Usefulness of remote magnetic navigation for ablation of ventricular arrhythmias originating from outflow regions

B.K.R. Schwagten, T. Szili-Torok, M. Rivero-Ayerza, E. Jessurun, S. Valk, L.J.L.M. Jordaens

Monomorphic ventricular tachycardia (VT) and symptomatic monomorphic PVCs originating from the region of the right and left outflow tracts are increasingly treated by radiofrequency (RF) catheter ablation. Technical difficulties in catheter manipulation to access these outflow tract areas, very accurate mapping and reliable catheter stability are key issues for a successful treatment in this vulnerable region. VT ablation from the aortic sinus cusp (ASC) in particular carries a significant risk of perforation, of creating left coronary artery injury and of damage to the aorta and the aortic valve.

This case series describes RF ablation of VT originating in the outflow region using the remote magnetic navigation system (MNS). Potential advantages of the MNS are catheter flexibility, steering accuracy and reproducibility to navigate to a desired location with a low probability of perforating the myocardium. This report supports the idea of using advanced MNS technology during RF ablation in regions which are difficult to reach and thin walled, such as parts of the outflow tract and the ASC. (*Neth Heart J* 2009;17:245-9.)

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B. Schwagten
T. Szili-Torok
M. Rivero-Ayerza
E. Jessurun
S. Valk
L. Jordaens

Department of Cardiology, Thoraxcenter, Erasmus MC, Rotterdam, the Netherlands

Correspondence to: B.K.R. Schwagten
Department of Electrophysiology, Thoraxcenter, Erasmus Medical Center, PO Box 2040, 3000 CA Rotterdam, the Netherlands
E-mail: b.schwagten@erasmusmc.nl

Monomorphic ventricular tachycardia and symptomatic monomorphic premature ventricular complexes (PVC) originating from the region of the right and left outflow tracts (RVOT, LVOT) are increasingly treated by radiofrequency (RF) catheter ablation. It seems that RF ablation of PVCs has finally 'found its disease' in impaired LV function induced by frequent ventricular arrhythmias.¹ However, technical difficulties in catheter manipulation to access these outflow tract areas, very accurate mapping and reliable catheter stability are key issues for a successful treatment in this vulnerable region.² Recent studies and case reports have described that tachycardias with similar morphology can be ablated from the RVOT, LVOT but also from the aortic sinus cusp (ASC).³ Ablation in this region carries a significant risk of perforating the myocardium, creating left coronary artery obstruction^{4,5} and damaging the aorta and the aortic valve.

The aim of this paper is to demonstrate the potential advantages of remote magnetic navigation (MNS) (Niobe, Stereotaxis, St.Louis, MO, USA) in ablation of PVCs or VT originating in the outflow region. Details of the MNS technique for use in ablation of ventricular arrhythmias have been previously described by our group.⁶⁻⁸

Case presentations

We present three cases where the MNS is used to eliminate arrhythmias originating from the outflow tract using an approach from the ASC, RVOT and LVOT.

Case 1

A 16-year-old female presented with very frequent palpitations that significantly impaired her quality of life. No syncope and no sudden cardiac death were reported in her family. Clinical examination was unremarkable. A resting 12-lead ECG during symptoms showed frequent isolated monomorphic PVCs with a right bundle branch block pattern. The PVCs had an inferior axis, small but broad R wave amplitude in V₁ and relatively early transitions (as depicted in figure 1A) suggesting a successful ablation site on the left side.³

Figure 1. Morphology of premature ventricular complexes ablated from the aortic sinus cusp (panel A), RVOT (panel B) and LVOT (panel C).

Twenty-four hour Holter ECG recordings demonstrated frequent monomorphic PVCs (>20,000/24 hours) and multiple episodes of monomorphic non-sustained ventricular tachycardias as well. However, sustained arrhythmias were never documented. Echocardiography showed normal systolic and diastolic left and right ventricular function and no significant structural abnormalities.

Electrophysiology and mapping procedure

The procedure was performed under general anaesthesia. Two electrophysiology catheters were used: a quadri-polar diagnostic catheter (Biosense-Webster, Diamond Bar, CA, USA) was inserted through the right femoral vein and positioned at the right ventricular apex and a magnetic catheter (Celcius RMT 4 mm, Biosense-Webster, Diamond Bar, CA, USA) was inserted through the femoral artery. From the right femoral artery we also engaged the left main coronary artery by a 6F standard Judkin's left coronary angiographic catheter. The magnetic catheter was remotely navigated to the LVOT (figure 2) using the MNS in conjunction with the Cardiodrive unit (Cardiodrive™, Stereotaxis, St. Louis, MO, USA). The earliest activation on the mapping catheter by the PVCs was detected in the left coronary cusp and pace-mapping was performed. This showed perfect 12 out of 12 lead ECG similarity with the clinical PVCs (figure 3).

Ablation procedure

The approximate distance between the orifice of the left main coronary artery and the ablation site was no more than 3 mm (figure 3). Therefore, RF ablation was performed using a very low initial energy level that was slowly amplified. After 10 seconds of RF energy delivery at 30 W the PVCs suddenly disappeared. As usual at this site (unpublished observations) no runs of VT with the same morphology as the clinical PVCs

Figure 2. The screen of the magnetic navigation system. The two large upper panels show an image of the full heart. The yellow arrow can be moved by the operator and indicates the desired vector. The green arrow represents the actual vector of the applied external magnetic field. The two large lower panels show the corresponding position of intracardiac catheters on fluoroscopy into perfect pace map position. The three small panels on the left side depict the vectors in relation to the full heart in three perpendicular projections (anteroposterior, right lateral and inferior), allowing a stepwise (1° angle) change of the vector in the corresponding plane. The system is integrated with the CARTO electroanatomical mapping system. The CARTO image in the right superior corner shows activation map within the left coronary cusp.

Figure 3. Upper panels: Standard LAO, AP and RAO fluoroscopy views showing the RF magnetic mapping and ablation catheter (black arrow) positioned in the left aortic cusp. Note the 6F Judkins angiographic catheter engaging the left main coronary artery (white arrow). The ablation catheter is placed approximately 3 mm downwards in the same plane in the same cusp.

Lower panels: This figure shows 12-lead match pace map of the position depicted in panel A. Note the small but broad R wave in V_1 and the early transition zone in the pre-cordial leads suggesting aortic cusp origin of the ventricular tachycardia.

were seen during ablation. The RF energy was further increased to 50 W and the ablation time was extended to 90 seconds. During RF ablation there were no signs of inadvertent reactions. In the remaining 30 minutes of the waiting period, not a single PVC was detected.

Follow-up period

Telemetric observation during hospitalisation revealed total absence of PVCs after RF ablation. Beta-blocker therapy was stopped five days before the procedure and was not reinstated afterwards. During a six-month follow-up the patient reported a complete change in her life: she had no more symptoms and there were no recurrences of palpitations at all.

Case 2

A 60-year-old female presented with frequent palpitations causing near-syncope and fatigue. Her personal and family history was uneventful. Clinical examination was unremarkable. A resting 12-lead ECG showed frequent isolated monomorphic PVCs with a left bundle branch pattern. The PVCs had an inferior axis and transitions after V_3 (figure 1B) suggesting a successful ablation site in the RVOT.³ Twenty-four hour Holter

ECG recordings demonstrated frequent monomorphic PVCs (8739/24 hours). Sustained arrhythmias were never documented. Echocardiography showed no significant structural or functional abnormalities.

Electrophysiology and mapping procedure

The procedure set-up was the same as in case 1 except for the arterial access. Using the MNS to guide the catheter, the earliest activation by the PVCs was detected in the RVOT and pace-mapping showed perfect 12 out of 12 lead ECG similarity with the clinical PVCs.

Ablation procedure

RF ablation using gradually increasing output was performed, similar to case 1. The PVCs suddenly disappeared and did not reappear during the procedure. No complications occurred.

Follow-up period

No PVCs reoccurred during hospitalisation and β -blocker therapy was not reinstated. During a six-month follow-up the patient reported no palpitations, fatigue or near-syncope.

Case 3

A 69-year-old male presented with frequent palpitations. Beta-blocker therapy was discontinued because of worsening of his chronic obstructive pulmonary disease. His family history was uneventful. Clinical examination was unremarkable. A resting 12-lead ECG showed frequent isolated monomorphic PVCs with a right bundle branch block pattern. The PVCs had an inferior axis and already large R wave amplitude in V_1 (figure 1C) suggesting a successful ablation site in the LVOT.³ Twenty-four hour Holter ECG recordings demonstrated frequent monomorphic PVCs (35,000/24 hours). Sustained arrhythmias were never documented. Echocardiography showed only minor mitral valve insufficiency.

Electrophysiology and mapping procedure

The procedure set-up was the same as in case 1. Using the MNS to guide the catheter, the earliest activation of the PVCs was detected in the LVOT and pace-mapping was performed again showing perfect 12 out of 12 lead ECG similarity with the clinical PVCs.

Ablation procedure

RF ablation using gradually increasing output was performed, similar to case 1. The bigeminy suddenly disappeared and did not reappear during the procedure. No complications occurred.

Follow-up period

No PVCs reoccurred during hospitalisation and no antiarrhythmic drugs were reinstated. During a six-month follow-up the patient reported no more palpitations.

Methods: magnetic navigation

The MNS is combined with a monoplane fluoroscopy system (AXIOM Artis, Siemens). The MNS consists of two permanent magnets situated on either side of the patient, which are computer-controlled via a workstation (Navigant, Stereotaxis, St. Louis, MO, USA) (figure 2) to allow for changes in the orientation of a stable magnetic field within the chest of the patient.⁶ A combined field strength of 0.08 T is produced in navigation mode. As navigation is best performed with a fixed table position, this must be optimised prior to the start of magnetic navigation. When the magnets are positioned next to the patient, only limited angulation of the C-arm is possible ($\sim 28^\circ$ in the right and left anterior oblique angulations). Remote catheter advancement and retraction from the control room was performed using a catheter advancer system (Cardiodrive™, Stereotaxis, St. Louis, MO, USA), positioned on the upper anterior thigh. Remote control of the fluoroscopy system is also performed from the control room. The mapping and ablation catheters are equipped with three small permanent magnets within the distal tip segment that align themselves with the direction of the externally controlled magnetic field, allowing

effective catheter orientation. By changing the orientation of the outer magnets relative to each other, the orientation of the magnetic field changes and thereby leads to deflection of the catheter. After the magnets are brought in next to the patient, the physician is free to leave the room and performs the rest of the procedure from the control room. A single nurse remains with the sedated patient to monitor vital signs and administer drugs when required.

Discussion

Reports on the use of the MNS in treatment of outflow tract related arrhythmias are scarce. However we experienced some major advantages when using the MNS in these settings.

Difficulties in treatment of outflow tract tachycardias

Catheter ablation in outflow tract regions using standard catheters has some limitations. Inability to reach the origin of the focal tachycardia or instability of the ablation catheter can cause procedural failure. A stable catheter position is mandatory for performing accurate pace-mapping and indispensable for a successful ablation, also in these difficult-to-reach areas. The use of manually controlled, relatively stiff RF ablation catheters carries the imminent risk of perforation, especially in these thin-walled regions. RF ablation at the LVOT and ASC in particular can cause obstruction of the left main coronary artery or can cause damage to the aorta and the aortic valve.

Potential advantages of the MNS

The use of the remote MNS for RF ablation in outflow tract regions combines several advantages.⁶⁻⁸ The soft and flexible magnetic navigation catheter allows access to regions that are otherwise practically inaccessible; moreover, the chance of perforating the myocardial wall with the extremely floppy catheter tip is very small. Very precise target or vector navigation can be achieved with an accuracy up to 1 mm or 1° and as long as the magnetic field is applied the catheter will remain at the desired location. In particular, in the first case where the ablation target was located extremely close to the ostium of the left main coronary artery as depicted in figure 3, the use of a standard manually manipulated catheter could have damaged these structures. This advantage is particularly important when dealing with young patients suffering from a relatively benign disease such as described in case 1. Increasing procedural safety can lower the threshold for performing these interventions which are mainly aimed at improving symptoms.

In order to define the precise origin or the mechanism of the arrhythmia the construction of an electro-anatomical (CARTO®) map can be useful. The more points taken from the region of interest, the more valuable the information gained will be. The MNS allows construction of very dense and reliable electro-

anatomical maps: electrical and anatomical properties of points separated by only 1 mm can be acquired separately as remote steering allows displacement of the catheter with a precision of 1 mm and due to the applied magnetic field the catheter tip remains at the desired location during acquisition of the information.⁹

Additionally, different locations can be stored in the workstation of the MNS and exact re-navigation is accomplished by reapplying these vectors. In doing so, the remote steering of the magnetic catheter has the potential to decrease procedural times and patient fluoroscopy exposure. Obviously the physician's radiation dose is extremely low as practically all catheter movements are performed remotely.

Limitations

Although higher numbers of patients are required to clearly demonstrate feasibility and safety of ablation in this region, we strongly believe that the use of the MNS has some unique features that could make radiofrequency ablation in the outflow tract region safer, easier and more accurate.

Conclusion

The use of the remote MNS for RF ablation in outflow tract regions combines catheter flexibility and stability, steering accuracy and reproducibility to navigate to a desired location with a low probability of perforating the myocardium.

In conclusion, this report supports the idea of using advanced MNS technology during radiofrequency

ablation in difficult-to-reach and potentially dangerous positions such as the outflow tract region in general and the ASC with close proximity to the coronary arteries in particular. ■

References

- 1 Belhassen B. Radiofrequency Ablation of 'Benign' Right Ventricular Outflow Tract Extrasystoles. *J Am Coll Cardiol* 2005;**45**:1266-8.
- 2 Kalavakolanu S, Rao HB, Kumar DN, Calambur N. Successful ablation of aortic cusp tachycardia from right ventricle outflow tract using a superior approach. *J Interv Card Electrophysiol* 2006;**16**:187-9.
- 3 Ouyang F, Fotuhi P, Ho SY, Hebe J, Volkmer M, Goya M, et al. Repetitive Monomorphic Ventricular Tachycardia Originating From the Aortic Sinus Cusp. *J Am Coll Cardiol* 2002;**39**:500-8.
- 4 Friedman PL, Stevenson WG, Bittl JA, Simon DI, Kay GN, Lerman BB, et al. Left main coronary artery occlusion during radiofrequency catheter ablation of idiopathic outflow tract ventricular tachycardia (Abstract). *Pac Clin Electrophysiol* 1997;**20**:1184.
- 5 Pons M, Beck L, Leclercq F, Ferriere M, Albat B, Davy J-M. Chronic left main coronary artery occlusion: A complication of radiofrequency ablation of idiopathic left ventricular tachycardia. *Pac Clin Electrophysiol* 1997;**20**:1874-6.
- 6 Thornton AS, Janse P, Theuns DAMJ, Scholten MF, Jordaens LJ. Magnetic navigation in AV nodal re-entrant tachycardia study: early results of ablation with one- and three-magnet catheters. *Europace* 2006;**8**:225-30.
- 7 Thornton AS, Res J, Mekel JM, Jordaens LJ. Use of advanced mapping and remote magnetic navigation to ablate left ventricular fascicular tachycardia. *Pac Clin Electrophysiol* 2006;**29**:685-8.
- 8 Thornton AS, Jordaens LJ. Remote magnetic navigation for mapping and ablating right ventricular outflow tract tachycardia. *Heart Rhythm* 2006;**3**:691-6.
- 9 Ernst S, Ouyang F, Linder C, Hertting K, Stahl F, Chun J, et al. Initial Experience With Remote Catheter Ablation Using a Novel Magnetic Navigation System. *Circulation* 2004;**109**:1472-5.