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PHYSIOLOGY

Dominant and Non-Dominant Structure of Ventricular Fibrillation in Canine Heart

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Organized activity of the myocardium manifested in dominant frequency structure of ECG was typical of the first 10 min of ventricular fibrillation in canine heart. The first minute of fibrillation was characterized by the most pronounced changes in the structure of oscillation frequency and transition from domination of high frequency oscillations (13-17 Hz) to domination of medium (8-12 Hz) and then low frequency (4-7 Hz) oscillations. The second minute was characterized by transition from domination of low frequency oscillations to domination of low and medium frequency oscillations; minutes 3-10 were characterized by domination of low and medium frequency oscillations; after 10 min, non-dominant ventricular oscillations were recorded.

Key Words: *ventricular fibrillation; canine heart; dominant structure; non-dominant structure*

In contrast to synchronized heart contractions providing effective hemodynamics, ventricular fibrillation (VF) is characterized by disordered asynchronous contractions of myocardial fiber bundles unable to maintain hemodynamics. VF serves as the main cause for sudden cardiac death in many countries including Russia [1,4]. VF is usually considered as a disorganized process [10]. Mapping of the myocardium showed that electrical activity is organized during minutes 1-2 of VF and then became disorganized [3,5,6]. However, mapping covered only 20% of epicardial surface of the myocardium, whereas VF involves all ventricular myocardium. In addition, previous experiments [3,5,6] do not provide quantitative parameters of VF.

Periods of organized activity were found after 3 min of VF [7,9]. Periods of organized activity lasted no more than 33% time during minutes 5-10 of VF alternating with longer periods of disorganized activity. Organized activity was local and was observed mostly in the subendocardial layer of the left ventricle, whereas activity of total myocardium assessed by ECG was disorganized during VF. Previous experiments [7,9] also did not contain precise quantitative criteria of local organized activity during VF.

Thus, we found no articles showing organized activity of the whole myocardium during the first 10 min of VF and presenting quantitative parameters of organized activity and its dynamics.

Our aim was to detect organized activity and to evaluate its quantitative parameters and dynamics during the first 10 min of VF in dogs by fast Fourier transform (FFT) analysis of ECG during VF. ECG characterizes electrical activity of the whole myocardium during VF, and FFT allows quantitative analysis of frequency and amplitude parameters of ECG [2,8].

MATERIALS AND METHODS

Ten *in situ* experiments were performed on canine heart in accordance with Regulations on Animal Ex-

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periments. The animals were anesthetized by intramuscular administration of zoletil (20-30 mg/kg; Virbac Sante Animale), in 5-10 min after the injection, 4 electrodes for ECG registration were positioned on fore and hind limbs and 2 electrodes for electrical stimulation were positioned on the chest.

In all dogs, ECG in standard lead III was recorded using a NeuroS-4U cardiograph (Neirobotiks) with digitizing frequency of 500 Hz. No pathological changes were found in initial ECG. Stimulation of the heart by alternating current (50 Hz, 30 W) for 2-3 sec induced VF in all dogs.

Analysis of frequency and amplitude (spectral analysis) of 1-sec intervals of ECG during VF was performed by FFT method using Neokorteks software (Neirobotiks). Spectral analysis was conducted in 5 frequency ranges: very low (1-3 Hz), low (4-7 Hz), medium (8-12 Hz), high (13-17 Hz), and very high frequencies (18-40 Hz). Relative contribution (%) of frequency oscillations (OL) of the studied ranges were estimated in 5-sec intervals of ECG in 10 dogs (total 50 measurements).

Statistical analysis was performed using SPSS 11.5 software and nonparametric Mann–Whitney test.

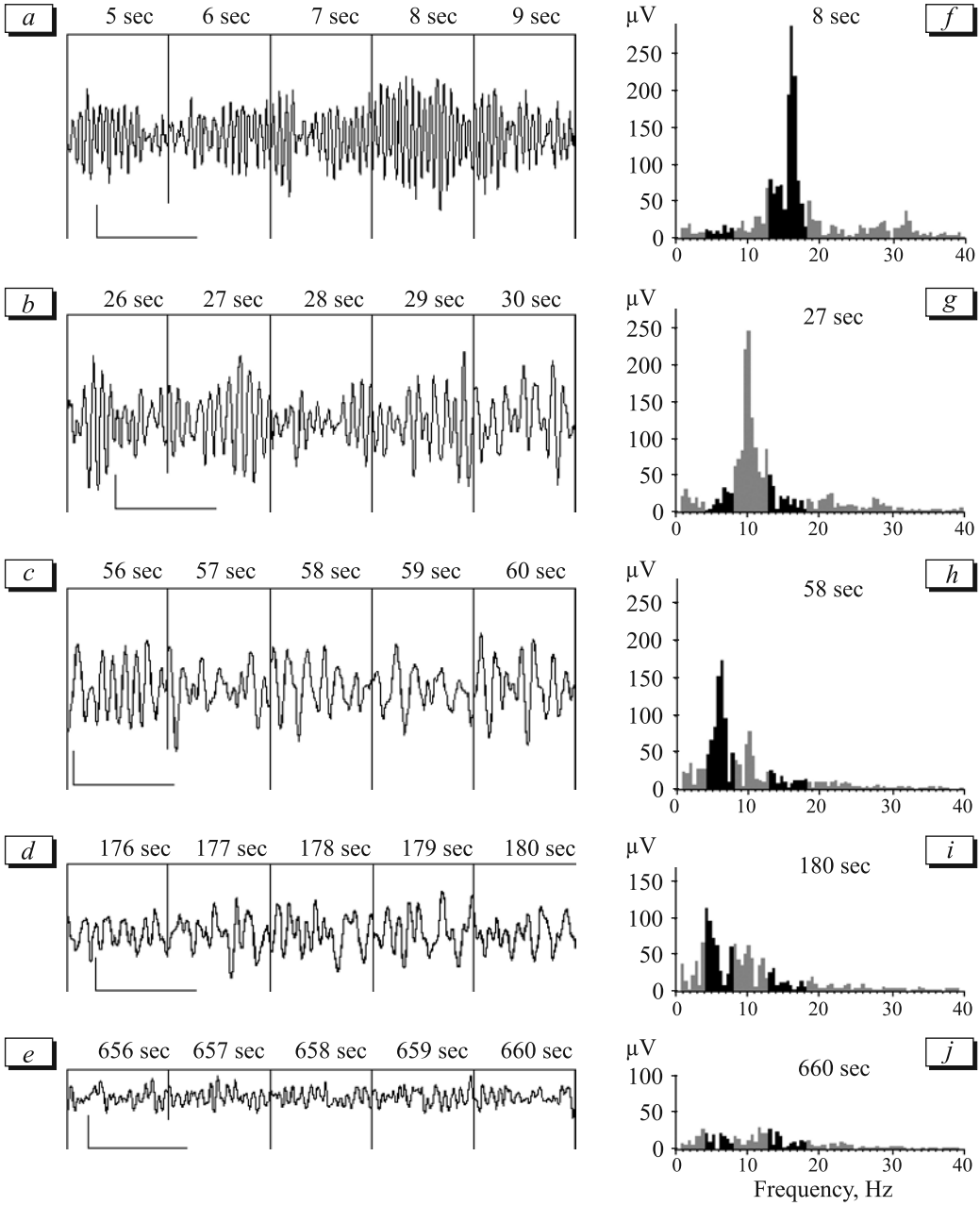

Fig. 1. Five-second intervals of ECG (*a*-*e*) and spectrograms of 1-sec intervals of ECG (*f*-*k*) on minutes 1-11 of VF in dogs. ECG calibration: 0.5 mV, 1 sec. Ordinate on spectrograms: amplitude.

RESULTS

On the 5th-9th seconds of VF, high frequency OL (13-17 Hz) organized into "fibrillation bundles" dominated in ECG. Domination of high frequency OL was confirmed by the analysis of spectrogram of 1-sec interval of ECG (Fig. 1, *a*, *f*). Domination of medium frequency OL (8-12 Hz) also organized into "bundles" on seconds 26-30 of ECG was also confirmed by spectrogram (Fig. 1, *b*, *i*). On seconds

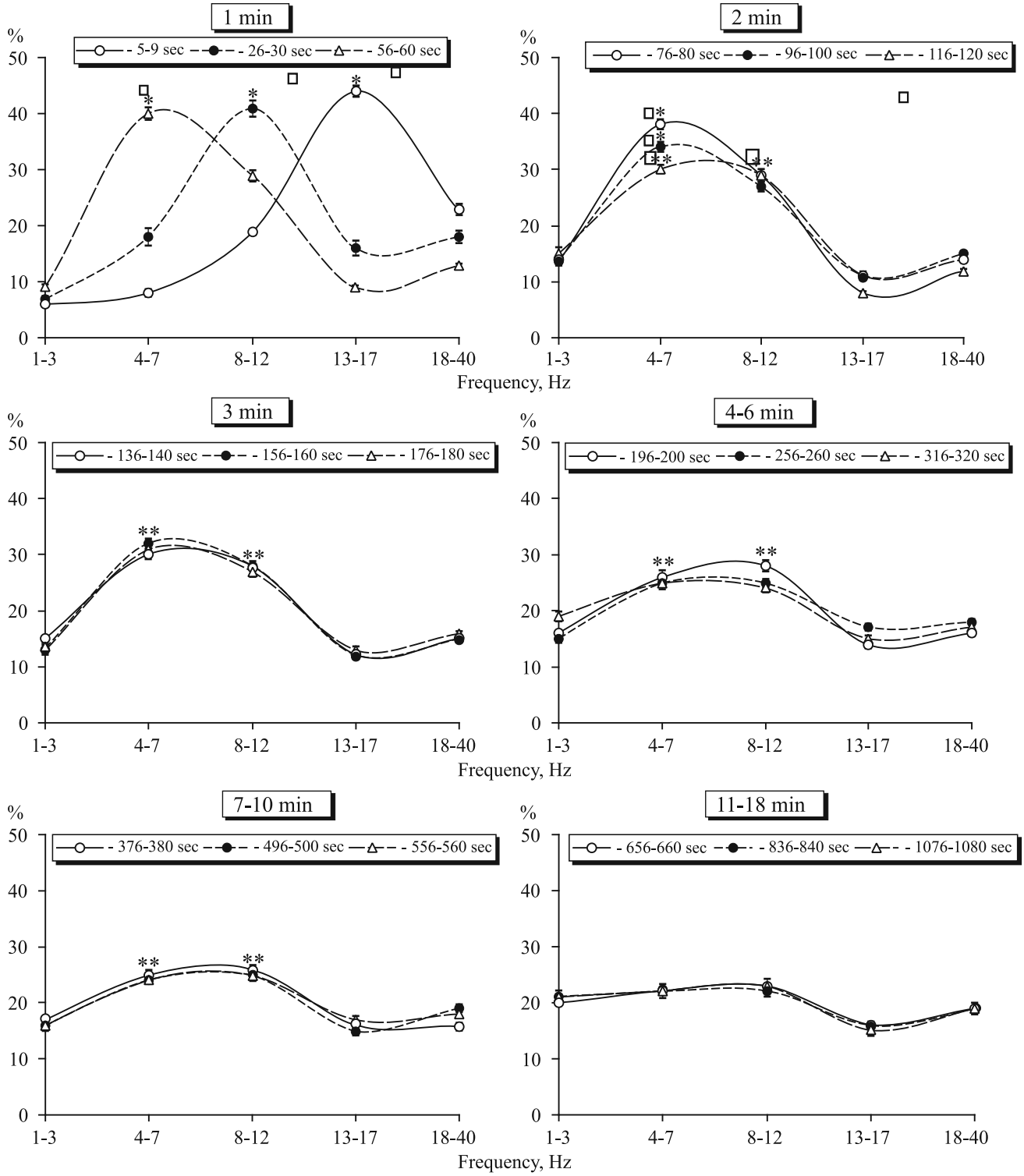

Fig. 2. Relative weight of OL of various frequencies at minutes 1-18 of VF in a dog. *$p<0.01$ in comparison with other frequencies; **$p<0.01$ in comparison with 1-3, 13-17, and 18-40 Hz.

56-60, low frequency OL (4-7 Hz) dominated in ECG and spectrogram (Fig. 1, *c*, *k*). Polymorphous OL with a frequency of 1-20 Hz (mostly non-organized) were registered on seconds 176-180 of ECG. However, spectrogram showed domination of low and medium frequency OL during this period (Fig. 1, *d*, *j*). On seconds 656-660, asynchronous OL with a frequency of 1-20 Hz were registered in ECG, but spectrogram indicated equally distributed (non-dominant) structure of ECG (Fig. 1, *e*, *k*).

Dominant and non-dominant structure of VF observed in a representative dog (Fig. 1) was typical of all dogs. High frequency OL (5/40 of all OL in the range of 1-40 Hz) constituted 44% of spectral power and dominated in the structure of OL frequencies at the beginning of the first minute of VF (Fig. 2, *a*). Medium frequency OL (5/40 of frequency range) constituted 41% of spectral power and dominated in the structure of OL frequencies in the middle of the first minute of VF (Fig. 2, *a*). Low frequency OL (4/40 of frequency range) constituted 40-38% of spectral power and dominated in the interval from the end of the first to the middle of the second minute of VF (Fig. 2, *a*, *b*). Low and medium frequency OL (9/40 of frequency range) constituted 61-49% of spectral power and dominated in the interval from the middle of min 2 to min 10 of VF (Fig. 2, *b*-*e*). Very low, low, medium, and very high frequency OL constituted 19-23% of spectral power and the difference between the relative contributions of these OL was insignificant, which indicated non-dominant structure of OL frequencies on minutes 11-18 of VF (Fig. 2, *f*).

Dominant structure of ECG reflects organized (synchronized) activity of the myocardium during VF. If cardiomyocytes generate action potential in a random way and independently from each other, sporadic summarizing of these potentials will be present on ECG as a random summary process with low amplitude high frequency asynchronous OL. Random process with regular distributed spectral density is observed only after 10 min of VF (Fig. 1, *e*, *k*; Fig. 2, *f*).

Thus, we showed that organized myocardial activity is typical of the first 10 min of VF in canine heart, which manifested in dominant structure of OL frequency. The first minute of VF was characterized by the most pronounced changes in the structure of OL frequencies with transition from domination of high frequency OL to medium frequency OL and then to low frequency OL. Less pronounced dynamics was observed during the second minute characterized by transition from domination of low frequency OL to domination of low and medium frequency OL. Low and medium frequency OL dominated on minutes 3-10, while after 10 min, non-dominant pattern was observed.

The results suggest that organized structure of VF is resistant to ischemia: organized structure remains unchanged for 10-min exposure of the myocardium to ischemia during VF (Fig. 2, *f*). Our results can be used for the development of an algorithm of automatic VF diagnostics for maximum protection human life and health in life-threatening VF.

REFERENCES

1. V. A. Vostrikov, *Klin. Anestesiol. Reanimatol*., **4**, No. 4, 2-7 (2007).
2. A. Amann, R. Tratnig, and K. Unterkofler, *Biomed. Eng. Online*, **4**, 60 (2005).
3. K. A. Cheng, D. J. Dosdall, L. Li, *et al*., *Am. J. Physiol. Heart Circ. Physiol*., **302**, No. 4, H992-H1002 (2012).
4. J. J. Goldberger, A. Basu, R. Boineau, *et al*., *Circulation*, **129**, No. 4, 516-526 (2014).
5. J. Huang, J. M. Rogers, C. R. Killingsworth, *et al*., *Am. J. Physiol. Heart Circ. Physiol*., **286**, No. 3, H1193-H1200 (2004).
6. J. F. Huizar, M. D. Warren, A. G. Shvedko, *et al*., *Am. J. Physiol. Heart Circ. Physiol*., **293**, No. 3, H1617-H1628 (2007).
7. L. Li, Q. Jin, D. J. Dosdall, *et al*., *Am. J. Physiol. Heart Circ. Physiol*., **298**, No. 6, H2046-H2053 (2010).
8. J. C. Newton, W. M. Smith, and R. E. Ideker, *Circ. Res*., **94**, No. 6, 836-842 (2004).
9. R. P. Robichaux, D. J. Dosdall, J. Osorio, *et al*., *J. Cardiovasc. Electrophysiol.*, **21**, No. 11, 1266-1273 (2010).
10. J. N. Weiss, A. Garfinkel, H. S. Karagueuzian, *et al*., *Circulation*, **99**, No. 21, 2819-2826 (1999).