Bypass Tracts Revisited

Samuel J. Asirvatham, MD; William G. Stevenson, MD

The study of atrioventricular bypass tracts remains an educational cornerstone for students of electrophysiology seeking to understand the principles of reentry, mapping, tachycardia mechanism diagnosis in the electrophysiology laboratory, and ablation. Surgical and subsequently catheter ablation procedures to eliminate these tracts derived from an understanding of their anatomic location, typically bridging the atrioventricular annulus allowing conduction from atrium to ventricle to bypass the normal atrioventricular node. With this appreciation of anatomy and physiology, pacing maneuvers can be applied and interpreted to clarify the presence and electrophysiological properties of atrioventricular bypass tracts in the electrophysiology laboratory.

In this segment of Teaching Points in Electrophysiology, Patel and colleagues present and carefully examine a different type of bypass tract, one connecting the right atrium to a pulmonary vein (PV) bypassing the left atrial myocardium. The underlying principle for PV isolation derives from the construct that the PV myocardium is solely activated via conduction from the left atrial myocardium across the PV ostium. The presence of an intercaval bundle creating a tract that electrically connects the posterior right atrium and the anterior aspect of the right superior PV makes isolation of this vein with left atrial ablation alone impossible.

Similiar tracts may also bypass the left atrium and connect a left PV to the coronary sinus (CS) musculature, to the left atrial appendage (LAA), or to an adjacent left PV. In the latter case, ostial encircling ablation lines will fail to isolate the vein. In the former 2 cases, even encircling antral ablation lines around the left PVs may fail to isolate these structures. In some patients, the remnant of the left superior vena cava— the ligament and vein of Marshall (VOM)—serves as the tract connecting the CS myocardium to a PV. The presence of these tracts has important implications. Because exit block cannot be achieved with left atrial ablation alone, the arrhythmogenic substrate within the vein remains and is capable of triggering atrial fibrillation. In addition, these tracts may participate in reentry and can produce complex reentry paths. In the case of the epicardially located VOM, the tract does not connect only to the CS and PV, but in its course as one of the oblique veins of the left atrium, it can connect to multiple sites on the left atrial epicardial wall, resulting in a complex reentry substrate. Occasionally, a large macroreentrant circuit involving Bachmann’s bundle, the right and left atria, the ostial LAA myocardium, the VOM, and the CS myocardium may occur, particularly in patients with prior atrial surgery.

The tract itself can also supply the trigger for atrial fibrillation. The myocardial sleeves surrounding the VOM are similar to those around the PVs and within the CS and may give rise to premature atrial contractions triggering atrial tachycardia and atrial fibrillation.

### Diagnosis and Ablation of Anomalous PV Connections

#### Confirming PV Activation

The first step is to show that potentials recorded from the vein are not produced by adjacent structures (eg, the LAA when recording from the left PVs), by showing that pacing within the PV does capture the local PV myocardium. The next step is to demonstrate that the earliest PV signal is not at the ostium, but within the vein. Without bypass tracts, the left atrium is the source for PV activation, and PV signals are earliest at the ostium and become progressively later as the catheter is moved deeper into the vein. With a bypass tract that inserts distal to the ostium, the antrum is activated later than the more distal PV tissue.

#### VOM Connections

##### High and Low Output Pacing in the CS for VOM Connections

High output pacing in the CS proximal to the VOM captures left atrium and CS myocardium, but at low output may capture only the CS myocardium. If there is no change in the timing of the PV potential between high and low output pacing (with CS and LA capture compared with capture of the CS alone) then a bypass tract is present and depends only on the CS myocardium to activate the PV myocardium via the VOM.

Pacing within the VOM will pull in the PV signals, activating them earlier, whereas pacing at other sites outside the PV (eg, the LAA) fails to do so.

Ablation of the VOM tissue or all of its connection can be difficult, but may be achieved by a variety of approaches:

1. Transmural ablation at the endocardial ridge anterior to the left PVs.
PV to PV Bypass Tracts
Myocardial bridges distal to the ostium that occur between individual PVs are particularly likely to occur when a narrow common ostium is present with later branching between the 2 PVs. When wide area circumferential ablation is done and both ipsilateral veins are isolated simultaneously, these bypass tracts are irrelevant. However, when individual PV isolation is done, then persistent PV conduction may occur through one of these tracts. Pacing in the ipsilateral vein will pull in the signals that remain in the vein that is already encircled with ablation lesions. Care must be taken to avoid direct capture of the adjacent vein by pacing in the ipsilateral vein on the side facing away from the vein being mapped. For example, if left upper vein isolation is failing to achieve entrance block, then pacing is performed in the left lower vein on its inferior wall.

LAA to Left PV Tracts
The VOM and left superior vena cava sulcus creates a plane of separation between the posterior wall of the LAA and the anterior wall of the left PVs. Some patients have myocardial connections that bridge this sulcus and diagnosis can be difficult. When this occurs, delineation of far-field signals arising from the LAA cannot be demonstrated in the usual manner by pacing in the LAA because the direct connection will cause the PV potentials to be pulled. In patients who have had a LAA closure device placed, pacing maneuvers may not be possible from within the LAA.

Confirming the Diagnosis
1. Depending on where these bypass tracts occur, the earliest PV activation is at that site distal to the ostium.
2. Pacing on the anterior wall of the LAA will pull in the PV signals with the same activation sequence.
3. Pacing on the posterior wall of the left PV will cause early activation within the LAA.

Ablation
1. During pacing of the left PV posteriorly, an activation map of the LAA can be created and the earliest site of activation targeted for ablation energy delivery.
2. If the LAA has been occluded with an endocardial device, circumferential isolation around the device of the LAA may be necessary to isolate the left PVs.

Disclosures
Dr. Asirvatham receives no significant honoraria and is a consultant with Abiomed, AtriCure, Biosense Webster, Biotronik, Boston Scientific, Medtronic, Spectranetics, St. Jude, Sanofi-Aventis, Wolters Kluwer, Elsevier. Dr. Stevenson is coholder of a patent on needle ablation that is consigned to Brigham and Women’s Hospital.

References
1. Patel PJ, D’Souza B, Saha P, Chik WWB, Riley MP, Garcia FG. Electroanatomic mapping of the intercaval bundle in right atrium or superior vena cava. These tracts are perhaps the best recognized of those described in this perspective. In addition to the inability to isolate the vein, these bypass tracts may constitute a limb of a reentrant circuit that involves the right atrium, left atrium, and the right-sided PVs when a gap in the encircling PV line is present. When slow conduction is present related to this gap, the tachycardias may be easily induced or incessant. Re-isolation of the vein or ablation at the right atrial entrance site for the bypass tract will terminate the macroreentrant tachycardia, but for isolation of the vein, both the left atrial gap and bypass tract must be eliminated.

1. Patel and colleagues elegantly describe a set of patients where targeted mapping and ablation of fibers that bypass the left atrial ostium and directly connect the anterior wall of the right PVs to the right atrium or superior vena cava. These tracts are perhaps the best recognized of those described in this perspective. In addition to the inability to isolate the vein, these bypass tracts may constitute a limb of a reentrant circuit that involves the right atrium, left atrium, and the right-sided PVs when a gap in the encircling PV line is present. When slow conduction is present related to this gap, the tachycardias may be easily induced or incessant. Re-isolation of the vein or ablation at the right atrial entrance site for the bypass tract will terminate the macroreentrant tachycardia, but for isolation of the vein, both the left atrial gap and bypass tract must be eliminated.


Key Words: ablation techniques ◼ anatomy ◼ atrial fibrillation ◼ bypass, cardiopulmonary ◼ pulmonary vein
Bypass Tracts Revisited
Samuel J. Asirvatham and William G. Stevenson

Circ Arrhythm Electrophysiol. 2014;7:1268-1270
doi: 10.1161/CIRCEP.114.002475

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/7/6/1268

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/