Long-term follow-up of minimally invasive video-assisted thoracoscopic surgery with epicardial radiofrequency ablation for complex cases of inappropriate sinus tachycardia

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Introduction

Inappropriate sinus tachycardia (IST) is a rare disorder defined as a nonparoxysmal rhythm originating from the sinus node associated with palpitations with a resting heart rate >100 beats/min and a 24-hour mean heart rate >90 beats/min, with all other potential causes of sinus tachycardia excluded.[1] Patients with IST may experience debilitating palpitations, lightheadedness, chest discomfort, poor exercise tolerance, and other multisystem complaints.[2] It has a complex pathogenesis with many proposed mechanisms, including increased resting sympathetic tone,[3] decreased parasympathetic response,[1,3] and increased intrinsic sinus node rate.[3]

Treatment of IST is variably successful in reducing symptoms. If β-blockers and calcium channel blockers are ineffective, ivabradine, an inhibitor of the hyperpolarizing sodium current, may be better tolerated.[4] For medically refractory symptoms, several methods of endocardial and epicardial ablation to modify the sinus node have been developed.[5–6] Long-term follow-up is unknown for many of these techniques. We report 2 patients with complex cases of IST and debilitating symptoms despite medical therapy and previous invasive interventions. Both patients were successfully treated with epicardial radiofrequency ablation facilitated by minimally invasive video-assisted thoracoscopic surgery (VATS), with no recurrence of sinus tachycardia after up to 4 years of follow-up.

KEYWORDS Epicardial; Inappropriate sinus tachycardia; Minimally invasive surgery; Pacing; Radiofrequency ablation; Sinus node modification; Video-assisted thoracoscopic surgery

ABBREVIATIONS **AV** = atrioventricular; **IST** = inappropriate sinus tachycardia; **SVC** = superior vena cava; **VATS** = video-assisted thoracoscopic surgery (Heart Rhythm Case Reports 2015;1:477–480)

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Case reports

Case 1

Background

A 22-year-old female patient presented to our institution with persistent symptoms of palpitations, exercise intolerance, and dizziness. She had a complex 5-year history beginning with dual-chamber pacemaker implantation for suspected viral-mediated complete atrioventricular (AV) block. She was subsequently diagnosed with IST after her intrinsic AV conduction recovered. Extracardiac causes of sinus tachycardia were excluded with laboratory evaluations, and her echocardiogram was normal with an ejection fraction of 60%. Her symptoms persisted despite medication trials (β-blockers, diltiazem, and clonidine), His bundle ablation, and upgrade to biventricular pacing to treat pacing-related dyssynchrony with multiple attempts at pacemaker reprogramming to optimize its settings. Previous electrophysiology studies demonstrated antegrade AV conduction with a cycle length of 660 ms with no retrograde conduction and no inducible atrial, AV nodal, or ventricular arrhythmias. Subsequent endocardial IST ablation attempts were aborted because of unacceptable diaphragmatic stimulation. Superior vena cava (SVC) stenosis developed and persisted despite venoplasty, limiting further intravenous interventions. She continued to have debilitating symptoms during tachycardia, and pacemaker interrogation demonstrated sinus rhythm with 100% biventricular pacing; histograms demonstrated rates 70–140 beats/min, with 10% of heart rates above 100 beats/min. Because of the previous difficulties during endocardial ablation, bilateral VATS with epicardial sinus node modification was performed. In addition, to eliminate the gradient in the SVC, an epicardial pacing system was implanted so that the endocardial leads could be extracted as a staged procedure, as previously described.[7]

Procedure

The patient underwent general anesthesia with double-lumen endotracheal intubation. She was in sinus rhythm with a

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KEY TEACHING POINTS

- Sinus node modification may allow relief of symptoms in patients with medically refractory inappropriate sinus tachycardia.
- Epicardial sinus node modification is a potentially successful treatment of inappropriate sinus tachycardia when endocardial sinus node modification is unsuccessful or cannot be performed because of limited vascular access or phrenic nerve proximity.
- Video-assisted thoracoscopic surgery has advantages in comparison with other endocardial and epicardial ablation techniques, which include avoiding complications such as phrenic nerve injury and superior vena cava stenosis, addressing complexities encountered in patients with multiple previous procedures, and achieving long-lasting freedom from tachycardia.
- Symptoms of inappropriate sinus tachycardia may recur despite successful elimination of tachycardia; therefore, ablative therapies remain a last resort after conservative medical therapy has failed.

cycle length of 600–630 ms. The right lung was deflated, and two 5-mm ports and a single 10-mm port were placed along the anterior axilla bilaterally (Figure 1). With direct visualization of the phrenic nerve, the pericardium was opened. The sinus node was mapped with a bipolar AtriCure (West Chester, OH) linear pen (Figure 2). The sinus node activation occurred 25–30 ms before the onset of the P wave. Ablation using the Coolrail system (AtriCure) was performed with a maximum power of 50 W until the impedance dropped. The earliest activation moved inferiorly down the sulcus terminalis, and ablation was continued cranial to caudal to the junction with the inferior vena cava. After completion of the epicardial ablation, a subdiaphragmatic incision was made,

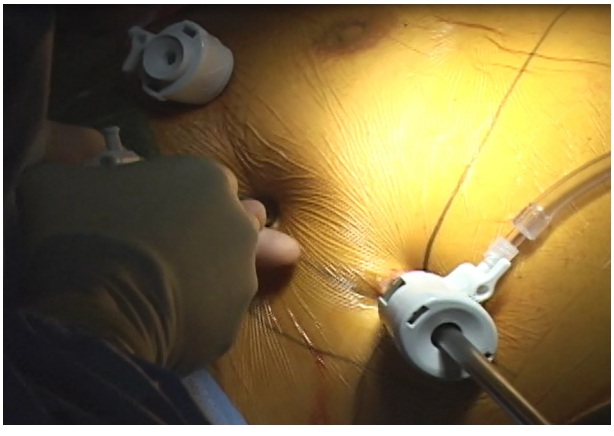

Figure 1 Video-assisted thoracoscopic surgery for sinus node modification in patient 1, with placement of ports in the right thorax.

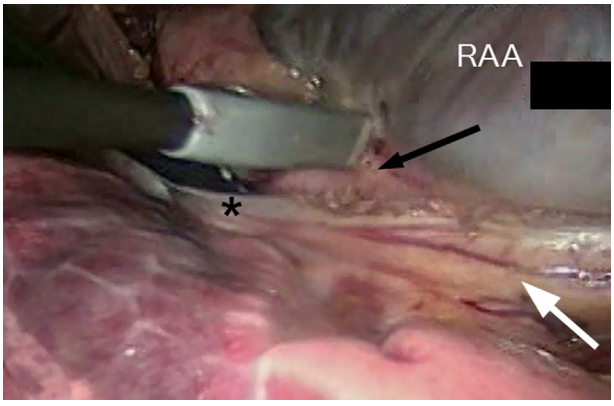

Figure 2 Mapping the right atrium at the junction of the superior vena cava, sulcus terminalis (black arrow), and right atrial appendage (RAA), with visualization of the phrenic nerve (white arrow). The pericardium is labeled with an asterisk.

and right atrial (Model 4965, Medtronic, Minneapolis, MN) and right ventricular (Model 5071, Medtronic, Minneapolis, MN) leads were placed under transesophageal echocardiographic guidance. The left thorax was also entered for direct epicardial placement of a left ventricular lead (Medtronic model 5071). The leads were then tunneled subcutaneously to the pocket in the left chest and connected to the pacemaker. At the conclusion of the procedure, the patient had a stable ectopic atrial rhythm with a superior P-wave axis and a cycle length of 790–820 ms. She experienced asymptomatic right hemidiaphragm elevation, which resolved within 48 hours. All sinus rate–lowering medications were discontinued. The endocardial leads were removed 3 months later after the confirmation of stable epicardial pacing. After 4 years of follow-up, she remains free of sinus tachycardia. Intermittent palpitations have been correlated to symptomatic premature ventricular beats that are now suppressed with flecainide. On cardiopulmonary testing, her exercise tolerance is improved but limited by the rate response of her pacemaker. Device interrogation confirms 100% atrial-biventricular sequential pacing with appropriate sensor-driven histograms.

Case 2

Background

A 36-year-old female patient presented to our institution for persistent symptoms of fatigue, reduced exercise tolerance, and intermittent palpitations over 8 years. Although serial Holter monitoring demonstrated sinus tachycardia and no other clinical arrhythmias, she had undergone at other institutions cavotricuspid isthmus ablation and pulmonary vein isolation for nonsustained atrial flutter and atrial fibrillation inducible with aggressive atrial stimulation and AV node slow pathway modification for dual AV node physiology with single echo beats. Her symptoms persisted, and an implantable loop recorder demonstrated recurrent sinus tachycardia with heart rates exceeding 120 beats/min at rest. Endocardial sinus node modification was transiently successful in reducing the patient's resting heart rate, but it

later increased to 90 beats/min, and her symptoms recurred despite trials of metoprolol, diltiazem, propafenone, sotalol, and ivabradine. Repeat Holter monitoring with metoprolol and ivabradine showed an average rate of 98 beats/min (range 76–141 beats/min). An electrophysiology study was repeated, and the earliest activation was mapped to the base of the right atrial appendage and SVC-right atrial junction, although there were no endocardial activations that preceded the P-wave onset. The sinus rate remained 90–100 beats/min throughout the procedure despite 34 radiofrequency applications in this location, and epicardial ablation by VATS was recommended.

Procedure

The patient underwent general anesthesia with double-lumen endotracheal intubation. Three ports were placed along the right axilla for thoracic access. With direct visualization of the phrenic nerve, the pericardium was opened. Mapping performed at the SVC-right atrial junction identified the earliest activation 165 ms before the onset of the P wave during isoproterenol infusion. Radiofrequency ablation was performed with the AtriCure linear pen at the site of earliest activation with a maximum power of 50 W. The site of earliest activation migrated laterally and inferiorly along the sulcus terminalis. An ectopic atrial rhythm at the base of the right atrial appendage was also ablated. Transmural lesions were confirmed by documenting the absence of local electrograms at each location ablated. The patient's resting heart rate decreased from 110 beats/min at the beginning of the procedure to 84 beats/min, now originating from an ectopic atrial focus. Her ivabradine was discontinued, but she remained on a reduced dose of β-blockers. On follow-up, Holter monitoring demonstrated an average heart rate of 86 beats/min (range 74–105 beats/min). She remains asymptomatic after 3 years of follow-up, and her exercise capacity as measured by cardiopulmonary exercise testing has more than doubled.

Discussion

Our cases show that long-term success in treating IST is possible by sinus node modification via an epicardial approach with VATS. Endocardial approaches to sinus node modification risk phrenic nerve palsy and SVC stenosis. These structures can be protected and the atrial anatomy and phrenic nerve directly visualized in a VATS approach. The VATS approach also facilitates epicardial pacing lead placement, which was required in the first case.[10] Long-term follow-up in both patients demonstrated no recurrence of sinus tachycardia or occurrence of other atrial arrhythmias.

Medical therapy for IST frequently does not completely relieve symptoms. A randomized crossover trial of 20 patients demonstrated persistent IST symptoms in 30% of patients on ivabradine compared with 55% of patients on metoprolol.[4] Symptoms also frequently recur after endocardial sinus node modification. Lee et al[7] reported 12 patients who underwent endocardial sinus node modification guided by intracardiac echocardiography; 2 patients had recurrent IST, and 4 others had recurrent palpitations. Man et al[5] reported 29 patients who underwent endocardial radiofrequency ablation and 34% had recurrent symptoms. Marrouche et al[6] reported a 44% recurrence of symptoms after 39 patients with IST underwent sinus node modification guided by nonfluoroscopic electroanatomic mapping and 28% required a second procedure.

Epicardial ablation may be necessary when endocardial ablation cannot be performed, such as patients with limited vascular access like patient 1, or when previous endocardial ablation attempts have failed, as in patient 2. Epicardial sinus node modification would theoretically be more effective than endocardial ablation because the sinus node is an epicardial structure. Multiple epicardial approaches to IST have been attempted. The VATS approach was described by Beaver et al[8] in a patient in whom endocardial ablation could not be performed because of proximity to the phrenic nerve. The procedure succeeded without complication and no recurrence after 1-month follow-up. Our observations confirm that this approach can produce long-lasting freedom from tachycardia. The largest series of patients undergoing an epicardial approach is a series of 5 cases performed via percutaneous epicardial access without direct visualization, with a mean follow-up of 30 months.[9] While VATS is a more complex procedure requiring single lung ventilation and thoracoscopy, direct visualization of the phrenic nerve and atrial structures (Figure 2) may reduce the risk of permanent complications compared with other epicardial approaches. Further studies directly comparing VATS and percutaneous epicardial approaches are required to determine the optimum approach to sinus node modification.

Because of the invasive nature of the procedure and the potential for recurrent symptoms despite reduction in atrial rate, ablation for IST is a last resort for debilitating, medically refractory symptoms.[1] Both our patients had undergone lengthy trials of multiple medications, with volume expansion, exercise training, and other conservative measures exhausted. Attempts at endocardial sinus node modification had either already failed or was not possible because of limited vascular access or phrenic nerve proximity. These cases show that epicardial sinus node modification via VATS can effectively eliminate tachycardia and tachycardia-related symptoms. Both our patients have had no recurrence of sinus tachycardia and no symptoms related to atrial arrhythmias after 3–4 years of follow-up.

Conclusion

IST is a rare disorder associated with debilitating symptoms that may persist despite pharmacotherapy and endocardial radiofrequency ablation. We present 2 patients with symptoms refractory to multiple interventions who were successfully treated by epicardial sinus node modification via VATS. The advantages of minimally invasive techniques include addressing complexities encountered in patients with

multiple previous procedures, avoiding complications, and achieving long-lasting freedom from tachycardia.

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