Remote Magnetic Navigation and Catheter Ablation of Ventricular Tachycardia: From Concept to Reality

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ABSTRACT. Radiofrequency catheter ablation (RFCA) of ventricular tachycardia (VT) remains a challenging electrophysiologic procedure, particularly in the setting of underlying structural heart disease. Remote magnetic navigation (RMN) is an emerging technology uniquely suited for catheter ablation of VT. This article describes key differences between manual and RMN catheter mapping and ablation of VT, including RMN catheter techniques facilitating ablation within the LV. Published data on success rates of RMN guided VT ablation in the structurally normal and abnormal heart are reviewed, highlighting an increase in RMN success rates with the introduction of an RMN open irrigation ablation catheter.

KEYWORDS. Radiofrequency ablation, catheter, ventricular tachycardia, remote magnetic navigation, mapping.

Introduction

The incidence of ventricular tachycardia (VT) radiofrequency catheter ablation (RFCA) is growing worldwide. Key factors driving this increase in this procedural volume include

- expanded indications for the use of implantable cardio-defibrillators (ICDs) in the setting of underlying structural heart disease;
- a growing number of cardiac electrophysiologists (EPs) and non-EP physicians implanting ICD devices;
- improvements in catheter and mapping technology, facilitating shorter ablation procedures with higher success and lower complication rates.

The recently revised European Heart Rhythm Association/Heart Rhythm Society (EHRA/HRS) expert consensus statement for the ablation of VT reflects an increasing awareness of the potential benefits of RFCA of VT in the structurally normal and the abnormal heart.1 Consequently, as these complex procedural volumes grow, newer technologies facilitating successful RFCA of these often challenging arrhythmias appear both attractive and necessary.

Magnetic catheter navigation and VT ablation

In the United States, one remote magnetic navigation (RMN) system has received FDA approval for clinical use in humans, the Stereotaxis RMN system (Stereotaxis, St. Louis, MO). The Stereotaxis RMN system is uniquely suited for RFCA in all four cardiac chambers and the epicardial surface owing to its very flexible catheter design and catheter stability.2,3 Whereas much attention has been paid to the ablation of supraventricular tachycardia (SVT) using RMN, recently published studies have highlighted the utility of this system in the ablation of VT.4-6

RMN and RFCA

Remote magnetic versus manual catheter manipulation

The Stereotaxis system operates by remotely navigating a magnetically tipped catheter within the heart via two large

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permanently affixed external magnets on either side of the patient table. Intracardiac catheter manipulation is accomplished by directionality of the catheter tip and advancement/withdrawal of the catheter using an external automated catheter advancement system. This is typically coupled with a three-dimensional (3D) electroanatomic mapping system such as Carto RMT (Biosense Webster, Diamond Bar, CA) or the Ensite system (St. Jude Medical, Minnetonka, MN). Figure 1 demonstrates a typical left ventricular (LV) endocardial map created the Carto RMT mapping system during an RMN ablation procedure.

When transitioning from manual to magnetic catheter ablation, the operator must learn to adjust his or her technique of catheter manipulation within the heart. With manual catheter positioning, proper catheter placement couples the manipulation of the catheter shaft to place the catheter tip in the desired location. With magnetic navigation, catheter shaft manipulation is far less critical than obtaining the appropriate magnetic vector for the catheter tip to be stably held in the proper location. Once the catheter tip arrives at the desired location, it may typically be maintained in this position indefinitely, with exceptional stability during both ventricular systole and diastole. This locational fidelity distinctly contrasts to the challenge of maintaining accurate endocardial contact within a contracting and torsing cardiac chamber throughout the cardiac cycle. This stability, however, comes at the expense of RMN catheter contact force, which rarely exceeds 15 g. Consequently, higher powers are typically required during RF application, particularly with the RMN open irrigation catheter (OIC) catheter to achieve lesion efficacy. Whereas traditional manual catheters are characterized by predefined unidirectional or bidirectional curvatures, the floppiness of RMN ablation catheters allows nearly unlimited flexibility within the cardiac chambers, potentially obviating the need for intraprocedural catheter swap-outs.

RMN catheters available for clinical use in the United States include non-irrigated 4-mm and 8-mm tips, as well as a 3.5-mm OIC tip available from a single manufacturer (Biosense Webster). These catheters contain three magnets located at their distal tips permitting RMN. Features of the RMN system critical to catheter ablation of VT are outlined in Table 1.

Ventricular access and catheter considerations specific to RMN
For endocardial LV VT RFCA procedures, the preferred route of LV access is antegrade through the mitral

Figure 1: Bipolar voltage electroanatomic three-dimensional map of the endocardial left ventricular cavity in a patient with prior myocardial infarction. The red dots represent the site of ablation delivery using the remote magnetic navigation open irrigation catheter (Biosense Webster, Thermocool Navistar RMT, Diamond Bar, CA).
Overview of RMN and VT RFCA studies

Basu Ray et al.\(^\text{11}\) compared manual and RMN catheter mapping of LV scar in a porcine model of healed myocardial infarction. In this study, conventional manual mapping was not significantly different from RMN for the calculated scar area or the degree of error in reaching prespecified endocardial targets. Notably, fluoroscopy times and mapping-induced premature ventricular contractions (PVCs) were significantly lower in the RMN group.

Aryana et al.\(^\text{4}\) reported a total of 27 cases of ablation of VT using the Stereotaxis RMN system. This series featured RV, LV and epicardial mapping and ablation utilizing a 4-mm tip non-irrigated RMN catheter. Eighty-one per cent of targeted VTs were able to be mapped and ablated successfully; when RMN ablation failed to successfully ablate VT, a manual OIC was used for further ablation. The complication rate related to RMN mapping and ablation in this series was essentially zero, further underscoring the potential safety advantage of RMN in these procedures.

Di Biase et al.\(^\text{5}\) reported a case series of mixed population of patients undergoing VT ablation with RMN using either the 4-mm or 8-mm-tip non-irrigated catheters.\(^\text{5}\) Comparing these catheters, no significant difference was found in efficacy when ablating in the structurally normal heart, primarily targeting RVOT VT. However, in patients with structurally heart disease (e.g. coronary heart disease, idiopathic dilated cardiomypathy), the 8-mm-tip catheter was found to be significantly more effective than the 4-mm catheter (59% vs 22% respectively, p<0.05). Nevertheless, the crossover rate from RMN to manual ablation with an OIC was 48% in this series.

Given the limitations of non-irrigated RMN catheters, recent work has focused on the use of the newly approved open irrigation RMN ablation catheter in the setting of VT ablation (Thermocool RMT, Biosense Webster). Early work by Haghjoo et al.\(^\text{12}\) reported the use of the RMN OIC with good success and a low complication rate in a small population of four patients with electrical storm and ICD therapies despite medical therapy. Using the RMN OIC, all clinical VTs were successfully ablated, with one residual non-clinical VT remaining inducible in one patient. One patient required repeat ablation within 1 week of the initial procedure. At 4 months’ follow-up, all patients remained free of VT and ICD therapies.

More recently, Di Biase et al.\(^\text{6}\) reported a much larger case control series of 110 patients undergoing RMN ablation of VT. These RMN patients were compared with a similar cohort of 92 patients having undergone manual ablation of VT by the same operator. In both groups, a majority of patients did not have structural heart disease. Patients with an LV or aortic cusp origin of VT were included in the analysis while RV VT was excluded. Most patients exhibited inducible VT, and in some cases template PVCs were targeted for ablation. In the RMN group, 100% of patients were reported to be free of

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Table 1: Features of remote magnetic catheter navigation during ventricular tachycardia (VT) ablation

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<th>Feature</th>
<th>Description</th>
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<td>1. Ability to accurately define healthy and diseased myocardium with precise density mapping.</td>
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<td>2. Maintenance of catheter stability during critical electrophysiologic maneuvers, e.g. entrainment, pace-mapping, etc.</td>
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<tr>
<td>3. Delivery of radiofrequency energy to eradicate template VT(s) with an open irrigation catheter facilitating deeper lesion creations.</td>
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<td>4. Reduced catheter induced ventricular ectopy as compared to manual navigation.</td>
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Adapted from Aryana et al.\(^\text{4}\)
inducible or sustained VT at the conclusion of the procedure. Crossover from RMN to manual occurred in 14% of cases, with 11% requiring manual OIC ablation to achieve procedural success. Overall complication rate was low, despite the use of higher powers (typically 40 W) during RF application. At 1 year of follow up, 85% of patients in the RMN group remained free of clinical VT (82% of these being off of antiarrhythmic drugs), comparable to the manual ablation control group (p=NS).

**Limitations of RMN**

One feature of existing RMN systems is its physical size. There are mandatory structural and magnetic shielding requirements necessary for the installation of the Stereotaxis Niobe system. This may limit its location within a hospital facility. Another drawback of the current technology is the relative lack of options in catheter selection for use with the RMN system. Once installed, the learning curve for the physician...
operator transitioning from manual to RMN catheter manipulation may be steep, prompting some operators to abandon RMN in favor of traditional ablation methods.

Conclusions

A growing body of clinical data supports the routine use of RMN in the ablation of VT in structurally normal and abnormal hearts. The advent of the open irrigation RMN catheter has led to increased procedural success rates and reduced intraoperative conversion to manual catheter manipulation. The safety profile of RMN in the ventricles, the outflow tracts, the epicardial space, and the aortic cusps appears excellent. Coupled with reduced fluoroscopy times and diminished operator fatigue, RMN appears uniquely situated as a valuable asset to centers performing VT ablation.

References