patients with more subtle ECG abnormalities, including microvolt T-wave alternans and heart wave turbulence, are at increased risk of subsequent fatal events (7). Post MI patients are at increased risk of sudden death in the first 30 days following MI even despite normal ventricular function (ejection fraction > 40%) (8).

Cardiac rehabilitation refers to a combination of integrated programs aimed at improving the outcomes in patients recovering from heart events. These programs involve exercise training, management of lipid abnormalities, hypertension, weight loss and nutritional and psychological education (9). Research on animal models and human subjects suggested that cardiac rehabilitation can reduce the risk of ventricular arrhythmia and sudden death (10, 11). Exercise training, a core component of rehabilitation programs, has proven efficacy on both heart function and modification of the underlying risk factors (12, 13). These noninvasive techniques can be implemented in patients with a wide range of heart problems, bearing favorable effects on most risk factors associated with high mortality (9).

2. Objectives

The present study aimed to evaluate early benefits of supervised exercise training on electrophysiological function of post-ischemic myocardium after MI. To this end, signal-averaged electrocardiogram (SAECG) was used. SAECG is superior to conventional ECG since it is able to remove noise signals, allowing for identification of small but significant variations in the QRS complex (14). Abnormalities in SAECG predicts subsequent occurrence of tachyarrhythmias with high sensitivity (15, 16). Herein, we assessed whether early in-hospital cardiac rehabilitation impacts electrophysiological abnormalities detected by SAECG in patients with MI.

3. Patients and Methods

Between May and September 2012, all patients admitted to our center with the diagnosis of acute MI were enrolled into this study. Patients were found eligible if their condition had been stabilized following the acute episode; i.e. (1) they had experienced no chest pain in the past eight hours, (2) no rise in serum concentrations of cardiac creatine kinase and troponin, and (3) they did not exhibit signs and symptoms of cardiac/respiratory distress including but not limited to dyspnea and bilateral rales. Patients with orthopedic conditions or rheumatologic diseases were excluded from the study since the ability of exercise training is limited in these patients. Patients with emergent Coronary Artery Bypass Graft (CABG) and long QRS complex (> 120 ms) were excluded, as well.

In this case-control study, every other patient was assigned into two groups receiving either inpatient cardiac rehabilitation (see below) plus standard post-MI care (training group) or only standard post-MI care (controls).

Before entering the study, a thorough medical history, including history of diabetes, hypertension, hyperlipidemia and smoking, was obtained and recorded using pre-designed questionnaires. All the patients gave verbal informed consent prior to entering the study. Local Ethics Committee also approved the study protocol.

3.1. Cardiac Rehabilitation Protocol

The patients received in-hospital cardiac rehabilitation supervised by a nurse and an experienced physiotherapist. Precise monitoring of heart rhythm, heart rate and blood pressure were performed during the sessions. For each patient, exercise training for 45 minutes daily was scheduled.

If the patients experienced chest discomfort, dyspnea and palpitation or if abnormalities emerged in ECG rhythm, exercise training was immediately halted.

3.2. Efficacy Assessment

Electrophysiological function was assessed by SAECG in all the patients at baseline and on day 5. SAECG was recorded by Cardioscan Resting 12-Lead (DM software Inc., California, US) during sinus rhythm with bipolar X, Y, and Z leads and bandpass filters at 25-250 Hz. In each assessment, three parameters were computed: (1) duration of filtered QRS complex, (2) root mean square of amplitude in terminal 40 ms and (3) duration of low amplitude signal. Abnormalities were detected if filtered QRS complex was longer than 114 ms, square of terminal signal was lower than 20 µV or low amplitude signal took longer than 38 ms. Patients were considered as having late potential if had abnormalities in at least two SAECG indices.

3.3. Statistical Analysis

Continuous variables, including SAECG parameters, presented as mean ± standard deviation. On the other hand, categorical variables displayed as proportions. Baseline characteristics were compared using Chi-square and Fisher's exact test. Besides, between group changes in SAECG indices were assessed using Analysis of Covariance (ANCOVA) with baseline measurement entering the model as covariates. In addition, changes in proportion of patients exhibiting late potentials between baseline and day 5 were investigated using McNemar test. All the analyses were performed using IBM SPSS Statistics 19 for Windows (IBM Inc., Armonk, NY, USA) and P- values less than 0.05 were considered as statistically significant.

4. Results

A total of 100 patients were recruited and assigned to receive standard care (control group) (n = 50) or standard care plus inpatient cardiac rehabilitation (the training group) (n = 50). The study participants included 44 females and 56 males with the mean age of 61.41 ± 11.60 years. Baseline characteristics of the recruited patients are presented in Table 1. Accordingly, no significant difference was found between patients in training and control groups regarding age, sex, type of MI and previous history of diabetes, hypertension, hyperlipidemia and smoking.

QRS complex duration. In the control group, the mean duration of filtered QRS complex was 110.5 ± 6.5 ms at baseline and increased to 113.2 ± 6.0 ms on day 5. In the training group, on the other hand, a declining trend was observed in this parameter, which diminished from 111.2 ± 6.1 to 104.8 ± 10 ms during the study course (Figure 1 A). ANCOVA revealed significant differences between the two arms of the trial regarding changes in QRS duration (P value < 0.001). Among the control group patients, 21 (42%) and 23 (46%) had abnormal QRS (longer than 114 ms) on the first and last days, respectively (P value = 0.013). In the training group, 23 subjects (46%) had abnormal QRS at baseline, which reduced to 3 (6%) on day 5 (P value < 0.001) (Table 2).

Root mean square of amplitude in the last 40 ms. The mean value of this parameter in the control group was 30.7 ± 20.8 µV at baseline and 27.0 ± 17.2 µV on day 5 (P = 0.12). In the training group, this value increased from 21.4 ± 12.2 to 28±11.9 µV after five days (P < 0.001) (Figure 1 B). Moreover, 20 patients in the control group (40%) had square amplitude less than 20 µV and this proportion did not change after five days (P value = 1). On the other hand, 29 subjects in the training group (58%) had this abnormality at baseline, but it was detectable in only 11 patients (22%) by the fifth day (P value < 0.001) (Table 2).
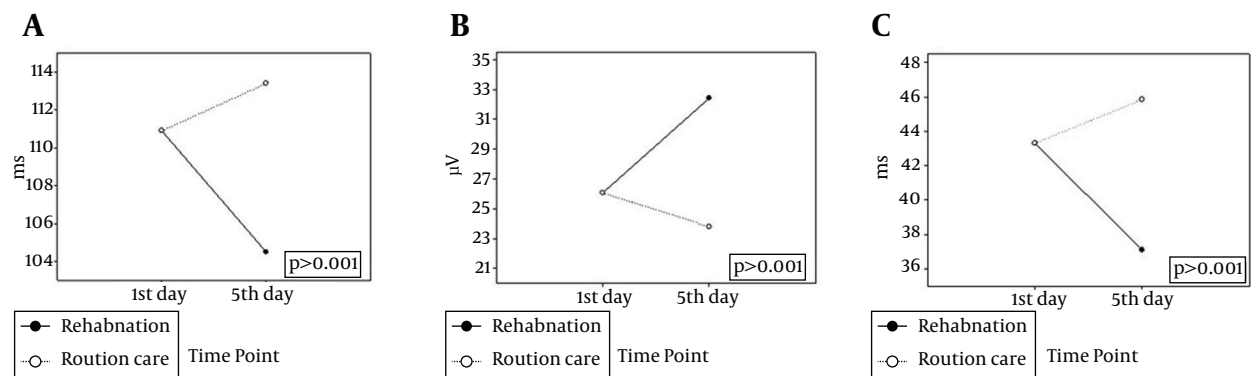
Duration of terminal signal with low amplitude (< 40 µV). Slight increase was noted in this parameter in the control group and the mean value increased from 42.3 ± 11.8 to 45.3 ± 11.0 ms (P = 0.039). The patients in the training group, on the other hand, experienced a decline from 44.3 ± 7.3 to 37.6 ± 5.6 ms (P < 0.001) (Figure 1 C). The proportion of patients with terminal signal longer than 38 ms is presented in Table 2.

Table 1. Baseline Characteristics of the Study Participants [a]

	Training Group (n = 50)	Control Group (n = 50)	P Value
Age, y	60.4 ± 11.9	62.4 ± 11.2	0.397
Type of MI			0.147
STEMI	22 (44)	15 (30)	
Non-STEMI	28 (56)	35 (70)	
Gender			1.00
Male	28 (56)	28 (56)	
Female	22 (44)	22 (44)	
Diabetes			0.836
Yes	19 (38)	18 (36)	
No	31 (62)	32 (64)	
Hypertension			0.635
Yes	30 (60)	28 (56)	
No	20 (40)	22 (44)	
Family history of MI			0.137
Yes	4 (8)	9 (18)	
No	46 (92)	41 (82)	
Smoking			0.822
Yes	13 (26)	14 (28)	
No	37 (74)	36 (72)	
Hyperlipidemia			0.687
Yes	21 (42)	23 (46)	
No	29 (58)	27 (54)	

[a] Data are presented as No. (%) or Mean ± SD.

Figure 1. Changes in Signal-Averaged Electrocardiogram Indices in Training and Control Groups at Baseline and After Five Days

Baseline values are adjusted to an arbitrary mean using ANCOVA; A, Durations of QRS complex; B, root mean square of amplitude in the last 40 ms, and; C, duration of terminal signal with low amplitude (< 40 μV).

Table 2. Proportion of Patients With Late Potentials at Baseline and Day 5 in Training and Control Groups [a]

	Training Group		Control Group	
	Before	**After**	**Before**	**After**
QRS duration				
Normal	27 (54)	47 (94)	29 (58)	27 (54)
Abnormal	23 (46)	3 (6)	21 (42)	23 (46)
P value [b]	< 0.001		0.013	
Square of amplitude in the last 40 ms				
Normal	21 (42)	39 (78)	30 (60)	30 (60)
Abnormal	29 (58)	11 (22)	20 (40)	20 (40)
P value [b]	< 0.001		1	
Duration of low amplitude segment				
Normal	13 (26)	31 (62)	23 (46)	16 (32)
Abnormal	37 (74)	19 (38)	27 (54)	34 (68)
P value [b]	< 0.001		0.092	
Late potential				
No	18 (36)	40 (80)	26 (52)	18 (36)
Yes	32 (64)	10 (20)	24 (48)	32 (64)
P value [b]	< 0.001		0.039	

[a] Data are presented as No. (%).
[b] Within group comparison using McNemar analysis.

Late potential. As described earlier, patients were considered as having late potential if had at least two abnormal SAECG parameters. Among the patients who only received routine care (control group), 24 (48%) and 32 (64%) had late potential on the first and fifth days, respectively (P = 0.039). However, cardiac rehabilitation resulted in amelioration of SAECG parameters; frequency of patients with late potential decreased significantly from 64% to 20% after five days (P < 0.001) (Table 2).

5. Discussion

The results of the current study suggested that in-hospital cardiac rehabilitation after an MI episode was associated with lower electrophysiological abnormalities as detected in SAECG. Based on the SAECG results, it is expected that patients who receive rehabilitation would have a lower risk of subsequent ventricular tachyarrhythmia and sudden death.

Recent studies pointed out that cardio protective effects of rehabilitation programs might be due to improved regulation of the autonomic nervous system. For instance, in a study by Malfatto et al. (17), short-term effects of exercise were investigated in 22 post-MI patients. The researchers proposed that eight weeks of exercise training could modulate cardiovascular autonomic function by increasing vagal (parasympathetic) tone, which is known to be associated with better cardiovascular outcome (18). Similar results were also obtained after rehabilitation in patients with Ischemic Heart Disease (IHD). Lucini et al. reported significant improvements in baroreflex sensitivity and increases in R-R interval in 29 patients who underwent exercise training compared to 11 individuals in the control group (19). Exercise training can also enhance heart rate variability in healthy older adults (20). Increased activity of parasympathetic nervous system paralleled with decreased sympathetic overdrive could subsequently lower the risk of sudden cardiac death due to fatal tachyarrhythmias. Exercise can also improve autonomic function indices like heart rate variability index (HRV) in patients with heart failure, but autonomic dysfunction can predict poor outcome after rehabilitation (21). In the present study, improvement in SAECG parameters was consistent with the aforementioned effects.

Tanaka et al. (22) demonstrated that regular exercise helped maintaining arterial elasticity and even reversed aging-related changes. Moreover, Luk et al. (23) observed that eight weeks exercise training could increase flow-mediated dilation, high density lipoprotein and decrease heart rate at rest. Beneficial effects of exercise training on endothelial function have been addressed by other research groups (24, 25). It has been suggested that enhanced release and activity of Nitric Oxide (NO) resulting in improved vasodilatation might be a key event in this regard (26, 27). In the same line, Hambrecht et al. (28) indicated that four weeks of physical activity could significantly improve endothelium dependent vasodilatation. Therefore, improvements in coronary artery blood flow gained by exercise training programs can limit the ischemic episodes of myocardium during future activities.

Despite the fact that cardiac rehabilitation has proven effects on patients' outcome, only 10-20% of patients with MI participate in rehabilitation programs in the U.S. (29). This has been attributed to lack of experience or necessary equipment in different regions, low referral rates in women and elderly and low socioeconomic status of patients (30, 31). These underlying factors also contribute to low utilization of rehabilitation programs in Iran. Yet, with increased awareness regarding short- and long-term benefits of such programs, more frequent use of cardiac rehabilitation programs is ensued.

5.1. Limitation of the Study

During the study, case group patients should stay in the hospital to complete their rehabilitation program. This strategy in some patients increased the cost of hospital stay and may outweigh the cost-effectiveness of complete protocol of in-hospital rehabilitation. Stratification of patients according to the duration of hospital stay may answer this question in future studies.

Supervised in-hospital exercise training was associated with improvements in SAECG parameters in post-MI patients. Nevertheless, further studies are required to investigate whether these promising preliminary findings favorably affect long-term patient outcomes to reduce fatal arrhythmia event.

Acknowledgements

Authors' Contributions

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