An electrocardiographic sign of idiopathic ventricular tachycardia ablatable from the distal great cardiac vein

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BACKGROUND Idiopathic ventricular arrhythmias (IVAs) can originate from the distal great cardiac vein (DGCV). However, inadequate distinction sometimes occurs when electrocardiographic (ECG) characteristics are used to distinguish ventricular arrhythmias (VAs) arising from the DGCV from those arising from the adjacent left ventricular endocardium (LV ENDO).

OBJECTIVE The purpose of this study was to identify distinct ECG features in patients with idiopathic IVAs originating from the DGCV.

METHODS A total of 32 patients with IVAs originating from the DGCV were identified from a consecutive group of 874 patients undergoing IVAs ablation. Patients with IVAs from the DGCV were compared with a consecutively chosen series of 40 patients with IVAs in whom the site of origin was the adjacent LV ENDO.

RESULTS Of the 32 patients with IVAs arising from the DGCV, 13 had distinct ECG characteristics compared with the LV ENDO group. Notches in both the upstroke and downstroke of the R wave in lead III were found in all 13 patients. However, the characteristic ECG pattern in lead III was found in 1 of 40 patients in the LV ENDO group. The ECG characteristic of both early notch and late notches in lead III has sensitivity of 40.6%, specificity of 97.5%, negative predictive value of 67.2%, and positive predictive value of 92.9% to predict VAs arising from the DGCV.

CONCLUSION The distinct ECG characteristics of VAs originating from the DGCV can help differentiate from adjacent LV ENDO sites of origin.

KEYWORDS Catheter ablation; Distal great cardiac vein; Electrophysiology; Epicardium; Idiopathic ventricular arrhythmia

Introduction

Idiopathic ventricular arrhythmias (IVAs), including premature ventricular complexes (PVCs) and ventricular tachycardias (VTs), are the most common arrhythmias observed in patients without structural heart disease, and they can arise from the left ventricular endocardium (LV ENDO) and from the epicardium.1-8 In recent studies, the reported incidence of an epicardial origin ranged from 2.5% to 15%.7 We previously reported that the coronary vein system (CVS) provides a potential route for mapping and ablating ventricular arrhythmias (VAs) arising from an epicardial site.2 However, inadequate distinction is made when electrocardiographic (ECG) characteristics are used to distinguish IVAs arising from the distal great cardiac vein (DGCV) from those arising from adjacent LV ENDO. We hypothesized that the ECG features of some VAs originating from the DGCV may be unique. The aim of this study was to identify ECG features of patients with IVAs originating from the DGCV.

Methods

Study population

The study population consisted of patients referred for radiofrequency catheter ablation (RFCA) of IVAs originating from the DGCV. Patients with IVAs originating from the other coronary venous branches, such as the anterior interventricular vein (AIVV) and the communicating vein (CV), were not included. No structural heart disease was apparent on physical examination, echocardiography, or coronary angiography. Before RFCA, a 12-lead ECG was performed, and 24-hour ambulatory ECG monitoring (Holter) was carried out at least once. The ECG was monitored for 24 hours before catheter ablation. Patients with IVAs from the DGCV were compared with a consecutively chosen series of 40 patients with IVAs in whom the site of origin was the
adjacent LV ENDO (region of aortomitral continuity). All subjects provided written informed consent. Studies and data collection were performed according to protocols approved by the Ethics Committee of the Second Affiliated Hospital of Wenzhou Medical University.

**Electrophysiological study and RFCA**

Electrophysiological evaluation and catheter ablation were performed as previously described. Standard multielectrode catheters were inserted through the femoral vein under fluoroscopic guidance. Surface ECG leads were placed in the standard positions and recorded with a bandpass filter at 0.05–100 Hz on a multichannel oscillographic recorder. Intravenous isoproterenol was administered to induce arrhythmia if VAs failed to occur spontaneously. For VAs with a left bundle branch block morphology, mapping was performed first in the right ventricular outflow tract (RVOT), followed by the aortic cusp, left ventricular outflow tract (LVOT), and CVS. For VAs with a right bundle branch block morphology, mapping of the aortic cusps and LVOT was performed first using a retrograde aortic approach, followed by the RVOT and DGCV via the CVS. Coronary venous anatomy was defined by coronary venous angiography before mapping.

The ideal target site of RFCA was determined by acceptable pacemapping (≥10–12-lead concordance of major and minor deflections) with the earliest local activation time. Coronary angiography was performed before radiofrequency (RF) application to access the potential risk of coronary artery damage. RFCA was performed in all patients using an irrigated-tip catheter at power of 20–30 W and maximum temperature of 45°C. If impedance within the CVS was too high for delivery of RF energy, the maximum rate of catheter open irrigation was increased to 60 mL/min. If the VAs were terminated within ≥15 seconds and PVCs and/or nonsustained VT occurred during ablation at the target site, additional current was applied for another 60–90 seconds.

Acute procedural successful ablation was defined as complete elimination of spontaneous or inducible VAs. Programmed electrical stimulation was repeated 30 minutes after the last application of RF energy to confirm the absence of inducible VAs before all catheters and sheaths were removed. If VAs did not terminate within 15 seconds, RF energy application was terminated, and another target site was sought. After ablation, coronary angiography was performed again to assess for patency of coronary arteries.

**Anatomic definitions**

Coronary venous angiography was performed to assess coronary venous anatomy. Coronary venous branches were defined under bilateral fluoroscopic guidance as previously described (Figure 1). The DGCV was defined as the distal segment of the great cardiac vein (GCV) traveling in the anterolateral portion of the atrioventricular groove and the AIVV as the portion traveling in the interventricular septum, anterior to the atrioventricular groove. The CV between the aortic and pulmonary annulus (summit-CV) was defined as the extended tributary of the DGCV located distal to the origin of the AIVV.

**Comparison of PVC/VT morphology**

The site of origin of VAs was determined based on activation mapping and successful elimination using RF energy application. The following ECG features were assessed as previously described in patients with VAs originating from the DGCV and adjacent LV ENDO: (1) QRS morphology of VAs in all 12 leads; (2) site of R-wave transition in the precordial leads; (3) axis deviation; (4) QRS notch in lead III (early notch indicates a notch in the upstroke of the R wave in lead III; late notch indicates a notch in the downstroke of the R wave in lead III); (5) measurement of H1/H2 ratio and H3/H4 ratio in lead III (H1 and H3 measured from the

![Figure 1](image-url)  
Coronary venous branches were defined under bilateral fluoroscopic guidance. The distal great cardiac vein (DGCV) was defined as the distal segment of great cardiac vein traveling in the anterolateral portion of the atrioventricular groove and the anterior interventricular vein (AIVV) as the portion traveling in the interventricular septum, anterior to the atrioventricular groove. The communicating vein (CV) between the aortic and pulmonary annulus (summit-CV) was defined as the extended tributary of the DGCV located distal to the origin of the AIVV. LAO = left anterior oblique; RAO = right anterior oblique.
isoelectric line to the early and late notches, respectively; H2 and H4 measured from peak of the R wave to early and late notching, respectively. H2 and H4 were measured from the isoelectric line to the early and late notches, respectively. H2 and H4 were measured from peak of the R wave to early and late notching, respectively. D: Pickelhaube, the German military spiked helmet. The QRS complex with both early and late notches in lead III resembles the “spiked helmet” sign.

Figure 2  A: Twelve-lead electrocardiograms of ventricular arrhythmias arising from the distal great cardiac vein at a speed of 100 mm/s and normal gain. Notches in both the upstroke and downstroke of the R wave in lead III are identified in each example. B: QRS complex of lead III amplified 2 times (speed 200 mm/s, 2 times normal gain). C: Example of measurement of H1/H2 ratio and H3/H4 ratio in lead III. H1 and H3 were measured from the isoelectric line to the early and late notches, respectively. H2 and H4 were measured from peak of the R wave to early and late notching, respectively. D: Pickelhaube, the German military spiked helmet. The QRS complex with both early and late notches in lead III resembles the “spiked helmet” sign.

isolectric line to the early and late notches, respectively; H2 and H4 measured from the peak of the R wave to the early and late notches, respectively) (Figure 2); (6) QRS complex duration; (7) pseudo–delta wave (PdW) (interval from beginning of the QRS complex to earliest fast deflection in any precordial lead) time; (8) intrinsicoid deflection time (IDT) (interval from beginning of the QRS complex to peak of the R wave in lead V2); and (9) maximum deflection index (MDI) (IDT divided by QRS duration). The QRS notch in lead III was reviewed at a speed of 100 mm/s and normal
gain, and at a speed of 200 mm/s and 2 times normal gain (QRS complex in lead III was amplified 2 times), respectively. The other ECG features were reviewed at a speed of 100 mm/s and normal gain. ECGs were analyzed by 3 investigators from our center who were blinded to the site of origin. In addition, the QRS notch in lead III was further assessed by 6 blinded observers from other institutions.

Follow-up
All patients underwent 24-hour ECG monitoring after the procedure. Holter monitoring was routinely performed 1 month after RFCA. Follow-up echocardiography and Holter monitoring were performed 3–12 months postablation. ECG and 24-hour ECG monitoring were performed whenever the patient had symptoms suggestive of VA recurrence.

Statistical analysis
Categorical variables are expressed as case number and percentage. Measurement data are expressed as mean ± SD. Shapiro-Wilk test was used for normal distribution. Continuous variables were compared with the Student t test for 2 groups and with 1-way analysis of variance for >2 groups in case of normal distribution. Between-group comparisons were performed using the Mann-Whitney U test, and the Kruskal-Wallis test was used in case of non-normal distribution (independent variable). Categorical variables were compared using the Pearson χ² test or the Fisher exact test when appropriate. Receiver operating characteristic curves were used to obtain the best values of sensitivity and specificity. Discriminant analysis was based on the canonical discriminant. P < .05 was considered significant.

Results
Patient characteristics
The study population consisted of 32 patients (22 men and 10 women; mean age 62 ± 11 years) with IVAs who underwent successful ablation of IVAs originating from the DGCV. These patients represent 3.7% of a larger cohort of patients with IVAs (n = 874) undergoing ablation at our center. The clinical characteristics of the patients are given in Supplementary Table S1. All patients had failed to respond to a trial of at least 1 antiarrhythmic drug. There were no significant differences with regard to age, gender, type of clinical symptoms, LV ejection fraction, PVC count, and type of VA between patients with VAs originating from the DGCV and those with VAs arising from the adjacent LV ENDO.

ECG characteristics
General characteristics
All IVAs originating from the DGCV displayed a right bundle branch block morphology with a monophasic R or Rs pattern in leads V1–V6, a monophasic R pattern in all inferior leads, and a QS pattern in leads aVR and aVL (Table 1). The precordial R-wave transition occurred earlier than lead V1 in all patients with IVAs originating from the DGCV.

Distinct ECG features of VAs originating from the DGCV
Review of VA morphology revealed a notch in both the upstroke and downstroke of the R wave in lead III in 13 of 32 patients (DGCV–early and late notches subgroup) (Figures 2A and 2B). The H1/H2 ratio of the early notch was 1.58 ± 0.44, and the H3/H4 ratio of the late notch was 0.50 ± 0.15 in the DGCV–early and late notches subgroup (Figure 2C and Supplementary Table S2). The QRS complex with both early and late notches in lead III resembles the “spiked helmet” sign (Figure 2D). The notch on the upstroke of lead III may be subtle when ECGs are reviewed at a speed of 100 mm/s and normal gain. However, the ECG characteristic in lead III becomes more apparent when the QRS complex is amplified at a speed of 200 mm/s and 2 times normal gain. In the study, all 9 blinded observers agreed on the spiked helmet sign in lead III in the 13 patients in the early and late notches subgroup when the QRS complex in lead III was amplified to 2 times the QRS complex at a speed of 100 mm/s and normal gain. Only a notch in the downstroke of the R wave was found in the remaining 19 patients (DGCV–only late notch subgroup) (Table 1). The H3/H4 ratio of the late notch was 0.51 ± 0.17 in the DGCV–only late notch subgroup. There was no significant difference in H3/H4 ratio, PdW time, precordial IDT, MDI, or QRS duration between the 2 subgroups.

Table 1  ECG characteristics of IVAs originating from DGCV and adjacent LV ENDO

<table>
<thead>
<tr>
<th>Variables</th>
<th>Early and late notches (n = 13)</th>
<th>Only late notch (n = 19)</th>
<th>LV ENDO (n = 40)</th>
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<tr>
<td><strong>Variables</strong></td>
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<td><strong>LV ENDO</strong></td>
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<td><strong>Limb leads</strong></td>
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<td></td>
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<tr>
<td>qS or qrs</td>
<td>2 (15)</td>
<td>6 (32)</td>
<td>6 (15)</td>
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<tr>
<td>rs or rs’ or rSr’</td>
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<td>12 (63)</td>
<td>29 (73)</td>
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<td>1 (5)</td>
<td>5 (13)</td>
</tr>
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<td>19 (100)</td>
<td>40 (100)</td>
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<td><strong>Inferior leads</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>13 (100)</td>
<td>19 (100)</td>
<td>40 (100)</td>
</tr>
<tr>
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<td>1 (3)</td>
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<tr>
<td>Only an early notch in lead III</td>
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<td>0</td>
<td>2 (5)</td>
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<tr>
<td>Only a late notch in lead III</td>
<td>0</td>
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<td>33 (83)</td>
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<td>4 (10)</td>
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<td>19 (100)</td>
<td>38 (95)</td>
</tr>
<tr>
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<td>0</td>
<td>2 (5)</td>
</tr>
<tr>
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</tr>
<tr>
<td>V1≤and≤V2</td>
<td>0</td>
<td>0</td>
<td>1 (3)</td>
</tr>
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</table>

Values are given as n (%).
DGCV = distal great cardiac vein; ECG = electrocardiography; IVA = idiopathic ventricular arrhythmia; LV ENDO = left ventricular endocardium.
Comparison of ECG features of IVAs originating from the DGCV and those arising from the adjacent LV ENDO

The characteristics of the QRS morphology of the IVAs originating from the DGCV were almost identical with those of the IVAs arising from the adjacent LV ENDO (Table 1, and Figures 3–5). The characteristic ECG pattern in lead III (both early and late notches) was found in 1 of 40 patients with IVAs originating from the adjacent LV ENDO (Table 1 and Figure 5). Two of 40 patients with IVAs originating from the adjacent LV ENDO had VAs with only an early notch in lead III; 33 of 40 patients with IVAs originating from the adjacent LV ENDO had VAs with only a late notch in lead III; and 4 of 40 patients with IVAs originating from the adjacent LV ENDO had VAs without any notch in lead III. The H1/H2 ratio in lead III was significantly higher in the DGCV–early and late notches subgroup compared with the LV ENDO group (1.58 ± 0.44 vs 0.89 ± 0.46; P < .05) (Supplementary Table S2). No significant differences in H3/H4 ratio were found among the DGCV–early and late notches subgroup, the DGCV–only late notch subgroup, and the LV ENDO group. The characteristic of both early notch and late notches in lead III had sensitivity of 40.6%, specificity of 97.5%, negative predictive value (NPV) of 67.2%, and positive predictive value (PPV) of 92.9% to predict VAs originating from the DGCV. Sensitivity, specificity, PPV, and NPV of PdW time, precordial IDT, MDI, and QRS duration are given in Table 2. Receiver operating characteristic analyses determined that the best cutoff value of PdW time, precordial IDT, MDI, and QRS duration that distinguished the DGCV group from the adjacent LV ENDO group was 43 ms, >77 ms, >0.51 ms, and >147 ms, respectively (Supplementary Figure S1 and Table 2). Discriminant analysis combining all 5 parameters revealed the accuracy of localization to be 93.1% (Supplementary Table S3).

Mapping and ablation outcome

Mapping and ablation outcomes are given in Supplementary Table S4. DGCV VAs with early and late notches comparable to those having only late notch had relatively more leftward VA origin (Supplementary Figure S2). There was no significant difference with regard to local ventricular activation time relative to QRS onset among the DGCV–early and late notches subgroup, DGCV–only late notch subgroup, and LV ENDO group. A perfect pacemap, matching the VAs in 12 of 12 leads, was present in 13 of 13 patients (100%) in the DGCV–early and late notches subgroup, 17 of 19 (89%) in the DGCV–late notch subgroup, and 28 of 40 (70%) in the LV ENDO group. RF application duration was significantly shorter and fluoroscopy time and procedure duration were significantly longer for VAs with DGCV origin than for those with LV ENDO origin (P < .01). RF energy was delivered at the maximal irrigation rate of 60 mL/min in 1 patient in the DGCV–only late notch subgroup because of high impedance. Acute success was achieved in all patients. No complications occurred during the procedure. Coronary angiography after ablation showed no coronary artery injury in the DGCV group. After an average of 20 ± 15 months of follow-up, no patient in the DGCV–early and late notches subgroup, 1 patient in the DGCV–late notch subgroup, and 3 patients in the LV ENDO group had recurrent VAs.

Discussion

Major findings

This study revealed that a part of VAs originating from the DGCV have unique ECG characteristics that distinguish this site from the adjacent LV ENDO origin. The ECG characteristic of both early notch and late notches in lead III (spiked helmet sign), which is a novel ECG observation in this study, was suggested to be highly specific for predicting VA origins in the DGCV. The ratio of H1/H2 in lead III was significantly higher for DGCV VAs with early and late notches compared to that of adjacent LV ENDO VAs. All DGCV VAs with the spiked helmet sign were eliminated successfully by RF ablation, with no recurrence on long-term follow-up.

ECG characteristics of VAs originating from the DGCV

Several previous studies have described different criteria for identifying the origin of VAs from the epicardium.¹,⁴,⁵ Berruezo et al⁶ demonstrated that the epicardial origin of activation produces a wider PdW in patients with structural heart disease. Vallès et al⁷ found that morphological ECG features that describe the initial QRS vector can help identify basal–superior/lateral epicardial VTs in patients with non-ischemic cardiomyopathy. Daniels et al⁸ found that wider PdW and greater MDI were useful to identify the epicardial origin of VTs in patients without structural heart disease. In the present study, we found that PdW >43 ms (96.9% sensitivity, 80.0% specificity), IDT >77 ms (93.7% sensitivity, 82.5% specificity), and MDI >0.51 (84.4% sensitivity, 87.5% specificity) indicate an epicardial origin of VAs in patients without structural heart disease. These interval criteria that identify slow conduction in the initial portion of the QRS were reliable for identifying endocardial vs epicardial origin in patients with and those without structural heart disease.¹,⁴,⁵ However, no studies demonstrated that the ECG pattern, except for these interval criteria, was specific for epicardial VAs. Bogossian et al⁹ found that an inferior axis and concordant R pattern in all precordial leads serve as diagnostic markers for an LVOT origin on the surface ECG and suggest high primary ablation success via the GCV. In the present study, we found that DGCV VAs share these ECG features, including right bundle block morphology with inferior axis, dominant Rs or rS pattern in lead I, monophasic R or Rs pattern in all precordial leads,
Figure 3  Example of successful ablation of premature ventricular complex (PVC) originating from the distal great cardiac vein (DGCV). A: Twelve-lead electrocardiographic morphology of the clinical PVC. The PVC had a notch in both the upstroke and downstroke of the R wave in lead III. B: Local ventricular activation time recorded at the DGCV preceded onset of the QRS complex by 37 ms. C: A perfect pacemap was obtained at the DGCV. D: Fluoroscopic view of catheter positions during coronary angiography of the left coronary artery. The ablation catheter tip (ABL) was ≥5 mm distant from any coronary artery. E: Electroanatomic activation map of the aortic valve cusps, DGCV, and adjacent left ventricular endocardium. F: Cessation of the target PVC is observed shortly after radiofrequency (RF) initiation. LAO = left anterior oblique; RAO = right anterior oblique.
monophasic R pattern in all inferior leads, transition zone beyond V1, and QS pattern in leads aVL and aVR. However, in this study the ECG pattern was almost identical to that of VAs originating from the adjacent LV ENDO. Therefore, it is difficult to differentiate whether VAs originate from the DGCV or LV ENDO by ECG pattern.

In this study, 13 of 32 patients with VAs originating from the DGCV exhibited the spiked helmet sign in lead

**Figure 4** Example of successful ablation of premature ventricular complex (PVC) originating from the endocardium below the aortomitral continuity (AMC) region. A: Twelve-lead electrocardiographic morphology of the clinical PVC. The PVC had a notch in the downstroke of the R wave in lead III. B: Local ventricular activation time recorded at the AMC preceded onset of the QRS complex by 32 ms. C: A perfect pachemap was obtained at the AMC. D: Pachemap at the distal great cardiac vein (DGCV). The QRS morphology with both early and late notches in lead III during pacing from the DGCV was not similar to the clinical PVC. E: Electromagnetic map of the aortic valve cusps, AMC, and DGCV. F: Fluoroscopic position of the successful ablation site. G: Cessation of the target PVC is observed shortly after radiofrequency (RF) initiation. ABL = ablation catheter; LAO = left anterior oblique; RAO = right anterior oblique.
III, whereas only 2.5% of patients (1/40) in the LV ENDO group had the ECG characteristic. In addition, the H1/H2 ratio in lead III was significantly higher in the DGCV–early and late notches subgroup compared with the LV ENDO group. The distinct ECG characteristics of DGCV VAs has never been reported in previous studies. We believe that the spiked helmet sign in lead III is very helpful for predicting an origin from the DGCV. The notch in the upstroke of the R wave and higher H1/H2 ratio in lead III may be related to slower spread of activation from a focus on the epicardial surface relative to the endocardium, producing a slurred initial part of the QRS complex, and they share a similar mechanism with the previous interval criteria for identifying endocardial vs epicardial origin.1,4,5 Our findings extend these observations to patients with idio-pathic DGCV VAs.

Figure 5 Representative 12-lead electrocardiographic morphologies of ventricular arrhythmias originating from the distal great cardiac vein (DGCV) (A, B) and the adjacent left ventricular endocardium (LV ENDO) (C–F). A, C: Both early notch and late notches in lead III. D: Early notch in lead III. B, E: Late notch in lead III. F: No notch in lead III.
QRS duration

Mapping and ablation
The outcome of the ablation procedure was closely related to the location of the site of origin within the CVS. Ablation of DGCV VAs has a higher success rate than ablation of AIVV or summit-CV VAs because of the greater difficulty in advancing an ablation catheter to the site of AIVV or summit-CV VAs and the greater likelihood of an inability to deliver sufficient RF energy due to higher impedance of AIVV or summit-CV VAs. Using a long deflectable sheath positioned inside the coronary sinuses enhances the maneuverability of the ablation catheter tip and helps to advance the ablation catheter to the site of interest.

In addition, use of irrigated catheters at the coronary sinus was useful for delivering effective RF ablation energy in the low-flow venous system because they can reduce the temperature and impedance of the ablation catheter. In this study, we found that DGCV VAs with early and late notches comparable with those of the late notch group were more leftward origin, which indicated that the origin in the DGCV was relatively proximal where the vessel size was sufficiently large to allow greater power. As shown in the study, VAs originating from the DGCV can be safely ablated, and RF application can be effectively delivered in the DGCV to obtain a highly acute and long-term success rate.

Although previous studies have proven that the transvenous approach is relatively safe and effective, it is vital to avoid complications, such as intramural thrombosis, cardiac tamponade, and creating stenosis in neighboring coronary arteries. Coronary artery injury probably is the most important risk when delivering RF ablation energy in the DGCV, which may become evident acutely or may not be detected until several weeks after the procedure. Preoperative coronary angiography is necessary to clarify the anatomic relationship between the RF target and the coronary artery. According to previous studies, the distance between the ablation catheter and the epicardium artery is 5–12 mm, which is a relatively safe distance. In this study, patency of the coronary artery closest to the ablation sites was confirmed after ablation within the CVS in all patients. If the site of earliest activation in the CVS is close to the coronary artery, ablation may be attempted at nearby sites inside the CVS or adjacent structures such as the left coronary cusp, LV ENDO, or septal RVOT. In the present study, RF energy was delivered at an irrigation rate of 60 mL/min in 1 patient in the DGCV–only late notch subgroup because impedance within the CVS was too high for delivery of RF energy. Coronary angiography and echocardiography after ablation in this patient showed no complication. The risk of using an irrigation rate of 60 mL/min during RF ablation within CVS may be underestimated because of the limited case.

Study limitations
First, the mechanism of the spiked helmet sign in lead III remains speculative. More detailed epicardial and endocardial electroanatomic mapping might have revealed a greater complexity for the basis of the pattern. Second, the low sensitivity and NPV limit the clinical utility of the spiked helmet sign. Third, this is a retrospective study and requires further prospective validation.

Conclusion
This study revealed the ECG characteristics of VAs originating from the DGCV. A spiked helmet sign in lead III, a novel ECG parameter proposed in this study, may be a very helpful criterion to predict VA origins in the DGCV, but the low sensitivity and NPV may limit the clinical utility of the spiked helmet sign.

Appendix

Supplementary data
Supplementary data associated with this article can be found in the online version at https://10.1016/j.hrthm.2020.01.027.

Table 2  Sensitivity, specificity, NPV, and PPV of ECG variables to identify ventricular arrhythmias arising from the adjacent LV ENDO and DGCV

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<th>ECG variables</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
<th>AUC</th>
<th>P value</th>
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<tbody>
<tr>
<td>“Spiked helmet” sign</td>
<td>40.6</td>
<td>97.5</td>
<td>92.9</td>
<td>67.2</td>
<td>—</td>
<td>&lt;.01</td>
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<tr>
<td>PdW time &gt; 43 ms</td>
<td>96.9</td>
<td>80.0</td>
<td>79.5</td>
<td>97.0</td>
<td>0.95</td>
<td>&lt;.01</td>
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<td>MDI &gt; 0.51</td>
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<td>84.4</td>
<td>87.5</td>
<td>0.88</td>
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<tr>
<td>QRS duration &gt; 147 ms</td>
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<td>67.5</td>
<td>69.8</td>
<td>93.1</td>
<td>0.85</td>
<td>&lt;.01</td>
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AUC = area under the curve; DGCV = distal great cardiac vein; ECG = electrocardiography; IDT = intrinsicoid deflection time; LV ENDO = left ventricular endocardium; MDI = maximum deflection index; NPV = negative predictive value; PdW = pseudo–delta wave; PPV = positive predictive value.

References
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