Validation of Non-Invasive Electrophysiological Mapping Accuracy Using Endocardial Pacing with Three-Dimensional Non-Fluoroscopic Electroanatomic Mapping

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Abstract

Preoperative non-invasive diagnosis of ventricular arrhythmias allows to predict the effectiveness of ablation, reduces the operation and radiation exposure time. Previous studies based on comparison of the early activation zone with the anatomic location of the pacemaker's tip showed high accuracy of noninvasive mapping in place of pacemaker implantation. But other anatomical areas accuracy is still unclear. To determine the accuracy of non-invasive mapping and examine the excitation patterns the endocardial ventricular pacing of different areas of myocardium with 3D Non-Fluoroscopic Electroanatomic Mapping was done. Results of invasive and non-invasive mapping were analyzed and qualitative comparison of pacing points was performed. Better results were obtained for free walls of ventricles and worse for septum, apical parts and outflow tracts.

1. Introduction

Non-invasive electrophysiological topical diagnostics of ventricular arrhythmias (VA) before operation allows to predict the effectiveness of ablation, reduces the operation time and radiation exposure time. Comparison of the early activation zone (EAZ) with the anatomic location of the pacemaker's tip in the previous studies showed high accuracy of noninvasive mapping in place of pacemaker implantation [1-4].

But accuracy in other anatomical areas is still unclear. It can be caused by difficulty and time-consuming of procedure. Sometimes it can be difficult to access some walls, the difficulty of achieving a stable position of the pacing catheter, high arrhythmogenicity of the ventricles which can lead to life-threatening rhythm disorders. Pacing verification of different parts of ventricles can clarify the accuracy of non-invasive mapping and improve the topical diagnostic of VA.
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2. Aim

To determine the accuracy of non-invasive mapping and examine the propagation of excitation by endocardial ventricular pacing of different areas of myocardium with Three-Dimensional Non-Fluoroscopic Electroanatomic Mapping.

3. Methods

The study was performed in University Medical Centre Mannheim (Mannheim, Germany). 27 years old man with ventricular tachycardia (VT) and indications for ablation was undergone non-invasive electrophysiological mapping before and during operation. Cardiac magnetic resonance imaging (MRI) was perfomed to reconstruct anatomical model of heart. Unipolar surface electrograms were recorded in 216 ECG channels with non-invasive mapping system ("Amycard 01C" EP Solutions SA, Switzerland). Carto LAT (Biosense Webster, Inc., US) mapping for LV and RV was done. During operation 27 points of the ventricles endocardial surfaces (11 in left ventricle (LV) and 16 in right ventricle (RV)) were paced according to standard scheme of anatomical segments. For this purpose Carto ThermoCool SmartTouch catheter (Biosense Webster, Inc., US) was used. For each pacing point the coordinates were determined and marked in the Carto 3 system. Epi and endocardial isopotential and activation maps were created. The EAZ was determined for each pacing point of epicardial surfaces of epi- and endocardial projects and for endocardial surface of endocardial projects. Results of invasive and non-invasive mapping were analyzed and qualitative comparison of pacing points was performed.

4. Results

The EAZ was located with sufficient accuracy. Maps were not completely identical but main activation patters were similar. On epicardial project matching of pacing areas of RV were obtained for septal and anterior parts of right ventricular outflow tract (RVOT), anterior, inferior, lateral basal walls of RV, RV apex. On epicardial project of LV matching of pacing areas were obtained for anterior middle, inferior-apical, inferior-basal, inferior-lateral, septal-basal, lateral-basal, lateral-mid walls, right aortic cusp, LV His system. For some points we showed the images of isopotential maps (Figures 1, 2, 3).
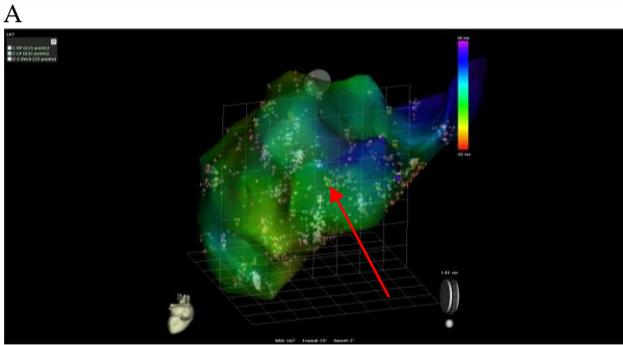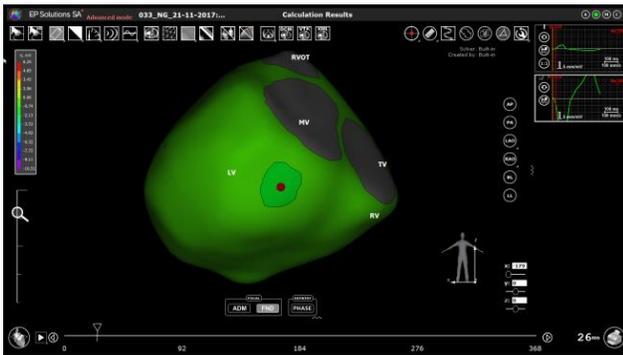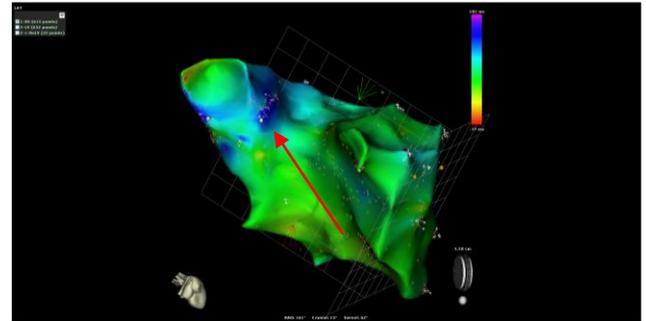

A

B

Figure 1. Epicardial projects of LV. A. Isopotential map of LV inferior-basal pacing point. B. Carto LAT map. The arrow indicates the point of pacing of inferior-basal segment of LV
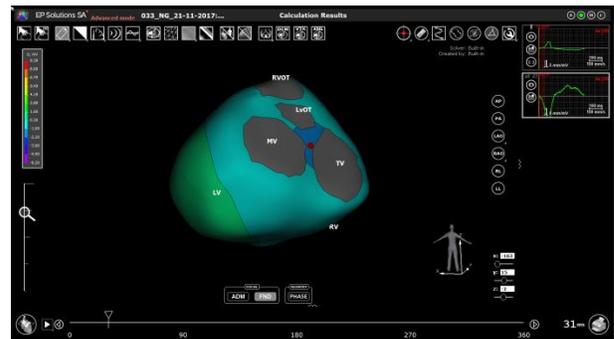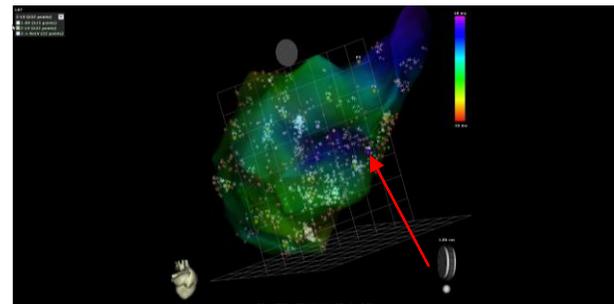

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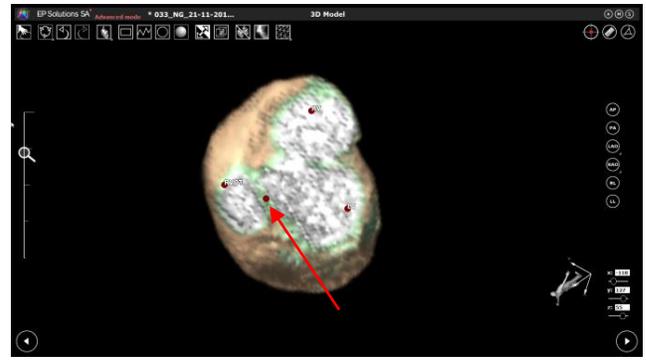
B

C

Figure 2. Epicardial and endocardial projects of ventricles. A. Endocardial project of ventricles. Isopotential maps of RVOT septal pacing point (indicated by arrow). B. Voxel 3D model of ventricles. C. Carto LAT map of RV. The arrows indicate RVOT septal pacing point.

A

B

Figure 3. Epicardial projects of ventricles. A,. Isopotential map of His system pacing point from LV. Red point in

interseptum - His system pacing point. B. Carto LAT map of LV. The arrow indicates the point of His system pacing of LV.

Worse results were obtained for the septal regions of ventricles (basal, middle parts of RV and apical part of septum of LV). It might have been caused by hidden localization septum on epicardial project. For example in full epicardial project the septal-middle pacing point area was undefined. After the RV removing we could clearly see the EAZ in the middle of LV septum, but the electrogram of this point was atypical and had RBBB form (Figure 4).
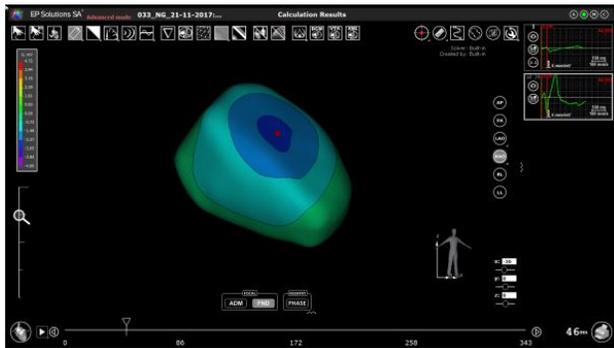

Figure 4. Epicardial project of LV. Isopotential map of LV septal-middle point after RV removing.

Also there was no complete coincidence for the apical regions of LV (LV apex - LV anterior-apical, LV lateral-apical), anterior-basal segment of LV. They were shifted to side about on 1 segment. And some other pacing point results were also shifted, but close to real pacing catheter position (for left aortic cusp EAZ was in right aortic cusp region, the RVOT lateral pacing point was in septal part of RVOT, the RV lateral-middle pacing point was showed in lateral part of RVOT, pacing of His from RV side showed EAZ in septal part of RVOT).

For endocardial projects matching of pacing areas were obtained for anterior and septal walls of RVOT, anterior, inferior, lateral-basal walls of RV, RV apex. On endocardial project of LV matching of pacing areas were obtained for LV anterior-middle, LV inferior-apical, LV inferior-basal, LV lateral-basal, LV lateral-middle, LV inferior-lateral walls.

Worse results also were obtained for septal regions (septal-basal and septal-middle of RV, septal-basal, septal-middle septal-apical segments of LV). But some results were improved after RV removing. For example after the RV removing for RV septal-middle pacing point EAZ completely matched and electrogram of this point was typical. There was also no coincidence for the apical regions of LV (anterior-apical, lateral-apical walls of LV, LV apex), anterior-basal segment of LV, left ventricular outflow tract (LVOT) (left and right aortic cusp), pacing of His system). For some points results were not completely certain. For example for LV anterior-basal pacing point on epicardial and endocardial projects the EAZ was on anterior wall of RVOT, but the RVOT slightly covered the anterior wall of LV. After removing the tract, the area of EAZ was clearly visible on the anterior-basal wall of the LV (Figure 5,6).

Figure 5. Epicardial projects of ventricles. Isopotential maps of pacing point from LV anterior-basal segment.
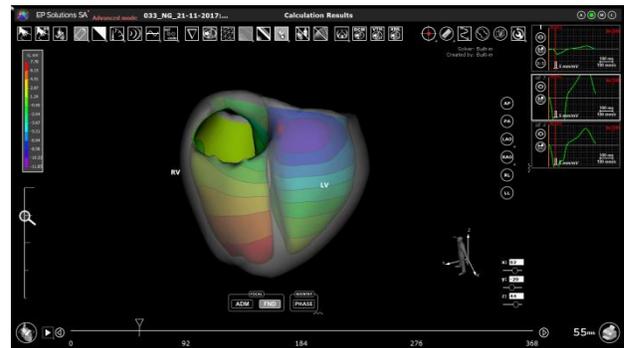

Figure 6. Endocardial projects of ventricles. Isopotential maps of pacing point from LV anterior-basal segment.

5. Discussion and conclusions

Better results were obtained for free walls of ventricles and worse for septum, apical parts and outflow tracts. Worse results of pacing of left and right outflow tracts might have been connected with close distance between them. Sometimes removing parts of ventricles could improve results due to decreasing influence of closest structures. Further quantitative analysis of the data and increasing the numbers of patients can give more accurate results. Artificial induction of premature ectopic activity allows to increase the validation group in order to evaluate the accuracy of non-invasive mapping and excitation patterns in the heart including patients with scars and fibrosis in combination with MRI in different areas of the myocardium. Moreover comparing of real endocardial and reconstructed electrograms of each pacing point can help improve inverse ECG problem, create database for further modeling studies to improve topical diagnosis of PVCs.

References

[1] Revishvili AS, Wissner E, Lebedev DS, Lemes C, Deiss S, Metzner A, Kalinin VV, Sopov OV, Labartkava EZ, Kalinin AV, Chmelevsky M, Zubarev SV, Chaykovskaya MK, Tsiklauri MG, Kuck KH. Validation of the mapping accuracy of a novel non-invasive epicardial and endocardial electrophysiology system. Europace. 2015 Aug;17(8):1282-8.

[2] Wissner E, Saguner AM, Metzner A, Chmelesky M, Tsyganov A, Deiss S, Maurer T, Kuck KH. Radiofrequency ablation of premature ventricular contractions originating from the aortomitral continuity localized by use of a novel noninvasive epicardial and endocardial electrophysiology system. HeartRhythm Case Rep. 2016 Feb 23;2(3):255-257.

[3] Wissner E, Revishvili A, Metzner A, Tsyganov A, Kalinin V, Lemes C, Saguner AM, Maurer T, Deiss SS, Sopov O, Labarkava E, Chmelevsky M, Kuck KH. Noninvasive epicardial and endocardial mapping of premature ventricular contractions. Europace. 2017 May 1;19(5):843-849.

[4] Tsyganov A, Wissner E, Metzner A, Mironovich S, Chaykovskaya M, Kalinin V, Chmelevsky M, Lemes C, Kuck KH. Mapping of ventricular arrhythmias using a novel noninvasive epicardial and endocardial electrophysiology system. J Electrocardiol. 2018 Jan - Feb;51(1):92-98.

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