chapter

14

Fusion of Electroanatomical Activation Maps and Multislice Computed Tomography to Guide Ablation of a Focal Atrial Tachycardia in a Fontan Patient

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Abstract

Introduction: Ablation of atrial tachycardia (AT) occurring late after cardiac surgery for congenital heart disease can be challenging due to the complexity of the arrhythmogenic substrate.

Methods and Results: We performed an ablation procedure in a Fontan patient with an AT using a new approach combining 3D electroanatomical mapping with Multi-slice Computed Tomography (MSCT). This technique visualizes the position of the catheter in relation to the endocardium, thereby improving delineation of scar tissue. The AT had a focal origin located between areas of scar tissue and was successfully ablated at the earliest activated site.

Conclusion: Ablation of complex arrhythmias can be facilitated by fusion of electroanatomical map and MSCT.

Introduction

Atrial tachycardia (AT) is frequently observed in patients who have had a Fontan procedure[1,2], and are a major cause of morbidity[3]. Catheter ablation provides a possible curative treatment option[2,4]. Most of the AT are caused by a macro-reentrant circuit, located between areas of scar tissue [5,6]. Less frequently, AT of focal origin also originate from scar tissue. Identification of scar tissue areas is therefore mandatory for a successful ablation procedure. However, accurate mapping in Fontan patients with dilated atria and distorted atrial anatomy may be difficult.

Case report

The current report concerns a 35-year old man with tricuspid atresia, transposition of the great arteries and an atrial septal defect (tricuspid atresia type IIb). The congenital heart defect was palliated with a classic Glenn shunt, which was followed by a Fontan operation (atriopulmonary connection) at the age of 8 years. Episodes of AT were first documented 11 years after Fontan surgery. Treatment consisted of electrical cardioversions, different anti-arrhythmic drugs and implantation of a pacemaker with epicardial leads. However, symptomatic episodes of AT persisted and the patient was referred for catheter ablation.

One day prior to the ablation procedure, a Multi-slice Computed Tomography (MSCT) scan was acquired to assess the exact anatomy of the right atrium and the Fontan conduit. Cranio-caudal scanning was performed on a 64-detector row system (Toshiba Medical Systems, Otawara, Japan) during an inspiratory breathhold, without electrocardiographic gating. A total amount of 100 ml non-ionic contrast material (Iomeron 400, Bracco Altana Pharma, Konstanz, Germany) was infused through the antecubital vein with an infusion rate of 3 ml/s. The complex anatomy was evaluated by analyzing the orthogonal planes and using multiplanar reformatting (**Figure 1**).

Before the ablation procedure, raw MSCT data were loaded into the 3D electroanatomical mapping system (CARTO XP™, Biosense Webster, California, USA) equipped with the newly developed CartoMerge™ Image Integration Module. To depict the structure

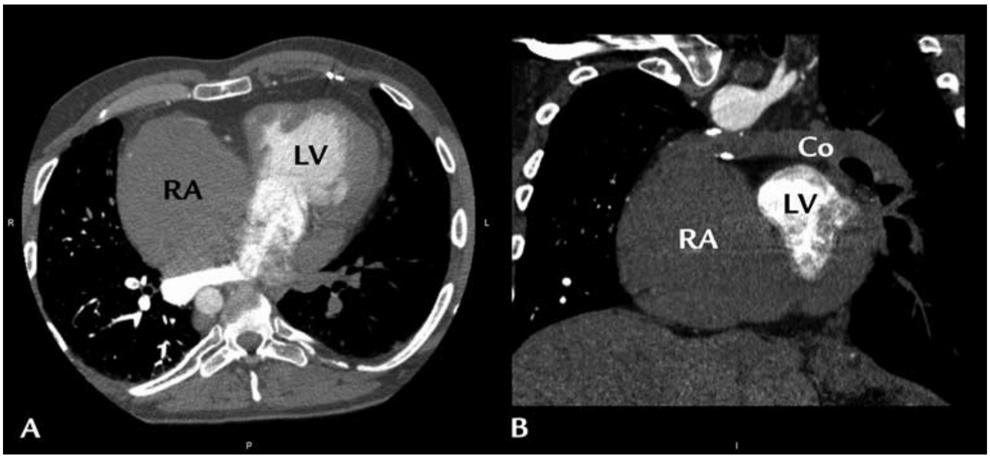

Figure 1.
MSCT image of our 35-year old patient with tricuspid atresia type IIb, treated with Glenn shunt and Fontan operation. A: Axial MSCT image demonstrating the enlarged right atrium. B: The coronal multiplanar reformatted image shows the Fontan conduit. RA = right atrium; LV = left ventricle; Co = Fontan conduit.

of interest (in this case the right atrium) out of the raw data set, a segmentation process was performed manually[7]. This process consisted of several phases. First, the borders of the structures of interest were delineated by setting the threshold intensity range. The presence of contrast allowed differentiation between endocardium (low intensity level) and blood pool (high intensity level). Subsequently, a 3D volume was created by labelling all volume units of the raw MSCT data within that range. To segment this volume into different structures, anatomical markers were placed in the middle of the different areas of the volume. An algorithm was now implemented to automatically depict the different structures of interest based on the placement of the anatomical markers and the borders. Finally, the result of the segmentation process was verified on axial slices. An adequate segmentation of the MSCT images of our Fontan patient was achieved, and the surface images were stored in the CARTO™ system.

Endocardial mapping was performed using the CARTO™ system. A 7F Navistar (4mm tip, 2 bipolar electrode pairs, inter-electrode distance 2 mm, Biosense Webster, USA) was used for mapping and ablation. A bipolar atrial electrogram recorded by a 6F diagnostic catheter positioned in the right atrium served as a temporal reference. A sensor taped on the back was used as the location reference. Bipolar activation/voltage maps were constructed during AT to identify the underlying mechanism and to select target sites for ablation. The local activation time was determined by automatic marking the maximum amplitude of each bipolar potential and the peak-to-peak amplitude was used to delineate scar tissue (cut-off value of 0.1 mV)[8].

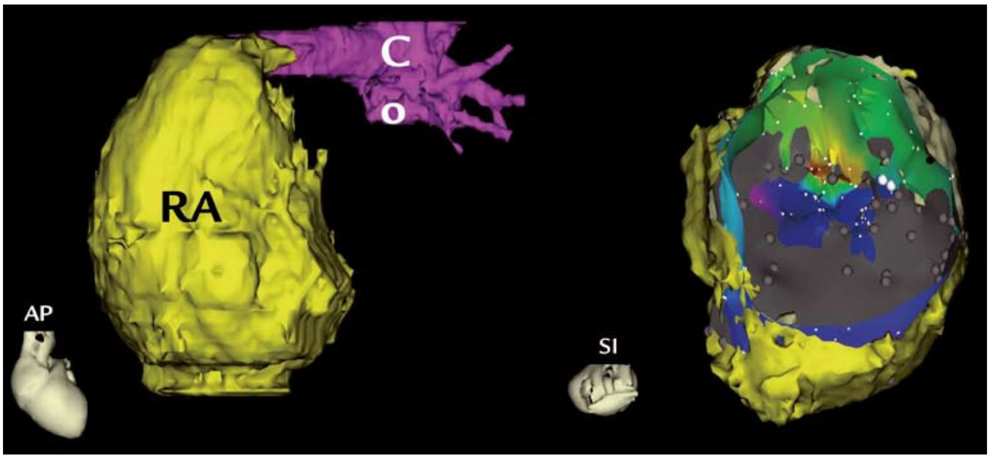

Figure 2.
MSCT surface image after segmentation and registration. The left panel demonstrates the MSCT surface image after completion of the segmentation process. The right panel (superior-inferior view into the right atrium) shows the fused electroanatomical activation map and the MSCT surface image. After the registration process, the fused MSCT surface image and the electroanatomical map can guide the catheter ablation procedure in an accurate way. RA = right atrium; Co = Fontan conduit.

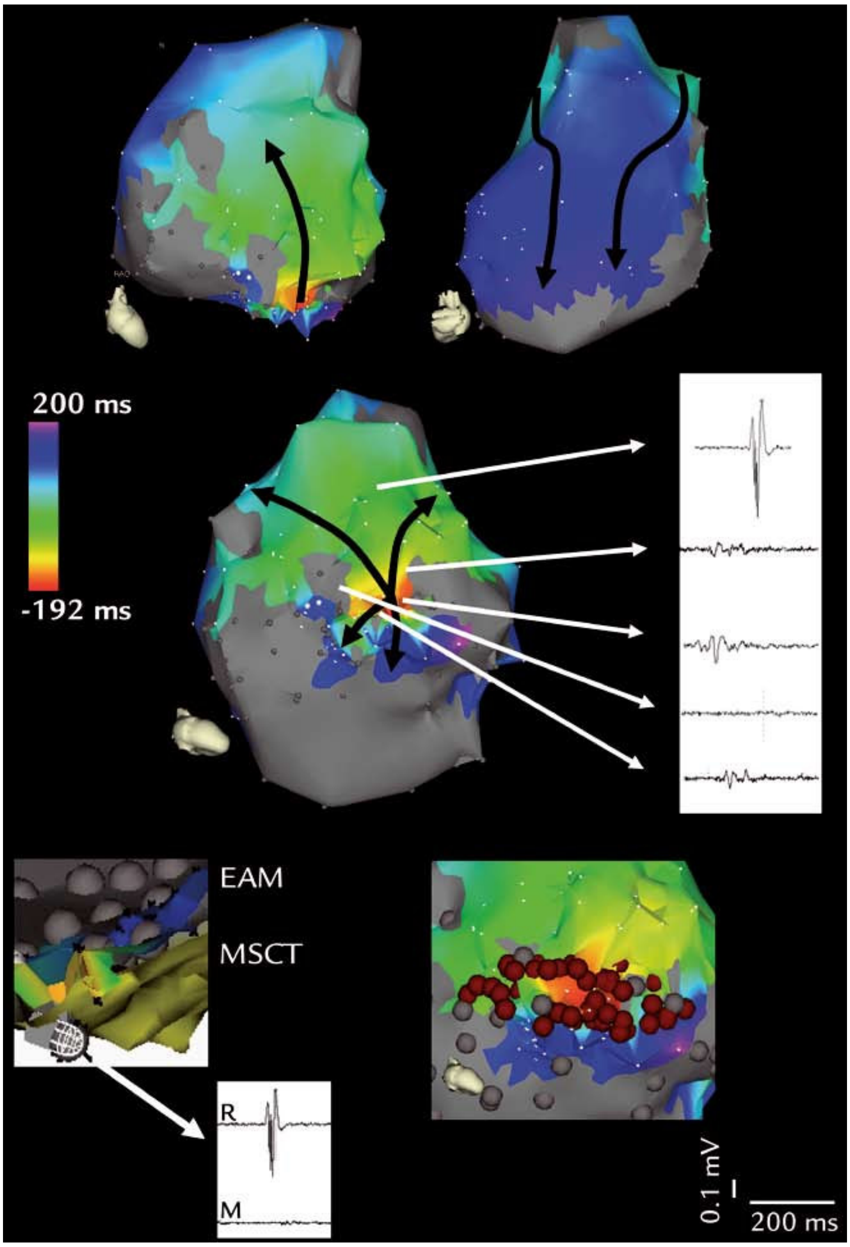

Figure 3.

Right atrial activation maps demonstrating a focal AT originating between two areas of scar tissue. Bipolar electrograms recorded at the origin consisted of low amplitude potentials. The lower left panel shows the position of the mapping catheter in relation to the MSCT surface image confirming that absence of electrical activity at this recording site represents scar tissue and not poor contact between the mapping electrode and the endocardium. In the lower right panel, red tags indicate sites of radiofrequency current delivery.

EAM = Electroanatomical activation map; MSCT = Multi-slice Computed Tomography surface image; R = reference catheter; M = mapping catheter.

After completion of the activation map a registration process was performed manually to fuse the MSCT images and the electroanatomical map (Figure 2). First, the 3D surface image of the MSCT was displayed on the CARTO™ system next to the electroanatomical map. The highest site on the right atrial septum was tagged on the activation map with a landmark using fluoroscopy. A second landmark was then placed on the same site on the MSCT image. Next, the surface registration algorithm was performed to align the MSCT surface image and the electroanatomical map. This algorithm composed the best fit of the two structures based on minimizing distance between the two landmarks (‘landmark registration’) and the distance between all mapping points and the MSCT surface image (‘surface registration’). Furthermore, the algorithm provided information about the accuracy of the fusion process. Mean distance between all mapping points and the MSCT surface was 2.4 ± 1.8 mm (range 0.0 - 7.9 mm).

Mapping revealed an AT (CL 400 ms) of focal origin emerging from a small region between areas of scar tissue. The fusion of the MSCT images and the electroanatomical activation map enabled visualization of the position of the catheter and the position of the recorded electrogram in relation to the endocardium. This facilitated discrimination between scar tissue and poor contact of the tip of the mapping catheter with the endocardial wall (Figure 3).

Ablation was performed at the site of earliest endocardial activity, using radiofrequency current (60 seconds, tip catheter set at 70°C, maximum output 50 W). The AT terminated during ablation at this site and sinus rhythm resumed. A circular lesion was then created around the AT origin (Figure 3).

Discussion

This case illustrates the advantage of using an integration system that permits fusion of 3D electroanatomical mapping and MSCT images in guiding catheter ablation procedures. Accurate catheter position and discrimination between scar tissue and poor contact may facilitate ablation procedures in patients with dilated atria and complex anatomy.

AT frequently occur in patients after cardiac surgery for congenital heart disease[1]. However, therapeutic effects of anti-arrhythmic drugs and antitachycardia pacing are limited in Fontan patients[9,10]. Catheter ablation has shown to be a treatment modality with good intermediate and long-term results[2,4]. The outcome of catheter ablation procedures in congenital heart disease patients depends on the ability to identify the arrhythmogenic substrate and to depict target sites for ablation. The use of electroanatomical mapping has provided more insight in the origin of AT in patients after Fontan surgery[5]. Several studies[5,6,11] have shown a macro-reentrant circuit as the cause of AT. The present case report demonstrates that a focal origin located between two areas of scar tissue may be the mechanism of AT in Fontan patients. Hence, mapping is essential for a correct diagnosis of the arrhythmia. We previously demonstrated that a bipolar voltage of 0.1 mV can be used as a cutt-off value to discriminate 'healthy' from 'diseased' myocardium[8]. Delineation of scar tissue therefore requires reliable measurements of the peak-to-peak amplitude of bipolar electrograms. This can be accomplished by a stable contact between the mapping electrode and the atrial wall. However, distorted atrial anatomy and surgically created barriers, like conduits, hamper mapping of the atria. As exact catheter positioning can be difficult, knowledge of the anatomy during the procedure may be helpful. Furthermore, visualization of the mapping catheter in relation to a 3D surface image of the atrial anatomy could facilitate ablation of complex arrhythmias[12]. In this patient, we used the new CartoMerge™ system to accurately distinguish between scar tissue and poor contact of the catheter tip with the endocardium by assuring that each electrogram was recorded on the endocardial surface of the atrial reconstruction. This was possible since the electroanatomical map and the MSCT surface image were fused with a mean distance between both reconstructions of about 2.5 mm. In addition, the orientation of the mapping electrode in relation to the endocardium is visualized for each recorded electrogram. However, differences in size between the MSCT surface image and the electroanatomical map may limit the fusion process. Furthermore, this mapping approach has become available only recently and validation studies are currently conducted.

This case report demonstrates that ablation procedures in patients with complex arrhythmias after surgery for congenital heart disease may be facilitated by fusion of MSCT images and 3D electroanatomical mapping.

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