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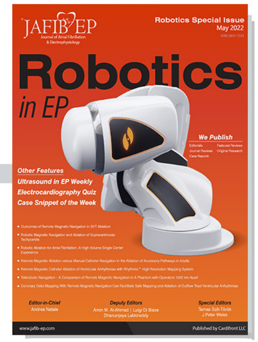

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Coronary Ostia Mapping with Remote Magnetic Navigation can Facilitate Safe Mapping and Ablation of Outflow Tract Ventricular Arrhythmias

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Abstract

Remote Magnetic Navigation (RMN) is a well-described technology with which a flexible catheter is guided through vascular and cardiac structures by a directional magnetic field. When utilized with EAM, the technology allows for atraumatic and precise creation of real-time anatomical representation as well as stable positioning of the ablation catheter tip at the time of energy delivery. The present report describes an alternative method utilizing RMN during 3D Electroanatomic mapping to safely provide real-time visualization of SOV anatomy, including the coronary ostia, in patients undergoing mapping and ablation for idiopathic VAs.

Introduction

The occurrence of both sustained and non-sustained ventricular arrhythmias (VAs) in patients without structurally normal hearts as well as nonischemic cardiomyopathy has been described since the mid-20th century and is thought to account for approximately 10% of VAs overall.[1,2] Such patients are commonly referred for catheter ablation. The majority demonstrate an inferior QRS-axis morphology and originate from the outflow tracts (OT) and adjacent regions of the ventricles, commonly described as right ventricular (RVOT), left ventricular (LVOT), left ventricular summit, and aortic sinuses of Valsalva (SOV).[3] Approximately 17% of these VAs are thought to originate from sites responsive to ablation from the SOV.[4] The involved structures reside in a relatively compact region with complex three-dimensional anatomical relationships that must be clearly understood in order to facilitate safe and effective mapping and ablation.[5,6,7]

Remote Magnetic Navigation (RMN) is a well-described technology with which a flexible catheter is guided through vascular and cardiac structures by a directional magnetic field allowing for atraumatic and precise creation of real-time anatomical representation as well as stable positioning of the ablation catheter tip at the time of energy delivery. The present report describes a novel method utilizing RMN during 3D electroanatomic mapping to safely provide real-time visualization of SOV anatomy, including the coronary ostia, in patients undergoing mapping and ablation for ventricular arrhythmias of outflow tract origin.

Key Words

Ventricular Arrhythmias; Mapping; Remote Magnetic Navigation; Ablation

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Methods

We performed a retrospective chart review on all patients who underwent catheter ablation for ventricular arrhythmias using RMN (GENESIS, Stereotaxis, Inc. St. Louis, MO) at a single center (Banner University of Arizona Medical Center, Phoenix, AZ, USA) between September 2020 and May 2021. Of these, 14 were identified who underwent ablation of idiopathic VA requiring mapping of the SOV utilizing RMN. The primary endpoints were successful mapping of the intended anatomy and rate of complications related to said mapping including ST/T-wave changes or any signs/symptoms of coronary injury. Success of the ablation in eliminating the clinical arrhythmia was evaluated as a secondary endpoint. Acute procedural success of ablation was defined as lack of inducible clinical arrhythmia following a minimum 30-minute waiting period including testing with isoproterenol infusion. Post discharge procedural success and complications were evaluated at follow-up within two weeks of the procedure as well as longer term follow-up as available. Baseline characteristics, medical history, procedural parameters, and follow-up were reviewed. Values are presented as mean +/- SD. All patients signed consent for electrophysiology study and ablation. The retrospective review did not require IRB approval.

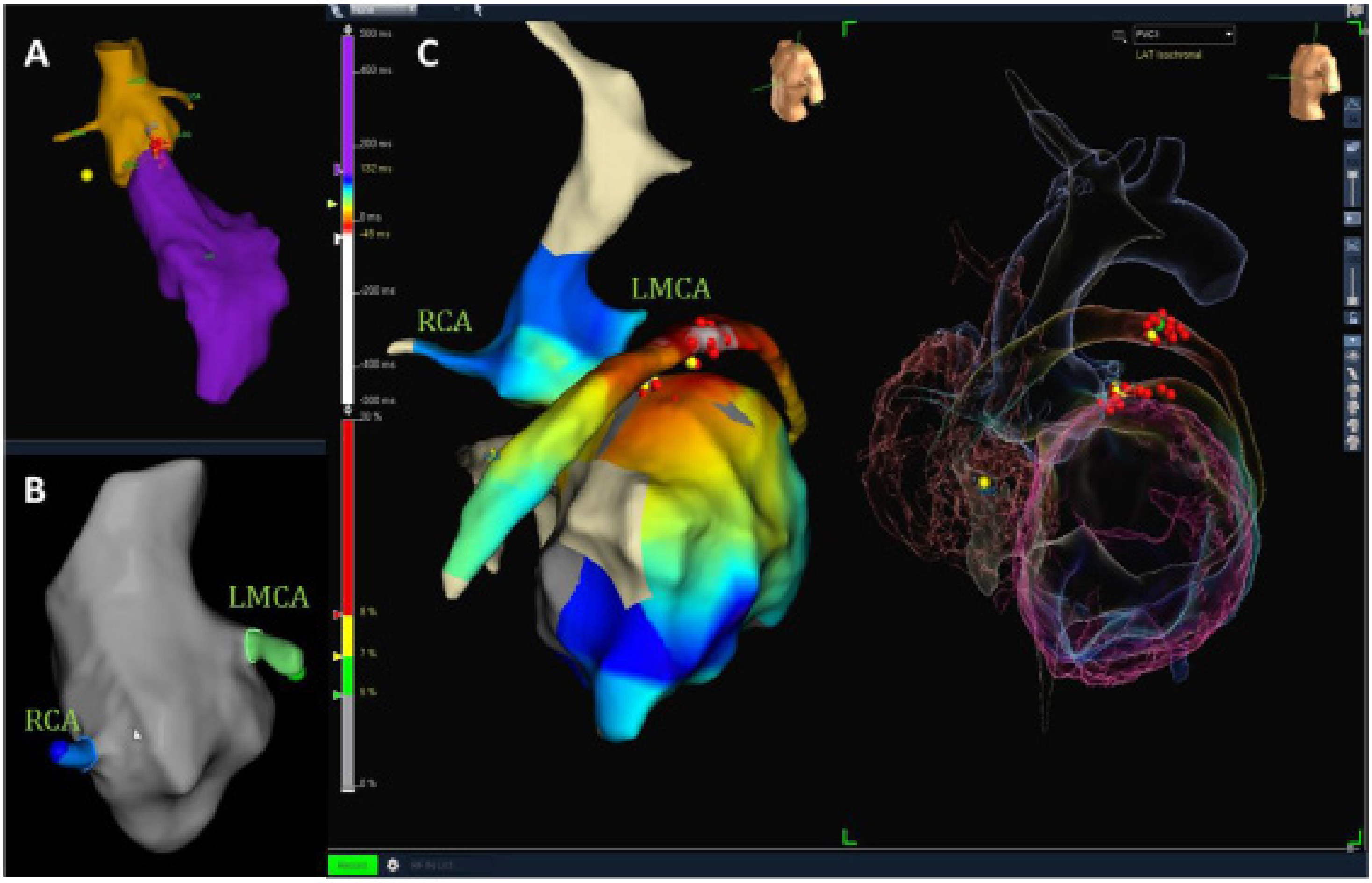

Figure 1: Representative electroanatomic maps displaying integrated mapping of the coronary ostia and proximal coronary arteries as created with the remote magnetic navigation catheter. Panels A and B created with the CARTO mapping system. Panel C created with the EnSite Precision mapping system with CT image integration displayed alongside.

Mapping of the Aortic Root and Coronary Ostia

Femoral arterial access was obtained under direct ultrasound guidance with Seldinger technique. Heparin was administered immediately following femoral access with activated clotting time target of 300-350 seconds while sheaths and catheters remained in the arterial circulation. After femoral angiography through the initial short access sheath, an 8.5F, 81cm, 135-degree LAMP sheath (Abbott Laboratories, Abbott Park, IL) was advanced to the ascending aorta. The RMN mapping and ablation catheter (Navistar Thermocool RMT, Biosense Webster, Diamond Bar, CA) was then advanced into the aortic root manually and connected to the Catheter Advancement System (CAS, Stereotaxis, Inc. St. Louis, MO) and brought under control of the magnetic navigation system. Per usual protocol, heparinized saline was continuously infused through the catheter at 2ml/min during mapping. Three-dimensional electroanatomic mapping was performed with either CARTO (CARTO3 v6 RMT, Biosense Webster, Diamond Bar, CA) or EnSite Precision (Abbott Laboratories, Abbott Park, IL) systems.

Mapping was initiated with navigation inferiorly towards the aortic valve and then omni-directionally in order to create 3D anatomy of the entire aortic root. Particular attention was paid to obtaining complete anatomical detail of each SOV. Catheter tip contact was confirmed by restriction of movement with further advancement, a vector-based contact indicator, and often with visualization on intracardiac echocardiography. Cannulation of the coronary ostia was at times achieved spontaneously during mapping of the aortic root. When this did not occur, the coronary ostia were canulated beginning with the catheter tip in the corresponding aortic cusp. The magnetic vector was then directed somewhat superior and towards the presumed location of the corresponding coronary ostium. The catheter was then withdrawn with 2mm movements. If the coronary ostium was not engaged, the movements were repeated with slightly altered vector orientation. Once the coronary ostium was engaged, the catheter would commonly advance into the proximal vessel of its own accord. Catheter advancement within the vessel was made with 2mm increments as permitted by anatomy. The catheter was then withdrawn as anatomical points were added to the map. This was performed efficiently with a goal of having the catheter within the coronary vessel for no longer than 30 seconds. The map was then edited to remove interpolated space and clearly define the coronary ostium and proximal vessel.

Ablation

Ablation was performed using the same RMN catheter as used for mapping with energy ranging from 20-50 watts for 30-120 seconds depending on location, local impedance, and response to initial ablation. Ablation within the SOV was typically performed at 35-45 watts no closer than 5mm to the coronary ostia as visualized on the 3D map.

Results

Fourteen patients (average age 57.71 years, 71% male) who underwent mapping and ablation of inferior axis VAs were included in the case series. The majority were referred for management of PVCs compared with VT (86% vs. 14%). Seven (50%) had normal left ventricular function, and seven (50%) had nonischemic cardiomyopathy (ejection fraction 34.8% +/- 8%). One patient had repaired congenital tetralogy of Fallot. One patient was post TAVR. Procedure and fluoroscopy times were 194 +/- 66 min and 3.5 +/- 2.5 minutes respectively.

With regard to the primary outcome, the right and left coronary ostia and proximal coronary arteries were successfully mapped using RMN in all patients and used to guide placement of ablation lesions (Figure 1). Angiography was not performed to guide placement of any ablation lesions within the SOV. One patient did require angiography as the mapping catheter was unable to move distal enough within the left coronary circulation to confirm a safe location for ablation within the great cardiac vein/anterior intraventricular vein bifurcation. No patient suffered an acute complication during the procedure related to mapping, including no occurrences of ST/T-wave changes. At two-week follow up there were no additional complications, although one patient had presented for minor groin bleeding managed conservatively.

With regard to clinical outcomes, acute procedural ablation success defined as elimination of the clinical arrhythmia was achieved in 13/14 (93%) of patients. Duration of longer-term follow up was highly variable, averaging 68 days (range 2 weeks to 6 months) based on patient and medical record availability. Based on available records 11/14 (79%) remained free of the targeted clinical arrhythmia at last evaluation. None had developed subacute or chronic complications attributable to the mapping strategy.

Discussion

Remote magnetic navigation was introduced into clinical practice in 2003 with demonstration of successful navigation and catheter contact.[8,9] Offering the characteristics of unique maneuverability and stability of catheter tip position in challenging anatomy, the system has demonstrated safetyand effectiveness in the treatment of ventricular arrhythmias.[10] This has included several reports specific to OTVT including those arising from the left coronary cusp.[11-14] RMN has also shown improved effectiveness in comparison with manual techniques in the treatment of idiopathic ventricular arrhythmias with a failed prior attempt.[15]At centers with access to this technology, it is often the preferred technique for treatment of patients with these arrhythmias. The current report presents a novel use of this technology to facilitate safe and efficient mapping and ablation in this region.

The unique characteristics of RMN are well suited to this task. In addition to maneuverability and consistent tissue contact, the soft and flexible distal end of the catheter renders it relatively atraumatic in comparison with traditional pull-wire directed manual mapping and ablation catheters[16]. The catheter has also proven to be particularly adept at accessing vascular anatomy such as the distal coronary sinus and anterior intraventricular vein during EP mapping and ablation procedures. It had been noted anecdotally that the RMN catheter would occasionally unintentionally cannulate the coronary ostia during mapping of the aortic root without any apparent adverse consequences.

Based upon these observations, intentional cannulation of the coronary ostia and proximal arteries in patients without coronary disease undergoing mapping of the aortic root for OTVT became part of clinical workflow. Using this technique, detailed anatomy of the aortic root and surrounding structures can be safely visualized in real time and fully integrated into the electroanatomic mapping system with a high level of precision. Distances between structures and catheter position can be easily measured. As the same mapped anatomy is used to guide and visualize catheter tip position during ablation, the operator benefits from a high level of understanding of the precise location of the catheter tip in relation to these structures therefore facilitating safe application of ablation energy.

Publications dating to the mid-1990s have demonstrated the initial approaches to, and efficacy of, catheter ablation in the treatment of these arrhythmias, beginning with those originating from the RVOT (approximately 60-70% of OTVA).[17] More recent publications have highlighted the challenges associated with mapping and ablation of these arrhythmias from non-RVOT sites. The ability to perform complete mapping of all relevant anatomical structures in this region, including relevant arterial and venous anatomy, can be essential to safe and successful ablation in more challenging cases, where the site of origin is likely to be intramyocardial between adjacent accessible structures.[18] In particular, delivery of RF energy in the SOV requires reliable real-time understanding of the relation between the catheter tip and the location of the coronary ostia.[19,20]

Several strategies have been developed to mitigate risk of injury to the coronary arteries during mapping and ablation of these VAs. The long-term standard practice utilizes angiography to visualize ablation catheter position relative to the coronary artery ostia and course to ensure safe distance for RF ablation.This method often requires additional arterial access for angiography and visual evaluation of the relative position of the ablation catheter tip. The use of intra-procedural angiography can be enhanced using image registration and integration software that allows for visualization of the coronary anatomy in direct relation to electroanatomic mapping.[21]This method allows for angiographic images to be obtained separately from when the ablation catheter is in position, thus reducing the need for separate arterial access and allowing continued mapping with continued reference to vessel position. However, angiography requires contrast exposure, additional fluoroscopy, the presence of expertise in coronary angiography, and carries the rare risks of coronary dissection and air embolism.[22]

To avoid the need for angiography, alternative imaging strategies have been described. Several investigators have published case series describing the use of intracardiac echocardiography (ICE), without angiography, in patients undergoing mapping and ablation of SOV arrhythmias.[23,24] Each report is a single-center case series performed at centers with notable experience in ICE utilization. While successful, the authors appropriately emphasize the importance of significant operator experience necessary to confidently obtain and interpret the images. Even then, several patients underwent angiography in cases where the coronary ostia, particularly on the right, could not be sufficiently visualized.

Another alternative is the import and integration of advanced imaging (CT/MRI) obtained prior to the procedure with the electroanatomic map created during the procedure.[25] This method has several important limitations including the difficulty of precise image registration and differences in surface representation using different imaging modalities. The acquisition of imaging pre-procedure also raises potential for changes in chamber volumes and therefore position of anatomical structures at the time of the procedure.

In comparison to other described techniques, the described method has several additional advantages. This technique avoids reliance on angiography and the associated additional procedural steps and potential risks involved. While ICE was also used during these procedures as adjunctive imaging, the presented technique avoids the challenges of occasional poor ultrasound visualization of these structures and reduces reliance on highly specialized expertise in ICE image acquisition and interpretation. It should also be noted that ICE may not be available or commonly used during EP procedures in some centers, especially outside the US. Import and registration of CT/MRI segmented images is prone to registration errors and cannot be updated in real time. With safety and effectiveness of ablation of OTVT requiring precision to the level of millimeters, the application of secondary imaging modalities that are not native to the primary mapping system being used introduces significant variables that may reduce the ability of the operator to confidently understand the real-time position of the catheter tip in relation to the anatomy and therefore impact the safety of the procedure.

Limitations

There are several limitations to the interpretation of this study and potential generalizability of this method. The present study is retrospective, non-randomized, and single center in design with operators who have extensive experience with RMN. As such, it should be considered a demonstration of “proof of concept” and not definitive demonstration of the safety and effectiveness of this method. Further study is warranted to further demonstrate validity. Moreover, the described technique will be limited to providers at the minority of centers with access to remote magnetic navigation technology, thereby limiting more widespread utilization.

Conclusion

The safety and effectiveness of ablation for idiopathic OTVT relies on detailed understanding and precise real-time localization of relevant anatomical structures and the position of the tip of the ablation catheter where energy is to be delivered. As opposed to traditional methods including angiography, ICE imaging, and CT/MRI integration, the use of RMN to directly map these structures into the electroanatomic map offers a highly precise, efficient, safe, and reproducible technique that can potentially optimize operator confidence and patient safety during these procedures.

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