

Phrenic nerve preservation using carbon dioxide insufflation during sinus node ablation procedure



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Introduction

Inappropriate sinus tachycardia (IAST) is a debilitating arrhythmia where drug therapy has limited success, and catheter ablation is seldom utilized owing to the lack of long-term durable results and high complication rates. Right phrenic nerve (RPN) injury is a concern during sinoatrial node (SAN) ablation owing to their close proximity, and displacing the RPN away from the target ablation site (using a balloon, air, or saline delivered through pericardial access) is crucial for a complete modification/ablation without risking RPN palsy. We present a case where carbon dioxide (CO₂) insufflation through a coronary vein protected the RPN during a SAN ablation procedure.

Case report

A 22-year-old woman with a structurally normal heart was referred for drug-refractory palpitation. Her history started with recurrent supraventricular tachycardia thought to be typical AV node reentry tachycardia. This tachycardia was ablated at another center with extensive radiofrequency (RF) ablation to the slow pathway region. Eleven months later, she developed a drug-refractory symptomatic long RP narrow complex tachycardia with a gradual onset-offset. Her symptoms failed to respond to bisoprolol, long-acting metoprolol, verapamil, flecainide, ivabradine, digoxin, and multiple drug combinations.

Diagnostic electrophysiology study showed a normal antegrade and retrograde nodal conduction with no evidence of free wall concealed accessory pathways. A long-VA narrow complex tachycardia with a breakout point

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KEY TEACHING POINTS

- Carbon dioxide insufflation technique appears to be a feasible and safe option to access the epicardial space when needed for catheter ablation.
- Carbon dioxide insufflation appears to be effective in displacing the phrenic nerve away from the right atrium–superior vena cava junction.
- Close monitoring for cardiac tamponade physiology is required when performing this technique.

in the high lateral right atrium (RA) was noted. Overdrive pacing from the site of earliest atrial activation yielded a post-pacing interval – tachycardia cycle length (PPI-TCL) of 120 ms, suggesting suppression of an automatic sinus node-mediated tachycardia (most likely IAST). High-output pacing at areas of interest leads to consistent RPN capture, limiting any ablation attempt. Another trial of medical therapy failed to control her symptoms, so a repeat electrophysiology study was performed with planned SAN modification utilizing carbon dioxide (CO₂) to preserve the RPN.

Using a 3-D mapping system (CARTO® 3 System; Biosense Webster, Baldwin Park, CA), we first marked areas of RPN capture along with the zone of earliest atrial activation during sinus rhythm (Figure 1A). Next, using a coronary sinus venogram (Figure 2), a Corsair microcatheter (Asahi Intecc Inc, Tustin, CA) was telescoped through an Agilis sheath into a lateral coronary vein where a Miracle 12 angioplasty wire (Asahi Intecc Inc) was used to perforate a lateral LV branch, then the microcatheter was advanced.

As previously described,¹ once the microcatheter tip is in the pericardial space, the CO₂ insufflation process started where a CO₂ tank connected in a sterile fashion to a 50-mL Luer-lock reservoir syringe. Then, 1.5 mL/kg of CO₂ was slowly injected using a reservoir syringe into the pericardial space with fluoroscopic observation of pericardial space

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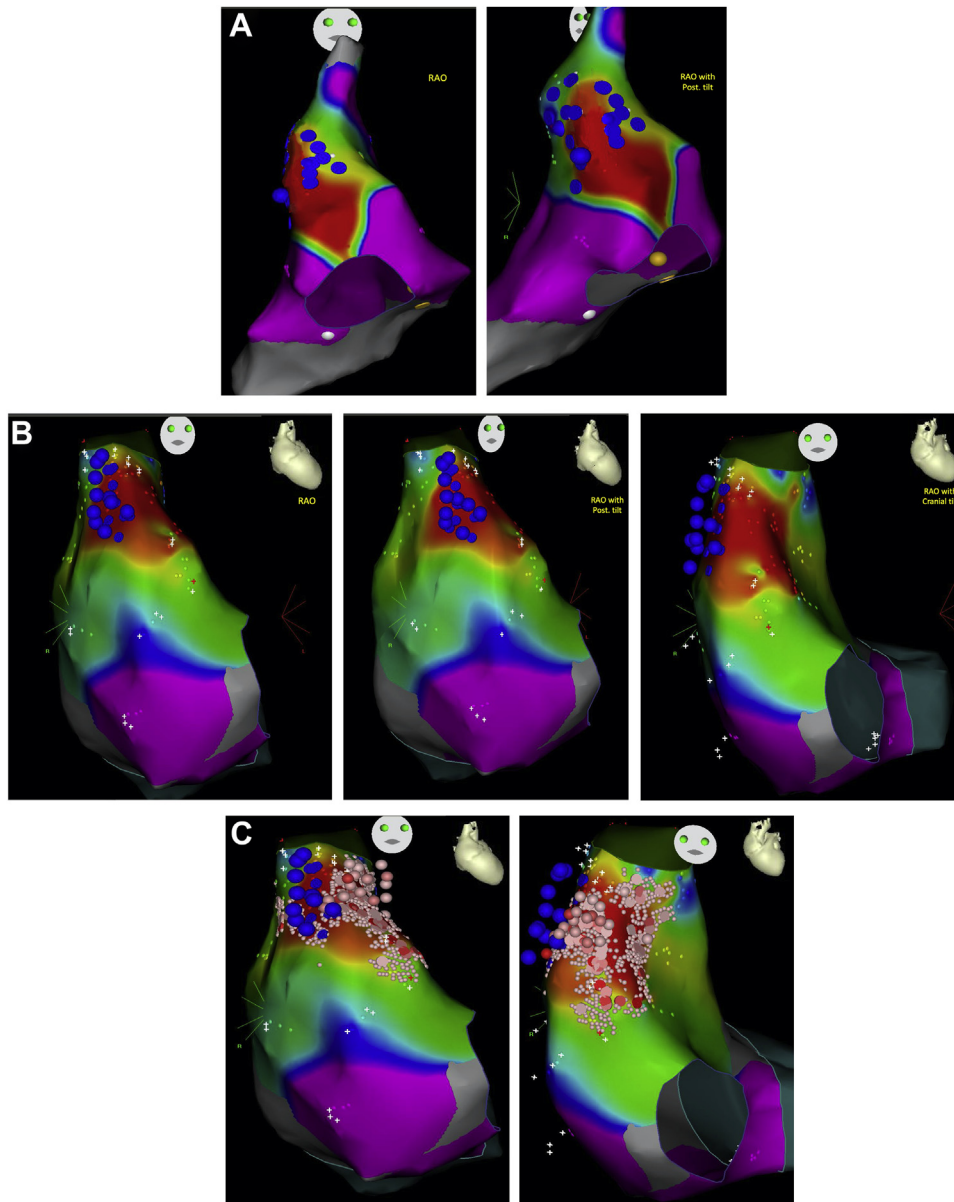


Figure 1 Right atrium CARTO® (Biosense Webster, Baldwin Park, CA) maps indicating the site of earliest atrial activation during sinus rhythm. Areas of consistent phrenic nerve (PN) capture during high-output (10 V @ 2 ms) pace-mapping is marked with blue dots. **A:** Before any CO₂ insufflation “prior procedure” **B:** Following adequate CO₂ insufflation into the pericardial space using the coronary vein perforation. **C:** Following sinus node modification. Note that the posterolateral aspect of the target zone continued to have PN capture and was spared from ablation.

expansion on left anterior oblique 30° view (Figure 3). The patient’s hemodynamics were continuously monitored using an arterial line, and she remained stable throughout. The pericardial–epicardial separation was monitored using a combination of intermittent fluoroscopy (every 5 minutes) and high-output pacing (10 volts @ 2 ms) prior to any RF delivery.

With adequate pericardial–epicardial separation radiographically, the SAN area was remapped for RPN capture that was present at its most posterolateral aspect (Figure 1B), and regions without PN capture were

successfully ablated (Figure 1C). As CO₂ gets absorbed rapidly,² additional boluses of 50 mL each were used to maintain pericardial–epicardial separation. Once SAN modification had been performed, intrapericardial CO₂, along with any blood left, were aspirated before removing the microcatheter. The patient tolerated the procedure well and was discharged home the next day (Supplemental Video). She had a transient improvement in her symptoms for a few weeks, but, unfortunately, her symptoms recurred and now reasonable control has been achieved on medical therapy.

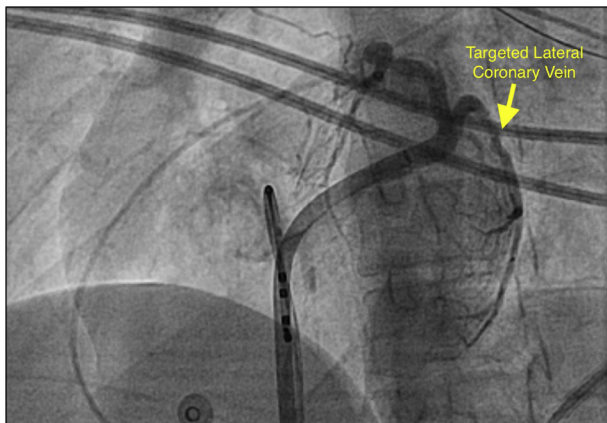


Figure 2 Left anterior oblique (LAO) coronary sinus venogram showing target lateral branch for perforation.

Discussion

IAST is diagnosed when the sinus heart rate persists above 100 beats per minute at rest (with a mean 24-hour heart rate above 90 beats per minute not due to primary causes)

and its symptoms can be debilitating.³ De novo cases appear to predominate, but reports linking IAST to ablation exist. Skeberis and colleagues⁴ reported more than 2 decades ago a 10% incidence of short-lasting IAST following RF ablation in the Koch triangle. Luckily most resolved in 1 week following the index ablation, except in 3 of 118 patients who had their fast pathway ablated as an atrioventricular nodal reentrant tachycardia treatment strategy. The exact etiology of such complications is unknown but is thought to be secondary to sympathetic denervation occurring with low right atrial septal ablation.⁵

Lifestyle modification and conventional medical therapy (beta-blockers, clonidine, or fludrocortisone) have been tried with limited success.³ Ivabradine is a novel therapy that showed promise in small randomized trials. Still, its use is considered off-label,⁶ with suboptimal results in 30% of patients who continued to have symptoms despite proper dose titration.⁷

RF ablation of IAST requires current delivery in the high lateral RA, which carries certain risks, such as the need for pacing, RPN injury, and transient superior vena

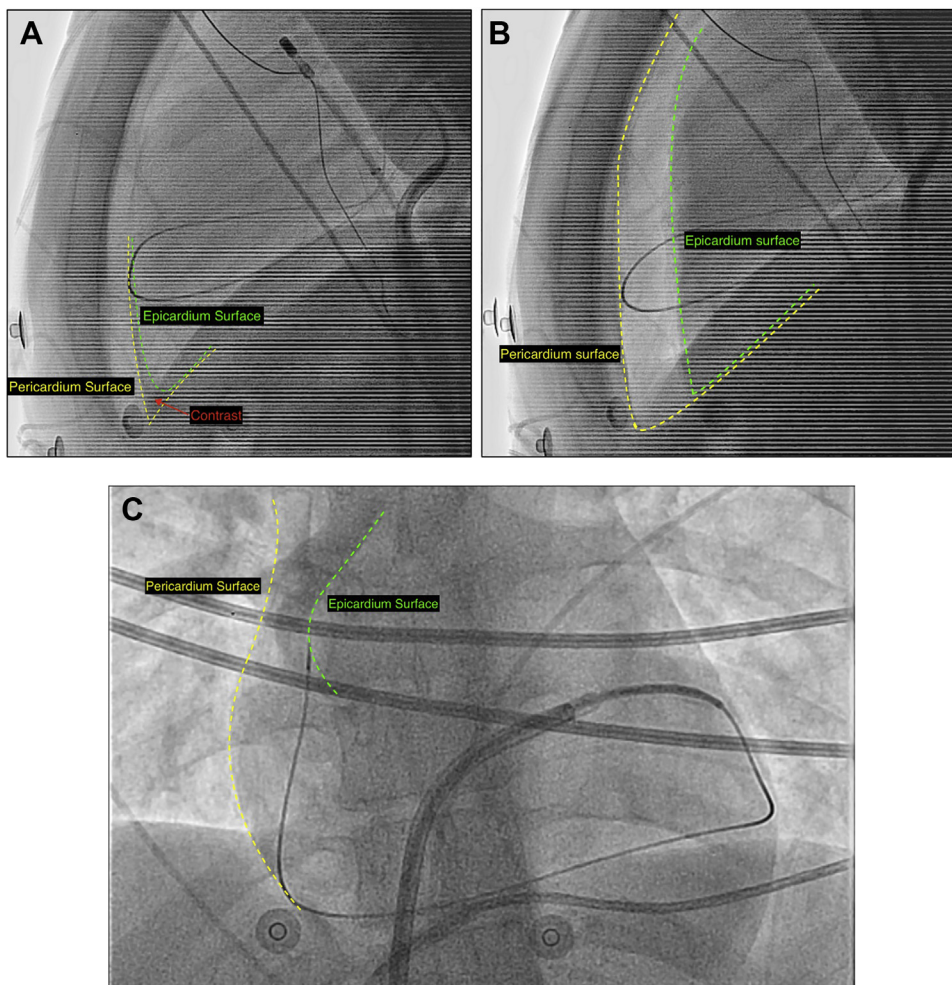


Figure 3 Left lateral (LL) view of thoracic cavity showing epicardial-pericardial separation. **A:** Before CO₂ insufflation. **B,C:** Following CO₂ insufflation with LL (**B**) and left anterior oblique (**C**) radiographic views.

cava (SVC) syndrome. The RPN courses along the right anterolateral surface of the SVC, where the pericardial space separates it from the SVC-RA junction.⁸ Utilizing the pericardial space to displace the RPN away from the SVC-RA junction can minimize paralysis risk. Multiple methods have been described in order to minimize RPN injury, starting from simple ventilation halt whenever a loss of RPN capture is noted during high-output pace-mapping, up to a mechanical displacement of RPN. All mechanical displacement methods described utilized a subxiphoid puncture through which air, saline, or a 14 mm vascular balloon is used to displace the PN away from the SVC-HRA junction.⁹

Accessing pericardium through a coronary vein is safer than a subxiphoid approach, as it avoids right ventricle injury frequently encountered during the subxiphoid approach used during epicardial ablation for ventricular tachycardia.¹ Also, CO₂ has high solubility (28 times more than oxygen²), making it more forgiving than air or saline in case issues with pericardial access arise and residual volume is left behind. Solubility will allow CO₂ to be used safely even when the estimation of amount needed is still being explored.

The RPN injury risk can be reduced by minimizing RF ablation lesion delivery in the SVC-RA junction area, targeting only areas of early activation during β -agonist-induced sinus tachycardia. This was performed while mapping with noncontact mapping array and high-density mapping catheters. Bonhomme and colleagues¹⁰ and Yoshizawa and colleagues¹¹ used the noncontact mapping array (EnSite™ array; Abbott, St Paul, MN) to map atrial breakout sites during sinus rhythm and β -agonist-induced tachycardia. At high rates, atrial breakout sites differed from ones at low rates, and were subsequently ablated.^{10,11} Behar and colleagues¹² used a high-density HD Grid mapping catheter (Abbott) and an infusion of low-dose isoproterenol to map and ablate the sites of the earliest breakout during tachycardia. Both mapping methods led to successful SAN modification without RPN injury, making them attractive options before attempting mechanical displacement. However, when areas of interest still possess RPN capture, the operating physician should be versed in safe techniques to displace it.

CO₂ insufflation has proven useful in facilitating subxiphoid epicardial access during epicardial ventricular tachycardia ablation.¹ To our knowledge, this is the first reported case of RPN preservation using intrapericardial insufflation of CO₂ through a coronary sinus branch.

This technique has its limitations, as repeated boluses of CO₂ were needed to maintain the epicardial–pericardial separation. Close hemodynamic monitoring is required during the procedure to avoid tamponade physiology. Besides, the exact distribution of insufflated gas within the pericardial space cannot be controlled. Lifting the patient's right side with a wedge-shaped cushion may be of use to shift insufflated gas to the pericardial space around the RA-SVC junction. Further refinements of this technique may help us advance one step closer toward a wider adoption of the ablative therapy in drug-refractory IAST.

Appendix Supplementary data

Supplementary data associated with this article can be found in the online version at <https://doi.org/10.1016/j.hrcr.2021.02.011>.

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