Novel method for earlier detection of phrenic nerve injury during cryoballoon applications for electrical isolation of pulmonary veins in patients with atrial fibrillation

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BACKGROUND Diaphragmatic electrogram recording during cryoballoon ablation (CB-A) of atrial fibrillation is commonly used to predict phrenic nerve palsy (PNP).

OBJECTIVE The purpose of this study was to investigate a novel method for predicting PNP at an earlier stage to prevent sustained PNP.

METHODS A total of 197 patients undergoing CB-A were enrolled. We attempted to detect PNP using fluoroscopic images of diaphragmatic contractions and by monitoring diaphragmatic compound motor action potentials (CMAPs) provoked by superior vena cava (SVC) and left subclavian vein (LCV) pacing during CB-A for bilateral pulmonary veins (PVs). Pacing of the SVC and LCV was performed at 2 outputs, 1 exceeding the pacing threshold by 10% (MIN) and the other at maximum output (MAX). The time from freezing to the initiation of PNP, values of the CMAP amplitude, and severity of PNP were compared for the 2 outputs.

RESULTS There was a significant difference in the time from freezing to initiation of PNP between MIN and MAX pacing (25.7 ± 5.7 vs 81.3 ± 7.4 seconds, $P < .01$). CMAP amplitudes also differed significantly (0.71 ± 0.39 vs 1.13 ± 0.42, $P < .0001$). SVC/LCV pacing with MIN output was able to detect PNP significantly earlier than MAX (27 ± 8 vs 91 ± 12 seconds, $P < .01$), and the time to PNP recovery was significantly shorter for the MIN output (20.2 ± 8.88 hours vs 4.8 ± 1.6 months, $P < .001$).

CONCLUSION Pacing the SVC and LCV with lower output detect PNP significantly earlier than maximal output pacing and leads to recovery from PNP on the order of hours postprocedure rather than months.

KEYWORDS Atrial fibrillation; Cryoballoon; Catheter ablation; Phrenic nerve palsy

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Introduction

Cryoballoon (CB; Arctic Front Advance, Medtronic, Minneapolis, MN) ablation (CB-A) for atrial fibrillation (AF) can create potentially continuous circumferential lesion sets around the pulmonary veins (PVs).[1–3] Phrenic nerve (PN) palsy (PNP) is the most frequently observed complication during CB-A for AF and occurs in approximately 7% to 9% of the procedures.[4–6] PNP, although self-resolving, may last on the order of months. PNP of the right PN is the most common, although left-sided PNP has been reported in sporadic cases.[7] To minimize PNP, operators pace the PN during CB-A and stop freezing when its injurious effects on the PN are provoked during CB-A. However, the long-lasting PNP has never been completely avoided with this method. In published reports to date, PN stimulation always appears to have been performed at maximum pacing output. We hypothesized that reducing PN stimulation output might minimize or prevent PNP.

Methods

Between July 2014 and July 2015, a total of 197 consecutive patients (57% male, average age 63.1 ± 11.6 years) with paroxysmal AF eligible for pulmonary vein isolation (PVI) who underwent ablation with the CB technique at our center were prospectively enrolled. Written informed consent was obtained from all patients. Transesophageal echocardiography was performed before PVI to assess left atrial (LA) diameter and to rule out any intracardiac thrombi in 97% of the study patients. Patients received conscious sedation with propofol combined with dexmedetomidine hydrochloride, which was administered at the start of the procedure and as

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needed after CB placement. Patients who had moderate-to-severe valvular disease, thrombi in the LA, uncontrolled thyroid dysfunction, significant coronary artery stenosis, contraindications for anticoagulation, pregnancy, or LA anteroposterior diameter >50 mm were excluded from the study. The study complied with the principles outlined in the Declaration of Helsinki and was approved by the local ethics committee.

Ablation procedure

Computed tomography of the LA was performed to examine PV anatomy. A single transseptal puncture was performed under fluoroscopic and intracardiac echocardiographic (Acuson, AcuNav, Biosense Webster, Diamond Bar, CA) guidance. Thereafter, heparin was administered intravenously to maintain an activated clotting time between 300 and 350 seconds. The CB catheter was introduced into the LA through a steerable sheath (FlexCath, Medtronic) and constantly flushed with heparinized saline. Finally, a mapping catheter (Achieve, Medtronic) was advanced within the CB to the PV orifice and positioned as close to the PV orifice as possible inside the PVs. Then, the CB was inflated and advanced to the ostium of each PV. Once the best possible occlusion was obtained, cryothermal energy was applied for 180–240 seconds with the CB. The second CB applications were performed when the first CB application failed to isolate the PVs. Further applications were performed until all PV potentials were abolished.

An electrode catheter was advanced into the superior vena cava for right-sided PN stimulation and into the left subclavian vein for left-sided stimulation as previously described.[8] The PN was paced continuously during each application of CB-A at 40 bpm with a cardiac electrical stimulator (SEC-4103, Nihon Kohden, Tokyo, Japan). Compound motor action potentials (CMAPs) of the diaphragm provoked by the PN pacing were continuously monitored during CB-A. In addition to the CMAP recordings, PN function was monitored continuously by palpation of the diaphragmatic excursion.

Pacing threshold of the PN

The pacing threshold of the PN was measured before cryoablation. During freezing, the PN was paced at either the maximum output (MAX; 10.0 V for 1 ms) or at an output exceeding the pacing threshold by 10% (MIN; 1 ms). In order to avoid variation in the pacing threshold of the PN with respirations, ventilation was controlled by the artificial respirator under general anesthesia. The pacing catheter was inserted through a deflectable long guiding sheath (Agilis, St. Jude Medical, Minneapolis, MN) for stable positioning of the catheter during pacing. The pacing site was carefully chosen where a stable pacing threshold was obtained during 5 respiratory cycles.

CMAP recording

Both right- and left-sided CMAP recordings were obtained using 2 leads: a standard surface left and right arm ECG electrode positioned 5 cm above the xiphoid and a right and left arm ECG electrode positioned 16 cm along the right and left costal margin.[9,10] CMAP signals were amplified using a bandpass filter setting between 0.5 and 100 kHz and recorded on a NavX (St. Jude Medical) recording system.

In 92 consecutive patients, PN pacing was performed with MAX pacing (group A), whereas MIN pacing was performed in the next 105 consecutive patients (group B) during CB-A (Figure 1). Before CB-A, the average maximum amplitude of the CMAP was measured during MAX and MIN pacing performed 5 times in all patients. Then, MAX pacing in group A and MIN pacing in group B patients were performed during the entire cryoablation procedure in order to detect any injurious effects on the PN. CMAP amplitude was measured from the peak to peak at baseline and during each ablation application for every PN stimulation. The average of the maximum amplitude of the CMAP was compared during pacing between that with the MAX and that with the MIN

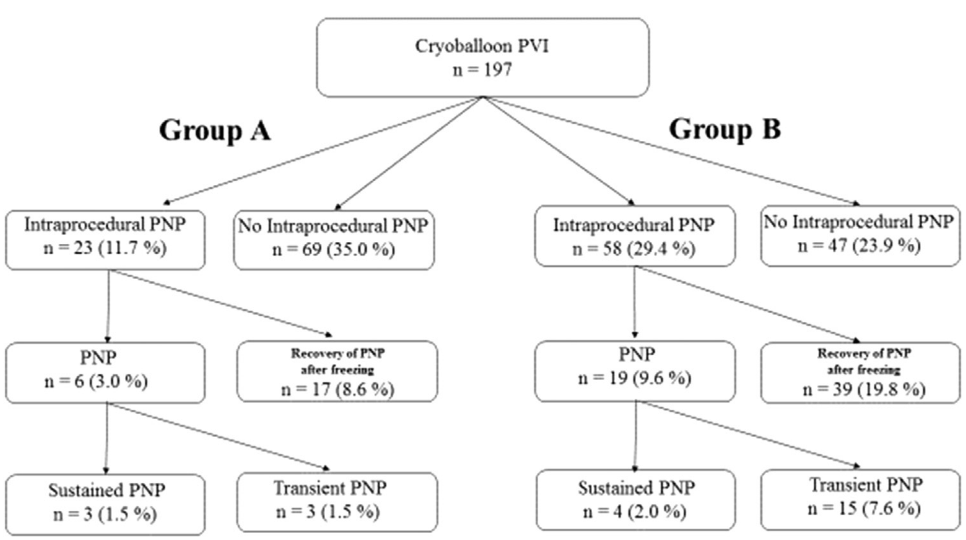

Figure 1 Occurrence of phrenic nerve palsy (PNP) and the time to recovery. PVI = pulmonary vein isolation.