Electroanatomic Mapping System – the useful tool for electrophysiology

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Abstract

During over 20 years of development of catheter-based technologies in the management of cardiac arrhythmias, electroanatomic mapping systems have evolved significantly. Unique features of the systems such a non-fluoroscopic catheter localization or displaying activation and voltage maps, allow to target more challenging arrhythmias, reduce fluoroscopy exposure and decrease complications occurrence. New types of fractionation and score maps help to identify origin of complex arrhythmias. These tools allow to a patient-tailored approach. We present the usage of electroanatomic mapping systems during procedures of arrhythmia ablation. The principles of creation of activation, voltage, fractionation and score maps and their implementation in clinical practice were discussed.

Key words:

electroanatomic mapping system, map, activation, voltage, fractionation, score, EnSite, EnSite Precision, 3D, cardiology, electrophysiology, heart, arrhythmia

Introduction

Electroanatomic mapping systems have been introduced into clinical electrophysiology over two decades ago [1-2]. In principle, such systems consist of three different parts: non-fluoroscopic catheter localization, calculation of electrical activation sequences and voltage maps [3-5], 3D display of the anatomy from serially generated catheter localization information [6]. These systems are used during cardiac ablations, aimed at destroying heart tissues responsible for the arrhythmia using flexible catheter [7]. The systems are based on non-fluoroscopic visualisation of mapping catheter and 3D reconstruction created by the manipulation of a mapping catheter [8]. Electrical information is recorded at a map and can be used for the color-coded display of the electrical activation sequence known as "activation mapping", or the display of unipolar/bipolar electrograms (recorded from catheter leads inside a heart) as part of "fractionation" or "voltage mapping" [9-11].
The systems also allow to display catheter position and stored electrograms with anatomic information of the target chamber generated through other imaging modalities, mainly computed tomography and magnetic resonance tomography [12]. This additional functionality is often referred to as image fusion [13].

In this context, achieving electrically continuous, transmural lesions in a beating heart is challenging and requires a reliable three-dimensional (3D) navigation, in order to avoid complications (AV nodal block, PV stenosis, perforation, phrenic nerve or esophageal injury) [14-15].

These systems have shown promising results for ablations and have been proven to reduce radiation and procedural duration and can lead to less complications and better results [16-18].

The concept of high-density mapping refers to the simultaneous acquisition and annotation of multiple electrograms, including activation and voltage information, which are then analyzed by automated algorithms in order to generate precise activation and substrate (voltage) maps. These algorithms were initially applied for macro-reentrant tachycardia, but then have been further developed and adapted for complex arrhythmias like atrial fibrillation.

In order to achieve this novel mapping catheters have been developed. Multiple electrodes serve for fast acquisition of data whereas a smaller electrode size and a shorter inter-electrode distance provide a better signal quality with less noise to far field ratio (Fig. 1) [19].

Mapping systems direct towards a new era of substrate characterization and individual ablation strategies. These tools aim to identify additional ablation targets and allow to a patient-tailored approach [20].

Electroanatomic Mapping System – useful tool for electrophysiology

Currently, there are few electroanatomic mapping systems available on the market. The most recent, launched on the market in 2016, is called EnSite Precision™ [Abbott (St. Jude Medical)]. This system meets all requirements in terms of forming reliable and stable 3D heart model, fast creating high-density activation and voltage maps and displaying them on the prepared geometry [21].

Activation Mapping

The capability of electroanatomic mapping systems to display activation sequences in 3D space has helped to identify critical sites of ventricular or supraventricular arrhythmias in patients with complex congenital heart defects or in patients ventricular tachycardias in structural heart disease and with idiopathic ventricular tachycardias. Additionally, patients with difficult arrhythmia substrate can often be treated only with such a mapping technology [22-24]. This kind of mapping is used during termination of reentrant (Fig. 2; e.g. atrial flutter) and focal (Fig. 3; e.g. ventricular ectopic beats) tachycardias [25-26]. As an example, with the introduction of never computer-driven mapping systems, it has become clear that the vast majority of typical atrial flutters were reentrant and involved the right atrial caval-triscupid isthmus in either a counterclockwise or clockwise rotational pattern [27].

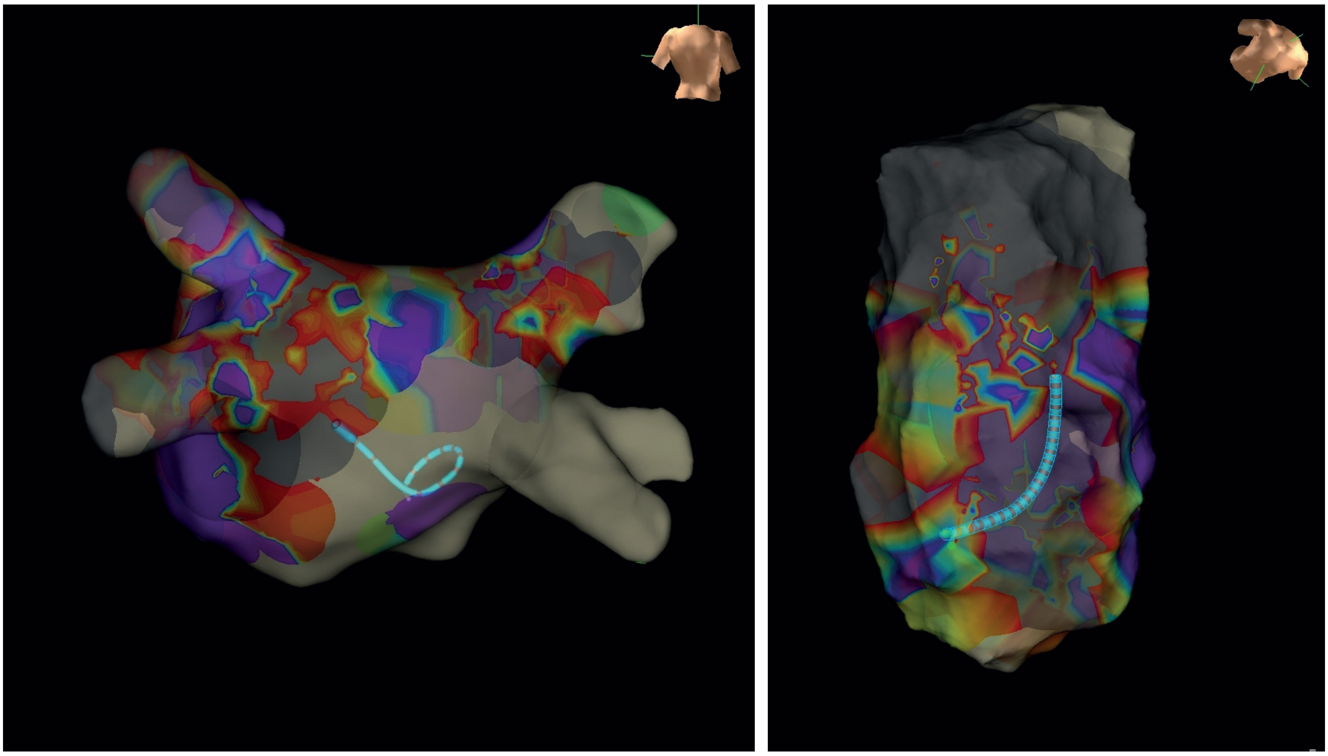

Fig. 1.
Acquisition of data using circualar decapolar mapping catheter AdvisorTM FL Sensor EnabledTM (Abbott (St. Jude Medical)) (right panel) and steerable duo-decapolar electrophysiology catheter LivewireTM (Abbott (St. Jude Medical)) (left panel)

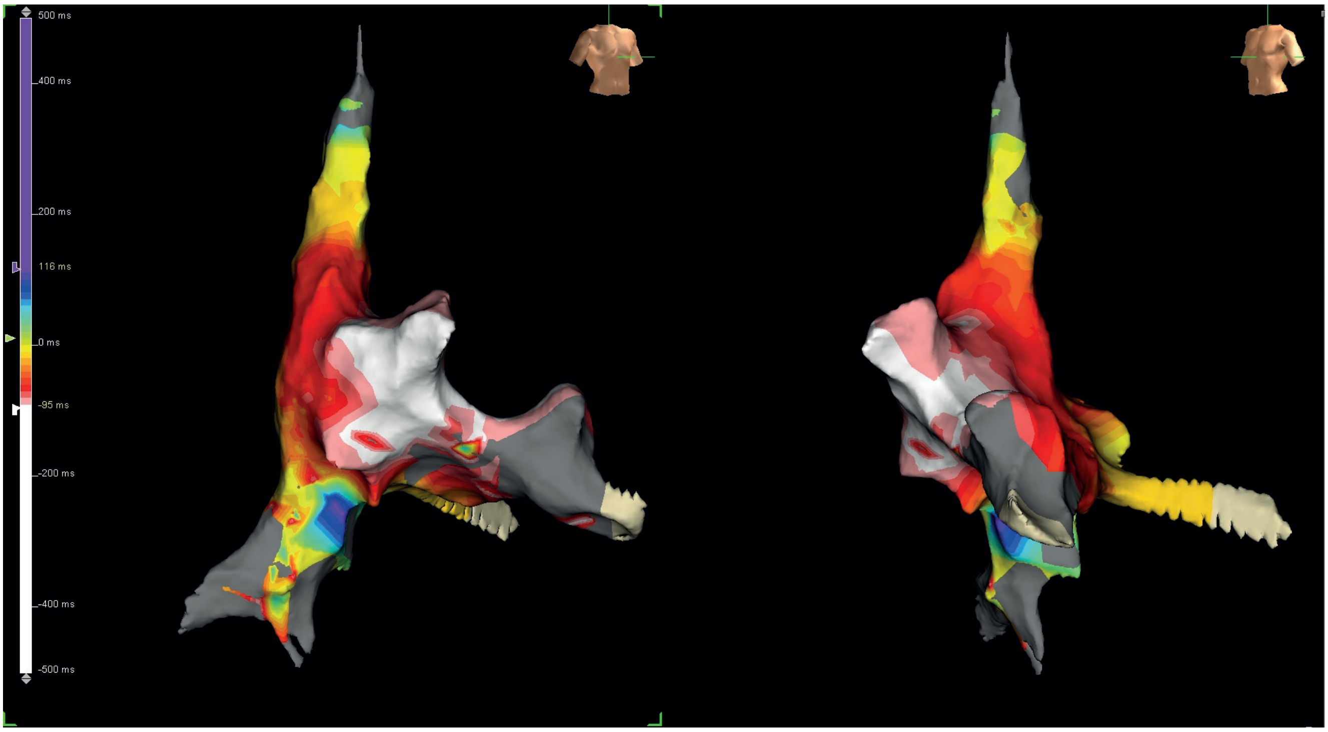

Fig. 2.
Example of the activation map (atrial flutter)

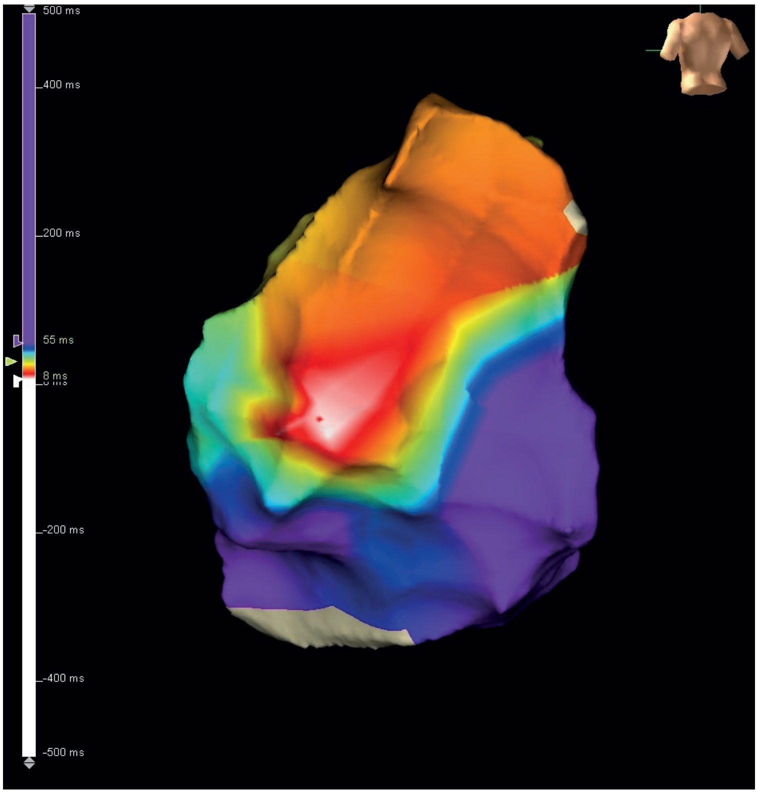

Fig. 3.
Example of the activation map (ventricular ectopic beats)

The principle of creating activation map is based on collecting and recording tissue electrical information during moving a catheter within a heart chamber and relates the gathered information to the defined reference point e.g. atrial activation in coronary sinus. Then the data are converted by mathematical algorithm and displayed as the color-coded electrical activation sequence that allows electrophysiologist to define characteristic and origin of the arrhythmia.

Voltage mapping

Similar to activation maps, voltage of local electrograms can be displayed in 3D space by electroanatomic mapping systems. As low local electrogram voltage is a paramount electrical sign of scar tissue, this feature has been used to identify areas of scar tissue during catheter ablation procedures. Voltage mapping is based on the correlation of low-voltage areas defined as <0,5 mV for atrium and <1,5 mV for ventricle (bipolar) with endocardial scar and/or structural defects as a substrate (Fig. 4) [20]. In case of unipolar mapping, a value of ≥8 mV defines normal endocardial and epicardial electrogram for left ventricle. Areas with <5 mV defines dense scar and intermediate values border zone (Fig. 5) [28-30]. Deployment of linear ablation lesions low-voltage scar areas is an important part of ablation procedures for different tachycardias [19, 31-33]. Supplementary ablation of low-voltage zones as an additional target to pulmonary vein isolation serves as an patient-tailored substrate modification (similar to unstable ventricular tachycardias) [34-38].

During manipulation of a mapping catheter, local potentials of the tissue are collected and then displayed as color-coded map on the 3D model.

Fractionation Mapping

Complex fractionated atrial electrograms (CFAEs) are regarded as surrogates of asynchronous activation of myocyte bundles through a fibrotic myocardium. They are defined as atrial electrograms with low voltage (≤0,15 mV) signals and ≥2 deflections of the

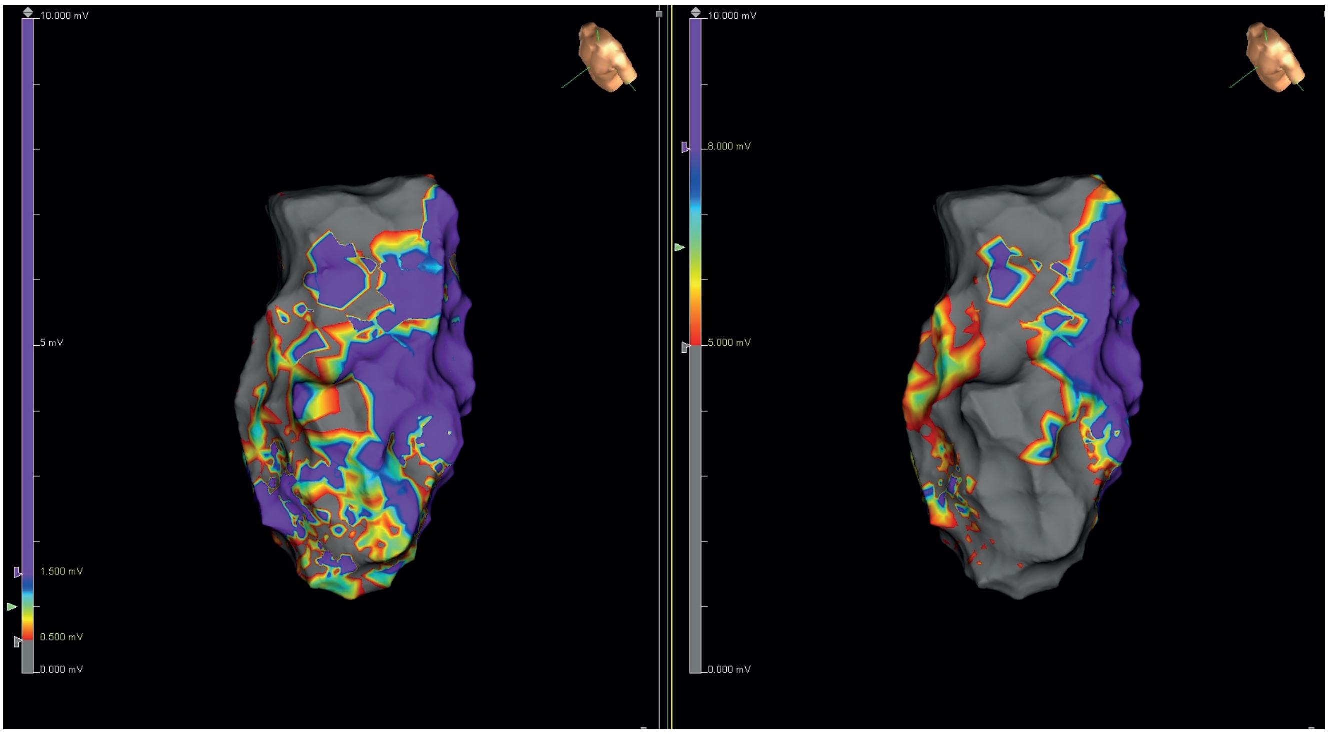

Fig. 4.
Examples of the corresponding voltage maps of a left ventricle: bipolar (left panel) and unipolar (right panel)

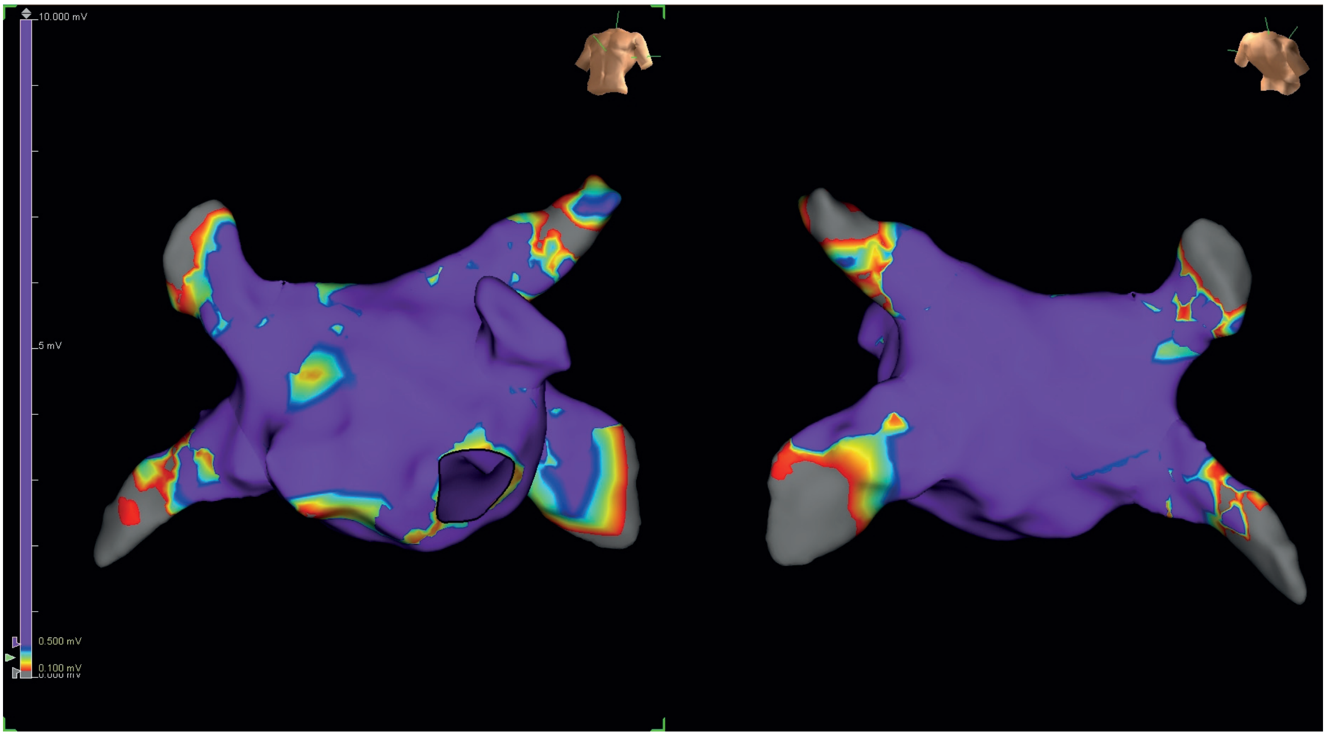

Fig. 5.
Example of the bipolar voltage map of a left atrium

baseline with continuous deflection of a prolonged activation complex and/or a very short cycle length (≤120 ms) with or without multiple potentials. Specifically, atrial electrograms (EGMs) demonstrating continuous fractionation and/or very short cycle length (CL) during atrial fibrillation may represent critical pivot points or rotors that are responsible for the maintenance of arrhythmia. Contemporary electroanatomic mapping systems integrate automated algorithms that provide CFAEs maps [20, 39-41].

Throughout the process of collecting voltage map, fractionated potentials are detected and displayed on the map (Fig. 6).

Score Mapping

Score mapping is a novel tool designed for new EnSite Precision™ system that helps to identify origin of the focal arrhythmias especially ventricular ectopic beats. In this case, once acquired clinical extra beat model is recorded and then all subsequent beats are compared to the arrhythmic beat morphology template (Fig. 7). System eliminates other beat that does not match the recorded template morphology and only arrhythmic beats are automatically acquired and displayed as color-coded map (Fig. 8).

Conclusions

The usage of contemporary electroanatomic mapping systems brings significant benefits. The systems allow to fast data acquisition and display them as a color-coded map on the created three-dimensional heart model. Such maps help to identify arrhythmia type or origin what leads to effective arrhythmia abolishment. Moreover, electroanatomic mapping systems influence on complications decrease and fluoroscopy exposure reduction showing that catheter ablation through a minimally fluoroscopic approach is feasible and safe. Mapping systems could direct the way to a new era of substrate characterisation and individual ablation strategies.

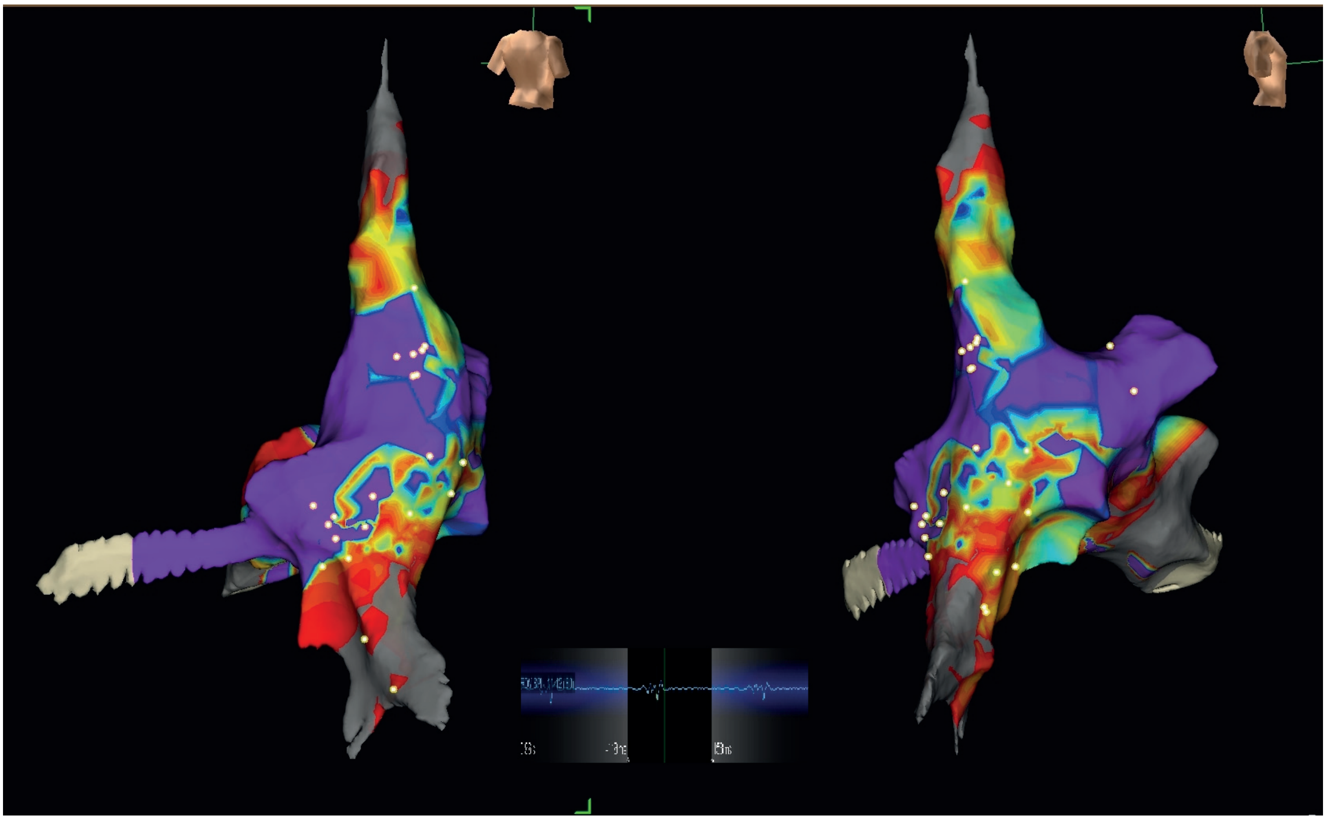

Fig. 6.
Example of the voltage map with marked fractionated potentials (white dots)

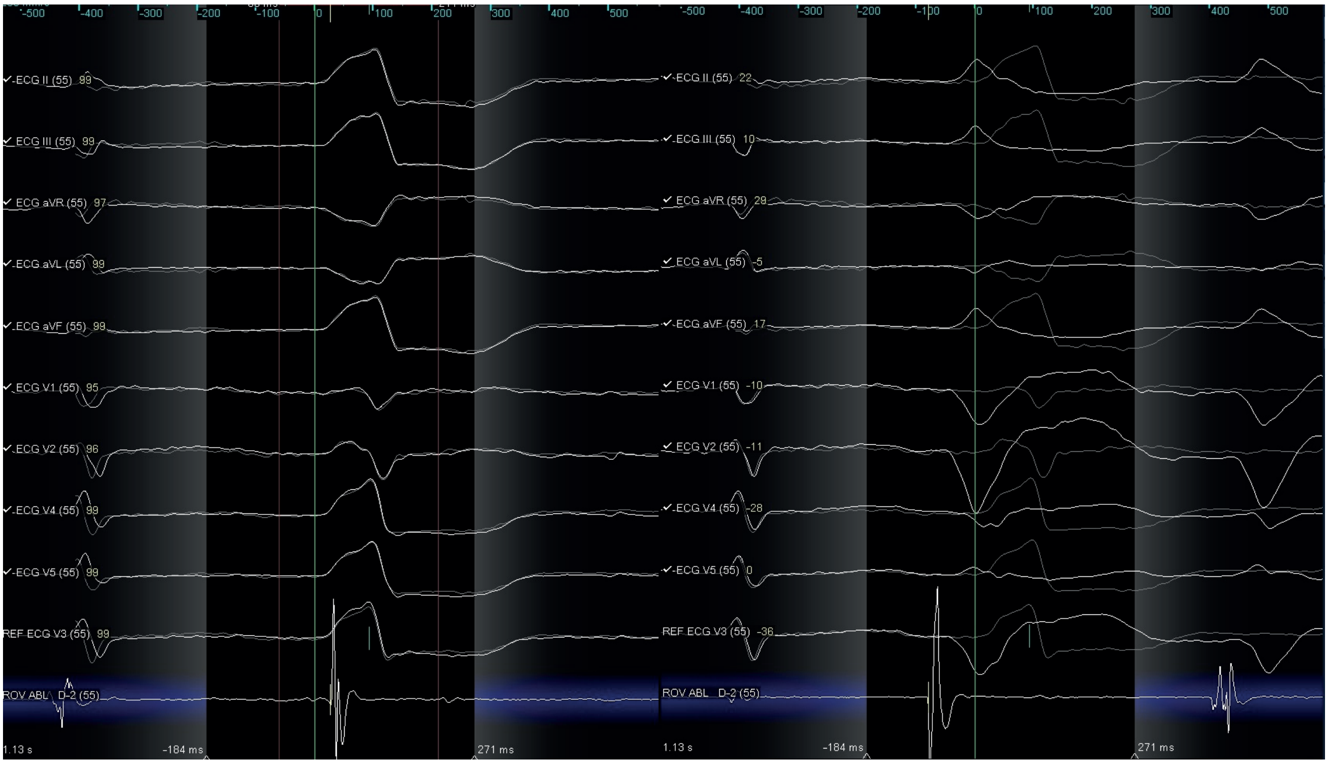

Fig. 7.
Extra ventricular beats comparison based on score algorithm

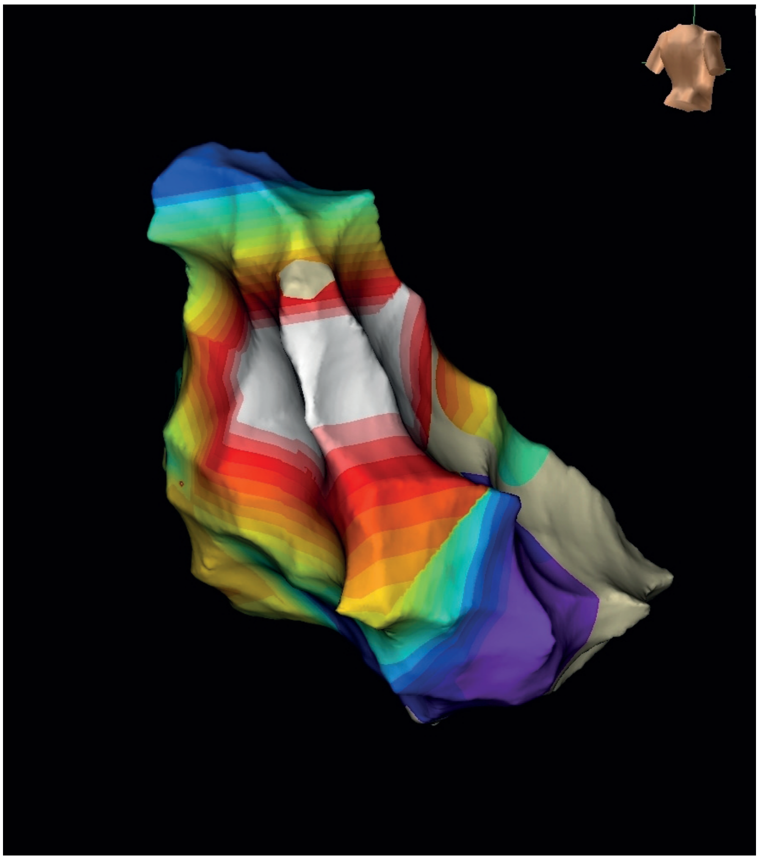

Fig. 8.
Example of the score map (ventricular ectopic beats)

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