A Novel Electrocardiographic Criterion for Differentiating a Left from Right Ventricular Outflow Tract Tachycardia Origin: The V2S/V3R Index

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V2S/V3R Index Distinguishes LVOT from RVOT Origins. ***Introduction:*** **Although several ECG criteria have been proposed for differentiating between left and right origins of idiopathic ventricular arrhythmias (VA) originating from the outflow tract (OT-VA), their accuracy and usefulness remain limited. This study was undertaken to develop a more accurate and useful ECG criterion for differentiating between left and right OT-VA origins.**

Methods and Results: **We studied OT-VAs with a left bundle branch block pattern and inferior axis QRS morphology in 207 patients who underwent successful catheter ablation in the right (RVOT; n = 154) or left ventricular outflow tract (LVOT; n = 53). The surface ECGs during the OT-VAs and during sinus beats were analyzed with an electronic caliper. The V2S/V3R index was defined as the S-wave amplitude in lead V2 divided by the R-wave amplitude in lead V3 during the OT-VA. The V2S/V3R index was significantly smaller for LVOT origins than RVOT origins (P < 0.001). The area under the curve (AUC) for the V2S/V3R index by a receiver operating characteristic analysis was 0.964, with a cut-off value of ≤1.5 predicting an LVOT origin with an 89% sensitivity and 94% specificity. In the AUC and accuracy, the V2S/V3R index was superior to any previously proposed ECG criteria in an analysis of all OT-VAs. This advantage of the V2S/V3R index over the V2 transition ratio and other indices also held true for a subanalysis of 77 OT-VAs with a lead V3 precordial transition.**

Conclusion: **The V2S/V3R index outperformed other ECG criteria to differentiate left from right OT-VA origins independent of the site of the precordial transition.** *(J Cardiovasc Electrophysiol, Vol. 25, pp. 747-753, July 2014)*

catheter ablation, electrocardiogram, premature ventricular contraction, ventricular outflow tract, ventricular tachycardia.

Introduction

The majority of idiopathic ventricular tachycardias (VTs) or premature ventricular contractions (PVCs) with a left bundle branch block and inferior axis QRS morphology originate from either the right ventricular outflow tract (RVOT) or the left ventricular outflow tract (LVOT). Radiofrequency catheter ablation has been established as a curative therapy for outflow tract ventricular arrhythmias (OT-VAs) with a high success rate.[1,2] Prediction of the OT-VA origin before the procedure has become increasingly essential because a different anatomical approach is required for mapping and catheter ablation of OT-VAs originating from the LVOT. Several electrocardiogram (ECG) algorithms have been proposed for differentiating an LVOT from an RVOT origin.[3-7] However, their accuracy and usefulness are still limited because the QRS morphology of OT-VAs can be affected by several factors such as the lead position, cardiac anatomy, cardiac rotation,[6,7] ventricular hypertrophy, physique, chest wall deformities, and preferential conduction,[8] and also because some ECG algorithms can be used only in OT-VAs with a specific ECG pattern.[6] This study was undertaken to develop a novel ECG criterion that could differentiate an LVOT from an RVOT origin more accurately independent of the ECG pattern in a large population of patients undergoing catheter ablation.

Methods

Study Population

This study population consisted of 244 patients who underwent catheter ablation of OT-VAs with a left bundle

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branch block pattern (R/S $\leq$ 1 in lead V1) and inferior axis (positive polarity in all inferior leads) QRS morphology. The patients with structural or ischemic heart disease (n = 22), bundle branch block (n = 5), a paced rhythm (n = 6), and unsuccessful elimination of VT/PVCs (n = 4) were excluded. The remaining 207 patients (83 men, mean age 48 $\pm$ 16 years) who underwent successful ablation in either the RVOT or the LVOT were studied. In the RVOT group (n = 154), the OT-VAs originated from the septal sites (n = 122), the free wall sites (n = 29), and within the pulmonary artery (n = 3). In the LVOT group (n = 53), the OT-VAs were successfully ablated from the left coronary cusp (n = 23), right coronary cusp (n = 10), junction between the left and right coronary cusps (n = 9), aorto-mitral continuity (n = 8), and great cardiac vein near its continuation as the anterior interventricular vein (GCV-AIVV; n = 3). Echocardiography and exercise stress testing or coronary angiography demonstrated no evidence of structural heart disease in any patient. Each patient gave written informed consent, and all antiarrhythmic drugs were discontinued for at least 5 half-lives before the study.

Electrophysiologic Study

Six-French quadripolar catheters were positioned through the right femoral vein across the tricuspid valve to record the His bundle activation and in the right ventricular apex for pacing. A 6- or 7-French decapolar catheter was positioned in the GCV-AIVV through the right femoral vein as previously reported.[9] This catheter was advanced as distally as possible into the GCV-AIVV. Mapping and pacing were performed using a 7-French, 4-mm-tip nonirrigated or 7.5-French, 3.5-mm-tip irrigated ablation catheter introduced from the right femoral vein (for the RVOT and GCV-AIVV) or femoral artery (for the LVOT). When few PVCs were observed at the beginning of the electrophysiologic study, induction of the VT or PVCs was attempted by burst pacing from the RVOT or right ventricular apex with or without an isoproterenol infusion. During mapping in the LVOT, intravenous heparin was administered to maintain an activated clotting time of >250 seconds.

Mapping and Radiofrequency Catheter Ablation

A 3-dimensional electroanatomic mapping system (CARTO, Biosense Webster, Diamond Bar, CA, USA) was used in all cases. First, activation mapping was performed in the RVOT during VT or PVCs. When VT or PVCs were infrequent, pace mapping was performed during sinus rhythm at a pacing cycle length of 500 milliseconds at an output just greater than a diastolic threshold as previously described.[10,11] The target site for the ablation was determined by the earliest bipolar electrogram preceding the QRS onset during the VT or PVCs and/or an excellent pace map (>11/12 leads). If suitable ablation sites were not found or the ablation was unsuccessful in the RVOT, further mapping was performed in the LVOT and GCV-AIVV. When the earliest ventricular activation was recorded above the aortic valve, selective angiography of the coronary artery and aorta was performed to assess the anatomical relationships between these structures and the location of the ablation catheter. Nonirrigated radiofrequency current was delivered in a temperature control mode with a target temperature of 55–60 °C and maximum power of 50 W. When the radiofrequency energy delivery was limited with a nonirrigated ablation catheter, it was switched to an irrigated ablation catheter. Irrigated radiofrequency current was delivered in a power-control mode starting at 20 W in the GCV-AIVV and 30 W in the RVOT and endocardial LVOT with an irrigation flow rate of 30 mL/min. The radiofrequency power was titrated to as high as 30 and 50 W, respectively, with the goal being to achieve a decrease in the impedance of 5–10 Ω and with care taken to limit the temperature to <41 °C. When an acceleration or reduction in the incidence of VT or PVCs was observed during the first 10 seconds of the application, the radiofrequency delivery was continued for 30–60 seconds. Otherwise, the radiofrequency delivery was terminated, and the catheter was repositioned. The endpoint of the catheter ablation was the elimination and noninducibility of VT or PVCs during an isoproterenol infusion (2–4 μg/min) and burst pacing from the right ventricle (to a cycle length as short as 240 milliseconds).

Follow-up after the procedure included clinic visits with 12-lead ECGs and 24-hour ambulatory (Holter) monitoring, and telephone calls to all patients and their referring physicians. All patients who reported symptoms were given a 24-hour Holter monitoring or event monitor to document the cause of the symptoms. Successful catheter ablation was defined as no recurrence of any OT-VAs during >6 months of follow-up.

Electrocardiographic Analysis

In all patients, the surface 12-lead ECGs were recorded during sinus rhythm and during the VTs or PVCs at a sweep speed of 25 mm/s with chest and limb leads placed in a standard position. In particular, the electrodes of leads V1 and V2 were placed at the fourth intercostal space with careful attention paid to their position because an incorrect electrode placement could markedly alter the QRS morphology of the OT-VAs.[12] The QRS morphology during the OT-VAs and sinus beats was analyzed on the same 12-lead ECG using an electronic caliper. The following measurements were made on the surface ECG of the first beat of VT or the PVC: (1) R- and S-wave amplitudes in leads V1–V6; (2) R-wave amplitude in leads II and III; (3) Q-wave amplitude in leads aVR and aVL; (4) total QRS duration; (5) R-wave duration in leads V1 and V2; and (6) the site of the R-wave transition in the precordial leads that was defined as the single precordial lead where the R-wave amplitude exceeded the S-wave amplitude. The following parameters were also measured on the surface ECG during the sinus beat: (1) R- and S-wave amplitudes in lead V2 for calculating the V2 transition ratio[6] and (2) the site of the R-wave transition in the precordial leads for calculating the transitional zone (TZ) index.[7] The total QRS duration of the OT-VA was measured from the site of the earliest initial deflection from the isoelectric line in any lead to the time of the latest activation in any lead. The R-wave duration was measured from the site of the earliest initial deflection from the isoelectric line to the time at which the R-wave intersected the isoelectric line.

The R-wave duration index was calculated by dividing the longer R-wave duration in lead V1 or V2 by the QRS complex duration.[5] The R/S-wave amplitude index was defined as the greater value of the R/S-wave amplitude ratio in lead V1 or V2.[5] The TZ index was calculated as follows: TZ score of the OT-VA minus the TZ score of the sinus beat.[7] The TZ score was graded with 0.5-point increments according to

the site of the R-wave transition (e.g., TZ in V2 = 2-point, V2–V3 = 2.5-point, V3 = 3-point, and V3–V4 = 3.5-point). The V2 transition ratio was calculated in lead V2 by dividing the percentage R-wave during VT $(R/R + S)_{VT}$ by the percentage R-wave during sinus rhythm $(R/R + S)_{sinus}$.[6] The area under the curve (AUC) was calculated by a receiver operating characteristic analysis of the ECG measurements. In order to develop a novel ECG criterion with the highest sensitivity and specificity, 2 ECG measurements exhibiting the greatest and second greatest AUC were identified. The sum, subtraction, multiplication, and division of these ECG measurements were calculated, and their AUCs were analyzed.

Statistical Analysis

Continuous data are expressed as the mean ± SD or median (interquartile range; 25th–75th percentiles), as appropriate. Comparisons between groups were performed using the unpaired *t*-test or Mann–Whitney *U*-test, as appropriate. Categorical variables were compared by a chi-square test. A receiver operating characteristic analysis was used to calculate the sensitivity and specificity, and the AUC was used to compare the accuracy among the ECG criteria. Statistical significance was selected at a value of $P < 0.05$.

Results

Clinical and Electrocardiographic Characteristics

The clinical characteristics of the study patients are shown in Table 1. The age and body mass index were significantly greater in the LVOT group than the RVOT group. The female gender was, approximately, 1.8 times more common than the male gender in the RVOT group, while the male gender was slightly more common than the female gender in the LVOT group. There were no significant differences in the LVEF, mean PVC burden, and VT classification between the 2 groups. The surface ECG measurements of the OT-VAs and sinus beats are also shown in Table 1. The Q-wave amplitude of the OT-VAs in lead aVR was significantly smaller in the RVOT group than the LVOT group. The R-wave amplitudes in leads V2–V6 were significantly greater in the LVOT group than the RVOT group. On the other hand, the S-wave amplitudes in leads V1–V4 were significantly smaller in the LVOT group than the RVOT group. The LVOT group showed an earlier precordial transition of the OT-VA than the RVOT group. The maximum precordial R-wave amplitude was observed in lead V4 in the LVOT group, but it was observed in leads V5 and V6 in the RVOT group.

The R-wave duration in lead V2, R-wave duration index, and R/S-wave amplitude index were significantly greater in the LVOT group than the RVOT group. The TZ index was significantly smaller in the LVOT group than the RVOT group. There were no significant differences in the total QRS duration and ECG measurements in leads II, III, and aVL between the 2 groups.

Development of a Novel ECG Criterion (V2S/V3R Index) and its Predictive Accuracy

The results of the AUC by a receiver operating characteristic analysis of the ECG measurements are shown in Table 1. Among all the ECG measurements, the R-wave amplitude in lead V3 exhibited the greatest AUC of 0.932, and the S-wave amplitude in lead V2 the second greatest AUC of 0.862. Among the sum, subtraction, multiplication, and division of these 2 ECG measurements, the V2S/V3R index (the S-wave amplitude in lead V2 divided by the R-wave amplitude in lead V3 during the OT-VA [Fig. 1]) exhibited the greatest AUC of 0.964 (Fig. 2A), and was defined as the novel ECG criterion. The V2S/V3R index was significantly smaller in the LVOT group than the RVOT group ($P < 0.001$). The optimal cut-off value to predict an LVOT origin was 1.5, which yielded a sensitivity of 89% and a specificity of 94% (Fig. 2B). This cut-off value yielded a positive predictive value of 84% and a negative predictive value of 96%. In the RVOT group, 114 (93%) of 122 OT-VAs successfully ablated from the septal sites, 28 (97%) of 29 from the free wall sites, and all 3 from the pulmonary artery exhibited a V2S/V3R index of >1.5. In the LVOT group, 21 (91%) of 23 OT-VAs successfully ablated from the left coronary cusp, 9 (90%) of 10 from the right coronary cusp, 7 (78%) of 9 from the junction between the left and right coronary cusps, 7 (88%) of 8 from the aorto-mitral continuity, and all 3 from the GCV-AIVV exhibited a V2S/V3R index of ≤1.5. The surface ECGs of the representative OT-VAs are illustrated in Figure 3.

Comparison of the V2S/V3R Index with the Previous Indices

In the overall analysis of 207 OT-VAs, the V2S/V3R index exhibited a greater AUC (0.964) than the TZ index (0.914), R/S-wave amplitude index (0.861), and R-wave duration index (0.690; Table 1). The comparison of the accuracy among the ECG criteria for predicting an LVOT origin is shown in Table 2. A V2S/V3R index of ≤1.5 predicted an LVOT origin with a sensitivity of 89% and specificity of 94%. A TZ index of <0 had a sensitivity of 83% and specificity of 93%. An R/S-wave amplitude index of ≥30% exhibited a sensitivity of 79% and specificity of 86%. An R-wave duration index of ≥50% had a high specificity of 92% but a low sensitivity of 45%.

A further receiver operating characteristic analysis was performed among the 77 OT-VAs with a lead V3 precordial transition (Tables 2 and 3; Fig. 4). The V2S/V3R index exhibited a greater AUC (0.898) than the V2 transition ratio (0.773). A V2S/V3R index of ≤1.5 exhibited a high sensitivity of 94% and a specificity of 78%. A V2 transition ratio of ≥0.6 exhibited a sensitivity of 81% and specificity of 61% in this study population.

Discussion

Main Findings

We developed a novel ECG criterion, the V2S/V3R index, for differentiating an LVOT origin from an RVOT origin by using the ECG measurements with the greatest and second greatest AUCs. A V2S/V3R index of ≤1.5 predicted an LVOT origin with a sensitivity of 89% and specificity of 94% in the overall analysis. In addition, the V2S/V3R index provided a higher predictive accuracy in OT-VAs with a lead V3 precordial transition than the previously proposed indices. Therefore, the V2S/V3R index may be a useful ECG criterion to accurately differentiate an LVOT from RVOT origin independent of the site of the precordial transition.

TABLE 1
The Comparison of the Patients Characteristics and Electrocardiographic Measurements Between the 2 Groups

	RVOT (n = 154)	LVOT (n = 53)	P Value	AUC
Age (years)	45 ± 15	56 ± 15	<0.001	
Male (%)	36	51	0.062	
BMI (kg/m^2)	24.0 ± 5.3	26.6 ± 4.9	0.004	
LVEF (%)	59.7 ± 10.1	61.1 ± 8.1	0.372	
PVC burden (n/24-hour Holter)	20,409 ± 13,980	21,892 ± 11,215	0.614	
Clinical arrhythmia			0.094	
Frequent PVCs	109	45		
Nonsustained VT	20	5		
Sustained VT	25	3		
Total QRS duration of OT-VA	161 ± 17	160 ± 16	0.537	0.524
Lead II and III				
R amplitude of OT-VA in lead II (mV)	1.67 ± 0.52	1.81 ± 0.53	0.074	0.571
R amplitude of OT-VA in lead III (mV)	1.61 ± 0.65	1.76 ± 0.62	0.132	0.568
R amplitude ratio in leads III to II	0.95 ± 0.21	0.98 ± 0.21	0.438	0.533
Lead aVR and aVL				
Q amplitude of OT-VA in lead aVR (mV)	0.88 ± 0.26	0.99 ± 0.33	0.030	0.579
Q amplitude of OT-VA in lead aVL (mV)	0.80 ± 0.41	0.89 ± 0.44	0.204	0.552
Q amplitude ratio in leads aVL to aVR	0.95 ± 0.50	0.97 ± 0.48	0.838	0.513
Lead V1				
R amplitude of OT-VA (mV)	0.19 ± 0.18	0.21 ± 0.24	0.537	0.501
S amplitude of OT-VA (mV)	1.49 ± 0.57	0.87 ± 0.49	<0.001	0.801
R-wave duration (milliseconds)	41.6 ± 26.7	40.3 ± 34.1	0.791	0.510
Lead V2				
R amplitude of OT-VA (mV)	0.35 ± 0.26	0.66 ± 0.44	<0.001	0.708
S amplitude of OT-VA (mV)	2.35 ± 0.92	1.15 ± 0.67	<0.001	0.862
R-wave duration (milliseconds)	52.0 ± 20.8	66.7 ± 28.6	0.001	0.697
R amplitude of sinus beat (mV)	0.45 ± 0.26	0.38 ± 0.26	0.100	
S amplitude of sinus beat (mV)	1.23 ± 0.64	1.12 ± 0.66	0.269	
Lead V3				
R amplitude of OT-VA (mV)	0.60 ± 0.28	1.37 ± 0.47	<0.001	0.932
S amplitude of OT-VA (mV)	1.37 ± 1.00	0.38 ± 0.51	<0.001	0.809
Lead V4				
R amplitude of OT-VA (mV)	0.95 ± 0.50	1.83 ± 0.76	<0.001	0.861
S amplitude of OT-VA (mV)	0.32 ± 0.56	0.10 ± 0.25	<0.001	0.643
Lead V5				
R amplitude of OT-VA (mV)	1.30 ± 0.64	1.80 ± 0.72	<0.001	0.710
S amplitude of OT-VA (mV)	0.06 ± 0.31	0.04 ± 0.14	0.589	0.506
Lead V6				
R amplitude of OT-VA (mV)	1.30 ± 0.50	1.49 ± 0.55	0.021	0.602
S amplitude of OT-VA (mV)	0.01 ± 0.06	0.03 ± 0.12	0.319	0.519
Precordial transitional of OT-VA			<0.001	
V2	0	13		
V3	41	36		
V4	85	3		
V5	26	1		
V6	2	0		
Precordial transitional of sinus beat			0.340	
V2	11	3		
V3	61	16		
V4	70	26		
V5	12	8		
V6	0	0		
Other parameters				
V2S/V3R index	4.1 (2.5–6.4)	0.8 (0.4–1.4)	<0.001	0.964
TZ index	1.0 (0–1.0)	–1.0 (–2.0 to –1.0)	<0.001	0.914
R/S-wave amplitude index (%)	16 (9–22)	53 (33–96)	<0.001	0.861
R-wave duration index (%)	35 (28–41)	46 (33–53)	<0.001	0.690

Data are expressed as mean ± SD or median (interquartile range). AUC = area under the curve; BMI = body mass index; LVEF = left ventricular ejection fraction; LVOT = left ventricular outflow tract; OT-VA = outflow tract ventricular arrhythmia; PVC = premature ventricular contraction; RVOT = right ventricular outflow tract; TZ = transitional zone; VT = ventricular tachycardia.

Anatomical Considerations and the V2S/V3R Index

The V2S/V3R index was mathematically developed based on the data in this study so that it might be the most reliable ECG criterion to differentiate an LVOT or an RVOT origin. However, the anatomical considerations would also support this approach. Anatomically, the aortic root occupies a central location within the heart, and the RVOT is located anteriorly and leftward to the aortic root.[13] This anatomical background likely results in a longer R-wave duration and higher R/S-wave amplitude ratio in the frontal leads V1 and V2 during OT-VAs originating from the aortic sinus of Valsalva (ASV) than those from the RVOT.[5,14-17] Therefore, it would be reasonable to develop an ECG algorithm by using the R- or

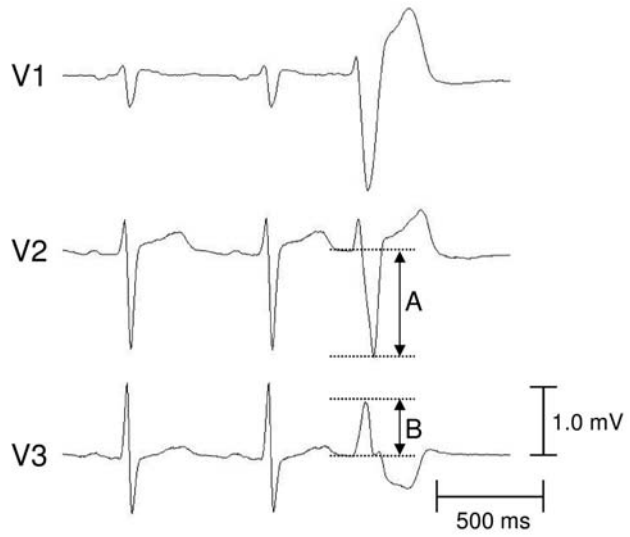


Figure 1. *Electrocardiographic measurements of the V2S/V3R index. The measurements are as follows: A: S-wave amplitude in lead V2 (mV). B: R-wave amplitude in lead V3 (mV). The V2S/V3R index was calculated with the following formula: (A/B).*

S-wave amplitude in lead V1 or V2. In this study, we noted the straight anatomical relationship among the RVOT, aortic root, and lead V3 position where the RVOT is located closer to the lead V3 position than the aortic root. This anatomical background might provide the largest difference in the R-wave amplitude in lead V3 between the LVOT and RVOT origins as compared with the other precordial leads. In fact, the R-wave amplitude in lead V3 exhibited the greatest AUC in this study.

Comparison with the Previous Indices

Ouyang *et al*. reported that the R-wave duration and R/S-wave amplitude indices were useful ECG criteria for differentiating an RVOT origin from an ASV origin with a high sensitivity and specificity.[5] In this study, the R/S-wave amplitude index demonstrated a high accuracy in the overall analysis whereas it exhibited a lower accuracy in patients with a lead V3 precordial transition. Two ECG criteria have been reported that took into account the cardiac rotation, respiratory variation, and lead positions by comparing the QRS morphology of OT-VAs with that of sinus beats.[6,7] The TZ index[7] demonstrated the same tendency as the R/S-wave amplitude index. The V2 transition ratio[6] did not have a high accuracy in this study.

It is noted that it is most difficult to differentiate a left or right origin of OT-VAs with a lead V3 precordial transition. The V2S/V3R index demonstrated a higher accuracy than the previously reported indices in not only the overall analysis but also in the subanalysis of patients with a lead V3 precordial transition. Moreover, the V2S/V3R index is easier to calculate than the other ECG indices and can be used even in patients with an abnormal sinus beat morphology and paced rhythm because it does not refer to a sinus beat morphology.

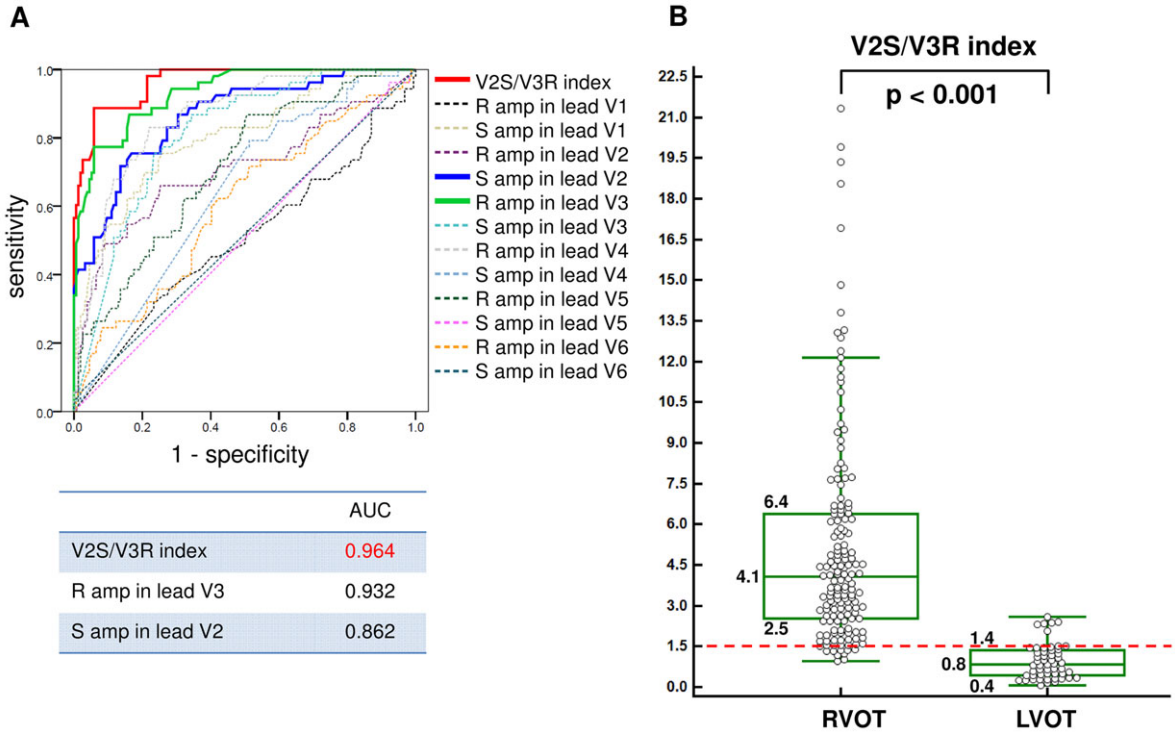


Figure 2. *The predictive accuracy of the V2S/V3R index in the overall analysis. A: The receiver operating characteristic analysis for the V2S/V3R index and the other ECG measurements. The V2S/V3R index (red line), which was calculated from the R-wave amplitude in lead V3 (light green line) with the greatest area under the curve (AUC) of 0.932 and the S-wave amplitude in lead V2 (blue line) with the second greatest AUC of 0.862, exhibited the greatest AUC of 0.964. R amp = R-wave amplitude; S amp = S-wave amplitude. B: The combined box-and-whisker and dot plot of the V2S/V3R index in patients with idiopathic ventricular arrhythmias originating from the right (RVOT) and left ventricular outflow tract (LVOT). A V2S/V3R index of ≤1.5 predicted an LVOT origin with a sensitivity of 89% and specificity of 94%. The red dotted line indicates the optimal cut-off value of 1.5. For a high quality, full color version of this figure, please see Journal of Cardiovascular Electrophysiology's website: www.wileyonlinelibrary.com/journal/jce*

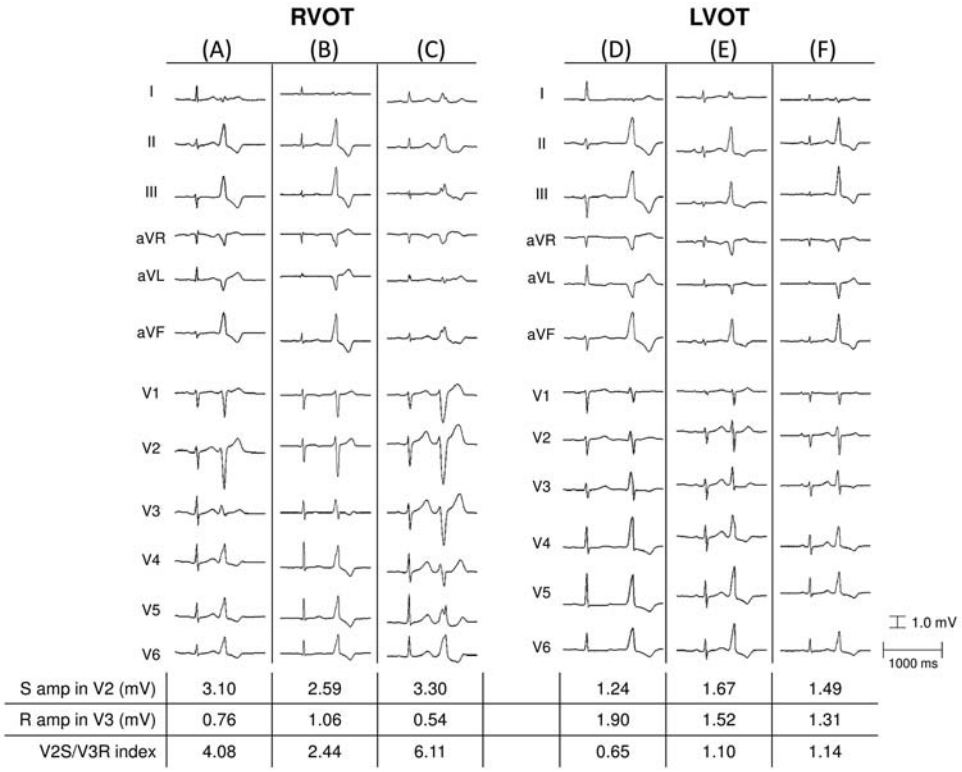


Figure 3. *The representative surface ECGs of OT-VAs. The first beat is a sinus beat and the second is a premature ventricular contraction (PVC) in each panel (A to F). The S-wave amplitude in lead V2, R-wave amplitude in lead V3, and V2S/V3R index are listed below each panel. All RVOT PVCs exhibited a V2S/V3R index of >1.5, while all LVOT PVCs exhibited a V2S/V3R index of ≤1.5. The PVCs were successfully ablated in the RVOT septum (A and B), RVOT free wall (C), left coronary cusp (D), right coronary cusp (E), and aorto-mitral continuity (F). The other abbreviations are as in Figure 2.*

TABLE 2

The Comparison of the Accuracy Among the ECG Criteria for Predicting the LVOT Origin

	Sensitivity	Specificity	PPV	NPV
All Patients (n = 207)				
V2S/V3R index ≤ 1.5	89%	94%	84%	96%
TZ index < 0	83%	93%	80%	94%
R/S-wave amplitude index ≥ 30%	79%	86%	66%	92%
R-wave duration index ≥ 50%	45%	92%	67%	83%
Patients with a Lead V3 Precordial Transition (n = 77)				
V2S/V3R index ≤ 1.5	94%	78%	79%	94%
TZ index < 0	78%	88%	85%	82%
V2 transition ratio	81%	61%	64%	78%
R/S-wave amplitude index ≥ 30%	78%	68%	68%	78%
R-wave duration index ≥ 50%	36%	88%	72%	61%

NPV = negative predictive value; PPV = positive predictive value. The other abbreviations are as in Table 1.

TABLE 3

The Comparison of the Indices Between the RVOT and LVOT Origins in 77 OT-VAs with a Lead V3 Precordial Transition

	RVOT (n = 41)	LVOT (n = 36)	P Value	AUC
V2S/V3R index	1.8 (1.5–2.2)	0.9 (0.6–1.4)	<0.001	0.898
TZ index	0 (0–0)	–1.0 (–1.0 to –0.8)	<0.001	0.827
V2 transition ratio	0.50 (0.31–0.79)	1.23 (0.71–1.74)	<0.001	0.773
R/S-wave amplitude index (%)	18 (8–33)	50 (32–66)	<0.001	0.776
R-wave duration index (%)	35 (27–43)	43 (30–50)	0.059	0.625

Data are expressed as median (interquartile range). The abbreviations are as in Tables 1 and 2.

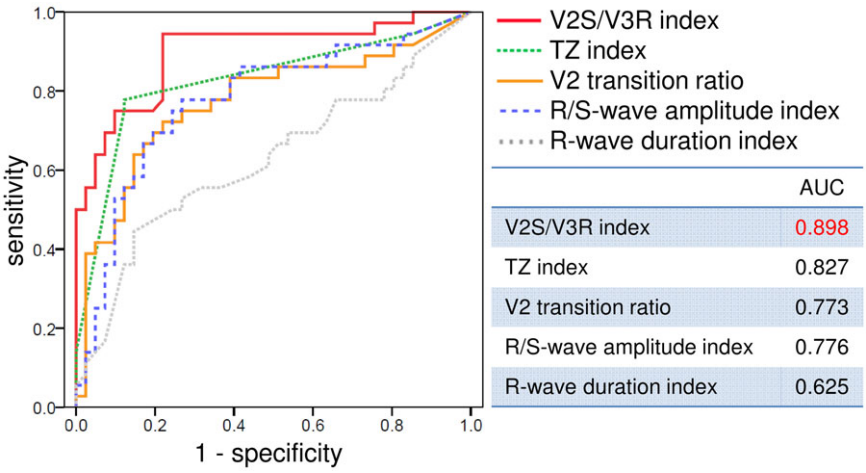
Clinical Implications

The V2S/V3R index can provide a rapid and accurate diagnosis of an OT-VA origin before the catheter ablation, allowing us to develop the best procedural strategy and to avoid any unnecessary arterial or venous punctures.

Study Limitations

In this study, the accuracy of the V2S/V3R index was tested retrospectively, and it would be better to perform a prospective validation of the V2S/V3R index in future studies. However, we believe that the accuracy of the V2S/V3R index, which was developed in this retrospective study, is sufficiently reliable for several reasons. First, the study population of 207 patients was much larger than any other previous studies on the ECG criteria. Second, the patient characteristics in this study were similar to those in the previous studies,[6,18,19] suggesting that there should not be any significant bias in the patient selection. Third, the V2S/V3R index was developed by means of a mathematical approach in such a large, nonbiased study population.

The V2S/V3R index demonstrated a higher accuracy in the overall analysis than the subanalysis of OT-VAs with a lead V3 precordial transition in this study. OT-VAs with a precordial transition either at and earlier than V2 or at and later than V4 are almost uniformly excluded from the RVOT or LVOT, respectively. This was also true in this study with



	AUC
V2S/V3R index	0.898
TZ index	0.827
V2 transition ratio	0.773
R/S-wave amplitude index	0.776
R-wave duration index	0.625

Figure 4. *The predictive accuracy of the V2S/V3R index and previous indices in the 77 OT-VAs with a lead V3 precordial transition. The area under the curve (AUC) of the V2S/V3R index was 0.898, which was the greatest among the 5 indices. For a high quality, full color version of this figure, please see Journal of Cardiovascular Electrophysiology's website: www.wileyonlinelibrary.com/journal/jce*

a specificity of 100% and 92%, respectively. These OT-VAs accounted for 63% of the study subjects, while the OT-VAs with a lead V3 precordial transition accounted for 37%. One might argue that the predictive value of this kind of ECG algorithm might be somewhat inflated by inclusion of a larger number of OT-VAs with a precordial transition except in V3. Therefore, this study performed a subanalysis of the OT-VAs with a lead V3 precordial transition, and thereby proved that the V2S/V3R index was more accurate than the other established ECG algorithms. In fact, the proportion of the OT-VAs with a lead V3 precordial transition in this study was similar to that of previous studies,[5-7] and there was no significant bias in the patient population of this study.

Conclusion

The novel V2S/V3R index is a simple and useful ECG criterion that can accurately differentiate LVOT from RVOT sites of ventricular arrhythmia origins independent of the site of the precordial transition.

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