Strategies for phrenic nerve preservation during ablation of inappropriate sinus tachycardia

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BACKGROUND Radiofrequency (RF) ablation can alleviate drug-refractory inappropriate sinus tachycardia (IST). However, phrenic nerve (PN) injury and other complications limit its use.

OBJECTIVE The purpose of this study was to characterize the maneuvers used to avoid PN injury and the long-term clinical outcomes.

METHODS The study consisted of a retrospective analysis of consecutive patients who underwent ablation for IST.

RESULTS RF ablation was performed on 13 consecutive female patients with drug-refractory IST. Eleven patients exhibited PN capture at desired ablation sites. In 1 patient, PN capture was not continuous throughout the respiratory cycle and ventilation holding sufficed to avoid PN injury. In 10 patients, pericardial access (PA) and balloon insertion was required. Initially (n = 4) a posterior PA was used, which was replaced by an anterior PA in the subsequent 6 cases. PA to optimal balloon positioning time was significantly lower in anterior vs posterior PA (16.3 ± 6 minutes vs 58 ± 21.3 minutes, $P = .01$), as was fluoroscopy time (15.66 ± 16.72 min vs 35.9 ± 1.8 min, $P = .03$). RF ablation successfully reduced sinus rate to <90 bpm in 13 of 13 patients. Procedure times and total RF times were not significantly different in anterior vs posterior PA. Major complications occurred in 2 patients, including unremitting pericardial bleeding requiring open-chested repair in 1 patient and sinus pauses mandating pacemaker implantation in the other patient. Long-term symptom control after follow-up of 811 ± 42 days was successful in 84.6%.

CONCLUSION Ventilation holding and/or pericardial balloon insertion are frequently warranted in IST ablation. Anterior PA appears to facilitate the procedure over posterior PA.

KEYWORDS Catheter ablation; Inappropriate sinus tachycardia; Phrenic nerve injury

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Introduction

Inappropriate sinus tachycardia (IST) syndrome is a tachyarrhythmia characterized by unexpectedly increased and symptomatic heart rates (HRs) during sinus rhythm, at rest, or in response to minimal physical activity and psychological stress.[1–3] It has been shown to be more prevalent in middle-aged women[4] and is associated with significant loss of quality of life.[1,5] Pharmacologic treatment aims to reduce HR and ameliorate clinical symptoms. Empirical first-line therapy with beta-adrenergic blocker, calcium channel blockers, or ivabradine has yielded low-to-moderate success.[2,6] Endocardial ablation/modification of the sinoatrial node (SAN) is a viable alternative in refractory cases of IST.[4,7] Limitations of this procedure stem from the predominantly epicardial location of the SAN,[8] in close proximity to the right phrenic nerve (PN), which could be damaged during radiofrequency (RF) delivery.[1,9,10] Information regarding the best approach to avoid PN injury remains scarce. Furthermore, gaps of knowledge persist regarding long-term symptom recurrence after IST ablative procedures.[11]

We sought to characterize the maneuvers used to avoid PN injury and the long-term clinical outcomes in a series of consecutive patients referred for IST ablation/modification.

Methods

Patient selection

This retrospective analysis included consecutive patients (n = 13) who underwent ablation for IST between September 2008 and August 2015 in a single tertiary center. IST was defined as HR >100 bpm at rest or with mild physical activity/psychological stimuli and associated symptoms.[7] Primary causes of sinus tachycardia were ruled out, as were other mechanisms of supraventricular tachycardia. Every patient underwent 12-lead ECG to confirm normal P-wave morphology. Additional evaluations included baseline

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blood testing (complete metabolic panel, thyroid function, blood count, renal function, electrolytes, drug testing, and serum and urine catecholamines)[3,12–14] and autonomic testing (tilt table testing in order to rule out postural orthostatic tachycardia syndrome). Patients who proved refractory to, or intolerant of, pharmacologic therapy were offered ablative treatment. Risks, benefits, and alternatives were explained at length, and patients provided written informed consent before the procedure. Data were reviewed under an institutional review board–approved registry.

Activation time and PN mapping

Patients were studied in the fasting state under general anesthesia without the use of paralytic agents. Antiarrhythmic drugs and beta-blockers were withheld at least five half-lives prior to the procedure. Under local anesthesia, a multipolar catheter was advanced through the left femoral vein into the right atrium (RA) and positioned with its distal 10 poles in the coronary sinus and the proximal poles within the tricuspid annulus. A tetrapolar catheter was placed in the His-bundle region. Mapping and ablation were performed using an open-irrigated 3.5-mm tip catheter. A 3-dimensional activation map was created using the CARTO (Biosense-Webster, Diamond Bar, CA; n = 9), NavX system (St. Jude Medical, St Paul, MN; n = 3), and Rhythmia mapping system (Rhythmia Medical/Boston Scientific, Marlborough, MA; n = 1). A baseline electrophysiologic study was performed to exclude other mechanisms of supraventricular tachycardia. A PN capture map was created along with activation mapping by unipolar pacing from the distal pole of the ablation catheter at a maximum output of 25 mA with a pulse width of 2 ms. Diaphragmatic contraction was confirmed by fluoroscopic visualization. Bipolar activation mapping was undertaken to identify the earliest site referenced to both an endocardial fiducial point (e.g., coronary sinus electrogram) and the surface P wave. After identification of the earliest endocardial activation, before RF delivery, high-output pacing was performed to confirm the absence of PN stimulation. The sites of PN capture were marked on the activation map. Figure 1 shows examples.

Pericardial access

If PN stimulation could not successfully be eliminated by minor adjustments in the orientation of the catheter tip and/or ventilation holding, pericardial access (PA) was then obtained. Percutaneous subxyphoid access to the pericardium was performed with a Tuohy needle as described by Sosa and Scanavacca.[15] In the first 4 cases, a posterior approach was used, whereby the needle was advanced from the subxyphoid access point at an approximately 30°–45° angle, aiming for the diaphragmatic wall of the heart silhouette. In the 6 subsequent procedures, an anterior approach was chosen, in which the needle was advanced at a shallow angle into the substernal space, as guided by a lateral fluoroscopy projection. Figure 2 shows examples. Once the needle tip reached the anterior mediastinal space, a steeper angle was adopted to enter the pericardium anterior to the right ventricle (RV). Upon entry into the pericardium, a long wire was advanced so that it wrapped around the entire cardiac silhouette, ensuring no entrance into the RV or the pleural space. A deflectable sheath (Agilis NxT, St. Jude Medical, Minnetonka, MN) was advanced over the wire into the pericardium. Its tip was deflected to direct the wire toward the superior vena cava (SVC)–RA junction. Subsequently, an 18-mm × 4-cm balloon dilation catheter (ATB Advance PTA; Cook Medical, Bloomington, IN) or in 1 case a 14-mm × 4-cm balloon dilatation catheter (Bard Atlas, Murray Hill, NY) was placed through the deflectable sheath on the lateral wall of the RA, aiming for a position between the ablation site and the PN. PN capture at the ablation site was verified after balloon positioning. If PN capture was still present, further balloon manipulations were performed until PN capture at the desired ablation site was no longer present. Figure 2 shows examples of posterior vs anterior PA and pericardial balloon (PB) positioning, respectively.

Ablation

After stable positioning of the catheter at the site of earliest activation was confirmed, RF energy was delivered for 60 seconds per lesion, with up to 35 W, 30 cc/min irrigation flow, while maintaining a temperature <43°C using a ThermoCool catheter (Biosense-Webster). Ablation was performed in the baseline state without isoproterenol in order to maximize catheter stability. With each change in HR or P-wave morphology, the site of earliest activation was reassessed. Subsequently, the new site of earliest activation was targeted with RF energy in an effort to shift the sinus rhythm more caudally as determined by a change in P-wave morphology or achievement of a junctional rhythm. The endpoint was achieved when there was a decrease in HR ≥20% from baseline off isoproterenol and an associated change in P-wave morphology in leads III and aVF from a positive to a flat or negative deflection.[1,8,11] Isoproterenol infusion was reinitiated postablation to demonstrate the persistent change in P-wave morphology and to show a lower site of early activation compared to the preablation state at the same dose of isoproterenol.

Clinical follow-up

Patients underwent ECG monitoring for 24 hours postablation. They were seen in the office 4–6 weeks postprocedure and then at 6-month intervals. A 12-lead ECG was performed at each visit, and repeat 24-hour Holter monitoring was performed at 6 months or at the onset of symptom recurrence if any.

Statistical analysis

Continuous data are reported as mean ± SD. Qualitative findings are reported as number and percentage. Preablation and postablation categorical variables were compared. Univariate analyses were performed using the paired and unpaired *t* tests. The χ^2 test was used to