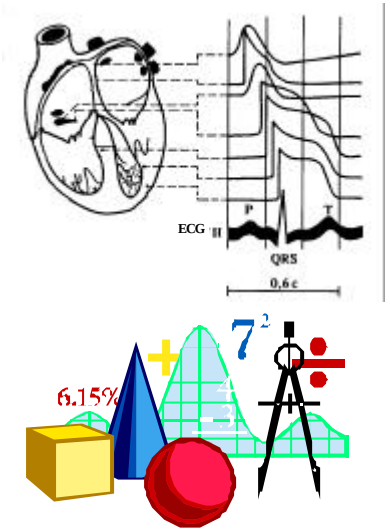

A new technique of ECG analysis and its application to evaluation of disorders during ventricular tachycardia

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Introduction

Ventricular arrhythmias are life-dangerous disorders of the heart activity. Despite considerable progress in recent years, the pharmacological treating of patients with ventricular fibrillation and polymorphic ventricular tachycardia remain little effective. In accordance with multicentered investigations (ESVEM, CASCADE etc.), the treating with antiarrhythmic drugs of all classes leads to the positive results in 58,5% of cases. Such low treating efficiency can be caused by poor differentiation of ventricular arrhythmias. It is expected that the more detailed diagnosis is made the more correct treating is prescribed.

The most widely used clinical tools for assessing arrhythmias is the body surface ECG. For detailed quantitative description of polymorphic ventricular arrhythmias to be introduced, we proposed a new technique for ECG analysis referred to as ANI-method [Biophysics 46(2):313-323].

The ANI-method was tested with the ECGs obtained both in physiological experiments [Biophysics 42(2):491-496] and in numeric simulations [Biophysics 48(2):303-312].

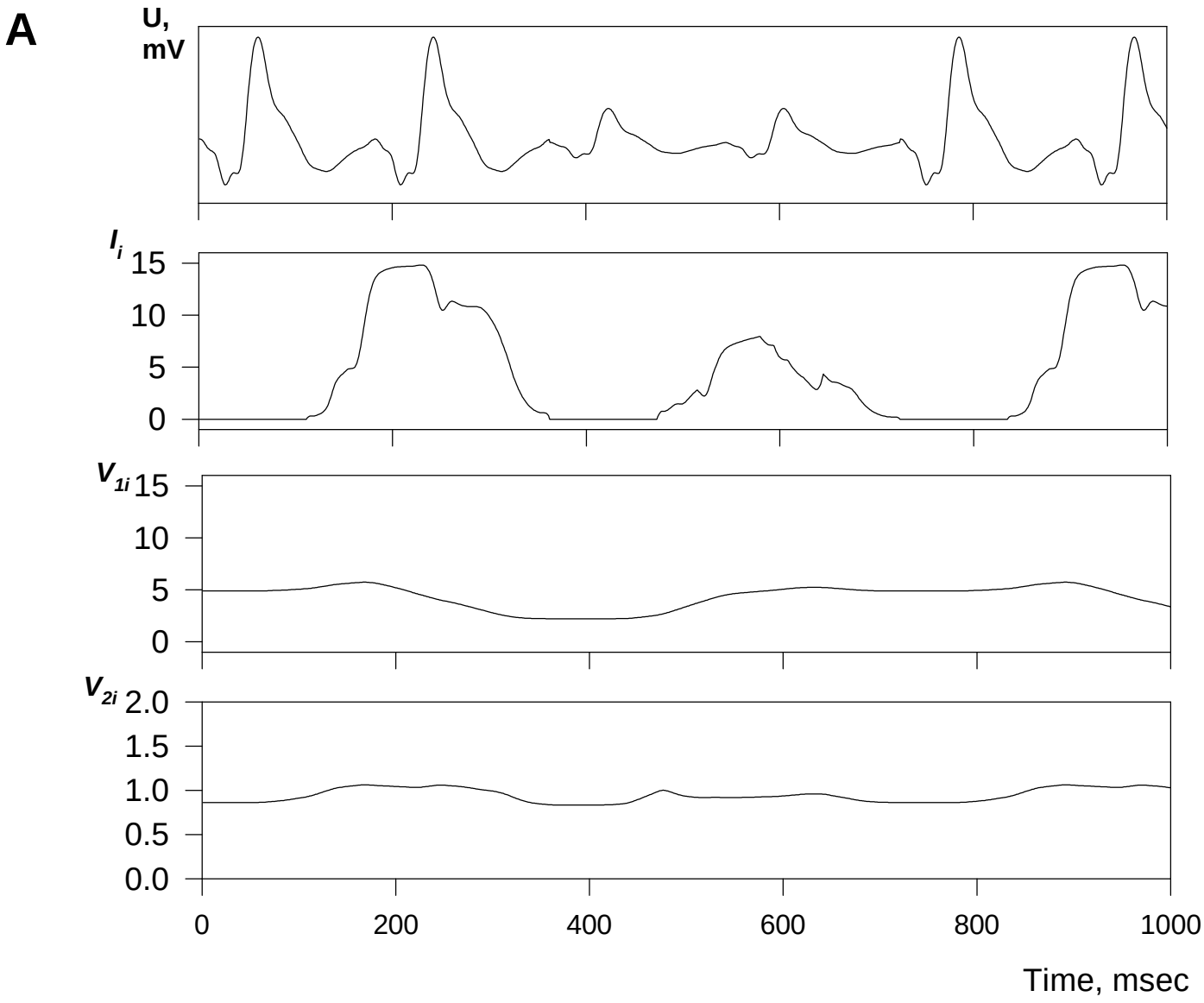
Results

The ANI-method maps ECG fragment to two real indices. The indices give evaluation of polymorphism, which is one of the qualitative ECG characteristics of cardiac arrhythmia degree. One of the indices characterizes the average evaluation of ECG segments unlikeness inside the fragment and the other is its variation. An indices sequence for successive ECG fragments draws a trajectory in the index space. The compared ECG segments correspond to similar intervals of adjacent cardiac cycles. **See Fig.1 on p.4-5**

In the index space, the regions corresponded to ECG with different polymorphism were picked out. On the base of peer review, the partial order was introduced for ECG polymorphism. It is induced the partial order in the index space. As result new detailed quantitative description of polymorphic ECGs was introduced. **See Fig.2 on p.6-7.**

It was found out that the trajectories of ECGs obtained in the physiological experiments usually groups in certain regions of the index space and are absent in the other regions. **See Fig.4 on p.9-10.**

The trajectories of ECGs obtained in the numeric simulations have significantly different location. But ECGs of both types have no evident visual differences. It is interesting that numeric ECGs are less "determinate" with respect to the indices than the physiological ECGs. Physiological and biophysical mechanisms of the phenomena described here have no explanation yet. **See Fig.5 on p.11-12.**


A
U, mV
I_i
15
10
5
0
V_{1i}
15
10
5
0
V_{2i}
2.0
1.5
1.0
0.5
0.0
0
200
400
600
800
1000
Time, msec

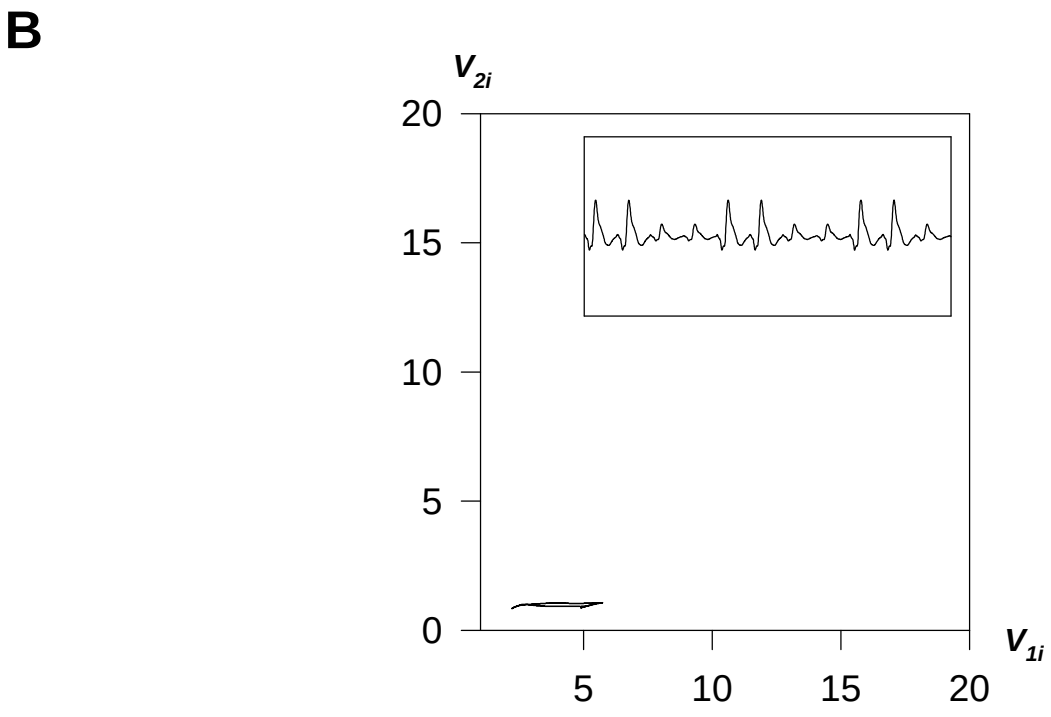

B
V_{2i}
20
15
10
5
0
5
10
15
20
V_{1i}

Fig 1

Fig 1. ECG variability estimation through the normalized-value analysis of electrocardiographic variability (NVAEV, or **ANI-method** in Russian).

(A) From top to bottom: $U(t)$ - ECG; I_i - for i^{th} moment of discrete time, the estimation of unlikeness of two ECG segments that correspond to similar intervals of adjacent cardiac cycles ; V_{1i} - average I_i in a sliding time-windows, V_{2i} - coefficient of variation (i.e. average divided by standard deviation) in the same time-window. Horizontal axes is the same for all the graphics.

(B) Trajectory in the (V_{1i}, V_{2i}) parameter plane corresponding to the ECG that is shown in the insertion. The ECG segment shown corresponds to 2000 msec.

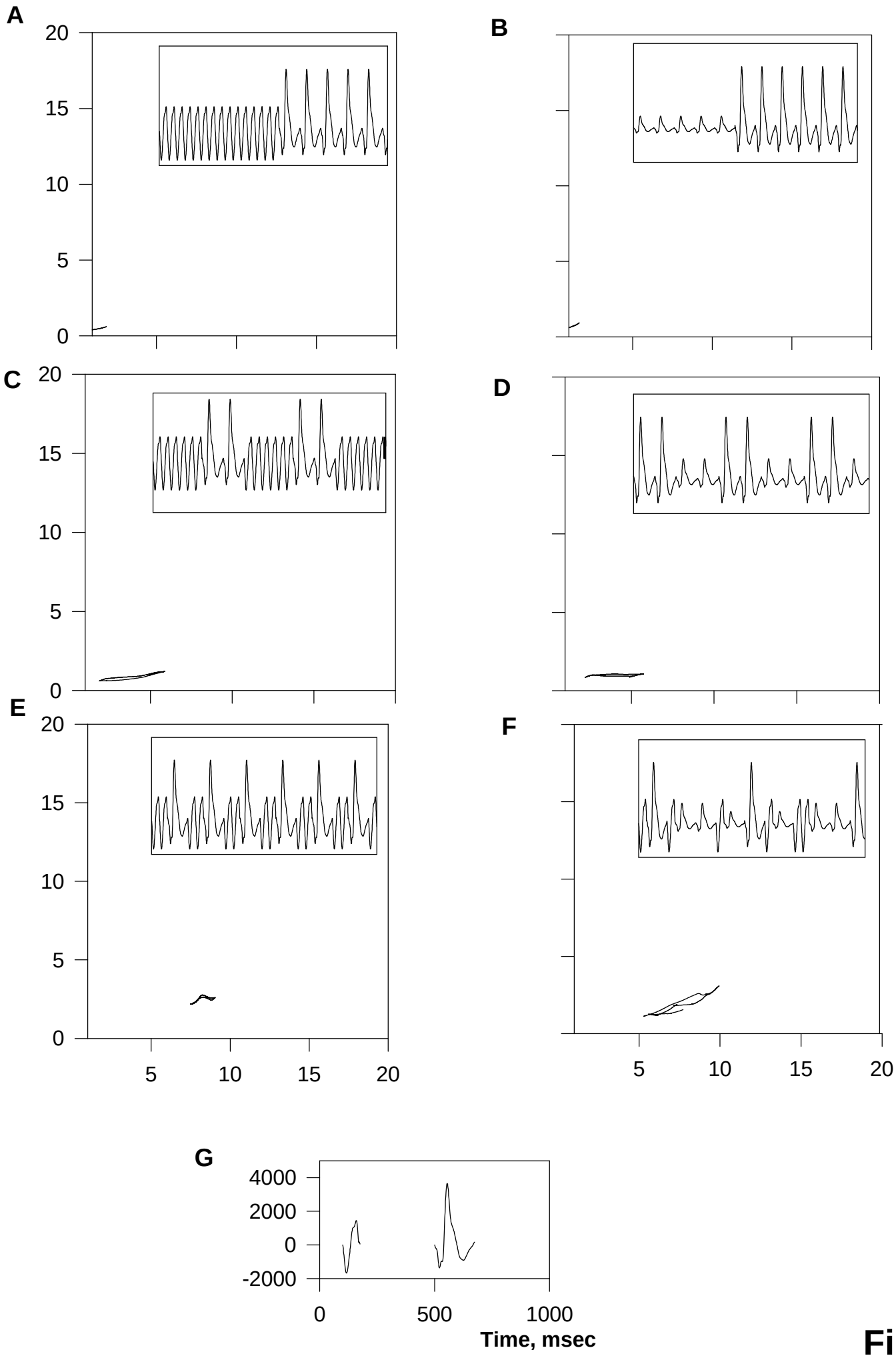

A
B
C
D
E
F
G
20
15
10
5
0
5
10
15
20
4000
2000
0
-2000
0
500
1000
Time, msec

Fig 2

Fig 2. The artificial ECGs and their trajectories in the (V_{1i}, V_{2i}) parameter plane. This kind of ECGs was obtained by different combinations of two ECG segments shown in **G.** Axes are the same as in the Fig 1.B. The ECG segments shown correspond to 2000 msec.

Any of cases **A** and **B** consists of two strongly monomorphic segments and has one transition from one state to another. In the (V_{1i}, V_{2i}) plane anyone can see that the ECG variability indices are about zero. In cases **C-F**, anyone can see that the more transitions appear per second the more the ECG variability indices increase.

The dependence the trajectories location on ECG polymorphism induces the partial order in the (V_{1i}, V_{2i}) index space.

Note that anyone cannot know the number of transitions in real ECGs obtained during polymorphic ventricular tachycardia or ventricular fibrillation. But anyone can use ANI-method to estimate this.

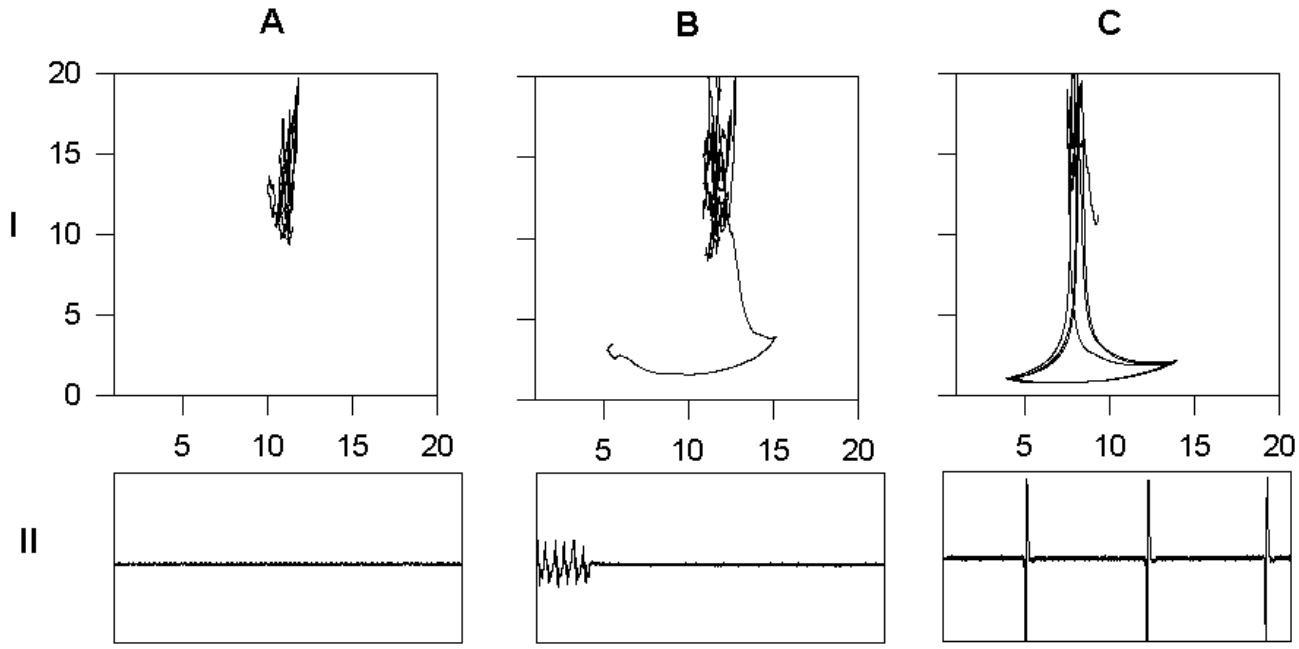


Fig 3

Fig 3 Some artifacts inherent in the ANI-method.

All the ECG examples are obtained in natural experiments.

Row **I -** trajectories, **II** - corresponding ECG.

A - noise and its trajectory location in the (V_{1i}, V_{2i}) parameter plane.

B - offset phenomenon: ECG recorded during end-stage arrhythmia and its trajectory in the (V_{1i}, V_{2i}) plane.

C - trajectory in the (V_{1i}, V_{2i}) plane during regular heart rhythm.

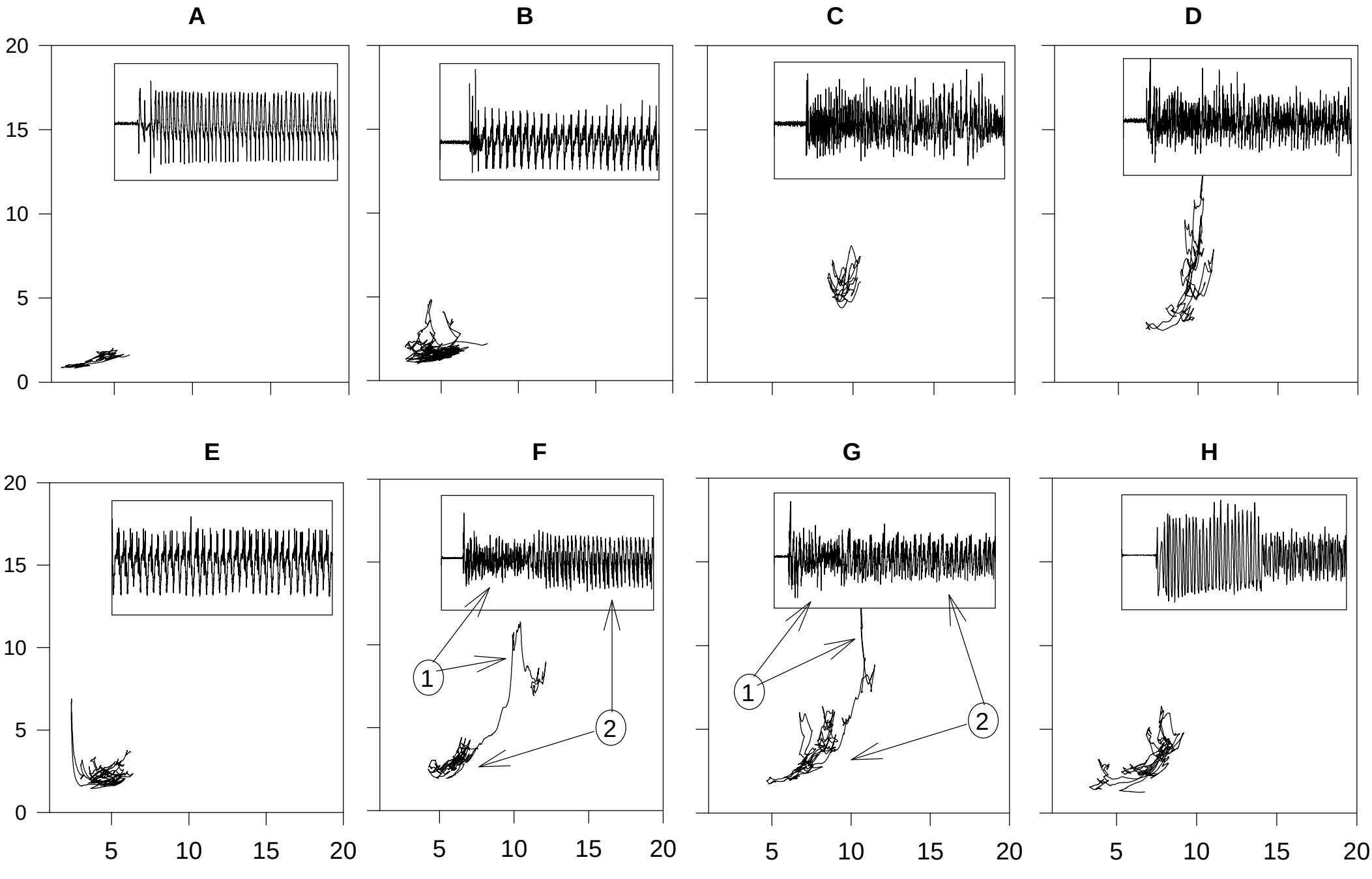


Fig 4

Fig 4. Pseudo-ECGs obtained in natural experiments and their trajectories in the (V_{1i}, V_{2i}) parameter plane. Axis are the same as in the Fig 1.B. The ECG segments shown correspond to 5000 msec. **A-D** demonstrate trajectories shift in (V_{1i}, V_{2i}) when corresponded arrhythmias appear more and more polymorphic. **E-H** demonstrate the cases with arrhythmia transition from one state to another. The mark **1 in circle** indicates the most polymorphic ECG segments and the mark **2 in circle** indicates less polymorphyc ECG segments.

Note the differences in **E-H** examples. In both **E** and **G,** ECGs have no obvious visual transitions, but anyone can see the transitions in corresponded (V_{1i}, V_{2i}) plane. This transitions indicates that arrhythmia state have changed. **H** demonstrates an opposite case, when anyone can see obvious visual ECG transition, but there is no transition in (V_{1i}, V_{2i}). So that we could make assumption that there no changes in essential arrhythmia mechanisms during case **H.**

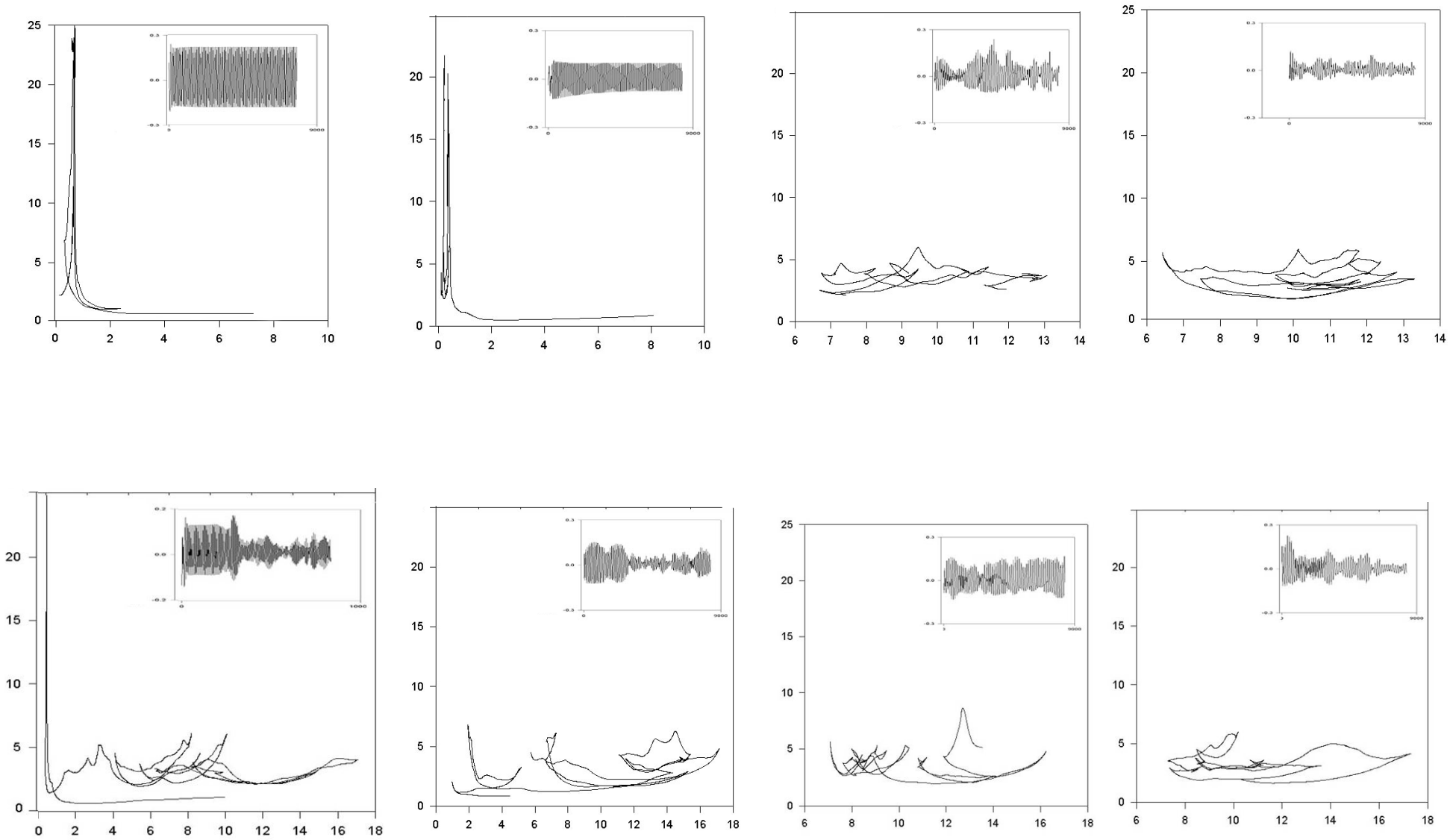


Fig 5

Fig 5. Pseudo-ECGs obtained in numerical experiments and their trajectories in the (V_{1i}, V_{2i}) parameter plane. The axis are the same as throughout.

Note the differences in the trajectories locations in the cases of the "numerical" ECGs in comparison with the "natural" ECGs (Fig. 4). Although the both kinds of ECGs visually appears quite similar, the trajectories location is clearly different.

The causes of this phenomenon stay still unexplained.

Conclusions

In this study we have shown that a novel technique for ECG analysis referred to as ANI-method could provide cardiologists with sensitive clinical tools for ventricular life-dangerous arrhythmias assessment. The estimates of ECG variation in this study reveal some unexpected details of ventricular arrhythmias dynamics, which probably will be useful for diagnostics of heart disorders.

This study has demonstrated the possibilities of ANI-method for quantitative distinction of ECGs during life-dangerous ventricular arrhythmias. The many of the

natural phenomena found are not understood because of complexity of heart activity during ventricular arrhythmias.

As regimes of circulation of excitation waves on myocardium is strongly determined by the state of membrane ionic channels [Chaos, Solitons and Fractals 1995;5:513-526], further development of ANI-method is suggested to turn the technique into new effective noninvasive procedure for evaluation of myocardial state.

Further work will also aim at the study how reentrant and focal arrhythmias could be distinguished from their ECGs.

Acknowledgments

This work has been supported by the Civil Research Development Foundation through the award of CRDF-RB0-676 (1999-2000) and CRDF-RB1-102 (1996-1998) grants.