Electrical connection between ipsilateral pulmonary veins: Prevalence and implications for ablation and adenosine testing

Fabien Squara, MD,[*] Ioan Liuba, MD,[†] William Chik, MD,[†] Pasquale Santangeli, MD,[†] Shingo Maeda, MD, PhD,[†] Erica S. Zado, PA-C, FHRS,[†] David Callans, MD, FHRS,[†] Francis E. Marchlinski, MD, FHRS[†]

From the [*]Department of Cardiology, Pasteur University Hospital, Nice, France, and [†]Electrophysiology Section, Cardiovascular Division, Hospital of the University of Pennsylvania, Philadelphia.

BACKGROUND Anatomic studies have reported the presence of shared myocardial fibers between approximately half of ipsilateral pulmonary veins (IPVs).

OBJECTIVE The purpose of this study was to assess the prevalence of electrical connection between IPVs and the impact of antral isolation with or without carina ablation on IPV connection.

METHODS Thirty consecutive patients undergoing atrial fibrillation (AF) ablation (14 redo) were included. Wide antral pulmonary vein isolation (PVI) was performed with or without carina lesions. For each PV set, IPV electrical connection was assessed before and after PVI by pacing and recording from the ostium of both IPVs using a circular mapping catheter and the ablation catheter. Adenosine was given after PVI to assess for acute PV reconnection.

RESULTS Before PVI without preceding AF ablation procedure, all the PVs had ipsilateral connection albeit frequently via the left atrium. After PVI, 65.6% of the IPVs were connected without carina ablation vs 17.7% if prior carina ablation ($P = .001$). Left vs right IPVs were connected in 57.1% and 72.2% of the cases without carina ablation, respectively, vs 30% and 0% of cases with carina ablation ($P = .19$ and $P = .001$). When transient PV reconnection was demonstrated during adenosine challenge, connected IPVs uniformly demonstrated simultaneous reconnection.

CONCLUSION Electrical connection between IPVs is uniformly demonstrated before any ablation. Two-thirds of the IPVs are connected after antral PVI, and carina ablation decreases IPV connection. Connected IPVs consistently show the same response to adenosine challenge; therefore, a single catheter positioned in either of the IPVs with electrical connection is sufficient to confirm reconnection in both veins.

KEYWORDS Atrial fibrillation; Ablation; Pulmonary vein; Connection

ABBREVIATIONS **AF** = atrial fibrillation; **CMC** = circular mapping catheter; **EAM** = electroanatomic mapping; **EGM** = electrogram; **ICE** = intracardiac echocardiography; **IPV** = ipsilateral pulmonary vein; **LA** = left atrium; **LIPV** = left inferior pulmonary vein; **LSPV** = left superior pulmonary vein; **PV** = pulmonary vein; **PVI** = pulmonary vein isolation; **RA** = right atrium

(Heart Rhythm 2015;12:275–282)

Introduction

Anatomic studies on normal human hearts have reported that 56% of the left pulmonary veins (PVs) and 39% of the right PVs share crossing myocardial connections, consistently running through the intervenous isthmus or carina.[1] Similarly, direct electrical connection between inferior and superior ipsilateral pulmonary veins (IPVs) has been described in several case reports[2–4] and in 2 studies.[5,6] The overall prevalence of electrical connections between ipsilateral PVs after ostial pulmonary vein isolation (PVI) has been reported to be only 10%[5] to 14%,[6] thereby raising the possibility that connecting fibers between the superior and inferior ipsilateral veins may be interrupted during carina ablations.

No previous study has specifically addressed the prevalence of electrical connections between IPVs and the impact of wide ipsilateral circumferential ablation with or without carina ablations. The present study was designed to prospectively evaluate the prevalence of IPV connections and the impact of catheter ablation and adenosine challenge on IPV connections.

Methods

Patient selection

Consecutive patients undergoing first-time or repeat atrial fibrillation (AF) ablation at the Hospital of the University of

Funded in part by the Mark S. Marchlinski and F. Harlan Batrus Research Funds. Dr. Squara has received a research grant from the Societé Francaise de Cardiologie, Sorin Group, and Endosense. **Address reprint requests and correspondence:** Dr. Francis E. Marchlinski, Electrophysiology Section, Cardiovascular Division, Hospital of the University of Pennsylvania, 3400 Spruce Street, 9 Founders Cardiology, Philadelphia, PA 19104. E-mail address: francis.marchlinski@uphs.upenn.edu.

1547-5271/$-see front matter http://dx.doi.org/10.1016/j.hrthm.2014.11.003

Pennsylvania were enrolled. Each patient's demographics were recorded, including age, gender, comorbidities, medications, and type of AF. For patients presenting for a redo ablation, the previous procedures were reviewed in detail to determine the ablation strategy, namely, PVI alone or associated with other ablation lines, and presence of previous carina ablations. All patients underwent preprocedural imaging assessment with either cardiac computed tomographic scan or magnetic resonance imaging.

Ablation procedure

All procedures followed the institutional guidelines of the University of Pennsylvania Health System, and each patient signed written informed consent. Antiarrhythmic medications were discontinued 5 half-lives before the procedure, except amiodarone, which was discontinued at least 2 weeks before the procedure. Our AF ablation procedure has been previously described in detail.[7] In brief, 2 decapolar catheters were positioned in the coronary sinus and crista terminalis within the right atrium (RA), respectively. An intracardiac echocardiography (ICE) catheter (5.5–10 MHz, 8Fr, AcuNav, Biosense Webster, Diamond Bar, CA) was advanced through a 9Fr sheath in the femoral vein to the RA. Double transseptal punctures were performed under fluoroscopic and ICE guidance with a standard Brockenbrough needle. An irrigated ablation catheter and decapolar circular mapping catheters (CMCs) (Lasso, Biosense Webster; adjustable circumference 15–25 mm, 8-mm interelectrode spacing) were advanced into the left atrium (LA) through an Agilis and SL1 sheath, respectively. A bolus of unfractionated heparin was administered before the first transseptal puncture, and infusion was then titrated to maintain an activated clotting time >350 seconds for the duration of the procedure. Electroanatomic mapping (EAM) was performed using CARTO (Biosense Webster) or NavX (EnSite, St. Jude Medical, St. Paul, MN). The LA EAM was created using multielectrode mapping catheter or point-by-point acquisition using the NaviStar ThermoCool or ThermoCool SF catheter (Biosense Webster; 3.5-mm distal tip electrode, 2-mm ring electrode with 1-mm interelectrode distance) or CMC. Criteria for an adequate LA EAM were ≥ 100 points that were homogeneously distributed to create the entire chamber using a fill threshold ≤ 15 mm. Adequate catheter–tissue contact was ensured using a combination of intracardiac echocardiography, orthogonal fluoroscopy, and electrogram (EGM) characteristics. Anatomic structures were defined on the EAM, including the mitral valve and individual PVs. Computed tomography or magnetic resonance imaging segmented LA anatomy was merged with the EAM shell.

Bipolar signals were recorded between the distal electrode pair (filtered at 16–500 Hz). Unipolar signals were recorded between the distal tip of the ablation catheter (cathode) and the Wilson central terminal (anode; filtered at 1–240 Hz). Both signals were displayed at 100 mm/s on a digitalized EGM recording system (Prucka Engineering, GE Medical Systems, Milwaukee, WI) and the NavX system.

The PVI ablation strategy consisted of antral circumferential ablation with 2 ipsilateral wide rings. Additional focal ablations were applied targeting non-PV triggers if initiating AF. The standardized trigger protocol included cardioversion of induced or spontaneous AF and infusion of up to 20 μg isoproterenol for 15–20 minutes either before and/or after PVI was achieved. The procedural end-point was PVI with confirmed entrance and exit block, and elimination of all non-PV triggers resulting in AF. Carina ablations were performed when the earliest PV potential was at the carina, only when PVI could not be achieved after completion of the ablation ring, and after careful remap of the ring to ensure absence of gaps. Impedance controlled point-by-point radiofrequency ablation lesions were delivered. The end-point was elimination of the local bipolar EGM, targeting an impedance drop of 10–12 Ω and 20- to 40-second lesions depending on anatomic location. Reduced power duration settings (20–25 W for 20 seconds) were used for posterior wall ablation close to the esophagus.

Assessment of ipsilateral PV electrical connections

In this study, the terms "isolated PV" and "PV isolation" refer to the PV–LA connection and not to the ipsilateral PV–PV connection. IPV electrical connections were first assessed before PVI, then after PVI was achieved. The aim was to document direct electrical connections due to shared myocardial fibers. This step was performed in sinus rhythm. Patients in AF were cardioverted.

A standardized sequence of maneuvers was performed for each PV set before and after PVI. Specifically, the CMC was positioned at the ostium of the superior PV while the ablation catheter was located at the ostium of the inferior PV or vice versa. Correct positioning of the mapping catheters was validated by ICE. The CMC was then fully deployed to enable optimal electrode–PV contact. ICE and orthogonal fluoroscopy validated the ablation catheter contact. Bipolar pacing at a cycle length of 600 ms with an output of 10 mA/2 ms was sequentially performed at each dipole pair of the CMC. Identification of early near-field EGM at the same cycle length, as recorded by the ablation catheter in the IPV, was considered consistent with electrical connection between the IPVs (Figure 1).

During CMC pacing, local PV capture was thoroughly assessed using PV sleeve capture visualization on any of the CMC dipoles. If the PV was not isolated, we also used atrial capture visualization. Care was taken to recognize and exclude any far-field capture of the LA appendage or superior vena cava during pacing. The catheter positions were then reversed by placing the CMC in the inferior PV and the ablation catheter in the superior PV. The same standardized maneuvers were repeated. Importantly, we excluded from analysis all PV sets that could not show local capture of both IPVs during pacing from the CMC. An alternate method to assess IPV connections in isolated PVs