Approach to the Difficult Septal Atrioventricular Accessory Pathway
The Importance of Regional Anatomy

Enzhao Liu, MD; Michael Shehata, MD; Charles Swerdlow, MD; Allen Amorn, MD; Eugenio Cingolani, MD; Vinod Kannarkat, MD; Sumeet S. Chugh, MD; Xunzhang Wang, MD

Radiofrequency catheter ablation is the preferred treatment for atrioventricular (AV) accessory pathway (AP) mediated arrhythmias, and success rates continue to depend on accurate AP localization. Owing to the complexity of the anatomy around the septal region that harbors AV accessory fibers, septal APs can be more difficult to ablate as compared with those in other locations. A higher recurrence rate and potential for AV block with ablation have also been reported in patients with septal APs. The posteroseptal area can be anatomically divided into right and left regions that correspond to the annuli of the tricuspid and mitral valves, respectively. A number of investigators have correlated ECG patterns to design algorithms that decipher the location of the ventricular insertion of the AP. Although it has been suggested that a positive delta wave in lead V1 can further differentiate left- from right-sided posteroseptal pathways, others have demonstrated the difficulty in discriminating left- from right-sided posteroseptal AP locations. Here we describe the anatomy of the posteroseptal region and APs ablated in this region.

Case Presentations

Case 1
A 14-year-old male had a history of episodic palpitations. He presented to emergency room in a tachycardia with left bundle branch block pattern. After the tachycardia terminated to sinus rhythm, preexcitation and a right bundle branch block pattern in lead V1 were present on the surface ECG (Figure 1A).

Case 2
A 9-year-old male with a history of recurrent abrupt onset palpitations during activity presented with narrow QRS tachycardia following an elective surgical procedure. A Holter monitor showed sinus rhythm with preexcitation and a right bundle branch block pattern in lead V1.

Electrophysiology study was performed in both cases. In case 1 (Figure 1B), orthodromic tachycardia with left bundle branch block aberrancy was induced by atrial programmed, as well as burst, stimulation. The earliest ventricular activation (–25 ms) was recorded at the posteroseptal tricuspid annulus (PSTA) region during sinus rhythm, but radiofrequency ablation at this region demonstrated only transient AP block. Mapping of the posteroseptal mitral annulus (PSMA) demonstrated a similar activation time to the PSTA region (–22 ms), and radiofrequency application delivered in this location eliminated AP conduction.

In case 2, the earliest ventricular activation was recorded at the PSTA region during sinus rhythm (–25 ms), and radiofrequency ablation was attempted in this location with temporary elimination of preexcitation. Following radiofrequency delivery, however, preexcitation recurred. A transseptal approach was performed to map the mitral annulus. Radiofrequency application at the PSMA region eliminated preexcitation, although the earliest antegrade ventricular activation (–20 ms) at this site was similar to right-sided activation.

Commentary
AV accessory pathways may occur anywhere along the AV annulus. APs that occur within the septum typically occur circumferentially along the annuli of the tricuspid and mitral valves. In many studies, ablation of the posteroseptal region has been identified as more challenging than other locations. An understanding of the anatomic relationship between atrial and ventricular myocardium is crucial for catheter ablation of APs in the septal region. Figure 2 was created using perpendicular dissections along the annulus with 1 cm of atrial and ventricular myocardium attached. The hatched area represents atrial myocardium adjacent to ventricular myocardium at the region of possible AP connections.

The atrial myocardium overlies ventricular myocardium at the right anterior, mid, and posterior septum. Mapping APs from the right septum (Section 2, Figure 2) will demonstrate a large ventricular and small atrial potential at the annular level due to a thinner atrial myocardium overlying thicker ventricular myocardium. In the majority of cases, there is no
atrial myocardium located at the left anterior and left mid-septal regions that are predominantly composed of fibrotic tissue near the aortic cusp; therefore, true AP connections are rarely found in this region.

In these 2 cases, the earliest ventricular activation was recorded at the PSTA, where only transient AP block occurred during radiofrequency applications; however, radiofrequency delivered at the PSMA eliminated AP conduction, although the ventricular activation time was not significantly earlier than the PSTA region. APs at this region have distinct ECG characteristics and are correlated with anatomic Section 3 (Figure 2), where a wide portion of atrial myocardium overrides ventricular myocardium spanning the PSTA to PSMA. A QS wave in lead V1 will identify AP connections at the PSTA, while an isoelectric initial QRS complex with rSR' pattern in lead V1 identifies AP connections closer to the mitral annulus; however, an ECG pattern with an initial slightly positive or isoelectric vector in lead II will be found in AP connections at both the PSTA and PSMA. In these 2 cases, the sinus rhythm ECG demonstrated an isoelectric initial QRS complex with rSR' pattern in lead V1. Transient block, but not elimination of AP conduction with ablation at the PSTA region, necessitated a left-side approach. Depending on the orientation, depth, or width of the AP, ablation at the PSTA region may not be able to produce a sufficient lesion to completely eliminate AP conduction. A left-sided approach or ablation at both PSTA and PSMA regions may be necessary, and a significantly earlier activation time at the PSMA region during sinus rhythm may not be necessary for successful ablation at this site.

Theoretically, APs may be present at either side of the posterior septum (left or right) or more centrally located (Section 3, Figure 2) and successful ablation will depend on which side of the septum the AP is located. The narrow QRS in lead V1 in the presence of preexcitation indicates a mitral annular location. Additionally, the right bundle branch block pattern during sinus rhythm in both of our cases indicates the ventricular insertion site of the APs may activate a proximal branch of left bundle, resulting in a terminal delay in right ventricular activation. This location may be difficult for catheter manipulation either via a transseptal or retrograde aortic approach due to the posteroseptal location.

Sections 4 and 5 in Figure 2 illustrates the continuation of right atrium into the coronary sinus (CS) ostium, with a funnel shape demonstrating a wide, thinner atrial myocardium overlying the ventricle. Radiofrequency application on the floor of the CS will eliminate AP connections with negative delta waves in lead II, except in cases where the AP is closer to the PSMA, which is distinguished by an isoelectric or slightly positive delta wave in lead II.

Some APs may not be eliminated by endocardial radiofrequency ablation. In Figure 2, Section 6, the CS begins to rise...
superiorly from the ventricular myocardium, with atrial myocardium still in wide contact with ventricular myocardium. When AP connections are located at the subepicardial region, it may be difficult to eliminate the AP from ablation within the CS. A negative delta wave in lead II identifies a subepicardial location (middle cardiac vein or coronary sinus diverticulum). CS venography is necessary for assessment of this type of AP before ablation, and ablation of these APs has been known to require radiofrequency energy within the middle cardiac vein or diverticulum (Section 6, Figure 2).

**Summary**

Ablation of accessory tracts in the posteroseptal region can be challenging, as illustrated by these 2 cases. Familiarity of the anatomy of this region and recognition of the ECG patterns can help identify the AP origin and potentially improve success rates of ablation. The isoelectric initial preexcited QRS complex with rSR’ pattern in lead V1 of the surface ECG but not the relatively earlier local ventricular activation at PSMA region may indicate a left-sided ablation approach for these APs.

**Disclosures**

None

**References**


**Key Words:** arrhythmia • heart rhythm disorders • catheter ablation • electrocardiography • electrophysiology mapping • tachyarrhythmia or tachyarrhythmias
EDITOR’S PERSPECTIVE

Drs Liu et al present an outstanding discussion of the difficulties associated with mapping and accurately targeting accessory pathways in the region of the cardiac septum. In addition to the insightful correlations made in their paper, there are important lessons for the electrophysiology student to take from this specific example and apply when analyzing the potential causes for difficulty with ablation in general. Why is the cardiac septum in the region of the atrioventricular annulus particularly problematic for mapping accessory pathways? The unique anatomy of this region, the fact that a significant part of this septum is not a septum (between right- and left-sided structures), and the complex relationship with the cardiac venous system and the cardiac valves in this location all contribute to the sometimes paradoxical results obtained with mapping and ablation. Further, the electrophysiology trainee needs to rethink what epicardial location actually means in the context of the cardiac crux.

Anatomy of the Interatrial Septum

An important cause for difficulty in conceptualizing the interatrial septum near the atrioventricular annulus is that more than just the right and left atrial myocardium lies opposite each other across the septum.

- The atrioventricular septum lies in the mid-annular portion of the cardiac crux. Here, this septum (technically a part of the interven- tricular septum) lies not between the atria or between the ventricles but between the right atrium and the interventricular septum. More specifically, a thin separation between right atrial myocardium and the complex summit of the interventricular septum primar- ily composed of left ventricular myocardium (Figure). Thus, if a posterior septal pathway connects the left atrial myocardium with the left ventricular myocardium, relatively early antegrade activation via this pathway will be found when mapping the right tricuspid annulus in the vicinity of the interventricular septum, but unless a large lesion is created, ablation will not be successful, and energy delivery on the left side of the heart (noral annulus) will be required.

- True versus false interatrial septum. The posterior interatrial septum near the atrioventricular grooves is a complex structure that does not represent a true septum between the right and left atria. Rather, this space includes cardiac veins, adipose tissue, and cardiac ganglia. Accessory pathways that traverse this space may involve the cardiac veins, right atrial myocardium, left atrial myocardium, and the ventricular myocardium. Complex relationships become possible, and without combined mapping or ablation on either side of this “septum” and the venous system, success is unlikely.

Limiting Energy Delivery

Some pathways in this region are deep to the endocardium, requiring increasing ablation duration and power to amplify lesion size for successful ablation. There is concern, however, that this increases the risk of heart block due to the proximity of the atrioventricular con- duction system, with the compact AV node being located on the mid-septum and the His bundle on the ventricular aspect of the anterior septum. Operators often limit energy delivery, compounding the difficulty with creating a transseptal/transmural lesion to eliminate the pathway. It is important to note that success with ablation and without AV nodal damage is not inherently less likely when ablating on the left side of this region and producing a large lesion, and it is well-known that AV conduction can be permanently disrupted with left-sided ablation; however, mapping on both sides of the septum is often essential to target the appropriate site. When pathway potentials are absent in all locations, and there is near-simultaneous activation on both sides, suggesting the true site is in between; then combined ablation on both sides is sometimes successful.

The Cardiac Valves and the Venous System

The thickness of the interatrial septum itself may make ablation of pathways in its depths difficult; however, the aortic valve and the cardiac veins invaginate into the interatrial septum superiorly and inferiorly, respectively. There are 2 important corollaries that arise from this fact of septal anatomy. First, the aortic valve and cardiac veins require targeted mapping when dealing with anterior and posterior septal arrhythmia origin. This is particularly important when multiple locations appear to be equally early, or, for reentrant arrhythmia, entrainment from multiple locations suggests a similar distance from the reentry circuit. Given the juxtaposition of these structures, care is required in interpreting the electrogram and assigning timing relative to a reference. Because the complex electrograms retrieved from these locations have both far- and near-field components, simply taking the earliest electrogram may result in the appearance of near-simultaneous activation at disparate sites. Focusing on the near-field components only largely ameliorates this problem and improves the chance of success. Because of the innervation of these cardiac structures into the septum, they offer vantage points for delivery of radiofrequency energy to reach the “deep” septum, with less chance of damaging conduction tissue compared with ablation from either the right or left sides of the septum.

Electrocardiographic Correlation

Liu et al point out that when a QS pattern is noted in lead V1 during preexcitation, ablation at the posteroseptal tricuspid annulus is typically successful, whereas with an RSR pattern, ablation at the posteroseptal mitral annulus may be required as illustrated in their cases. This useful observation, along with those that have been well-described, can be helpful with pathway ablation; however, given the complexity of the regional anatomy, vagaries of specific cardiac orientation in different patients, body habitus, and the degree of preexcitation, the ECG findings represent guidelines rather than absolute criteria and, as the authors stress, in no way preclude detailed mapping before making a judgment as to where energy should be delivered. The authors also conjecture on typical right bundle branch block pattern in lead V1, potentially resulting from direct activation of the proximal left bundle. This is an interesting insight, and, given the typical insulation of the His and proximal right bundle, one would have to conjecture a complex pathway that breaches this insulation and directly activates the left bundle.

What Does Epicardial Mean?

When mapping the endocardial surface, we often hypothesize the existence of epicardial arrhythmogenic substrate based on a far-field early signal or failure of endocardial ablation. In the context of the interatrial septum near the atrioventricular annulus, findings that suggest an epicardial pathway (ie, away from the endocardial catheter site) have multiple possible causes. These include accessory pathways causing early activation on the other side of the septum (left when mapping endocardial right atrium), near the aortic valve, in musculature around the coronary sinus and cardiac veins, and in the complex summit of the heart in the region of the atrioventricular septum. A careful study of the examples and discussion provided by Liu et al offers multiple potentially valuable teaching points when mapping and ablation in this and other complex electroanatomical sites in the heart.

References

Approach to the Difficult Septal Atrioventricular Accessory Pathway: The Importance of Regional Anatomy
Enzhao Liu, Michael Shehata, Charles Swerdlow, Allen Amorn, Eugenio Cingolani, Vinod Kannarkat, Sumeet S. Chugh and Xunzhang Wang

*Circ Arrhythm Electrophysiol*, 2012;5:e63-e66
doi: 10.1161/CIRCEP.112.971135

*Circulation: Arrhythmia and Electrophysiology* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2012 American Heart Association, Inc. All rights reserved.
Print ISSN: 1941-3149. Online ISSN: 1941-3084

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circep.ahajournals.org/content/5/3/e63

**Permissions**: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Circulation: Arrhythmia and Electrophysiology* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

**Reprints**: Information about reprints can be found online at:
http://www.lww.com/reprints

**Subscriptions**: Information about subscribing to *Circulation: Arrhythmia and Electrophysiology* is online at:
http://circep.ahajournals.org/subscriptions/