Advanced Mapping and Navigation Techniques for Radiofrequency Ablation

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Summary

Radiofrequency ablation has become the first choice of therapy in the treatment of most supraventricular and ventricular tachyarrhythmias. However, catheter ablation of more complex tachyarrhythmias (e.g., incisional and focal arrhythmias, atrial fibrillation, ventricular tachycardia) is still difficult, resulting in high recurrence rates. Modern mapping and navigation tools are helpful to improve the quality of diagnostic procedures and reduce fluoroscopy and procedure times. With the use of a multi-electrode array placed in the heart chamber, the EnSite noncontact mapping system generates three-dimensional endocardial isopotential maps. The Carto electro-anatomic sequential mapping can visualize endocardial activation with the use of isochronal maps. Both systems are able to detect and navigate the introduced ablation catheter without fluoroscopy. The LocaLisa and the Realtime Position Management navigation systems were developed to make more precise positioning and re-positioning of the catheters possible. With the use of these devices, more complex and precise lesions can be created using less fluoroscopy time. By using these advanced mapping and navigation devices, more sophisticated diagnostic procedures and more effective ablation therapy can be performed.

Key Words

Radiofrequency ablation, electro-anatomical mapping, navigation systems

Introduction

Radiofrequency (RF) catheter ablation is a well-established treatment in patients with AV-nodal reentrant tachycardia, pre-excitation syndrome, or typical atrial flutter [1-4]. In other complex arrhythmias, such as focal atrial tachycardia, ventricular tachycardia, incisional arrhythmias, atypical atrial flutter, or atrial fibrillation, RF ablation is feasible but associated with relatively low success rates, high recurrence, and, in some cases, with a long fluoroscopy time [5-7]. The aim of the latest developments is to make RF ablation safer and faster, and to minimize fluoroscopy time and recurrence rates even in complex arrhythmias. Mapping electrodes register intracardiac electrograms in order to visualize reentrant circuits or the site of origin of focal tachyarrhythmias. With the use of navigation systems, the ablation catheter can be more precisely positioned and repositioned at the pre-selected site in the heart. An additional feature of some systems is the possibility of controlling the exact position of the catheter without fluoroscopy. This can minimize X-ray exposure to the patient and hospital staff members. The combination of mapping and navigation electrodes as offered by most companies seems to be feasible for the diagnosis and therapy of complex arrhythmias. The purpose of this article is to discuss devices that combine both mapping and navigation systems.

Mapping Systems

The *EnSite System* (Endocardial Solutions, USA) consists of the multi-electrode array (MEA), the patient interface unit, and the computer workstation. The MEA is a 9 F 64-polar electrode wire braided around a fluoroscopy balloon filled with 7.5 ml of contrast

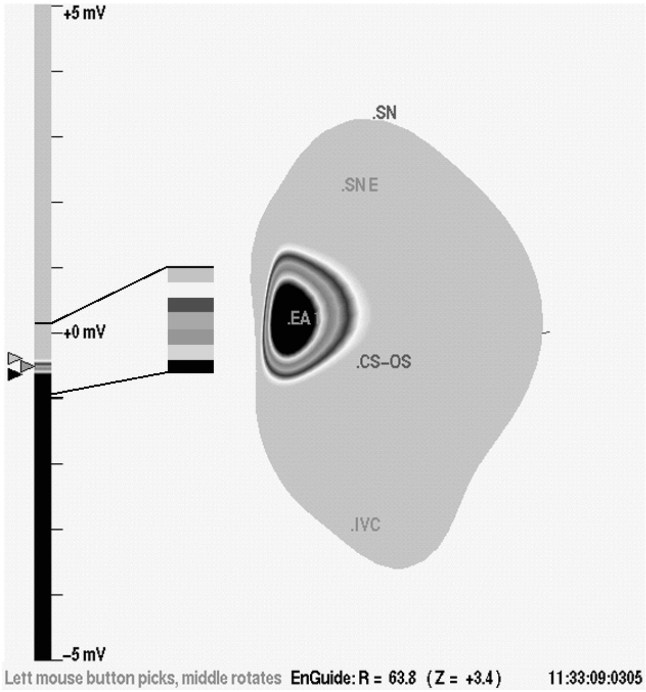

Figure 1. EnSite mapping (Endocardial Solutions, USA). Site of earliest activation (EA1) in a case of focal right atrial tachycardia. Sinus node (SN), coronary sinus ostium (CS-OS) and inferior vena cava (IVC) are marked.

medium. Through a 0.0025-inch break in insulation, each wire records a unipolar far-field ECG. A ring electrode on the proximal shaft of the MEA serves as a reference for unipolar recordings. By receiving collected unipolar electrograms via the electrode wire, the custom-made software is able to reconstruct 3,360 virtual, simultaneous, endocardial electrograms.

Using an electrical signal generated by the system (locator signal), a conventional ablation catheter is localized in the heart chamber and is also displayed on the computer screen. After placing the MEA and the ablation catheter in the chamber to be examined, the landmarks in the chamber (i.e., in the right atria, the superior and inferior vena cava, coronary sinus, tricuspid ring, septum, lateral, anterior and posterior wall) are defined by dragging and rotating the ablation catheter. Using these marked sites, the software constructs a three-dimensional anatomical computer model of the endocardium. In the next step, color-coded isopotential maps are generated based on the "on-line" (during the tachycardia) registered and calculated virtual electrograms. The isopotential maps of the tachycardia beats are then projected "off-line" (in sinus rhythm) onto the anatomical map (Figure 1). After the investigator has identified the possible ablation site(s) and marked it on the computer screen using the locator signal, the ablation catheter can be navigated without fluoroscopy at the pre-selected site. In almost all cases, the ablation can be performed in sinus rhythm.

The *Carto electro-anatomical mapping device* (Webster Biosense, USA) consists of a location pad positioned under the patient, two catheters fitted with a sensor and reference catheter, a mapping system, and a computer workstation. The location pad generates a magnetic field of very low intensity. In the distal part of the mapping and ablation catheters, a sensor is mounted. This sensor provides highly accurate information (0.8 mm and 5°) about the position of the catheter in space. From the distal tip of the catheter, intracardial signals can be recorded whose timing is related to a reference signal. In this way, activation times are obtained in relation to the position of the catheter. By dragging the catheter along the endocardium, sequential recording of several points is obtained, resulting in the real-time construction of a three-dimensional (3D) isochronal activation map. An icon of the mapping or ablation catheter is displayed on the computer screen, together with this 3D map, which enables catheter manipulation without fluoroscopy.

The *"Basket" Catheter* (e.g., Constellation, Boston Scientific/EP Technologies, USA) is another mapping tool consisting of a contact multi-electrode array of 64 bipolar electrodes. With additional software, color-coded isochronal maps of complex arrhythmias can also be generated.

Navigation Systems

The *Realtime Position Management* (RPM) ultrasound system (Cardiac Pathways Corporation, USA) consists of a position acquisition module that transmits and receives ultrasound waves to measure the distance between transducers that are mounted on specialized diagnostic and ablation catheters. The signal acquisition module is an amplifier that filters cardiac signal data and transfers it to the arrhythmia-mapping computer for processing and display. The reference catheters are placed in the coronary sinus and in the apex of the right ventricle. Each 7 F reference catheter

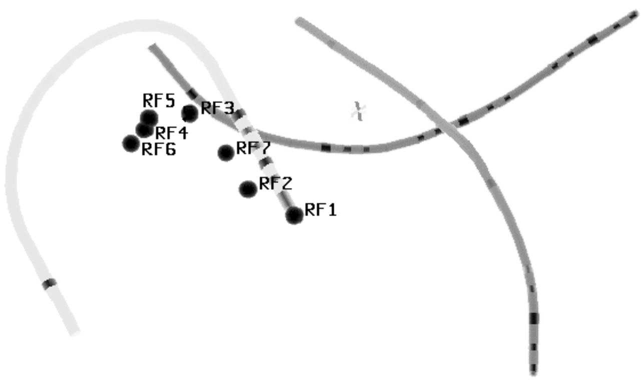

Figure 2. Realtime Position Management ultrasound navigation (Cardiac Pathways Corporation, USA). Three-dimensional (3D) depiction of catheters. Two reference catheters (dark gray) and the ablation catheter (grey) are depicted in 3D as seen on the computer screen. Black dots indicate RF applications (RF 1 – 7).

contains four ultrasound transducers that are used for transmitting and receiving ultrasound waves. The 7 F cooled, steerable ablation catheter contains three transducers to determine its position in the chamber and in relation to the reference catheters. Each reference catheter also contains standard electrophysiologic electrodes that can be used for electrogram recording and for stimulation. A continuous cycle of ultrasound pulses is transmitted to the transducers. The time of pulse receipt on all transducers is used to determine the distance between transducer pairs, and the catheters can then be displayed on the computer screen (Figure 2).

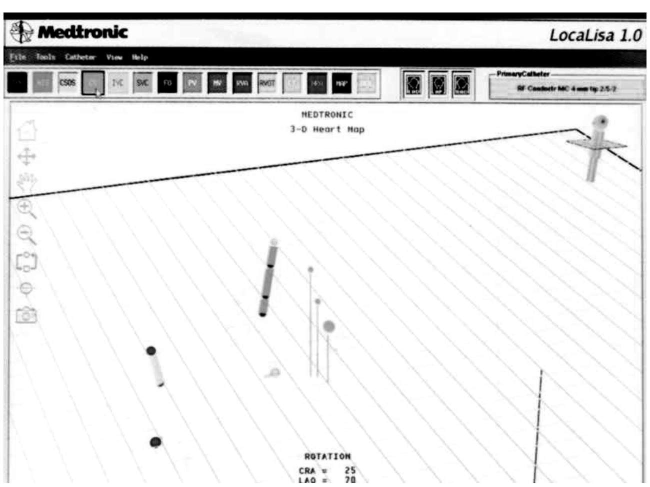

Figure 3. LocaLisa system (Medtronic, USA). The introduced catheters are displayed on the computer screen.

The *LocaLisa system* (Medtronic, USA) can visualize a maximum of any ten electrodes within the heart simultaneously. The device operates on the principle that a voltage gradient can be measured along the axis of an electrical field. With a pair of electrodes placed on the body, LocaLisa generates a low-power electrical field across the body. This field creates a voltage gradient along its axis. While using any intracardiac electrode placed into this field, the system measures the local voltage at the site of the electrode and then calculates its position along the field axis from the measured voltage. When three pairs of electrodes are placed on the body in the orthogonal directions LocaLisa generates three similar fields in each of these directions. A 3D space within the body can then be defined from these signals. When an intracardiac electrode is attached to the system, it can detect the field strength in each of the three fields and then the X-Y-Z coordinates can be calculated and displayed on the computer screen (Figure 3).

Discussion

Extended mapping systems were designed to help electrophysiologists treat complex arrhythmias and visualize the endocardial activation. Simultaneous mapping devices such as EnSite and the basket catheters collect multiple electrograms from endocardial target sites at the same time. Using this technique, a few beats of the tachycardia are theoretically enough to define the site of origin or the breakthrough site of the arrhythmia. This is very helpful in cases of short atrial runs or when the patient is hemodynamically unstable (with some VTs) from an arrhythmia. The major advantage of combined mapping and navigation systems (EnSite) is the ability of the device to lead the ablation catheter to the "off-line" marked target site without fluoroscopy [8,9]. During sequential mapping (Carto) electrograms are collected from multiple target sites to create a 3D activation map. This requires more stable and sustained arrhythmias. The system is ideal for treating incisional tachycardias, atypical flutter, or focal arrhythmias [10-12]. An additional advantage of these mapping systems is the capability to validate linear ablation lesions. Previously, complex and time-consuming pacing measurements were needed to show conduction delay or block between the two sites of a single lesion. Visualizing the endocardial activation during pacing in the opposite sites of a lesion can easily demonstrate gaps in a particular ablation line [13]. Navigation systems such as RPM and LocaLisa help electrophysiologists to place and replace ablation and diagnostic catheters in a previously defined position. The accuracy of the available devices ranges between 0.8 – 2 mm. The major advantage is the capability to reduce fluoroscopy time even in cases of complex ablation. Following sequential recordings of anatomic landmarks (e.g., His-bundle, sinus node, vena cava, tricuspid valve, pulmonary veins), a more precise and safer orientation in the selected chamber is possible. After the "off-line" definition of the ablation line (e.g., typical atrial flutter, right or left atrial compartmentalization) or of a circle (isolation of pulmonary veins) on the computer screen, the point-to-point ablation is possible by dragging the ablation catheter along the preselected line or circle. Fluoroscopy time can be significantly reduced because the exact position of the catheter is also displayed on the screen [14].

Conclusion

In conclusion, the advanced mapping and navigation systems are feasible and safe in the treatment of different atrial and ventricular arrhythmias. However, at this time, except for the most popular EnSite and Carto systems, only limited data are available regarding the real clinical advantages of the other described products. A further disadvantage of the widespread use of these techniques is the significant costs of hardware and catheters. Finally, we believe that up-to-date diagnostics and treatment of arrhythmias will not only directly benefit the patient, but will also provide a better understanding of the complex mechanism of cardiac arrhythmias.

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