# A Novel Method for Sinus Node Modification and Phrenic Nerve Protection in Resistant Cases

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**Endocardial Catheter for IST Ablation.** **This is a case report of inappropriate sinus tachycardia in a patient who had a previous unsuccessful endocardial ablation, which had been limited due to concerns of phrenic nerve injury. The patient required a repeat ablation that utilized a novel combined epicardial and endocardial approach for sinus node modification and simultaneous protection of the phrenic nerve via an epicardial balloon.** *(J Cardiovasc Electrophysiol, Vol. 20, pp. 689-691, June 2009)*

*inappropriate sinus tachycardia, epicardial, ablation, phrenic nerve*

## Case Report

**A 33-year-old female presented with previous diagnosis of noncompaction of the left ventricle, who had a dual chamber implantable cardioverter-defibrillator (ICD) placed many years ago for primary prevention of sudden cardiac death. Since that time, she has been repeatedly symptomatic of tachycardia. Initially, she had typical right atrial flutter diagnosed and had a successful cavotricuspid isthmus ablation. Recurrent symptomatic tachycardia, and occasional syncope, led to an empiric slow pathway modification due to the presence of dual pathways and typical atrioventricular (AV) nodal echoes, but she had no inducible supraventricular tachycardia. During this study, a heart rate increase of 25 beats per minute (bpm) was seen after a 1 $\mu$g i.v. bolus dose of isoproterenol, which was suggestive but not diagnostic of the diagnosis of inappropriate sinus tachycardia (IST).[1] All other potential causes of sinus tachycardia were excluded, and the clinical scenario was felt to be most consistent with IST. The patient also has a long history of multiple syncopal events and a tilt-table test consistent with vasovagal syncope. Recurrent syncope after ICD implantation occurred without any arrhythmic events except sinus tachycardia. The treatment for her IST was limited by baseline hypotension made worse by beta-blockers. The addition of low-dose calcium channel blockers was not tolerated. Because of the history of cardiomyopathy, fludrocortisone and midodrine were not prescribed.**

**An attempt at endocardial sinus node modification was made using a noncontact array (NavX Array; St. Jude Medical, St. Paul, MN, USA). Escalating the doses of isoproterenol increased the sinus rate but did not change the site of earliest activation by more than a few millimeters. Lesions were delivered using an internally irrigated RF ablation catheter (Chilli; Boston Scientific, Natick, MA, USA), but it was limited by phrenic nerve capture at optimal ablation sites. Several of these sites had to be ablated with a 6-mm cryotherapy catheter (CryoCath, Montreal, Quebec) during phrenic nerve pacing from a quadripolar catheter in the superior vena cava. There was only a modest effect on the P-wave amplitude and resting sinus rate. Within a few weeks, she had recurrent severe symptoms and extreme hypotension, limiting medical therapies. Examination of her ICD showed frequent spontaneous heart rates greater than 150 bpm. She returns for a repeat sinus node modification with an epicardial approach. The prespecified endpoint of this procedure was complete sinus node ablation with a junctional escape rhythm.**

**A single quadrapole electrophysiology (EP) catheter was placed in the right atrium (RA). Under general anesthesia, epicardial access was obtained, as previously described.[2] Two wires were placed through a single sheath, the sheath was then removed, leaving both wires entering the pericardial space. Then, one long 8-F sheath and one steerable sheath (Agilis NxT; St. Jude Medical) were placed over a wire, into the pericardial space. Endocardial phased-array intracardiac echo (AcuNav; Biosense Webster, Diamond Bar, CA, USA, and Acuson; Siemens Healthcare, Malvern, PA, USA) was also used to help guide epicardial access and ablation. A 14-mm $\times$ 4-cm peripheral balloon (ATB Advance PTA; Cook Medical, Bloomington, IN, USA) was placed within the pericardial space through the nonsteerable sheath to protect the phrenic nerve. The earliest epicardial activation, and also the unipolar electrogram (uEGM) morphology, was mapped with a sinus rate of 121 bpm using a magnetoelectroanatomic mapping system (CARTO XP; Biosense Webster).**

**Several ablation lesions were delivered using first a 4-mm radiofrequency (RF) ablation catheter at the site of earliest activation (SEA) that also showed a QS complex on the uEGM (Fig. 1). As ablation was performed, the SEA shifted inferiorly along the terminal groove (Fig. 2). This was associated with a change in the P wave to a more superiorly directed axis (Fig. 3). Because of recurrence of sinus tachycardia, an 8-mm ablation catheter was then used. Many times during RF energy, sinus arrest was induced, and an accelerated junctional rhythm at 75 bpm was seen. Because of recovery of sinus node function, a 3.5-mm Chilli RF ablation catheter (Boston Scientific) was used. Sinus arrest was achieved, and it persisted for longer periods, but kept recurring until a few lesions were placed endocardially at the superior crista terminalis, where local activation preceded the P wave by approximately 80 ms. After ablation at this site, sinus rhythm did not recover. Isoproternol infusion up to 10 $\mu$g/min caused the junctional rhythm to increase to 120 bpm, but sinus rhythm was not recurrent. A total of 71 RF lesions were delivered, with a total RF time of 3,651 seconds.**

**At each ablation site, high-output (30 mA or greater) pacing was performed to test for phrenic nerve capture. If there was capture, the epicardial balloon was repositioned prior to ablation and pacing was again performed to confirm phrenic protection. At no time during balloon inflation did the patient experience a significant decrease in blood pressure. The balloon was visually examined at the end of the procedure, and it showed no sign of thermal damage. Both free-breathing fluoroscopy at the end of the case and a full-inspiration chest**

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Manuscript received 12 September 2008; Revised manuscript received 8 October 2008; Accepted for publication 29 October 2008.

doi: 10.1111/j.1540-8167.2008.01383.x

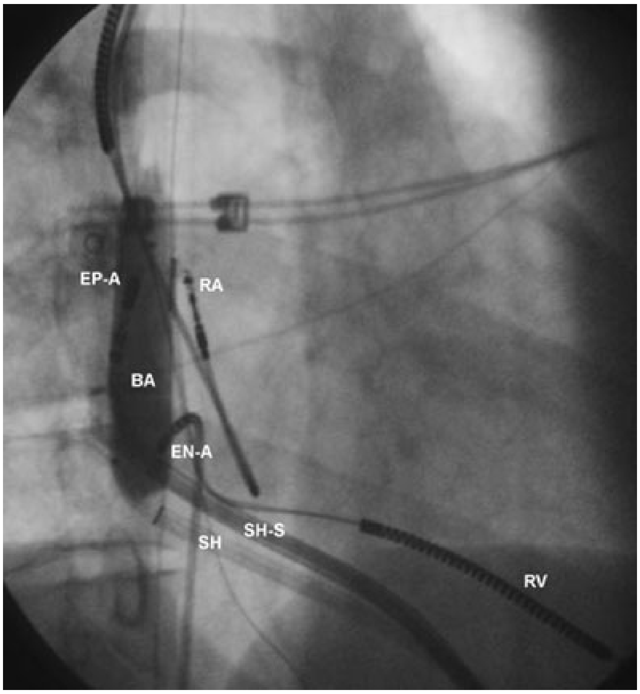


**Figure 1.** *RAO view early in the procedure. The epicardial ablation catheter is at the superior aspect of the sinus node. RA = right atrial permanent ICD lead; RV = right ventricular permanent ICD lead; BA = epicardial balloon; EP-A = epicardial ablation catheter; EN-A = endocardial catheter; SH = fixed epicardial introducer sheath; SH-S = steerable epicardial introducer sheath.*

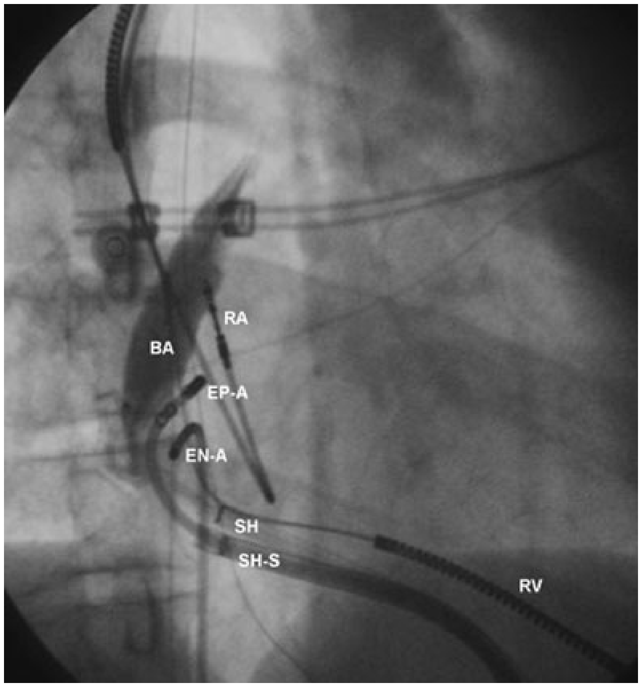


**Figure 2.** *RAO view after achieving a slower sinus rate. The epicardial ablation catheter is located at the more inferior aspect of the sinus node. RA = right atrial permanent ICD lead; RV = right ventricular permanent ICD lead; BA = epicardial balloon; EP-A = epicardial ablation catheter; EN-A = endocardial catheter; SH = fixed epicardial introducer sheath; SH-S = steerable epicardial introducer sheath.*

**radiograph the following day when the patient was extubated and awake showed normal right diaphragmatic excursion.**

**At 1-month follow-up, the patient reports near-complete resolution of her symptoms. Examination of her ICD showed all spontaneous heart rates to be no more than 110 bpm.**

## Discussion

IST is a supraventricular tachycardia characterized by a P-wave morphology indistinguishable from sinus rhythm, with tachycardia at rest or disproportional to the physiologic needs.[3–6] This syndrome is often a diagnostic and treatment dilemma for the clinicians, and may have a prevalence as high as 1.1% in a middle-aged population.[7] Several ablation techniques have been described[8–10] but they are difficult due to the predominantly epicardial location of the sinus node and phrenic nerve proximity. Previous studies on endocardial RF ablation success have ranged from 23% to 79%.[8,10] Combined epicardial and endocardial ablation strategies[11] as well as surgical approaches[12] for resistant cases have been described in case reports. The approach described in the current report may be considered when endocardial sinus node ablations have either failed outright or were incomplete due to phrenic nerve capture. In the series by Marrouche *et al.*, 21% of patients had a recurrence and required a repeat procedure. Additionally, 2 patients displayed phrenic nerve capture with pacemapping. One of these patients did suffer phrenic injury.[10] On the basis of these results, an epicardial approach may be useful in up to 26% of patients.

Phrenic nerve injury is a recognized complication of catheter ablation procedures, and specifically in IST ablations.[13] Pacemapping can identify locations to avoid where phrenic nerve damage is possible, but these may be the critical areas for ablation. Cryoablation may be safer than RF ablation in these areas, but is less likely to be effective.[14] Phrenic nerve protection by balloon placement in the epicardial space has been previously described in a case report for a ventricular tachycardia ablation.[15]

In this case, the patient had a sinus node modification ablation attempted endocardially. There were several areas that required ablation, but pacemapping showed phrenic nerve capture. Cryoablation was attempted in these areas, but with minimal success. Because of this, the decision was made to proceed to a combined epicardial/endocardial ablation strategy and use an epicardial balloon to lift the phrenic nerve off the cardiac surface and minimize the risk of phrenic nerve injury.

During the ablation, the site of the earliest sinus node activation migrated occasionally epicardially and occasionally endocardially as each site was ablated. Having ablation catheters both in the epicardial and the endocardial space allowed for optimal positioning of each ablation lesion and likely contributed to the success of the case.

A 4-mm ablation catheter was used initially for higher mapping resolution because of the fact that a larger tip catheter would be unlikely to have maximal lesion size without the cooling effects of blood flow. An 8-mm ablation catheter was used after the 4-mm catheter was ineffective, and it did achieve better results. These catheters were utilized first to allow for mapping with CARTO, but it became essential to use an irrigated tip catheter, at which time, Chilli was used to good effect. Despite the issue of multiple failed catheters, this case illustrates that the sinus node is a large

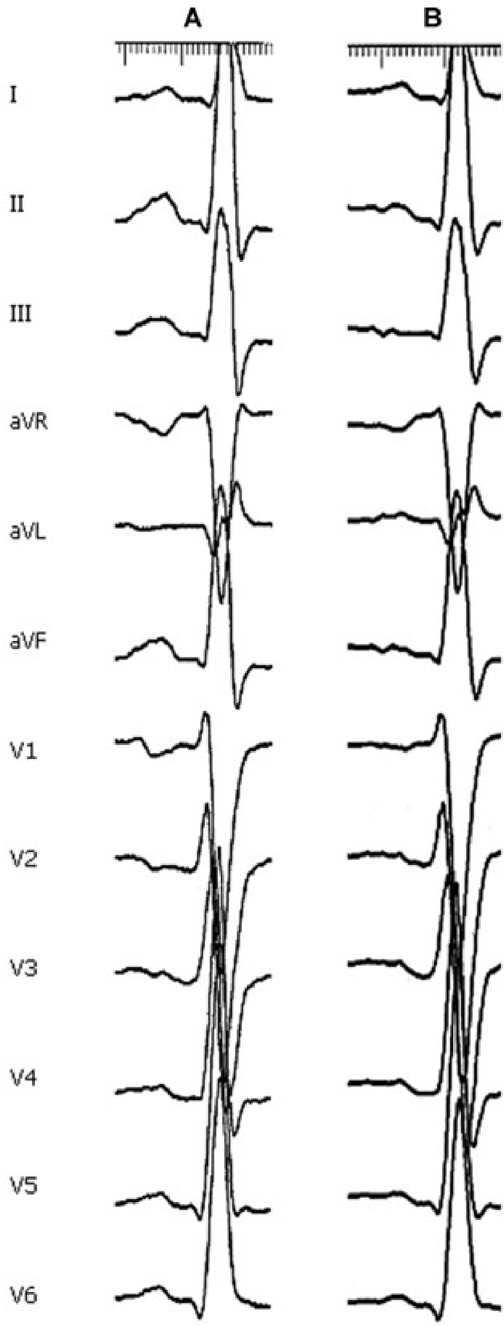


**Figure 3.** *Twelve-lead surface ECG demonstrating shift from a normal P-wave axis pre ablation (column A) to a more superiorly directed P-wave axis with ablation (column B).*

structure that can extend quite inferiorly along the terminal groove, and that endocardial lesions may still be required.

The balloon was initially positioned lateral to the lateral border of the RA and was inflated. When pacemapping revealed phrenic nerve capture, the balloon was repositioned until the phrenic nerve capture disappeared. No phrenic nerve injury was observed either during the case or afterwards, suggesting adequate protection from the epicardial balloon.

## Conclusion

Using a combined epicardial and endocardial catheter approach to IST ablation can be an effective technique, and it allows the additional use of an epicardial balloon for phrenic nerve protection.

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