УДК 616.12-008.313.3-073.97-71-08
https://doi.org/10.20538/1682-0363-2021-3-213-218

The first experience of using non-invasive real-time mapping in an electrophysiology laboratory for treatment of ventricular arrhythmia

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ABSTRACT

A clinical case of treatment for ventricular arrhythmia from the right ventricular outflow tract using non-invasive real-time electrophysiological mapping and the "Astrocard" navigation system ("Meditek", Russia) is presented. This clinical case demonstrates the accuracy of non-invasive real-time mapping for the diagnosis and treatment of ventricular arrhythmias.

Key words: non-invasive multichannel cardiac mapping, electrophysiological mapping, ventricular arrhythmias, radiofrequency ablation.

Conflict of interest. The authors declare the absence of obvious or potential conflict of interest related to the publication of this article.

Source of financing. The study was carried out within the Russian Science Foundation grant (Project No. 19-15-00406).

For citation: Artyukhina E.A., Dedukh E.V., Yashkov M.V., Revishvili A.Sh. The first experience of using non-invasive real-time mapping in an electrophysiology laboratory for treatment of ventricular arrhythmia. *Bulletin of Siberian Medicine.* 2021; 20 (3): 213–218. https://doi.org/10.20538/1682-0363-2021-3-213-218.

Первый опыт использования неинвазивного картирования в режиме реального времени в условиях электрофизиологической лаборатории для лечения желудочковой аритмии

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РЕЗЮМЕ

Представлен клинический случай лечения желудочковой аритмии из выводного отдела правого желудочка с использованием неинвазивного электрофизиологического картирования в режиме реального времени и отечественной навигационной системы «Астрокард» (АО «Медитек», Россия). Данное клиническое наблюдение демонстрирует точность неинвазивного картирования в режиме реального времени для диагностики и лечения желудочковых нарушений ритма сердца.

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Ключевые слова: неинвазивное многоканальное картирование сердца, электрофизиологическое картирование, желудочковые аритмии, радиочастотная аблация.

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

Источник финансирования. Работа выполнена в рамках гранта Российского научного фонда (проект № 19-15-00406).

Для цитирования: Артюхина Е.А., Дедух Е.В., Яшков М.В., Ревишвили А.Ш. Первый опыт использования неинвазивного картирования в режиме реального времени в условиях электрофизиологической лаборатории для лечения желудочковой аритмии. *Бюллетень сибирской медицины.* 2021; 20 (3): 213–218. https://doi.org/10.20538/1682-0363-2021-3-213-218.

INTRODUCTION

Radiofrequency catheter ablation is the main method of interventional treatment for premature ventricular contractions (PVCs). It improves the patient's quality of life and prevents the development of cardiomyopathies and heart failure [1]. High-density mapping and ablation catheters with contact force monitoring help operators in mapping and eliminating PVCs, but the effectiveness and safety of such procedures still depend on the localization of the arrhythmia focus [2]. Also, the mapping process complicates the occurrence of rapid, unstable, and polymorphic ventricular tachycardia (VT) and sometimes makes it impossible.

Diagnostic algorithms using electrocardiography (ECG) can identify the area of origin of ventricular arrhythmias, but their spatial localization is not accurate enough due to various factors (the patient's obesity, peculiarities of the heart location in the chest, and abnormalities in the placement of ECG leads) [3].

A more accurate method for diagnosing PVCs is non-invasive mapping. Although the effectiveness of non-invasive mapping in the topical diagnosis of PVCs localized in the right ventricular outflow tract (RVOT) is known and previously reported [4, 5], the technique described in this clinical case was used to diagnose ventricular arrhythmias for the first time. This technique makes it possible to carry out real-time mapping of the right and left ventricles (intraoperatively) and identify the PVC localization by its absolute location.

The aim of this clinical case was to test the method by comparing the localization of PVC on the map obtained via non-invasive real-time mapping and the localization of the focus on the 3D navigation mapping system during catheter ablation.

CLINICAL CASE

Patient A., 64 years old, complains of irregular heartbeat and fatigue.

Medical history. From a young age, irregular heartbeat has been noted. During the routine medical examination, PVCs were detected on the ECG. In recent months, attacks have become more frequent, and increased fatigue has appeared.

Preoperative examination. ECG – sinus rhythm, frequent PVCs with morphology of the left bundle branch block (Fig.1).

24-hour Holter monitoring. Basic rhythm – sinus rhythm, the average frequency is 81 bpm. Single PVCs – 28,937; bigeminy – 58; paired PVCs – 42; unstable ventricular tachycardia (VT) – 9. The longest VT consisted of 26 complexes.

Echocardiography. Right ventricle – inflow tract: 28 mm. The Simpson's ejection fraction (EF) – 47%. The thickness of the left ventricular myocardium was normal. There were no local contractility disorders. Moderate mitral and slight tricuspid regurgitation. Tachyarrhythmia (extrasystole). There were no blood discharges. During the study, an attack of tachycardia with a heart rate of 127–133 beats per minute occurred, as a result of which the Simpson's EF decreased to 38%, and the area of mitral regurgitation increased.

Coronary angiography. Balanced type of coronary blood supply. No hemodynamically significant stenoses of the coronary arteries were revealed.

Non-invasive multichannel mapping. Registration of surface electrograms from 224 surface electrodes from the patient's torso, followed by multispiral computed tomography (MSCT) in the ECG synchronization mode with contrasting of the ventricles. Further, in the electrophysiological laboratory, the patient was diagnosed with unstable ventricular tachycardia; the data were registered in the AMICARD 01K complex. Data processing and analysis took place intraoperatively (Fig. 2).

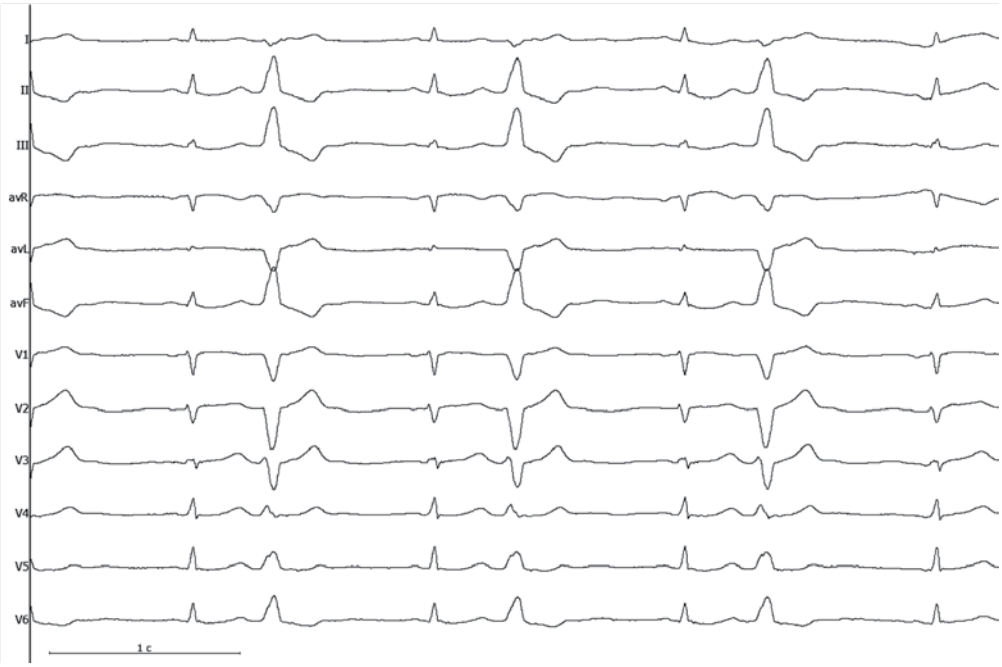

Fig. 1. 12-channel ECG, sinus rhythm with ventricular bigeminy

Fig. 2. The process of PVC mapping and treatment in the electrophysiological laboratory: *a* – fluoroscopic control and data from the "Astrocard" navigation system ("Meditek", Russia), *b* – the AMICARD 01K hardware and software complex ("Amikard", Russia)

When analyzing the obtained 3D model of the heart ventricles, the area of early activation was detected on the endocardial surface in RVOT. The result of non-invasive real-time mapping was an isochronous map of the heart ventricles (Fig. 3), which was imported into the navigation mapping system. This made it possible to more accurately compare the localization of the early activation site during ventricular tachycardia.

Fig.3. Results of real-time multichannel mapping performed intraoperatively in the electrophysiological laboratory: a map of the early activation site (red) in RVOT

INTRAOPERATIVE MAPPING AND RADIOFREQUENCY ABLATION

In the electrophysiological laboratory, the right femoral and left subclavian veins were punctured, through which the electrode was positioned into the coronary sinus. Frequent PVCs and episodes of unstable VT with the spread of electrical activity from RVOT were recorded.

The anatomical reconstruction of the right ventricle was performed using the domestic "Astrocard" navigation system, where the data of non-invasive mapping were imported. A right ventricle activation map was constructed.

Endocardial mapping data were constantly compared with non-invasive mapping data by visualizing the right ventricle in appropriate projections (Fig. 4).

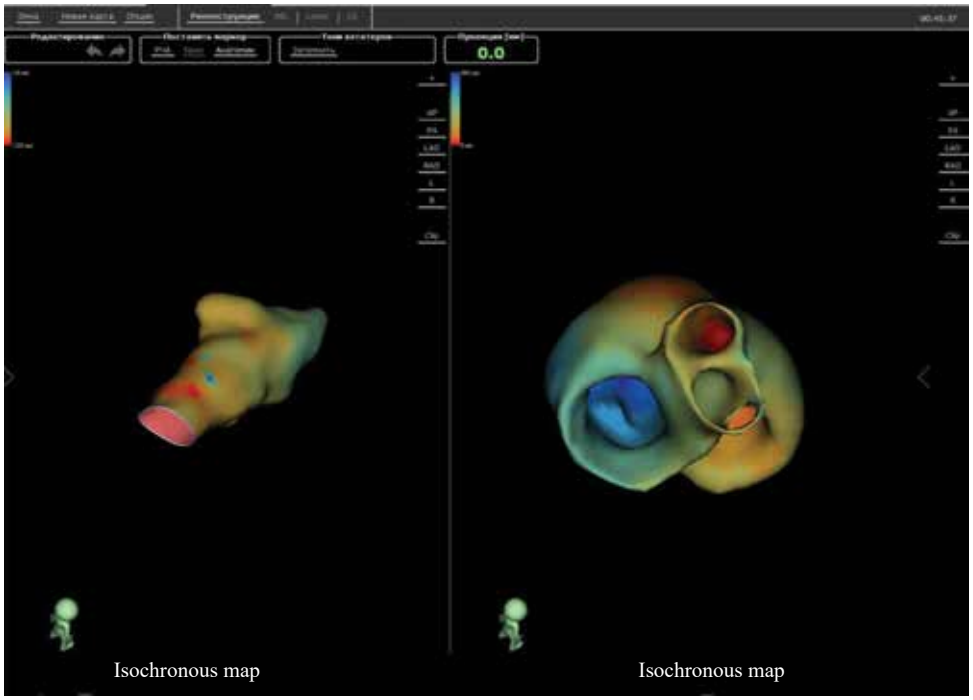

Fig. 4. Endocardial mapping of the right ventricle in the electrophysiological laboratory: the result of non-invasive mapping was imported into the navigation system (presented on the right side of the screen)

When performing imaging in the propagation of excitation mode, the early activation zone was in the RVOT area, which completely coincided with the results of non-invasive mapping. In this area, radiofrequency exposure was performed. After the exposure, complete elimination of ventricular activity was achieved.

The total duration of the exposure was 7 minutes. The parameters of radiofrequency exposure using an irrigated ablation electrode were 35 W. The absence of PVC after the exposure was registered within 20 minutes. Arrhythmias were not induced by stimulation methods. The follow-up period was 3 months, arrhythmias were not recorded.

Despite the fact that this clinical case describes the typical and most common localization of PVCs, the technique used in this clinical case was used for the first time. It will be able to demonstrate the possibilities of real-time mapping for the diagnosis of ventricular arrhythmias, which will be an extremely important step in mapping rapid and polymorphic VT to study the mechanism of their occurrence and successful interventional treatment.

DISCUSSION

The two most common systems for non-invasive cardiac mapping are CardioInsight Technologies Inc., Cleveland, Ohio [6, 7] and EP Solutions SA, Yverdons-les-Bains, Switzerland [8–10].

In a study by S. Jamil-Copley et al., 24 patients with PVCs localized in the right ventricular outflow tract (18 patients) and the left ventricular outflow tract (6 patients) were examined [6]. All patients included in the study underwent non-invasive mapping at the preoperative stage. The accuracy of determining the PVCs localization according to the non-invasive mapping data in comparison with the invasive mapping data was 96%.

E. Wissner et al. showed in their study that in 18 (86%) of 21 patients with PVC / VT, the correct ventricular segment was diagnosed as a result of non-invasive mapping by single extrasystoles [11].

In fact, the non-invasive mapping technique has the potential to accurately diagnose the epicardial or endocardial origin and the chamber of origin of PVCs. This clinical case compared the PVC localization obtained following the analysis of the ECG and the data of invasive endocardial mapping, as well as the data of non-invasive real-time mapping. In previous studies, epicardial breakouts obtained using both methods resulted in very large mean absolute errors exceeding 70 mm [12].

To date, the electrophysiological nature of polymorphic VT and ventricular fibrillation (VF) is still not fully understood. This is prevented by the patient's hemodynamic instability during the development of these arrhythmias, which requires immediate cardioversion. Currently, the main method for studying the mechanisms of arrhythmias is endocardial electroanatomical mapping of the heart. Arrhythmia mapping in order to study its mechanism is possible only with a large number of points that record the local activity of the heart during arrhythmia. This is possible only with periodic and stable arrhythmias, in which stable hemodynamics is maintained.

VF and polymorphic VT cause dramatic depression of central hemodynamics. They can spontaneously stop or transform into other, more dangerous arrhythmias. This makes it impossible to perform endocardial electroanatomical mapping. Therefore, an extremely important task for studying the mechanisms and interventional treatment of life-threatening ventricular arrhythmias is the development of a method that allows for VT mapping with minimal recording of myocardial electrical activity during arrhythmias.

The non-invasive real-time mapping technique described in this case will overcome many of these limitations.

This technique can provide important information about the basic mechanism of arrhythmia using a single ectopic beat, which will be recorded in the electrophysiological laboratory, where, based on these data, it is possible to perform interventional treatment of ventricular arrhythmia.

CONCLUSION

The key findings from this study:

1) The new method of non-invasive real-time mapping worked successfully and identified the PVC localization in RVOT.

2) High accuracy of non-invasive real-time mapping was demonstrated in comparison with invasive mapping. This made it possible to effectively eliminate PVCs by catheter ablation.

3) From a theoretical and mathematical points of view, this technology has the potential to determine the transmural distribution of sites of origin (epicardial or endocardial origin).

Although this study provides only preliminary results, it will help to map life-threatening, rapid and polymorphic VTs that impair hemodynamic stability.

Non-invasive real-time mapping further enhances the benefits of the non-invasive mapping system and expands clinical applicability of the method in treatment of life-threatening ventricular arrhythmias.

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Received 25.11.2020

Accepted 29.09.2020