Transient ST-segment-elevation during pulmonary vein ablation using circumferential coiled microelectrodes in a prospective multi-centre study

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Aims Paroxysmal atrial fibrillation (PAF) is predominantly triggered by focal ectopies located within the pulmonary veins (PV). The BITMAP Study (Breakthrough and Isolation Trial: Mapping and Ablation of Pulmonary Veins) investigated prospectively the safety and efficacy of a catheter design with circumferential mapping and ablation electrodes. We report the phenomenon of ST-segment-elevation during catheter placement in the left atrium (LA) and superior PVs in this multi-centre study.

Methods and results Forty-three patients (57 ± 10 years) with PAF were included in this study. Radiofrequency catheter (RFC) ablation supported by the 4F REVELATION Helix microcatheter (Cardima Inc., Freemont, CA, USA) with eight distal-coiled microelectrodes for bipolar mapping and ablation. RFC was applied at the ostial region of PV (30 W, 45–50 °C) with a maximum of four RFC applications per electrode. In four of the 43 patients from three centres, we recorded the occurrence of ST-segment-elevation greater than 0.2 mV and accompanying left thoracic discomfort. The ECG changes and the symptoms started abruptly and lasted for 4.2 ± 2.2 min. Pericardial effusion could instantaneously be excluded by echocardiography in all cases. Coronary angiograms were performed in three patients with the longest episodes; no thrombotic material or air emboli were present. The symptoms and the ECG changes resolved completely in all patients.

Conclusion The phenomenon of ST-segment-elevation during LA- and PV-mapping in patients with PAF may be a common occurrence. In this prospective multi-centre trial, we demonstrated the reversibility of this phenomenon; no cardiovascular or cerebral damage was reported during both the procedure and the follow-up. Although the mechanism is still unclear, vasospasm may contribute to this phenomenon because of autonomic dysregulation.

Keywords Catheter ablation; Atrial fibrillation; ST-segment-elevation; Pulmonary vein

Introduction

Since its introduction, radiofrequency (RF) ablation has been widely used to treat triggers located in the pulmonary veins (PV) in people who suffer from paroxysmal atrial fibrillation (PAF).1 Complications of RF ablation targeting the initiating triggers inside the PV or using an ostial approach to disconnect PVs have been described and investigated, especially the development of pulmonary vein stenosis and pulmonary vein occlusion.2,3 Recently, a neurological case report of cerebral air embolism complicating cardiac ablation procedures,4 as well as the risk of thrombo-embolic cerebrovascular events5 have been published. We report the occurrence of another potentially hazardous complication in patients undergoing ablation for PAF. In this multi-centre study, investigating a new catheter design for bipolar mapping and ablation, we recorded the phenomenon of transient ST-segment-elevation in the inferior leads and the symptoms of angina pectoris during catheter placement and mapping in the left atrium (LA) and superior PVs.

Methods

Patients between 21 and 80 years were included in this study with evidence of symptomatic PAF. Atrial fibrillation had to be...
documented by at least two 12-lead ECGs, and at least two refractory treatments with anti-arrhythmic drugs from different classes were mandatory. Exclusion criteria included LA dilatation of more than 50 mm, patients with significant structural heart disease, or previous ablation of PAF.

After approval from the Local Ethics Committee and informed consent obtained from the patients, a 4F fixed wire microcatheter (REVELATION Helix, Cardima Inc., Fremont, USA) with eight coiled platinum electrodes (length 6 mm) and an antenna tip was used for mapping and ablation.

After standard trans-septal puncture and introduction of the trans-septal sheath a deflectable guiding catheter (Naviport, Cardima Inc.) was introduced and a continuous heparinized saline infusion was administered to prevent embolism. During the procedure, the ACT maintained a range between 250 and 300 s using either heparin during the continuous saline administration or a heparin bolus injection. After angiography of PVs using the Naviport catheter, the Helix catheter (15 mm or 20 mm) was placed at the ostium of the PVs (Figure 1). Local electrograms were analysed during sinus rhythm and during programmed atrial stimulation and the electrical breakthrough was identified. The sequential temperature controlled application of unipolar RF energy was administered at the ostial region of the pulmonary veins up to 30 W with 45-50°C with a duration of 60–90 s. The selected endpoints of the ablation procedure were complete PV disconnection or the reduction of the PV amplitude by at least 50%.

Results

Basic data

Forty-three patients (25 male) were included in this study with a mean age of 56.7 ± 9.7 years. Of this, 74% of the patients had idiopathic AF, whereas a quarter of the patients presented with underlying heart disease: CAD (n = 5), hypertension (n = 3), implanted pacemaker (n = 3), for bradycardia (n = 2), or sick-sinus-syndrome (n = 1). Classified according to the New York Heart Association (NYHA) classification, 16 patients (37%) had no limitations (NYHA 1), whereas 27 patients (63%) had discrete limitations of activity (NYHA 2).

Acute results

A total number of 129 PVs were targeted for PV ablation. In 113 PVs one of the two endpoints were reached: a complete abolition of PV potentials was possible in 45 PVs (35%), an amplitude reduction of greater than 50% of PV amplitude in 68 cases (53%). In 16 PVs no endpoints could be reached (12%), and no PV potentials were present in 43 PVs.

Ablation procedure and acute complications

During the procedure and after the trans-septal puncture and placement of the sheath through the septum, it was attempted to place the guiding wire and then the Helix ablation catheter, inside the Naviport catheter, near the pulmonary veins. In four of the 43 patients from three centres, we recorded the occurrence of ST-segment-elevation greater than 0.2 mV and angina pectoris (Table 1). The ECG changes and the symptoms started abruptly and lasted for 4.2 ± 2.2 min. In three of four cases we recorded the ECG changes in lead II, III, and aVF, and in one case also in lead V2–V4 (Figure 1). Pericardial effusion could be excluded instantaneously by echocardiography in all cases. Coronary angiograms were performed in three patients (Patient 1, 3, and 4) who presented with the longest episodes, but neither thrombotic material nor emboli were present during the selective angiography. The angiography started in these cases quickly, averaging 3–5 min after the onset of ischaemia. The symptoms and the ECG changes resolved completely in all four patients (Table 2). The administration of intravenous nitroglycerin was performed in two patients, the symptoms and ECG changes resolved immediately. During the follow-up of the study at 3, 6, and 12 months these four patients showed no further signs of myocardial ischaemia and were free of episodes of angina pectoris.

Discussion

The current study demonstrates that transient ST-segment-elevation may be an occurrence in patients undergoing left atrial ablation for treatment of PAF. In this multicentre trial, these effects were not user dependent. Manipulation of the guiding wire after successful trans-septal puncture as well as the antenna tip of the ablation- and mapping-catheter in the left atrium were possibly related to this effect.

The observation of potentially life-threatening ST-segment-elevation during pulmonary vein isolation has been first described using a through-the-balloon circumferential ultrasound ablation system in a catheter feasibility trial. The authors attributed this effect to coronary spasm triggered by air embolism. Three cases of myocardial ischaemia during ablation of left atrial tachycardia and pulmonary veins for atrial fibrillation have been reported. The authors attributed this to the occurrence of spasm, which could be reversed with intracoronary nitrates. In two cases in our study, the administration of intravenous nitroglycerin during the angiography led to an immediate reversal of ischaemic symptoms, and also the ECG changes resolved immediately. In our view, this supports the fact that the aetiology of ischaemia was not caused by air embolism.
There have been two reports of ischaemic complications during catheter ablation, both concerning ablation of accessory pathways located at the left free-wall.\textsuperscript{8,9}

In the cases we present, coronary angiograms were performed within the timeframe that was previously published, but we could not detect direct or indirect evidence of air embolism such as slow flow within the coronary arteries.

We, therefore, conclude that a different mechanism may account for this.

The same transient ischaemic effects after catheter ablation of a left free-wall accessory pathway in an infant was reported recently from a Spanish paediatric electrophysiology centre,\textsuperscript{10} using a trans-septal approach. Coronary angiography showed normal coronary arteries; in addition they also could not find evidence hinting at air embolism.

Nevertheless, coronary air embolism is a known complication in invasive cardiac procedures like coronary angiography\textsuperscript{11} and interventional angioplasty,\textsuperscript{12} as well as in balloon mitral valvuloplasty.\textsuperscript{13} Continuous saline perfusion of the sheath should prevent air bubbles entering the system; also the occurrence of ischaemia was in no case related to the exchange of catheters or guide wires.

Although we cannot totally rule out air embolism being the cause of ischaemia, a limitation of our study might have been the use of a 10F sheath for the trans-septal puncture and passage across the septum to allow catheter movement with the guiding catheter Naviport and the 4F Helix catheter (Figure 1). The large diameter of the sheath may be a contributing factor for the possible entry of air into the system because other experienced interventionalists have not or very seldom encountered this problem using 8F sheath.

There have been numerous case reports and investigations regarding the differential diagnosis of coronary artery spasm vs. air embolism.\textsuperscript{14–17} Interestingly, in our cases, the ECG changes occurred dominantly in the inferior leads but the question remains open why only these leads were affected. Another description of ischaemic events during

### Table 1 Basic data

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Sheath</th>
<th>Time after TSP (min)</th>
<th>Duration of ST-elevation (min)</th>
<th>Localization of ST-elevation in 12-lead ECG</th>
<th>Catheter</th>
<th>Hypotension Y/N</th>
<th>Bradycardia Y/N</th>
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<td>65</td>
<td>St. Jude 10F</td>
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<td>II, III, aVF</td>
<td>GW</td>
<td>N</td>
<td>N</td>
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<tr>
<td>2</td>
<td>M</td>
<td>59</td>
<td>Cook 10F</td>
<td>64</td>
<td>22</td>
<td>II, III, aVF V2-V4</td>
<td>GW</td>
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<td>N</td>
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<tr>
<td>3</td>
<td>F</td>
<td>62</td>
<td>Cook 10F</td>
<td>33</td>
<td>4</td>
<td>II, III, aVF</td>
<td>GW</td>
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<td>N</td>
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<tr>
<td>4</td>
<td>M</td>
<td>44</td>
<td>DAIG 10F</td>
<td>45</td>
<td>4</td>
<td>II, III, aVF</td>
<td>HELIX</td>
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M, male; F, female; TSP, trans-septal puncture; GW, guide wire; H, helix catheter; Y, yes; N, no.

### Table 2 Heart rate before, during, and after ischaemia

<table>
<thead>
<tr>
<th>Patient</th>
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<th>HR during ST</th>
<th>HR after ST</th>
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<td>46</td>
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<tr>
<td>4</td>
<td>73</td>
<td>Paced CS</td>
<td>Paced CS</td>
</tr>
</tbody>
</table>

Heart rate in b.p.m. before, during and after ST-segment-elevation. Paced CS, pacing in coronary sinus because of sinus arrest.

Figure 2 (A–C) 12-lead ECG before, during, and after ischaemia. (A) 12-lead ECG from Patient 3 at rest before ablation. (B) ST-segment-elevation in lead II, III, and aVF; 33 min after successful trans-septal puncture. All pulmonary veins were angiographically displayed. While manoeuvring the guide wire from the right upper PV to the left upper PV, the ischaemic events started and lasted for 4 min. The heart rate increased from 55 to 66 min, the 62-year-old female patient complained of left thoracic pain. No hypotensive periods were recorded during or after the event. Immediately after the ST-segment-elevation vanished, the patient was symptom-free and (C) was recorded.
interventional cardiac procedures has included the closure of atrial septal defects with the Amplatzer septal occluder. 18–20

One aspect that interventional cardiac procedures like closure of atrial septal defects and left atrial ablation procedures have in common is the puncture and manipulation of the septum as well as the insertion of one or two sheaths across the septum to reach the left atrium. During the course of the intervention, multiple manipulations of the catheters as well as the sheath itself are required, possibly involving the atrial septum and adjacent structures. In our study, standard trans-septal puncture with sheath and trans-septal needle was performed without recording the pressures.

Two decades ago a complication of trans-septal catheterization and the simultaneously recorded angiography showed so-called slow flow in the coronary artery, 21 a reflex increase in arteriolar resistance with the transient ischaemia was suspected. Because no obstruction has been verified yet, an autonomic response to the manipulations of the septum and the dorsal and lateral wall of the left atrium seems likely. Anatomically, histologically, and histochemically this has been well characterized in humans and in animal species. 22–26 In short, the atrial ganglionated plexuses have been well characterized in humans and in animal species. 22–26 In short, the atrial ganglionated plexuses have been well characterized in humans and in animal species.

In short, the atrial ganglionated plexuses were identified at the dorsal atrial wall, the interatrial septum, the left superior caval vein, 23 as well as the intrinsic cardiac ganglia and their vagal innervation at the rostro-lateral interatrial septum. 24 In addition, this has been reported as a Bezold–Jarisch-like reflex during trans-septal puncture, a mechanical effect on the interatrial vagal network. 25 These are the locations we suspect to be part of an autonomic mechanism from the results of our clinical work as described earlier.

Clinical implications

The phenomenon of ST-segment-elevation can happen during LA- and PV-mapping in patients with PAF. So far, the ischaemia resolved completely in all of our cases and the reported cases in the literature, although each individual case represents an emergency-like situation in the electrophysiology laboratory and should be handled accordingly. We conclude that manipulations with catheters when working in the left atrium should be minimized.

References


