Electrical superior vena cava isolation using a novel pace-and-ablate technique under diaphragmatic electromyography monitoring

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BACKGROUND Diaphragmatic compound motor action potential (CMAP) amplitude monitoring is a standard technique to anticipate phrenic nerve injury during cryoballoon ablation.

OBJECTIVE The purpose of this study was to evaluate the feasibility of a novel superior vena cava isolation (SVCI) technique using simultaneous pacing and ablation through the tip of a single mapping/ablation catheter.

METHODS Fifty-four patients with atrial fibrillation were included. Radiofrequency energy was delivered point by point uniformly for 20 seconds with a power of 20 W until achieving SVCI. Diaphragmatic CMAPs were obtained from modified surface electrodes by high-output pacing from the mapping/ablation catheter throughout the procedure (pace-and-ablate group). Applications were interrupted if CMAP amplitudes significantly decreased without fluoroscopy. The data were compared with those of the 54 patients undergoing conventional SVCI (conventional group).

RESULTS Successful SVCI procedures were achieved in all with a mean of 10.3 ± 2.9 applications. In total, among 559 ablation sites, CMAPs were recorded at 95 (17.0%) with baseline amplitudes of 0.45 ± 0.23 mV. In 10 patients (18.5%), isolation was achieved without any radiofrequency deliveries at CMAP-recorded sites. Among the 95 applications, 6 (6.3%) were interrupted because of CMAP amplitude reductions. At the remaining 88 sites, 20-second radiofrequency applications were delivered without any amplitude decrease (from 0.45 ± 0.21 to 0.46 ± 0.23 mV; $P = .885$). Phrenic nerve injury occurred in 1 patient in the pace-and-ablate group, which recovered 3 months later, and in 3 conventional group patients, of whom 1 recovered 1 month later ($P = .308$). The total procedure time tended to be shorter (14.5 ± 6.3 minutes vs 16.7 ± 9.2 minutes; $P = .153$) and fluoroscopy time significantly shorter (3.9 ± 3.0 minutes vs 6.7 ± 5.7 minutes, $P = .002$) in the pace-and-ablate group than in the conventional group.

CONCLUSION A novel and simple pace-and-ablate technique under diaphragmatic electromyography monitoring might be feasible for an electrical SVCI.

KEYWORDS Phrenic nerve injury; Superior vena cava; Compound motor action potential; Catheter ablation; Atrial fibrillation

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Editor's Note: After this manuscript was accepted for publication, Biosense Webster, Inc., the manufacturer of the CARTO® 3 System, issued a field notification reminding operators that the CARTO® 3 System Instructions for Use recommends avoiding ablation while pacing from the same electrode of the ablation catheter. Biosense Webster, Inc. explained that this practice could be a factor contributing to current leakage, which has a small risk of inducing ventricular fibrillation. Biosense Webster, Inc. recommends avoiding simultaneous pacing and ablating when using the CARTO® 3 system.

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Introduction

Pulmonary vein (PV) isolation (PVI) is the cornerstone therapy in the catheter ablation of atrial fibrillation (AF). It eliminates the predominant triggers responsible for the initiation of AF and modulates the left atrial substrate liable for the maintenance of AF.[1–4] Despite the favorable impact, the success rate of a sole PVI is limited because of non-PV AF foci, such as from the superior vena cava (SVC). The SVC acts as the trigger and driver of AF as well as the PVs.[5] Although electrical SVC isolation is an established treatment strategy for arrhythmogenic SVCs,[6] right phrenic nerve injury (PNI) is the major concern[7] because of the anatomical proximity.[8]

With the spread of balloon ablation for PVI,[9] the clinical use of monitoring diaphragmatic compound motor action potentials (CMAPs) to anticipate PNI has been established.[10–12] We have recently reported the potential use of diaphragmatic CMAP monitoring to prevent right PNI during electrical SVC

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isolation.[13] However, in this technique, an additional pacing catheter is required with a stable placement in the right subclavian vein throughout the procedure, and phrenic nerve capture needs to be evaluated before each radiofrequency (RF) application by high output pacing from the tip of the ablation/mapping catheter. In the present study, we assessed the feasibility of a novel SVC isolation technique using simultaneous pacing and ablation through the tip of a single mapping/ablation catheter with CMAP monitoring to simplify these issues.

Methods

Study population

This prospective study consisted of 54 consecutive patients with paroxysmal AF or short-lasting persistent AF who underwent their first SVC isolation using a novel pace-and-ablate technique (pace-and-ablate group) in our institute. PVI was performed with either a cryoballoon or an irrigated-tip catheter before SVC isolation. The data were compared with those of the 54 consecutive patients who underwent conventional SVC isolation before the introduction of this technique (conventional group). AF was classified according to the latest guidelines.[4] All patients gave their written informed consent. The study protocol was approved by the hospital's institutional review board. The study complied with the Declaration of Helsinki.

Mapping and ablation protocol

All antiarrhythmic drugs were discontinued for at least 5 half-lives before the procedure. Preprocedural cardiac enhanced computed tomography was performed to evaluate cardiac anatomy. The surface electrocardiogram and bipolar intracardiac electrograms were continuously monitored and stored on a computer-based digital recording system. The procedure was performed under moderate sedation obtained with dexmedetomidine. A 100 IU/kg body weight of heparin was administered immediately after the venous access, and heparinized saline was additionally infused to maintain the activated clotting time at 250–350 seconds. After a single transseptal puncture, PVI was performed using either a 28-mm second-generation cryoballoon (Arctic Front Advance, Medtronic, Minneapolis, MN) or an irrigated-tip catheter under the guidance of a 3-dimensional mapping system (CARTO 3, Biosense Webster, Diamond Bar, CA) as described previously.[13]

Electrical SVC isolation using a novel pace-and-ablate technique

A circular mapping catheter was placed anatomically just above the SVC-RA (right atrium) junction at the level of the left atrial roof; then, we optimized the position electrophysiologically to observe separated SVC potentials during pacing the ablation catheter located in the RA.[14] RF energy was delivered point by point uniformly for 20 seconds on each site using either an irrigated-tip catheter (FlexAbility, St. Jude Medical, Minneapolis, MN, or Surround Flow, Biosense Webster) with a power of 20 W or a 4-mm non–irrigated-tip catheter (Fantasista, Japan Lifeline, Tokyo, Japan) in a temperature-controlled mode with a power of 20 W and maximum temperature set at 55°C (CABL-ITII, Japan Lifeline). When the target power could not be obtained, the maximum temperature was increased up to 58°C and the catheter contact was slightly changed to reach the target power.

Throughout the SVC ablation procedure (during both mapping and ablation), high output bipolar pacing (output 10 V; pulse width 2 ms) was continuously performed from the distal electrode pair of the ablation catheter at 30 beats/min (pacing interval 2000 ms) (Cardiac stimulator BC-1100, Fukuda Denshi, Tokyo, Japan), which enabled the identification of the phrenic nerve location during mapping, and also monitored the CMAP amplitude during the RF delivery. The order of ablation was the septal, posterior, and anterior SVC-RA junction, and those areas were routinely ablated. Then, the conduction breakthrough at the lateral side of the SVC-RA junction was targeted in order to minimize the potential risk of right PNI. During the RF applications at sites with phrenic nerve capture, the amplitude of the CMAP was carefully monitored, and ablation was immediately terminated upon any perceived reduction in the strength of the diaphragmatic contractions or a significant reduction in the maximal diaphragmatic CMAP amplitude from baseline without fluoroscopy. In the conventional group, high output pacing was performed before the RF delivery, and the diaphragmatic movement was evaluated during the RF delivery on fluoroscopy when RF energy was applied at the phrenic nerve capture site. The end point of ablation was bidirectional conduction block between the SVC and the RA.

CMAP recording

No paralytic agents that inhibited phrenic nerve capture were administered. For monitoring the right diaphragmatic CMAPs, 2 additional standard surface electrocardiogram electrodes were positioned 5 cm above the xiphoid process and 16 cm along the right costal margin.[10–12] This simple technique was initially introduced into clinical use by Franceschi et al.[10] These electrodes were directly connected to a central computerized electrophysiology workstation (Bard recording system, LabSystem PRO, Boston Scientific, Cambridge, MA) where bipolar electromyography signals were amplified using a band-pass filter between 1 and 100 Hz (voltage range 5 mV; notch filter 50 Hz). The maximum CMAP amplitude was measured from peak to peak. Before the start of the procedure, it was ensured that the CMAP was obtained by stimulating the phrenic nerve and recorded. It was correlated with the fluoroscopic visualization of the contraction of the right hemidiaphragm and simultaneous palpation of the abdomen for the thrust.

Evaluation of PNI

The diaphragmatic movement was evaluated throughout the procedure in the supine position. In addition, a chest radiograph (standard posteroanterior view) was undertaken during