Bronchial effects of cryoballoon ablation for atrial fibrillation

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BACKGROUND Damage to extracardiac structures, including the esophagus and phrenic nerve, is a known complication of cryoballoon ablation (CBA) during pulmonary vein (PV) isolation for atrial fibrillation (AF). Other adjacent structures, including the pulmonary bronchi and lung parenchyma, may be affected during CBA at the PV ostia.

OBJECTIVE The purpose of this study was to prospectively study the bronchial effects of CBA in humans undergoing CBA for PV isolation.

METHODS Ten patients undergoing CBA for AF under general anesthesia were enrolled in an institutional review board–approved prospective observational study. Real-time bronchoscopy was performed during cryoablation of PVs adjacent to pulmonary bronchi to monitor for thermal injury. Patients were followed for the development of respiratory complaints postprocedure.

RESULTS In 7 of 10 patients (70%) and in 13 of 22 freezes (59%), ice formation was visualized in the left mainstem bronchus during CBA in the left upper PV. Ice formation was not seen in the right mainstem bronchus during right upper PV CBA. The average time to ice formation was 89 seconds. There was no significant difference ($P = -.45$) in average minimum balloon temperature during freezes with ice formation (−48.5°C) and freezes without ice formation (−46.3°C). No patients went on to develop respiratory complications.

CONCLUSION Unrecognized ice formation occurs frequently in the left mainstem bronchus during CBA for AF. This information helps explain the source of cough and hemoptysis in some patients who undergo CBA. The long-term consequences of this novel finding and the implications for procedural safety are unknown.

KEYWORDS AF ablation; Cryoablation; PV isolation; Bronchoscopy; Atrial fibrillation

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Introduction

Cryoballoon ablation (CBA) for atrial fibrillation (AF) is an effective and increasingly common method used to achieve pulmonary vein isolation (PVI).[1] It is widely considered technically simpler and easier to learn than radiofrequency ablation. Published studies have shown similar efficacy between the 2 methods.[2,3] Although generally considered safe, there is an extensive literature devoted to the extracardiac complications due to CBA, including phrenic nerve injury, periesophageal vagal injury, esophageal injury, and atrioesophageal fistula formation.[4–6] Preventive methods are now routinely applied in the electrophysiology laboratory to try and limit these complications.

An often-overlooked anatomical relationship is that between the pulmonary bronchi, the left atrial roof and pulmonary veins (PVs). Anatomical studies relying on computed tomography (CT) scans have shown that the left mainstem bronchus (LMB) and right mainstem bronchus (RMB) are closely located to the PVs and often in direct contact with the left superior PV (LSPV) and right superior PV (RSPV).[7,8] In addition, there have been multiple reports of pulmonary complications of CBA within the literature, including persistent cough, hemoptysis, and a recent unfortunate case of fatal atriobronchial fistula formation.[9–15] There has been some debate with regard to the exact mechanism of these complications.

The purpose of this study was to prospectively study the bronchial effects of CBA in humans undergoing CBA for PVI.

Methods

The research protocol was approved by the institutional review board of Northwestern University in Chicago, Illinois. All procedures were performed after obtaining written informed consent according to institutional guidelines of Northwestern University.

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Ablation protocol

Ten consecutive patients who were undergoing CBA under general anesthesia (GA) at our institution were identified. Each patient had a transesophageal echocardiogram and underwent preprocedure cardiac magnetic resonance imaging or cardiac CT to evaluate pulmonary venous anatomy. Three-dimensional postprocessing of cardiac magnetic resonance imaging and CT images was performed using Vitrea software (Vital Images Inc., Plymouth, MN) to calculate the minimum distance between the pulmonary venous ostium and the nearest airway. All patients were intubated and mechanically ventilated during GA for the duration of the procedure. Standard techniques were used to perform CBA for PVI. The procedures were performed with guidance from fluoroscopy and intracardiac echocardiography (Acunav, Siemens-Ultrasound, Erlangen, Germany). Intravenous heparin was administered before transseptal puncture, and the Achieve catheter (Medtronic, Inc., Minneapolis, MN) was used to record electrogram activity before, during, and after ablation lesions. All patients underwent ablation with the 28-mm Arctic Front Advance cryoballoon (Medtronic, Inc.). Before cryoablation, balloon occlusion of the PV of interest was assessed with a combination of color Doppler imaging on intracardiac echocardiography and intravenous contrast injection. An esophageal temperature probe (Smiths Medical, St. Paul, MN) was variably positioned depending on the balloon location for intraluminal esophageal monitoring. Tactile sensation as well as compound motor action potential monitoring was used to assess for phrenic nerve injury during freezes. A minimum of two 180-second CBA lesions were applied at the ostium of each PV. Additional lesions were given at the investigators discretion if PVI was not achieved with 2 freezes. Early termination of the freezes was at the discretion of the electrophysiologist performing CBA and was irrespective of the findings on bronchoscopy. No patient received more than 3 freezes in any PV, and radiofrequency ablation was not used in any patient.

Bronchoscopy protocol

All patients consented to undergo real-time bronchoscopy during CBA. Bronchoscopies were performed by a board-certified interventional pulmonologist. An Airway Mobilescope (Olympus, Tokyo, Japan) was passed via the endotracheal tube into the LMB and RMB for the duration of the ablation lesion. Complete airway inspection was performed during CBA. The LMB was visualized during LSPV isolation in all patients, and the RMB was visualized during RSPV isolation in 2 patients. The attached 2.5-in digital video recorder and monitor allowed for image and video capture of any visualized airway abnormalities. Endobronchial biopsies were not performed.

Outcomes

Outcomes of interest included the visualization of any endobronchial changes during a freeze, time to development of any thermal injury, and the development of any post-procedure respiratory complaints.

Statistical methods

Continuous data are presented as mean ± SD. Continuous variables were analyzed using a 2-sample *t* test. A *P* value of $<.05$ was considered statistically significant.

Results

The baseline clinical characteristics of the study patients are summarized in Table 1. Eight out of ten (80%) of patients were men, and seven out ten (70%) had paroxysmal AF. Left atrial volume index was mildly dilated on average, mainly driven by 1 patient with severe left atrial enlargement. Fluoroscopy during the first patient's procedure revealed the close anatomical relationship between the LSPV and the LMB (Figure 1). During LSPV isolation in multiple patients, ice formation was frequently seen in the LMB, just proximal to the secondary carina. There were also 2 instances of

Table 1 Baseline characteristics of the study patients

Patient no.	Age (y)	Sex	Ejection fraction (%)	Creatinine level (mg/dL)	LA volume index (mL/m^2)	AF type	CAD	HTN	Diabetes	CHA_2DS_2-VASc score	Prior AAD
1	68	Female	55	0.86	19.1	Persistent	No	Yes	No	3	Yes
2	72	Male	45	0.78	23.4	Paroxysmal	Yes	Yes	No	3	Yes
3	55	Female	65	0.72	21.3	Persistent	No	Yes	No	2	Yes
4	67	Male	65	1.1	22.9	Paroxysmal	No	Yes	Yes	3	Yes
5	55	Male	60	1.2	31.8	Persistent	No	Yes	Yes	2	Yes
6	48	Male	50	1	28.5	Paroxysmal	No	Yes	No	1	Yes
7	64	Male	56	0.83	32.2	Paroxysmal	No	Yes	No	1	Yes
8	61	Male	57	0.99	25.5	Paroxysmal	No	Yes	No	1	Yes
9	56	Male	55	0.81	24.6	Paroxysmal	No	No	No	0	No
10	73	Male	24	2.1	64	Paroxysmal	Yes	Yes	No	3	No
Total (mean ± SD)	61.9 ± 8.3		53 ± 11.94	1.04 ± 0.4	29.33 ± 12.91					1.9 ± 1.1	

AAD = antiarrhythmic drug; AF = atrial fibrillation; CAD = coronary artery disease; HTN = hypertension; LA = left atrium. CHA_2DS_2-VASc=congestive heart failure/left ventricular ejection fraction ≤ 40%, hypertension, age 75 years of age and older, diabetesmellitus, stroke/transient ischemic attack/TE history, vascular disease, age 65–74 years old, female.