Analysis of the Influence of Parasympathetic Postganglionic Neurons on Cardiac Response in Ventricular Fibrillation

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Abstract

Physical training modifies the sympathetic-vagal balance of autonomic nervous system. Previous studies have shown that such training also produces intrinsic modifications of cardiac electrophysiological properties in isolated heart during Ventricular Fibrillation (VF).

Ten NZW trained rabbits were studied to test if the modifications are related to the activity of postganglionic parasympathetic neurons. Two records per subject were acquired during VF: before (G1) and after (G2) the infusion of atropine to inhibit the activity of neurons. Mapping records were obtained using a 240-channel electrode array located in the left ventricle of isolated heart (perfused by Langendorff system). VF was induced by stimulation at increasing frequencies.

To analyze the time course of fibrillation, the records were processed in 4-second consecutive segments. For each channel and segment, the following parameters were computed: 1) Dominant Frequency (DF), obtained by the Welch periodogram b) Normalized Energy (NE) in a frequency band centered at the DF; c) Regularity Index (RI), which analyzes the similarity of local activation waves in every segment and channel; d) Coefficients of Variance of DF (CVDF), NE (CVNE) and RI (CVRI).

For each segment, we obtained the average value of each of the parameters analyzed for all electrodes. The results are: a) DF (G1: 13.671 ± 0.509 Hz, G2: 14.783 ± 0.455 Hz), b) NE (G1: 0.398 ± 0.014; G2: 0.380 ± 0.013); c) RI (G1: 0.855 ± 0.017; G2: 0.865 ± 0.015), d) CVDF (G1: 0.109 ± 0.009; G2: 0.098 ± 0.008), e) CVNE (G1: 0.398 ± 0.014; G2: 0.380 ± 0.013) f) CVRI (G1: 0.084 ± 0.009; G2: 0.078 ± 0.008).

None of these parameters showed significant differences between groups. Thus, the parasympathetic postganglionic neurons seem to have no effect on the cardiac response in VF due to physical training.

1. Introduction

Physical exercise modifies the sympathetic-vagal balance of autonomic nervous system, generating an increase in parasympathetic activity which is manifested in a reduction in heart rate [1, 2], and producing an antiarrhythmic effect by increasing vagal activity [3].

Studies on models of sudden cardiac death have shown that treadmill running improves parasympathetic regulation, increasing cardiac rate variability (HRV) and protecting against the occurrence of VF induced by acute myocardial ischemia [4]. Changes have also been reported in the maximum heart rate (HRmax), although the mechanisms that trigger these changes are not fully established [5].

In addition to these changes induced by the autonomic nervous system, regular exercise also produces intrinsic effects. An increase in the action potential duration of ventricular cardiomyocytes has been observed [6]. Studies in isolated rabbit heart during VF show that there are significant differences between groups of trained and untrained subjects in spectral characteristics and regularity of the fibrillatory signal, showing a more stable cardiac response in the trained subjects [7,8].

These studies [7,8] have been made in isolated heart to eliminate the influence of the autonomic nervous system. The aim of this study is to analyze whether the effects observed in isolated heart may be partly due to the activity of postganglionic parasympathetic neurons and not entirely to intrinsic causes.

2. Methods

Mapping records of VF were acquired in the Cardiac Electrophysiology Laboratories of the University of Valencia using a commercial 256 channel mapping

system (Maptech, Waalre, the Netherlands). The records were acquired using an electrode array of 240 electrodes located in the left ventricle of rabbit isolated heart, perfused with a Langendorff system.

Ten NZW rabbits were trained on a treadmill following a protocol of certain intensity. For each subject, two 5-minute records at 1kHz sampling frequency were acquired. VF was induced by stimulation at increasing frequencies. The first record corresponds to VF prior to the infusion of atropine to inhibit the activity of neurons (G1). Following its acquisition, VF was reverted and after atropine administration (1 mM) VF was again induced and the second record (G2) was acquired.

In all cases, preprocessing was performed to analyze the quality of the record, discarding those channels with low amplitude or presence of noise. To analyze the temporal evolution of fibrillation, the records were processed in 4-second consecutive segments.

For each segment and channel, the spectrum was obtained by Welch periodogram, using Hanning window, two non-overlapping sections, and zero padding. The analysis in the frequency domain includes obtaining the dominant frequency of the spectrum (FD) and normalized energy (NE), defined as the spectral energy in a window FD ± 1Hz, and normalized by the spectral energy in the band of interest (5-35Hz).

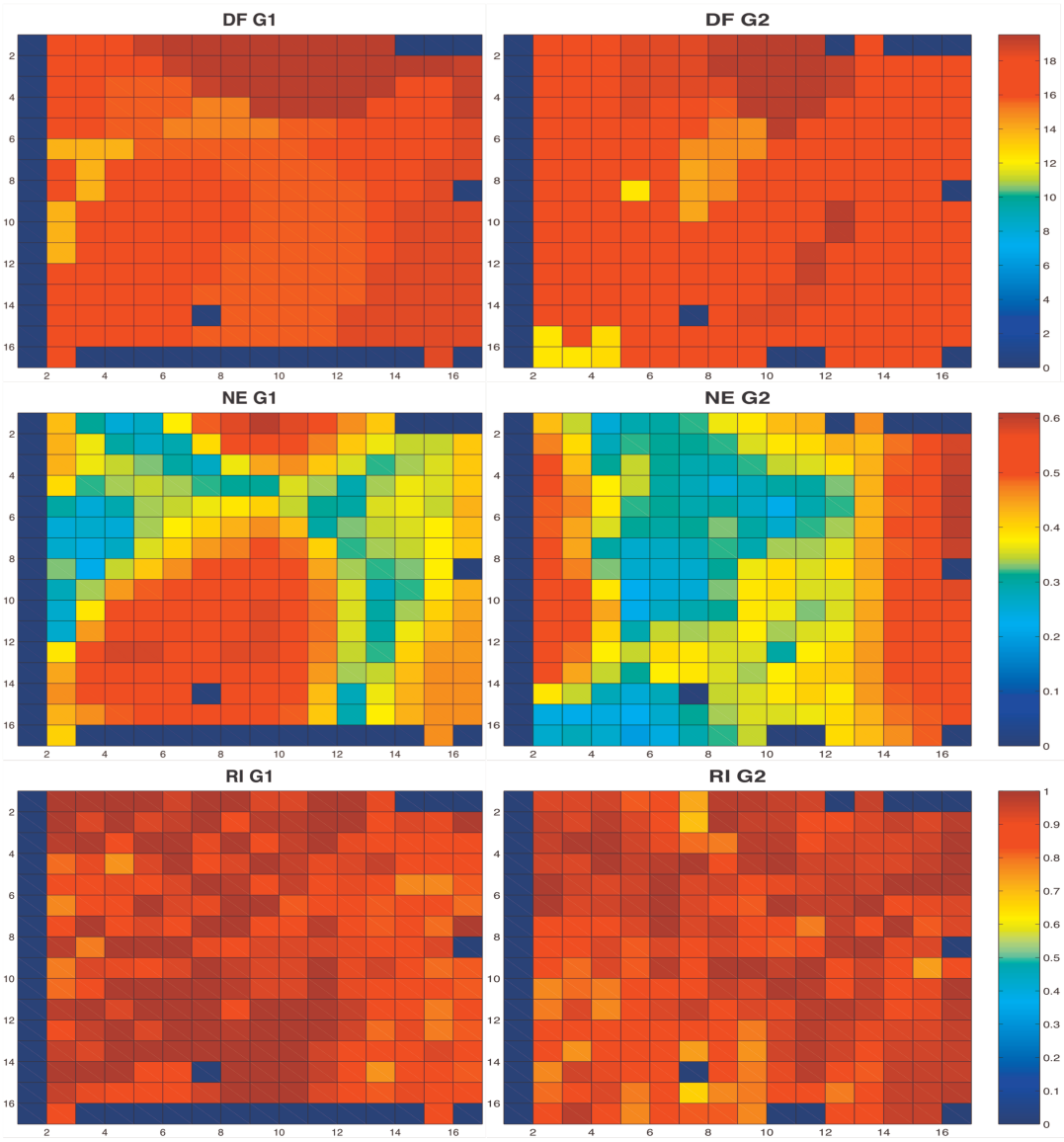

Figure 1. Example of maps corresponding to the value of DF, NE, and RI in the 240 electrode array at the same time sequence of the same record before (G1) and after (G2) to the administration of atropine.

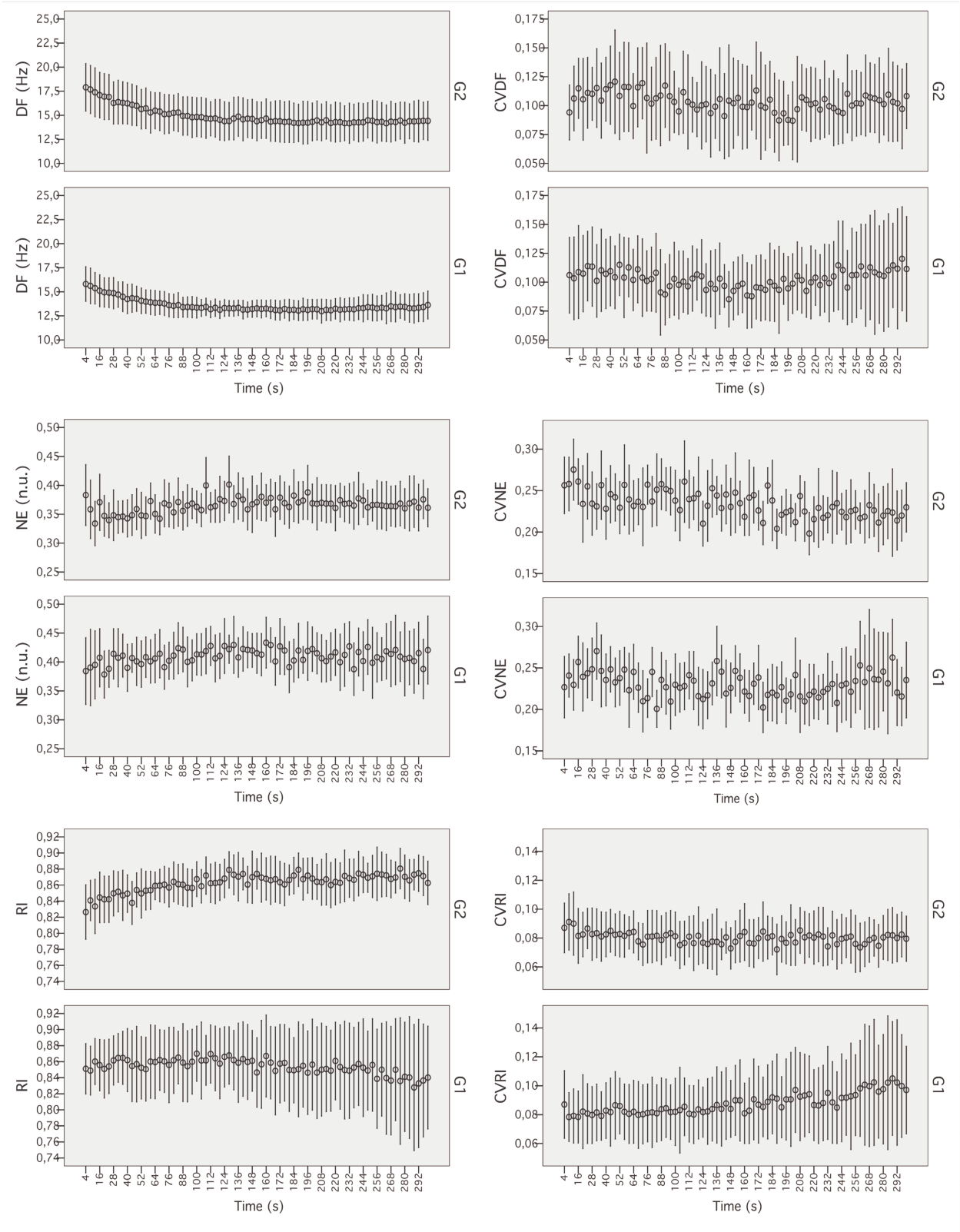

Figure 2. Temporal evolution of the average values of the parameters for G1 and G2 records.

The analysis of regularity of the VF was performed by calculating, for each segment and channel, the regularity index (RI), which quantifies the regularity of the signal by analyzing the similarity of local activation waves along each channel. The used algorithm is based in [9], but modified in order to fit the electrophysiological properties of the used heart model [7,8].

For each time segment, a map for the value of DF, NE, and RI for all electrodes was generated (Figure 1). From this map, we calculated the average value of the parameters in the set of electrodes and their coefficients of variance (CVDF, CVNE and CVRI).

For all the parameters, normality test of Kolmogorov-Smirnov, Levene test for equality of variances and Mauchlys test for sphericity were applied. An analysis of variance with repeated measures for two factors (time and group) was performed.

3. Results

Table 1 shows the average results of all the records for all time instants according to the group. Figure 2 shows the time evolution of these values for each parameter.

Table 1. Mean and standard deviation values for the parameters (DF, NE, RI and their coefficients of variance) for both groups.

	G1	G2
DF	13.671 ± 0.509	14.783 ± 0.455
NE	0.398 ± 0.014	0.380 ± 0.013
RI	0.855 ± 0.017	0.865 ± 0.015
CVDF	0.109 ± 0.009	0.098 ± 0.008
CVNE	0.398 ± 0.014	0.380 ± 0.013
CVRI	0.084 ± 0.009	0.078 ± 0.008

Both values and their evolution profile are similar for both groups. For RI and CVRI there was some difference between the situation before and after application of atropine, but neither these nor the rest of parameters showed significant differences depending on the group to any point in time.

4. Conclusions

This work studies the possible effect that parasympathetic postganglionic neurons can have on intrinsic modifications of cardiac response induced by physical training during VF. The study has been performed on isolated hearts to eliminate the influence of nervous system. Two groups of records have been obtained, before and after administration of atropine to inhibit the activity of neurons. Three parameters and their coefficients of variance have been analyzed (DF, NE, RI, CVDF, CVNE, CVRI).

Although some parameters show differences depending on the group, in any case these differences reached statistical significance. Therefore, the findings suggest that the parasympathetic postganglionic neurons seem to have no effect on the cardiac response in VF due to physical training.

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