EMERGING TECHNIQUES

Improved Signal Interpretation using Mini Electrodes during Ablation of Right Atrial Arrhythmia in Structural and Congenital Heart Disease

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ABSTRACT. Catheter ablation is a routine management strategy for cavotricuspid isthmus-dependent intra-atrial re-entrant tachycardia. Patients with structural heart disease commonly have re-entrant circuits that do not involve the cavotricuspid isthmus, and can be more challenging to cure with catheter ablation. We illustrate the advantages of catheter ablation of intra-atrial re-entrant tachycardia in these patients using a novel catheter that has mini electrodes within the ablation tip.

KEYWORDS. atrial flutter, congenital heart disease, mini electrodes, radiofrequency ablation, structural heart disease.

Introduction

Intra-atrial re-entrant tachycardia (IART) involving the cavotricuspid isthmus (CTI) is a common arrhythmia that can be cured by catheter ablation across the CTI. Such a strategy is routinely recommended and performed as a first-line strategy for those patients with either recurrent or persistent arrhythmia.1 Catheters traditionally used for this ablation consist of large (8–10-mm)-tip non-irrigated or 4-mm-tip open irrigated systems. Large-tip catheters have been demonstrated to reduce procedure duration compared with open irrigated 4-mm-tip catheters,3 however, the large tip can make differentiation between near-field and far-field myocardial signals challenging.

A novel 8-mm-tip non-irrigated radiofrequency ablation catheter with mini electrodes, IntellaTip Micro Fidelity (MiFi) XP (Boston Scientific, Boston, MA), has been demonstrated to enhance near-field myocardial signal identification.4 In addition to the standard distal and proximal bipoles, this catheter has three 1.19-mm mini electrodes arranged radially at 120 degrees to each other, 2 mm from the catheter tip (Figure 1). These mini electrodes are positioned such that they are in the midpoint of the ablation lesion created compared with the conventional distal bipole, where the ablation lesion is distal to the signals obtained (Figure 2). The IntellaTip MiFi XP catheter is safe and effective in CTI ablation, during both first-time and re-do procedures.5,6 IART in the presence of congenital heart disease, or following cardiac surgery for structural heart abnormalities, is commonly non-CTI-dependent and can involve scar associated with previous surgery or atrial substrate.7 Multiple circuits frequently exist in the same patient and the differences in rate and electrogram morphology may be subtle. This paper reports the incremental benefit of the mini electrodes in the management of both CTI-
non-CTI-dependent IART in adults with structural and congenital heart disease.

Case 1

This patient is a 24-year-old male, with coarctation of the aorta and severe mitral regurgitation, who underwent a subclavian flap repair for his coarctation and mitral valve repair before his first birthday. He subsequently developed progressively severe mitral regurgitation, and underwent a mitral valve replacement using a 25-mm Carbomedics (Sorin Group, Milan, Italy) prosthesis at the age of 16 years. Two years later he experienced recurrent palpitation with electrocardiogram (ECG) documenting IART. At the age of 20 years he underwent an electrophysiology study, proving the IART to be CTI-dependent, which was managed by catheter ablation using a 4-mm-tip open irrigated ablation catheter. He had been well for 3 years following this, but then developed recurrent palpitation, with ECG again documenting IART. He came forward for a repeat electrophysiology study with a view to catheter ablation as management for his recurrent IART.

He was in sinus rhythm on arrival in the electrophysiology laboratory. A deflectable decapolar catheter was positioned within the coronary sinus, and a fixed Courand curve quadrupolar catheter was positioned lateral and superior within the right atrium. A geometry and voltage map of his right atrium was created using the Velocity (St. Jude Medical, St. Paul, MN) three-dimensional (3D) mapping system with an Inquiry AFocus II catheter (St. Jude Medical). There was evidence for bidirectional conduction across the CTI, and non-sustained typical IART was induced. A CTI line was created from the tricuspid annulus to the inferior vena cava in a six o’clock position when viewed 40 degrees to the left anterior oblique view using a 65-mm 3.5-mm-tip open irrigated Tacticath Quartz (St. Jude Medical). Sixty-second 35-W lesions were created with greater than 10g of contact force at each lesion. Bidirectional block could not be achieved and a 10-mm-tip Intellatip MiFi XP catheter was used to identify a gap in this line. A single 100-W, 60°C lesion at this site resulted in bidirectional block across the CTI (Figure 3a).

Subsequent atrial stimulation induced sustained IART. Entrainment mapping demonstrated this to propagate around the lateral right atrium at a site of previous atriotomy. The 10-mm IntellaTip MiFi XP catheter was...
used to create a line of ablation from the lateral tricuspid annulus to the inferior border of this atriotomy scar (Figure 3b). IART termination occurred during ablation, and the ablation strategy was completed during sinus rhythm. At the onset of ablation during sinus rhythm, local signals, as seen by the mini electrodes, were seen to exhibit a signal of injury prior to becoming split (Figure 4). No arrhythmia was inducible following this line of ablation.

**Case 2**

This patient is a 65-year-old male who had a mitral valve repair and pericardial patch repair of a small secundum atrial septal defect 2 years earlier and dual-chamber permanent pacemaker 6 years earlier as management for sinus node dysfunction. The mitral valve repair was performed as management for severe mitral regurgitation as a consequence of P2 prolapse in the context of left ventricular dilation with preserved systolic function. Right ventricular size and function were normal. Postoperatively he had mild mitral regurgitation and moderate impairment of left ventricular systolic function with an ejection fraction of 40–45%. No atrial arrhythmia had been observed preoperatively, and a single self-limiting paroxysm of atrial fibrillation was observed in the immediate postoperative period. He had onset of persistent IART 1 year following surgery, and despite beta-blockade his pacemaker rate histogram log demonstrated poor ventricular rate control. He therefore came forward for electrophysiology study with a view to catheter ablation as management of IART. IART was present at the time of the electrophysiology study. A deflectable decapolar catheter was positioned within the coronary sinus and the atrial activation pattern during was from proximal to distal. Entrainment mapping proved this IART to be CTI-dependent. A 10-mm IntellaTip MiFi XP catheter was taken, and a line of ablation was created from the tricuspid annulus to the inferior vena cava using discontinuous 60-s 100-W 60°C lesions. During the sixth lesion there was clear splitting of the local electrogram seen on the mini electrodes, which was associated in a step out in tachycardia cycle length from 238 ms to 274 ms (Figure 5). Subsequent entrainment mapping demonstrated the new IART was non-CTI-dependent, and was propagating about lateral right atrial scar at the site of previous atriotomy. A line of ablation was created from the inferior aspect of this scar.
to the inferior vena cava. Tachycardia terminated to sinus rhythm during this ablation. Bidirectional block across the CTI was then proven.

Case 3
This patient is a 24-year-old female with Scimitar syndrome, who had a complete repair at the age of 6 years. A small atrial septal defect persisted following the repair, with minimal left to right shunting, and has therefore been managed expectantly. At the age of 19 years she developed complete heart block, and had a dual-chamber pacemaker implanted via the left subclavian vein with the ventricular lead positioned at the apex of the right ventricle. There has been no recovery of atrioventricular node conduction, and her right ventricle is 100% paced. She developed persistent IART 1 year earlier, and coincident with this has seen a deterioration in left ventricular systolic function and mild heart failure symptoms. At present she has severe impairment of left ventricular systolic function with an ejection fraction of 25–30%. She came forward for an electrophysiology study with a view to catheter ablation of her IART, in order to restore atrial contractility, prior to upgrading her pacemaker to cardiac resynchronisation therapy with a defibrillator.

She was in IART on arrival in the electrophysiology laboratory. A deflectable decapolar catheter was positioned within the coronary sinus, where the atrial activation pattern during flutter was from proximal to distal. Entrainment mapping proved this IART to be CTI-dependent. A 10-mm IntellaTip MiFi XP catheter was taken, and a line of ablation was created from the tricuspid annulus to the inferior vena cava using discontinuous 60-second 100-W 60°C lesions. Sinus rhythm was restored, and bidirectional block achieved with three lesions. A geometry and voltage map of her right atrium was created using the Velocity 3D mapping system with an Inquiry AFocus II catheter. This demonstrated minimal atrial scarring, and no arrhythmia was inducible following this line of ablation.

Discussion
Ablation of IART in patients with structural and congenital heart disease can be challenging because of a number of factors. This includes the presence of anatomical abnormalities, fibrosis from suture lines, and...
combination with areas of naturally occurring functional conduction block such as the crista terminalis. These challenges can become further compounded by atrial dilation, fibrosis, and/or hypertrophy if adverse hemodynamic conditions persist. Our cases demonstrate the ability of the 10-mm IntellaTip MiFi XP catheter to achieve acute procedural success in patients with structural and congenital heart disease. As seen in those with structurally normal hearts, we have found the electrograms provided by the mini electrodes useful in identifying gaps in lines of ablation. As demonstrated in the second case, we have also found these electrograms useful for suggesting a change in IART location upon achieving a line of block by ablation. Here the tachycardia cycle length increase was associated with split atrial signals documented by the mini electrodes. We recommend careful evaluation of the IART circuit location when this phenomenon is observed. We also report on the mini electrode finding of a local signal of injury at the onset of ablation. The clinical significance of this is uncertain, though it seems likely to represent adequate catheter–tissue contact.

Conclusions
These cases demonstrate the technical feasibility of achieving acute procedural success using mini electrode-guided ablation for both typical and atypical right atrial flutter in patients with structural and congenital heart disease. Signals from these electrodes also provide additional useful information about local injury, and about the development of local block associated with a change in rhythm. Additional data are required to determine if this catheter is superior to existing methods for treating right atrial flutter in these patients.