Intramural Outflow Tract Ventricular Tachycardia
Anatomy, Mapping, and Ablation

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Idiopathic ventricular tachycardia (VT) originating from the outflow tract has been treated with a relatively high success rate by radiofrequency catheter ablation. However, a small percentage of failure in these patients may be because of an inaccessible site of origin from an intramural location. The region of the interventricular septum between the right (RVOT) and left ventricular outflow tracts (LVOT) can be mapped by using thinner multielectrode catheters advanced via the septal perforating venous tributaries of the great cardiac vein (GCV). 1,2 The following case series is a description of these intramural VTs and the anatomic analysis in this region.

Case Report

Case 1
A 56-year-old man with a history of high-burden premature ventricular contractions (PVCs) that were refractory to medical therapy underwent catheter ablation. The morphology of the PVC by ECG showed a rS wave with S wave notch at lead I and a rS wave in V1 (Figure 1A). The earliest ventricular activation timing at the RVOT was −19 ms. Mapping of the GCV and vein tributaries was then performed using a 3.5-mm irrigated ablation catheter guided by venography (Figure 1B). The GCV and lateral veins of the GCV were mapped with no optimal early ventricular activation located. However, the earliest activation was located at a septal perforating branch (SPB) vein of the GCV with a timing of −39 ms. Pace mapping at the target area completely matched with the clinical PVC. Ablation was performed at the earliest SPB vein site using an irrigated catheter with 15 W and an infusion rate of 17 mL/min with impedance range of 150 to 180 Ohms (Figure 1C), with complete elimination of PVCs during radiofrequency delivery. After the ablation procedure, there were no recurrent PVCs during a 2-year follow-up period.

Case 2
A 46-year-old woman with a history of newly diagnosed cardiomyopathy with a very high burden of ventricular ectopy (70% of all QRS complexes) on a 24-hour Holter monitor that was refractory to medical therapy presented to our center. Twelve-lead ECG showed a QS pattern in lead I and a rS with relatively narrow QRS pattern in lead V1 (Figure 2A). Mapping of the RVOT, GCV including SPB veins, as well as LVOT and aortic cusps was performed. The early site of ventricular activation in the RVOT was slightly later than that mapped to the SPB vein (−38 ms; Figure 2C). Initially, ablation was performed at the RVOT site using a 4-mm irrigated electrode with 40 W and only transient suppression of PVCs (Figure 2B, middle panel). Subsequently, ablation was performed within the SPB vein using a 4-mm nonirrigated electrode with 5 W at 80°C with an impedance of 180 Ohms, which resulted in complete elimination of PVCs. The LV ejection fraction was noted to have completely recovered at 3-month follow-up, and the patient remained free of PVCs during a 2-year follow-up period.

Discussion
Intramural septal sites of origin for VT or PVCs are an increasingly recognized location for outflow tract tachycardias. The GCV has been a target of great interest for idiopathic VT mapping since 1998 when it was described by dePaola et al.3 One of the first series looking at using both radiofrequency ablation as well as cryoablation in the GCV region was described in a multicenter case series in 2006.4 The SPB veins of the GCV may allow for access to otherwise endocardially inaccessible sites. The recent single-center experience of Yokokawa et al2 has described an intramural focus in 8% of patients with outflow tract VT.

The anatomy of this region is complex and is demonstrated in a schematic diagram in Figure 3. The dissection is made horizontally above the mitral and tricuspid annuli and below the aortic cusps. Figure 3, top right panel, shows the septal myocardium separating the RVOT and LVOT. The septal aspect of the RVOT is adjacent to the right coronary cusp posteriorly and the septal portion of the left coronary cusp (LCC) anteriorly. Another dissection was made perpendicularly at the junction of the LCC and right coronary cusp and shows that the aortic cusps lay above the thicker septal myocardium that separates the RVOT and LVOT (Figure 3, bottom right panel). The SPB veins of the GCV may allow access to the anterior or middle septal myocardium; however, venous

Received April 3, 2014; accepted July 5, 2014.
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(Circ Arrhythm Electrophysiol. 2014;7:978-981.)
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Circ Arrhythm Electrophysiol is available at http://circep.ahajournals.org
DOI: 10.1161/CIRCEP.114.001744
978
branches have significant variability in size. The GCV anatomically follows a purely epicardial course and thus has a more limited role in truly intramural septal origins in contrast to the SPB veins that are intramural in location. The anterior portion of the LCC is at the septal aspect of the LVOT. The right coronary cusp is located more posteriorly at the septal aspect of the LVOT. The slightly anterior aspect of RVOT, GCV, and LCC form a triangle with similar distance between them. Equally early ventricular activation times during mapping at the site of the anterior RVOT, LCC, and GCV may indicate a deeper intramural septal origin. Mapping of the GCV guided by venography or the use of smaller multielectrode catheters may be useful. Other options to ablate intramural septal sites of origin can be ablation via the endocardial surface of the RVOT or LVOT/aortic cusps. Additionally, coronary arteriography should be performed; however, the SPB veins are usually somewhat distant from any main coronary artery branches.

Multiple ECG algorithms have been devised to predict the site of origin for outflow tract tachycardias. However, there are different ECG characteristics in our 2 cases with the same origin. One reason may be preferential conduction to either aspect of the ventricular septum. For this reason, comprehensive mapping of the GCV and SPB veins can be useful to precisely delineate the location of origin.

Disclosures
None.

References

**Key Words:** catheter ablation | tachycardia, ventricular | ventricular premature complexes
Figure 1. A, Twelve-lead ECG of the premature ventricular contraction in a bigeminal pattern with an rS pattern in lead V1 and rS wave with S wave notch in lead I. B, Top panels demonstrate venography in left anterior oblique (LAO) and right anterior oblique (RAO) projections with an array mapping balloon in the right ventricular outflow tract. Bottom panels demonstrate positioning of a 3.5-mm irrigated ablation catheter electrode in the septal perforating branch (SPB) vein and 4 mm ablation electrode in the anterior aspect of right ventricular outflow tract in LAO and RAO projections. C, Intracardiac electrograms from mapping of the SPB vein with the ablation catheter electrode at the successful target site. AIV indicates anterior interventricular vein; and LLB, left lateral branch.
Figure 2. A, Twelve-lead ECG demonstrates premature ventricular contractions with a rS and relatively narrow QRS in V1 and QS wave in lead I. B, Coronary arteriography shows the relationship of left coronary artery, 4 mm ablation electrode in the right ventricular outflow tract (RVOT), and mapping electrode in the septal perforating branch (SPB) vein (left and middle). The rightward panel shows coronary sinus venography after successful ablation within the SPB vein causing stenosis of that branch (right). C, Intracardiac electrograms from ablation catheter positioned within the SPB vein showing earliest activation time at the successful ablation site. HIS indicates the HIS bundle location; LAO, left anterior oblique; and RAO, right anterior oblique.

Figure 3. The horizontal dissection was made above the mitral and tricuspid annuli and below the aortic valve with a caudal view. The septal myocardium separates the right (RVOT) and left ventricular outflow tracts (LVOT) with septal perforating branch (SPB) veins extending into the myocardium. The dissection was made perpendicularly at the junction of left (LCC) and right coronary cusp (RCC), showing the aortic cusp positioned above the thicker septal myocardium and separating the RVOT and LVOT. The septal portion of myocardium usually extends above the pulmonary valve. AV indicates aortic valve; FO, foramen ovale; GCV, great cardiac vein; LAD, left anterior descending artery; LVIT, left ventricular inflow tract; NCC, noncoronary cusp; PA, pulmonary artery; PV, pulmonary valve; RA, right atrium; and RVIT, right ventricular inflow tract.