Multielectrode mapping catheters- an indispensable tool for cardiac ablation strategy guidance

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Abstract

Radiofrequency catheter ablation is a proved interventional approach used for treatment of various cardiac arrhythmias. Although, radiofrequency ablation is indicated by a distinctive success rate, understanding some of arrhythmias remains challenging. Especially, substrate-based approach requires an accurate and detailed identification of scar or slow conducting areas, that can be visualized as high-density maps performed with multielectrode catheters. Arrhythmogenic tissue targeting and ablation strategy guidance are feasible by high-density mapping and offers the possibility of improving patient quality of life.

Key words:

multielectrode catheter, cardiac ablation, substrate mapping, cardiology, electrophysiology, heart, arrhythmia

Introduction

Throughout last two decades, cardiac rhythm treatment has evolved significantly [1,2]. Currently, the most widely spread interventional approach used for interventional treatment of cardiac arrhythmias is catheter ablation. The abnormal tissue, responsible for the discordant cardiac conduction, is heated up and destroyed due to delivered radio frequency (RF) current [3]. In the 90s, parallelly with deeper medical understanding of arrhythmia mechanisms, more advanced technology was brought into this field. With the assistance of recording and three-dimensional (3D) electroanatomic mapping systems (EMS), via offering multiple functions (e.g. activation and voltage mapping), arrhythmogenic tissue targeting and guidance the ablation strategy, has become more efficient and effective [4].

Although RF ablation showed a distinctive success rate [5-7], understanding some of arrhythmias remained challenging, especially post-ablation atrial tachycardias (AT) [8-10] or ventricular tachycardias (VT) [11-13].

Prevalence of the AT is associated with complex fractionated atrial electrograms (CFAEs) and additional lines (e.g. roof line, mitral isthmus line, anterior line) performed above standard pulmonary vein isolation (PVI) during atrial fibrillation (AF) ablation. Gaps along the lines may potentially play a role in arrhythmia occurrence as a part of the reentry circuit [14]. Moreover, specific tissue properties, identified by fractionated electrograms [15], and a heterogeneous atrial substrate [16], are associated with AF sustainment, so considering AF, PVI alone is less effective and additional substrate ablation is frequently performed [17-19]. Combination of anatomical and electrical data of the tissue helps to identify arrhythmia mechanism and can be used for individual patient therapy approach [20].

In treatment of structural heart disease the detailed knowledge of the VT substrate is mandatory to identify the potential VT circuits [21]. VT ablation procedures are technically challenging with a non-negligible risk of complications [22-24], usually associated with long ablation time due to the presence of multiple VT circuits or extend substrate [25,26] that can be identified and targeted during voltage mapping [27-29] or by analyzing the activation sequence of the delayed local component of abnormal electrograms (EGMs) within the scar region [30,31]. The identification of scar, may be based on bipolar or/and unipolar voltage mapping [32,33]. Ablation of arrhythmogenic substrate is an effective ablation strategy for patients with noninducible or hemodically poorly tolerated VT [34,35] and offers the possibility of improving patient quality of life, reducing mortality as well as painful defibrillator interventions and heart failure hospitalizations [36-38].

Current substrate ablation strategies aim to completely abolition of abnormal EGMs [39-41]. Therefore, substrate-based approach requires an accurate and detailed identification of scar or slow conducting areas, which can be visualized as high-density maps performed with multielectrode catheters [42,43]

Substrate mapping strategies rely on point-by-point signals acquisition to identify ablation targets, predominantly performed using 4-poles linear ablation catheter with typical distal electrode size of 3.5-4 mm. Electrodes spacing varies from 2 to 2.5 and proximal electrodes are 1-2 mm long [44,45].

Bipolar EGMs, obtained by these type of catheters, represent the electrical activity from an underlying tissue area ranging from 1 to 2.4 cm^2 [46]. Catheters with 1 mm electrodes, 2 mm interelectrode spacing and 3 mm center-to-center interelectrode distance, record EGMs from a smaller field, dependent on catheter orientation [47].

Although, point-by-point mapping is time consuming and is associated with prolonged procedure time, these catheters have been widely exploited during last years [44].

Multielectrode mapping catheters

Promising alternative for conventional point-by-point mapping are multielectrode catheters. Smaller electrodes with closer interelectrode spacing of multielectrode catheters, led to higher mapping resolution that can identify heterogeneity within the low-voltage area [34], localizing channels of surviving bundles [17], allowing more accurate time annotation [18] due to screening signals from a smaller tissue area. Through the features of multielectrode catheters the effectiveness of the ablation may be increased and procedure time is shortened what is extremely important in patients who are in unstable hemodynamic conditions [44].

Initially, the plain multielectrode catheters have been used for high-density mapping, especially during substrate guided left ventricular tachycardias (Fig. 1) in both, endo- and epicardial arrhythmogenic tissue localization [48]. These catheters (e.g. Livewire™ Duo-Deca, Abbott) are characterized by soft shaft, particularly important in retrograde (transaortal) access, and multitude narrow electrodes with small interelectrode distance.

The circular multielectrode catheters (e.g. Advisor™ FL SE™, Abbott) (Fig. 2) are widely used during AF ablation procedures at different levels: firstly, for fast anatomical mapping and 3D model creation [49]; secondly, for voltage scanning to identify atrial fibrotic regions [50]; thirdly, for confirmation of pulmonary veins electrical isolation [51]; fourthly, for activation mapping when AF terminates and converts into AT [52] (Fig. 3. A-D).

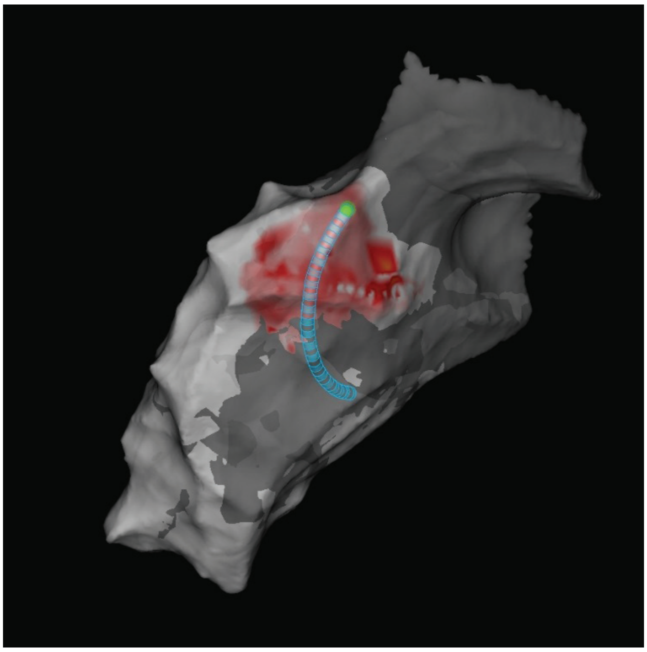

Fig. 1.
Activation map presenting late-diastolic activity (red area) performed with the plain multielectrode catheter (Livewire™ Duo-Deca) visualized by electroanatomic mapping system (EnSite Precision™)

Circular uni- or bidirectional mapping catheters consist of the multielectrode (ten or twenty) fixed or variable loop that facilitates collection of anatomical and electrical pulmonary veins characteristics, i.e. diagnose reconnection, estimate the reconnection site, and check the isolation after ablation [53].

Another tool that can facilitate atrial and ventricular mapping is a PentaRay® (Biosense Webster). This star-shaped 20-pole catheter is composed of five flexible 3F branches, with four small 1 mm electrodes located within each of them, allowing high resolution and density mapping. PentaRay® is used in conjunction with Carto® (Biosense Webster) EMS to create a three-dimensional reconstruction.

With all advantages of using PentaRay® catheter, its potential disadvantage is the mechanical induction of premature beats that could degenerate into ventricular fibrillation [54].

Apart from more traditional catheters as linear, circular or star-shaped catheters, the mapping deployment basket (IntellaMap Orion™, Boston Scientific) has been developed to rapidly obtain a high resolution electroanatomical map. This 8F irrigated catheter has a 64-electrode basket array divided in eight splines with 2.5 mm interelectrode spacing. Mapping can be performed from all electrodes simultaneously. The basket localization is identified by a combination of a magnetic and an impedance sensing and can be visualize by Rhythmia™ (Boston Scientific) electroanatomic 3D system [55].

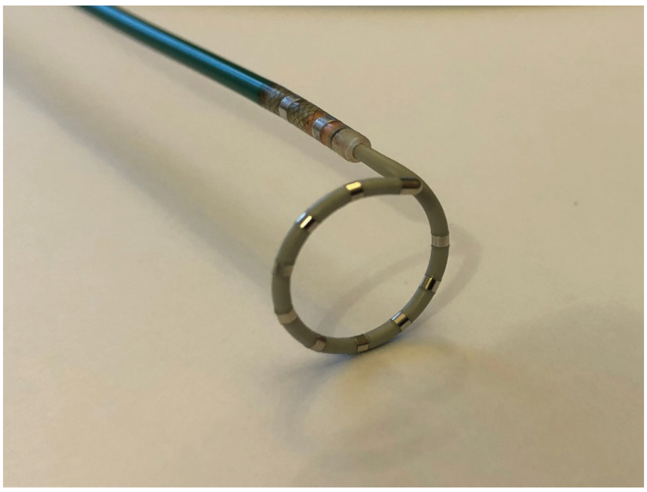

Fig. 2.
Advisor™ FL SE™- circular multielectrode mapping catheter

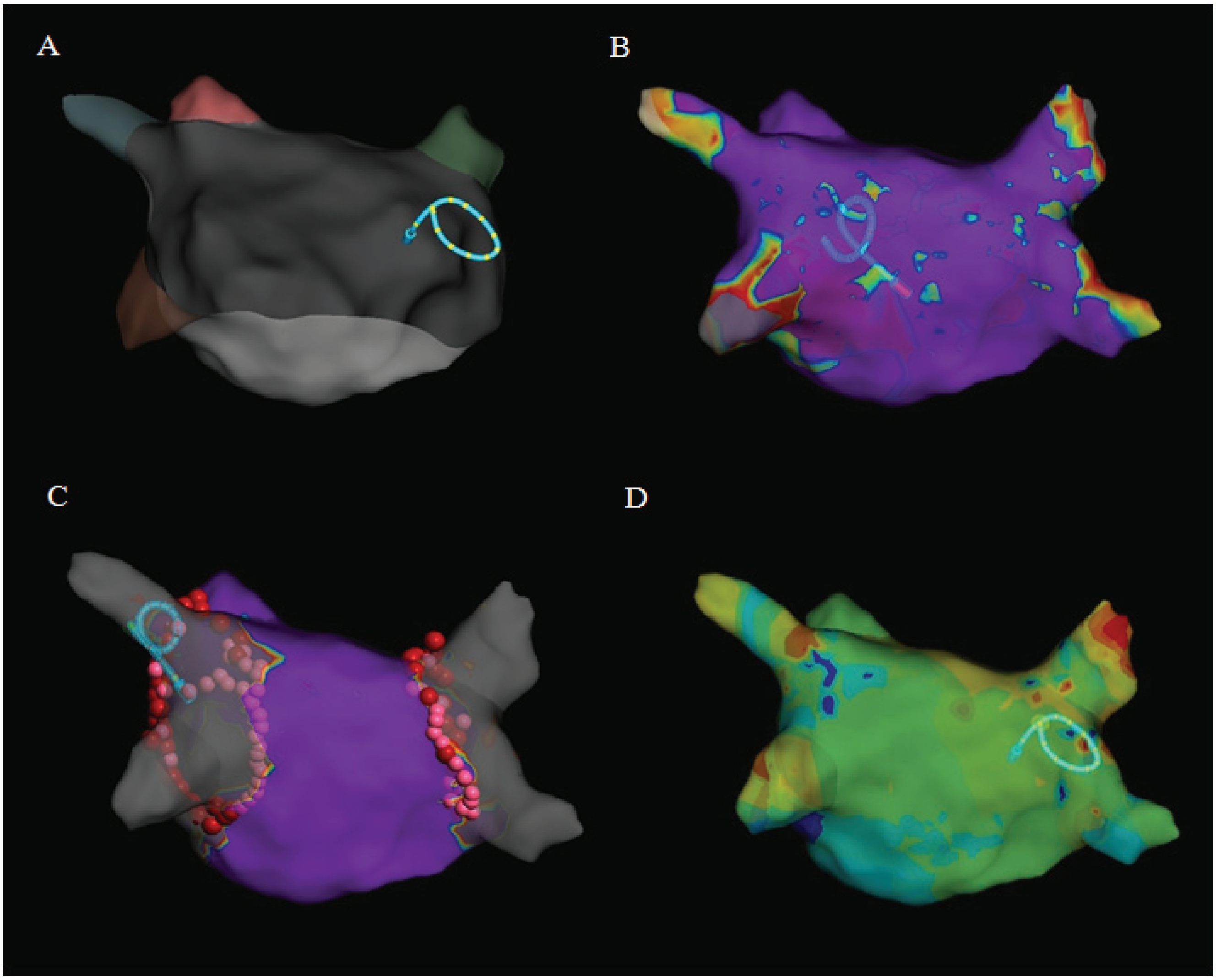

Fig. 3.
Different usage of the cilcular multielectrode catheter (Advisor™ FL SE™) visualized by electroanatomic mapping system (EnSite Precision™). A: anatomical mapping (3D model of left atrium). B: voltage mapping (purple area- healthy tissue, grey area- scar or non-conductive tissue, red/yellow/blue- low voltage area). C: electrical pulmonary vein isolation (represented by grey color) confirmation. D: activation mapping (different colors represent circuit activity – white/red – early; cyan/blue – late)

Basket-type multielectrode catheters can be used to verify and anatomically identify conduction gaps by an analysis of the signals and activation map [56].

The most recent mapping catheter, still limitedly released on the market, is Advisor™ HD Grid SE™ (Abbott) (Fig. 4) intended to acquire atrial and ventricular electrograms. The 18-electrode irrigated catheter has been design with equidistant (3-3-3) electrode spacing. Unique four-spline shape of the mapping end allowing for recording signals along and across the spline dependently on activation wave directionality. This concept leads to reduction in variability in EGMs characteristics associated with differential orientation of the catheter relative to the propagating wavefront [57].

In conjunction with EnSite Precision™ EMS, compering parallel and perpendicular activation towards electrodes, only the highest amplitude data is collected and displayed on the map (Fig. 5) [58].

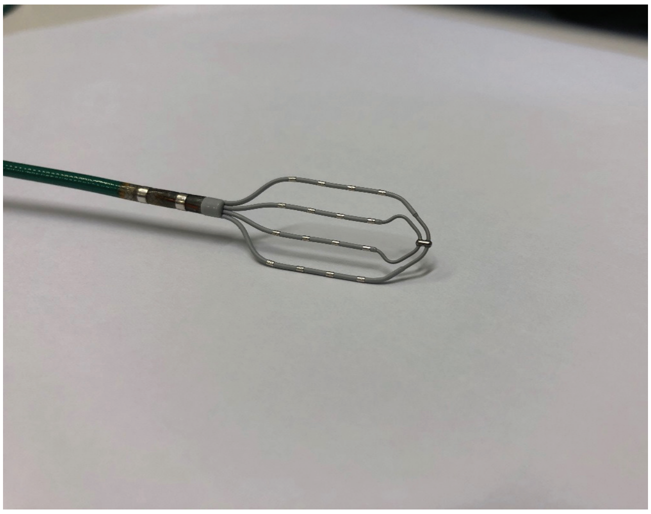

Fig. 4.
Advisor™ HD Grid SE™ – multielectrode mapping catheter

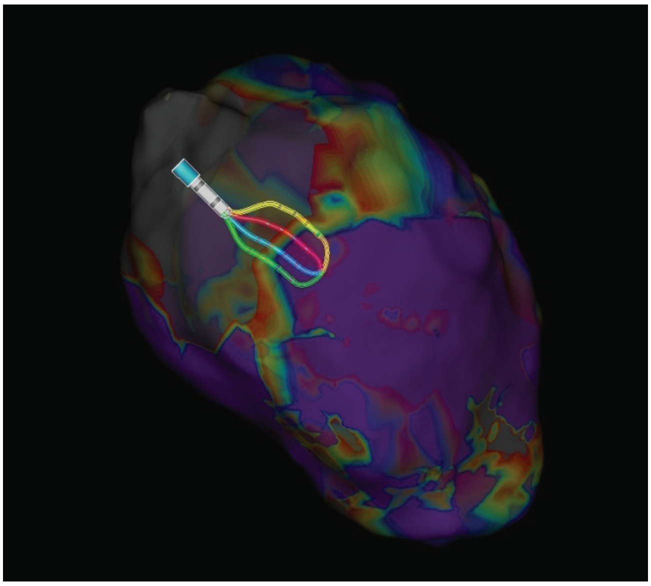

Fig. 5.
High-density bipolar voltage map (purple area – healthy tissue, grey area – scar, red/yellow/blue – low voltage area) performed with Advisor™ HD Grid SE™ multielectrode catheter visualized by electroanatomic mapping system (EnSite Precision™)

Conclusions

Huge progress in the medical technology, observed in the last years, led to development of new high-density diagnostic catheters. Multipolar catheters with smaller electrodes and shorter interelectrode distances represent more effective tools for high-density mapping than conventional catheters used so far. Still, such catheters do not have a contact force sensing technology, which could result in the acquisition of internal points and can artificially produce a low-voltage area.

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