Effect of cryoballoon inflation at the right superior pulmonary vein orifice on phrenic nerve location

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BACKGROUND Cryoballoon catheter ablation was developed to simplify ablation for atrial fibrillation (AF). Initial enthusiasm for its widespread use has been dampened by phrenic nerve (PN) injury (PNI).

OBJECTIVE The purpose of this study was to assess the effect of cryoballoon inflation at the right superior pulmonary vein (RSPV) orifice on PN location and to elucidate the potential mechanism of PNI.

METHODS Twenty patients with paroxysmal atrial fibrillation underwent ablation performed with a second-generation 28-mm cryoballoon catheter. Before ablation, the pacing-determined PN course was delineated along the right atrium. PN location and its relation to the RSPV as well as RSPV surface distortions after balloon inflation were established with a NavX mapping system.

RESULTS During RSPV ablation, the inflated balloon surface extended anteriorly 6.3 ± 1.8 mm outside the RSPV. This narrowed the distance between the PN capture points in the RSPV vs PN location from 11.4 ± 5.0 mm to 7.5 ± 5.0 mm ($P = .0002$) and increased the PN capture area from 1.9 ± 1.3 cm^2 to 3.2 ± 1.8 cm^2 ($P = .0004$). Furthermore, the PN capture points shifted toward the orifice within the RSPV and after balloon inflation were located significantly closer to the orifice in the 3 patients with transient PNI than in those without PNI.

CONCLUSION Cryoballoon inflation at the RSPV orifice alters PV/left atrial surface geometry, reducing the distance between the energy delivery source and the PN and increasing PN area, possibly explaining the mechanism of PNI. PN pacing within the RSPV after balloon inflation may be useful for preventing PNI.

KEYWORDS Second-generation cryoballoon; Atrial fibrillation; Pulmonary vein isolation; Phrenic nerve injury

ABBREVIATIONS 3D = 3-dimensional; **AF** = atrial fibrillation; **CMAP** = compound motor action potential; **CT** = computed tomography; **LA** = left atrium; **PN** = phrenic nerve; **PNI** = phrenic nerve injury; **PV** = pulmonary vein; **RSPV** = right superior pulmonary vein; **SVC** = superior vena cava

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Introduction

Pulmonary vein (PV) isolation with a second-generation cryoballoon catheter has emerged as an effective alternative to conventional radiofrequency catheter ablation for atrial fibrillation (AF).[1,2] However, phrenic nerve (PN) injury (PNI) is the most frequently observed complication of cryoballoon ablation of right PVs, with a reported incidence of 6% to 11%.[1,2] Although methods for avoiding PNI, such as monitoring diaphragmatic motion and recording compound motor action potentials (CMAPs), have been proposed,[3] PNI may not be fully preventable despite an immediate interruption of ablation after abnormal diaphragmatic motion becomes apparent. Thus, it is important to delineate the precise course of the PN before cryothermal applications and to predict its proximity to the target right PVs.[4] Clinically, phrenic pacing from a catheter placed in the superior vena cava to the right atrium and in the right PVs to the left atrium (LA) is the only way to predict the relative distance from the PN.[5] However, the PN location varies among patients, and LA/PV distortion caused by balloon inflation may affect the locational relation between the targeted right superior pulmonary vein (RSPV) orifice and the PN.[6] This study was conducted to assess the effect of cryoballoon inflation at the RSPV orifice on PN location and to elucidate the potential mechanism of PNI.

Methods

Study patients

Twenty consecutive patients (10 men, 10 women; age 65.6 ± 8.9 years) who underwent second-generation cryoballoon catheter ablation for paroxysmal AF between September

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2014 and March 2015 were included in the study. All were treated at our institution. Adequate oral anticoagulation therapy was given for at least 1 month before the ablation procedure, and all antiarrhythmic drugs were discontinued for at least 5 half-lives before the procedure. The study was approved by the Institutional Review Board of Nihon University Itabashi Hospital, and all patients provided written informed consent for their participation.

Electrophysiologic study and cryoablation

Electrophysiologic study was performed with patients under conscious sedation achieved with dexmedetomidine and fentanyl. After vascular access was obtained, single transseptal puncture was performed, and intravenous heparin was administered to maintain an activated clotting time >300 seconds. The 3-dimensional (3D) geometry of the LA and the 4 PVs was reconstructed with an EnSite NavX mapping system (St. Jude Medical, Minneapolis, MN) from data obtained with a 20-pole circular mapping catheter (Inquiry AFocus II, St. Jude Medical). Thereafter, a 28-mm cryoballoon (ARC-Adv-CB, Arctic Front Advance. Medtronic PLC, Minneapolis, MN) with an inner lumen mapping catheter (Achieve, Medtronic) was inflated and advanced to each PV orifice through a steerable 15Fr sheath (FlexCath Advance, Medtronic). Once optimal PV occlusion, as assessed by contrast injection, was achieved, cryothermal energy was applied to each target PV, first for 180 seconds then for 120 seconds. Before cryoablation of the RSPV, the PN course was reconstructed on the 3D geometry by using the results from PN pacing, and the relation of the balloon to the PN location was assessed as described in the section of "assessment and measurement of PN location". A (SVC) decapolar catheter was advanced in the superior vena cava, and the PN was paced continuously during cryothermal energy application to the RSPV and the right inferior PV at a cycle length of 1000 ms, current of 25 mA, and pulse width of 2 ms. In addition to palpation of the diaphragmatic excursion, diaphragmatic CMAP was assessed for PNI monitoring. Details of the CMAP recordings were reported previously.[3] Cryothermal energy application was discontinued when either the diaphragmatic excursions decreased on palpation or a >30% reduction in CMAP amplitude occurred. After each cryoapplication, PV isolation was confirmed with a Lasso catheter (Biosense Webster, Diamond Bar, CA). If necessary, Lasso-guided touch-up lesions were created with an 8-mm-tip catheter (Freezor MAX, Medtronic). Thirty minutes after the last cryothermal application, 30 mg of adenosine triphosphate was administered for reassessment of PV entrance block, and exit block was confirmed by sequential pacing from the Lasso catheter.

Assessment and measurement of PN location

Details of the assessment and measurement of the RSPV orifice and PN location before and after balloon inflation are shown in Figure 1. Before RSPV cryoballoon isolation, the estimated course of the PN was delineated on the 3D mapping system according to the sites of PN capture by pacing from a decapolar mapping catheter placed in the superior vena cava (SVC) to the right atrium. Thereafter, the PN sites captured by pacing from the RSPV orifice to the LA were marked on the 3D LA/PV geometry before balloon inflation, and the PN capture area in the RSPV orifice was calculated. After the balloon was inflated, the decapolar mapping catheter was carefully manipulated around the balloon surface, which was now in contact with the endocardium at the RSPV orifice, and the PN capture area was reassessed by pacing from the RSPV orifice and LA (Figure 2). To minimize distortion by the mapping catheter, a 3D geometric image of the distorted RSPV surface was created during pullback of the mapping catheter. PN pacing

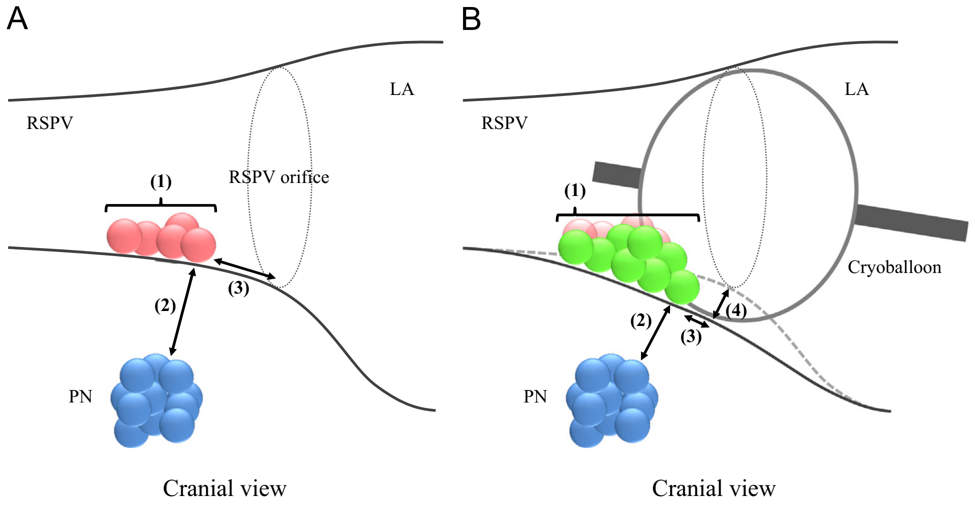

Figure 1 Schematic diagram of measurements before (**A**) and after (**B**) cryoballoon inflation. The left atrium (LA)/right superior pulmonary vein (RSPV) and virtual delineated phrenic nerve (PN; *blue tags*) are indicated. The following measurements were obtained: (1) PN capture area/points in the RSPV (*pink tags* before inflation, and *green tags* after inflation); (2) the shortest distance between the PN capture point closest to the RSPV orifice and the delineated PN location; (3) the shortest distance between the PN capture point closest to the RSPV orifice and the RSPV orifice; and (4) the distance between the anterior surface of RSPV orifice and that of interpolated RSPV orifice after balloon inflation.