The QRS morphology pattern in V5R is a novel and simple parameter for differentiating the origin of idiopathic outflow tract ventricular arrhythmias

Miyako Igarashi, Akihiko Nogami*, Yukio Sekiguchi, Kenji Kuroki, Hiro Yamasaki, Takeshi Machino, Yoshiaki Yui, Kojiro Ogawa, Ahmed Karim Talib, Nobuyuki Murakoshi, Keisuke Kuga, and Kazutaka Aonuma

Cardiovascular Division, Faculty of Medicine, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8575, Japan

Received 9 September 2014; accepted after revision 21 October 2014; online publish-ahead-of-print 6 January 2015

Aims
There are many reports on the ECG characteristics of idiopathic outflow tract ventricular arrhythmias (OT-VAs) to predict their origin. However, differentiating near regions using 12-lead ECGs is still complicated. The synthesized 18-lead ECG derived from the 12-lead ECG can provide virtual waveforms of the right-sided chest leads (V3R, V4R, and V5R) and back leads (V7, V8, and V9). The aim of this study was to develop a simple and useful parameter for differentiating OT-VA origins using the 18-lead ECG.

Methods and results
We studied 28 and 73 patients with idiopathic VAs in a pacemapping study and validation cohort, respectively. In the pacemapping study, several sites out of five different sites were paced in each patient: the anterior and posterior right ventricular OT (RVOT-ant and RVOT-post), right and left coronary cusps (RCC and LCC), and junction of both cusps (RLJ). The 18-lead ECGs during pacemapping among the five sites were compared for establishing a simple parameter to predict VA origins. A novel parameter using 18-lead ECGs was tested prospectively in 73 patients. In the pacemapping study, the dominant QRS morphology pattern in the synthesized V5R significantly differed among those sites (RVOT-ant: Rs, RVOT-post: rS, RCC: QS, RLJ: qR, and LCC: R). The patients in the validation cohort were divided into five groups depending on those QRS morphology patterns during VAs in the synthesized V5R. Each V5R QRS morphology pattern could predict a precise origin of the OT-VAs with an overall accuracy of 75%.

Conclusion
The QRS morphology pattern in V5R was a simple and useful parameter for differentiating detailed OT-VA origins.

Keywords
Outflow tract • Ventricular arrhythmias • Right-sided chest leads • Electrocardiogram • Radiofrequency catheter ablation

Introduction
It has been reported that frequent outflow tract (OT) ventricular arrhythmias (VAs) may cause left ventricular dysfunction and heart failure. Radiofrequency catheter ablation (RFCA) is safe and becoming a standard therapeutic strategy for idiopathic OT-VAs. Therefore, it is important to predict the origins of OT-VAs to smoothly perform RFCA. There have been many reports about the ECG characteristics of idiopathic OT-VAs. However, the overlap of the parameter values among the VA origins is not small and the algorithms to differentiate near regions using the 12-lead ECG are still complicated.

The synthesized 18-lead ECG derived from the 12-lead ECG can provide virtual waveforms of the right-sided chest leads (V3R, V4R, and V5R) and back leads (V7, V8, and V9). In this specialized electrocardiograph, the information on these right-sided leads and back leads is provided by a mathematical computation, so only the standard 12 leads are used and additional leads or techniques are not needed. The usefulness of the right-sided chest leads for diagnosing acute myocardial infarctions in the right ventricle, or Brugada
syndrome has been reported. The aim of this study was to develop a simple and useful parameter for differentiating OT-VA origins using the synthesized 18-lead ECG.

**Methods**

**Patient population and study design**

A simple parameter to predict the origin of OT-VAs using the synthesized 18-lead ECG was developed by pacemapping and correlating the pre-ablation ECG with the RF ablation site in 28 patients with idiopathic VAs who underwent RFCA (pacemapping study: 14 men, 14 women, mean age 55.0 ± 16.7 years, range 15–80 years). Subsequently, the parameter was tested prospectively in 73 patients with drug-refractory, symptomatic OT-VAs who underwent RFCA to assess its accuracy in predicting the optimal ablation site (validation cohort: 40 men, 33 women, mean age 51.9 ± 17.2 years, range 13–80 years). During the clinical VA, the surface ECG showed a single bundle branch block morphology with an inferior axis in all patients. Twenty-six patients (37%) had monomorphic QRS morphology with an inferior axis in all patients. Twenty-six patients (37%) had monomorphic ventricular tachycardia clinically, which was defined as three or more consecutive ventricular premature contractions (VPcs). All patients had structurally normal hearts, defined by a normal trans-thoracic echocardiogram and normal coronary angiography. The study was approved by the Institutional Committee on Human Research at University of Tsukuba.

**Electrophysiological study**

After informed consent was obtained and after withdrawal of all antiarrhythmic drugs, an electrophysiological (EP) evaluation and RFCA were performed. Catheters were introduced into the RV apex, RVOT, His-bundle region, and coronary sinus, percutaneously under fluoroscopy via the right femoral vein and subclavian vein. Programmed ventricular stimulation was performed from the RV apex and RVOT at two drive cycle lengths with up to three extra stimuli. In addition, incremental burst pacing at a cycle length up to 250 ms was performed. If the clinical arrhythmia did not occur spontaneously and was not induced in the baseline state, intravenous isoproterenol (0.5–3.0 μg/min) was administered to induce the clinical arrhythmia. A steerable, phased-array, ultrasound catheter (SoundStar; Biosense Webster Inc.) was also inserted in the right atrium. The anatomical mapping including the right ventricle and coronary cusps were obtained using the SoundStar provided on a three-dimensional electroanatomical mapping system (CARTOSOUND; Biosense Webster).

In the pacemapping study patients (n = 28), pacemapping from various sites out of the five different OT sites was performed. The pacemapping sites were the anterior and posterior right ventricular outflow tract (RVOT-ant and RVOT-post), right and left coronary cusps (RCC and LCC), and junction of those cusps (RLJ). Pacemapping was performed at the pacing threshold and the precise pacing sites were confirmed by CARTOSOUND and biplane fluoroscopy (see Supplementary material online, Figure 1).

**Synthesized 18-lead electrocardiogram**

The 12-lead ECG was recorded in the patients during the EP study including pacemapping using an EP recording system in the normal way (CARDIOMASTER: Nihon Kohden Inc.). After the procedure, the necessary parts of data including the pacemapping were picked out and used as data for the virtual right-sided chest leads and back leads were calculated using specialized software.

The synthesized ECG mathematically derived the additional V3R, V4R, and V5R leads from the standard 12-lead ECG. The heart vector (V) is estimated using the standard 12 leads (j) and then projected onto the additional leads (i). In the actual calculation, each additional lead (i) is derived with a matrix calculation of each coefficient (ai) for the standard 12 leads (j). The coefficients (ai) are previously obtained from approximately 150 recordings of each right-sided ECG lead with the least-squares method.14-19

\[ V_i = \sum a_j V_j \]

The actual 12-lead ECG and synthesized right-sided chest leads were compared. The actual right-sided chest leads were simultaneously recorded to confirm the accuracy of the synthesized 18-lead ECG. There was no difference in the QRS morphology between the synthesized and actual right-sided chest leads (see Supplementary material online, Figure 2).

**Radiofrequency catheter ablation**

Radiofrequency catheter ablation was performed by well-trained electrophysiologists who did not know the results of the synthesized 18-lead ECG. Activation mapping and pacemapping were performed to identify the origins of the OT-VAs. Radiofrequency catheter ablation was performed using an 8-Fr 3.5 mm tip open irrigation catheter (ThermoCool Surround Flow: Biosense Webster Inc.), or 4 mm tip non-irrigated catheter (Navistar or Celsius: Biosense-Webster or Blazer II: EP Technologies). When the targeted sites had a local activation time preceding the surface QRS onset during the clinical VAs and had a good match during the pacemapping (10–12/12 match), RF current was delivered with 30–40 W for the RVOT and 25–30 W for the aortic sinus cusps with a maximum temperature of 42°C in the temperature controlled mode when we used an irrigation catheter. For the non-irrigated catheter, the RF energy was delivered with a maximum power of 50 W and temperature of up to 50°C. Successful RFCA was defined as the elimination of the VAs during the RF energy deliveries and the VAs could not be induced after the RFCA procedure. The successful ablation sites were confirmed by fluoroscopy and/or CARTOSOUND. The relationship between the QRS morphology pattern in V5R and successful ablation sites was analysed.

**Statistical analysis**

The continuous variables are expressed as the mean ± standard deviation. The Student’s t-test was used to compare the two groups. An
analysis of variance (ANOVA) was used to compare the groups. When group differences were found, a one-way ANOVA was followed by the Turkey test to test the significance of the difference among the means in all groups. Categorical variables were compared by a χ² analysis or Fisher’s exact test. The sensitivity, specificity, and predictive accuracy for predicting the origins of VAs were also assessed using the standard formula. A P-value < 0.05 was considered statistically significant.

Results

Pacemapping results

In a total of 87 sites in 28 patients, the ECG characteristics during pacemapping were analysed. The previously reported parameters using the 12-lead ECG are shown in Table 1. Although, the values of those parameters significantly differed among those five areas, one parameter alone was not enough to differentiate those areas. For the R-wave amplitude in lead III, there was a significant difference between the RVOT-post and RCC. Furthermore, there were also significant differences among the three cusp sites. However, a large overlap was observed with this parameter as shown in Figure 1.

The QRS morphology patterns in the right-sided chest leads during pacemapping were analysed. Most waveforms in the RVOT-groups had a biphasic RS pattern in the right-sided chest leads. However, during the pacing from the RVOT-ant, an Rs pattern was dominant in V5R. On the other hand, during the pacing from the RVOT-post, an rS pattern was dominant in V5R. Therefore, the dominant morphology pattern in V5R during pacemapping differed between those two RVOT sites (Figure 2).

During pacemapping at the RCC and RLJ, a q-wave was observed in VSR in most patients. However, during the pacemapping at the RCC, a QS pattern was dominant. On the other hand, pacemapping at the RLJ dominantly exhibited a qR pattern in the right-sided chest leads. During the pacing from the LCC, most patients had a tall R in the right-sided chest leads. Especially in VSR, all the pacemaps showed a single R. The dominant QRS morphology patterns in the right-sided chest leads differed among the five areas as shown in Figure 2. Especially in VSR, the overlap was the smallest among those three leads.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>RVOT-ant 19 sites</th>
<th>RVOT-post 19 sites</th>
<th>RCC 18 sites</th>
<th>RLJ 17 sites</th>
<th>LCC 14 sites</th>
<th>P-value ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-wave amplitude in lead II, mV</td>
<td>1.4 ± 0.4</td>
<td>1.5 ± 0.5</td>
<td>1.4 ± 0.5</td>
<td>1.6 ± 0.7</td>
<td>1.8 ± 0.7</td>
<td>0.364</td>
</tr>
<tr>
<td>R-wave amplitude in lead III, mV</td>
<td>1.4 ± 0.4</td>
<td>1.1 ± 0.5</td>
<td>0.7 ± 0.4a</td>
<td>1.4 ± 0.6b</td>
<td>1.9 ± 0.7b,cd</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>R-wave amplitude ratio (lead II/III)</td>
<td>1.1 ± 0.2</td>
<td>1.5 ± 0.5</td>
<td>2.2 ± 1.5ad</td>
<td>1.1 ± 0.3b</td>
<td>0.9 ± 0.1b</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>R-wave amplitude in lead I, mV</td>
<td>0.2 ± 0.3</td>
<td>0.5 ± 0.4</td>
<td>0.9 ± 0.7a</td>
<td>0.6 ± 0.4</td>
<td>0.4 ± 0.4</td>
<td>0.003</td>
</tr>
<tr>
<td>Presence of S-wave in lead I, n (%)</td>
<td>8 (42)</td>
<td>1 (5)</td>
<td>0 (0)</td>
<td>10 (59)</td>
<td>13 (93)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>R/S amplitude index</td>
<td>0.1 ± 0.1</td>
<td>0.2 ± 0.2</td>
<td>1.3 ± 2.1</td>
<td>1.7 ± 2.1a</td>
<td>1.7 ± 1.6</td>
<td>0.005</td>
</tr>
<tr>
<td>R-wave duration index</td>
<td>0.3 ± 0.1</td>
<td>0.3 ± 0.1</td>
<td>0.5 ± 0.2a</td>
<td>0.7 ± 0.3b,cd</td>
<td>0.9 ± 0.2b,cd</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Transitional zone ≤V2, n (%)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>6 (33)</td>
<td>12 (71)</td>
<td>11 (79)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

**Table 1** The comparison of the previously reported parameters during pacemapping among the five different sites

**Prospective study**

The QRS pattern in the synthesized VSR was tested prospectively in 73 patients (validation cohort) to assess its accuracy in predicting the optimal ablation site. The R in VSR was recorded in 27 patients (37%) during the clinical VAs. An Rs was observed in 13 patients (18%) and an rS in 23 (31%). A qR in VSR was observed in seven patients (10%) and QS in the remaining three patients (4%). The successful ablation site was located in the RVOT in 38 (52%), LVOT in 33 (45%), and RV inflow area in 1 (1%). In this patient who had a successful ablation at the RV inflow, while VSR exhibited a QS pattern, pacemapping at the RV inflow (a more superior area than the para-Hisian region) exhibited a good match and the local ventricular activation in that area preceded the QRS by 15 ms. Because the VPCs were successfully eliminated by the RFCA at the RV inflow, mapping in the RCC was not performed. In the remaining patient, the VAs could not be eliminated by the RFCA. In that patient, VSR during the clinical VPCs exhibited an R pattern. However, pacemapping at the LCC did not result in a good match and the local ventricular activation did not precede the QRS, either. Therefore, an RF current application was not delivered at the LCC and multiple RFCA applications at the aorto-mitral continuity with a good pace match failed to suppress the VA. The relationship between the QRS morphology pattern in the synthesized VSR and the result of the RFCA of idiopathic VAs is shown in Table 2.

Representative cases of each VSR pattern are shown in Figure 4. Each patient underwent RFCA in different regions and their VAs were cured successfully. The accuracy of the QRS morphology pattern in VSR for predicting the origin of idiopathic VAs is shown in Table 3. The specificity of each morphology pattern was high. The overall accuracy was 75% (55 over 73). Moreover, an RS biphasic pattern, including both an ‘Rs’ and ‘rS’, could predict the RVOT origins with an 87% sensitivity, 91% specificity, 92% positive predictive value, and 87% negative predictive value.
Discussion

The results of this study demonstrated the following findings: (i) In the pacemapping study, the previously reported parameters significantly differed among the origins of the OT-VAs including the RVOT-ant, RVOT-post, RCC, RLJ, and LCC. However, one parameter was not enough to differentiate those areas and the overlap of the values of the parameters among those different sites was large in most of them. (ii) The dominant QRS morphology patterns in the synthesized V5R during pacemapping differed significantly among those five areas. The dominant morphology pattern in the synthesized V5R was an Rs during pacing from the RVOT-ant, rS during pacing from the RVOT-post, QS during pacing from the RCC, qR during pacing from the RLJ, and R during pacing from the LCC, respectively. (iii) In the prospective study, a QRS morphology pattern in the synthesized V5R could significantly predict the origin of the OT-VAs.

The ECG characteristics of idiopathic VAs have been reported previously in many papers. However, many of those studies were retrospective and the OT-VA origins were decided depending on the successful RFCA sites. However, it is generally difficult to decide the precise successful ablation sites, because commonly we attempt RF energy applications in several regions and all may have an effect on eliminating the OT-VAs. Therefore, we thought the overlap of the values of the parameters among the different origins was large.

Figure 1  The comparison of the previously reported parameters for differentiating the five different pacing sites in the ventricular outflow tract. (A) R-wave amplitude in lead III, (B) R-wave amplitude ratio (lead II/III), (C) R/S amplitude index, and (D) R-wave duration index. These parameters were useful for differentiating the pacing sites, especially those in the LVOT from the RVOT. Furthermore, the R-wave amplitude in lead III and R-wave duration index had significant differences among the three cusp sites. However, a big overlap among the five different sites was also observed.

RVOT-ant, anterior right ventricular outflow tract; RVOT-post, posterior right ventricular outflow tract; RCC, right coronary cusp; RLJ, junction between the right and left coronary cusps; LCC, left coronary cusp; * indicates the significant difference from the RCC; † indicates the significant difference from the RLJ; ‡ indicates the significant difference from RVOT-ant; and § indicates the significant difference from the RVOT-post.
Figure 2  QRS morphology pattern in the synthesized right-sided chest leads during pacemapping. The dominant QRS morphology pattern in the synthesized right-sided chest leads, especially in V5R, differed among the pacing five sites in the ventricular outflow tract. RVOT-ant, anterior right ventricular outflow tract; RVOT-post, posterior right ventricular outflow tract; RCC, right coronary cusp; RLJ, junction between the right and left coronary cusps; LCC, left coronary cusp.
because of the inaccuracy of the origins. We hypothesized that the overlap among the five areas during pacemapping may be smaller than that in the retrospective studies if the precise pacing sites were confirmed using CARTOSOUND, X-ray fluoroscopy, and/or angiography. However, even though the pacing sites were precisely determined, the overlap was still large for the previously reported parameters in this study. They might be affected by the chest wall, aorta deformities, obesity, or medications.10,20 Despite these limitations, these 12-lead ECG parameters were useful for differentiating the detailed sites of origin if a 12-lead ECG algorithm including several of those parameters were used.3,10

Furthermore, many previously reported parameters focused on differentiating the RVOT and LVOT. It is very important to predict an LVOT origin before the RFCA because the strategy is different from that for VAs originating from the RVOT. However, various origins of VAs in the LVOT are known to exist within a very small region, including the aortic sinus cusp region including the RCC, RLJ, LCC, non-coronary cusp (NCC), aorto-mitral continuity, and...
Table 2  The relationship between the QRS morphology pattern in the synthesized V5R and the results of the RFCA of idiopathic VAs

<table>
<thead>
<tr>
<th></th>
<th>RVOT-ant</th>
<th></th>
<th>RVOT-post</th>
<th></th>
<th>RCC</th>
<th></th>
<th>RLJ</th>
<th></th>
<th>LCC</th>
<th></th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Septal</td>
<td>Lateral</td>
<td>Septal</td>
<td>Lateral</td>
<td>RLJ</td>
<td>U-V</td>
<td>U-V</td>
<td></td>
<td>Cusp</td>
<td>U-V</td>
<td></td>
</tr>
<tr>
<td>Rs n = 13</td>
<td>10 (77%)</td>
<td>–</td>
<td>1 (8%)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2 (15%)</td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rS n = 23</td>
<td>3 (13%)</td>
<td>2 (9%)</td>
<td>11 (48%)</td>
<td>6 (26%)</td>
<td>1 (4%)</td>
<td>–</td>
<td>–</td>
<td></td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QS n = 3</td>
<td>–</td>
<td>–</td>
<td>11 (48%)</td>
<td>6 (26%)</td>
<td>–</td>
<td>–</td>
<td>1 (4%)</td>
<td>–</td>
<td>–</td>
<td>1 (33%)</td>
<td></td>
</tr>
<tr>
<td>qR n = 7</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>6 (75%)</td>
<td>1 (25%)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R n = 27</td>
<td>5 (18%)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1 (4%)</td>
<td>1 (4%)</td>
<td>–</td>
<td>12 (44%)</td>
<td>7 (26%)</td>
<td>1 (4%)</td>
<td></td>
</tr>
</tbody>
</table>

RVOT-ant, anterior right ventricular outflow tract; RVOT-post, posterior right ventricular outflow tract; RCC, right coronary cusp; RLJ, junction between right and left coronary cusps; LCC, left coronary cusp; U-V, under the valve.

aRight ventricular inflow region.
bUnsuccessful RFCA.

Figure 4  Representative 18-lead ECGs during the clinical OT-VAs. The 12-lead ECG and synthesized right-sided chest and back leads of the clinical OT-VAs are shown. The QRS morphology pattern in the synthesized V5R in each case differed. Each patient with OT-VAs, which were successfully eliminated by the RFCA at different sites, had different QRS morphology patterns in the synthesized V5R. OT-VA, outflow tract ventricular arrhythmia; RFCA, radiofrequency catheter ablation.
epicardial region. Especially, the RCC and RLJ are closely related to the posterior aspect of the RVOT. Therefore, the 12-lead ECG characteristics are similar and difficult to differentiate in those regions. This pacemapping study exhibited different morphology patterns obtained with the synthesized V5R between these two close areas. A QS in V5R was dominant in the RCC and an rS in V5R was dominant in the RVOT-post.

### Right-sided chest leads

The usefulness of right-sided chest leads for diagnosing acute myocardial infarctions involving the right ventricular wall and Brugada syndrome has been reported. Therefore, they are supposed to be useful for differentiating OT-VA origins. It has also been reported that the synthesized right-sided chest leads are useful for estimating OT-VA origins in a retrospective study. In that previous study, the transitional zone in the right-sided chest leads may suggest an OT-VA origin in the RVOT septum.

### QRS morphology pattern in V5R

In this study, first, a pacemapping study was performed to obtain the QRS morphology pattern in the synthesized right-sided chest leads because we wanted to find a simple parameter to differentiate the detailed origin sites. In the synthesized V5R, the dominant QRS morphology pattern significantly differed among the different sites including the RVOT-ant, RVOT-post, RCC, RLJ, and LCC. In the prospective study, this simple parameter was very useful for differentiating the origins including those five regions. However, it was difficult to distinguish that below the valve, or epicardial origins from LVOT origins. Moreover, it was also difficult to distinguish the RVOT lateral wall from the RVOT septum (see Supplementary material online, Table 1, Supplementary material online, Figure 3).

For differentiating these areas, detailed analyses of the 12-lead ECG including the R-wave amplitude, duration, and presence of notching in the inferior leads, and the S-wave depth in the precordial leads, are needed. Despite these limitations, to check this parameter was helpful to differentiate OT-VA origins, and it was easy to understand because of its simplicity. The overall accuracy of 75% using V5R seems to be high for predicting the five precise sites including close sites in small areas.

### Presumed mechanism

Figure 5A is magnetic resonance imaging (MRI) showing the RVOT and coronary cusps. Figure 5B is an MRI image showing the RV and LV. V5R is placed on the right and lateral side of the chest wall. The activation wave from the RCC may propagate from the most anterior site of the LVOT in a postero-lateral direction. Therefore, this activation may travel away from V5R. On the contrary, an activation wave from the LCC would propagate from a more posterior site of the LVOT in an antero-lateral direction, which may travel towards V5R (Figure 5B).

Because the initial septal stimulation by a VPC from the RLJ area travelled away from V5R, we could first see a q-wave in V5R. On the contrary, the septal stimulation by an RVOT VPC travelled towards V5R and we could first see an R-wave. However, the entire stimulation propagated away, from right to left, so later an S wave could be seen. Interestingly, the QRS patterns in V5R for the RCC and LCC looked the opposite. Moreover, that for the RLJ and RVOT also looked the opposite (Figure 5C).

### Study limitations

This study had several limitations. First, in the prospective study, the sample size was small. Especially, patients with VAs, which were successfully ablated in the RCC, were rare. However, the results were similar to the pacemapping study. Therefore, we believe that those results are reliable. Secondly, we did not check the actual right-sided chest leads in all patients. However, there are some previous reports comparing the synthesized and actual right-sided chest leads. Thirdly, in the pacemapping study, pacemapping at all five different sites was not performed in each patient. For example, in some patients, pacemapping was performed at only RVOT sites and pacemapping at only the coronary cusps was performed in other patients depending on the RFCA target sites of their VAs. Furthermore, it was difficult for the pacemapping to selectively capture sites on the OT septum. That might be one of the reasons for the low sensitivity of the pacemapping study in the RVOT sites. Furthermore, it was also difficult to obtain ventricular capture at the aortic sinus cusp even with a high output in some patients. Fourthly, the long-term success was not confirmed in this prospective study. The definition of a successful RFCA was only acute success. Therefore, there might be late recurrence cases in the long-term period in these subjects.

### Table 3 The usefulness of the QRS morphology pattern in the synthesized V5R for differentiating the origins of idiopathic VAs in the prospective study

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>'R's' for predicting RVOT-ant</td>
<td>50</td>
<td>94</td>
<td>77</td>
<td>83</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>'r'S' for predicting RVOT-post</td>
<td>94</td>
<td>89</td>
<td>74</td>
<td>98</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>'Q'S' for predicting RCC</td>
<td>67</td>
<td>99</td>
<td>67</td>
<td>99</td>
<td>0.003</td>
</tr>
<tr>
<td>'q'R' for predicting RLJ</td>
<td>78</td>
<td>100</td>
<td>100</td>
<td>97</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>'R' for predicting LCC</td>
<td>91</td>
<td>85</td>
<td>70</td>
<td>96</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

RVOT-ant, anterior right ventricular outflow tract; RVOT-post, posterior right ventricular outflow tract; RCC, right coronary cusp; RLJ, junction between right and left coronary cusps; LCC, left coronary cusp; PPV, positive predictive value; NPV, negative predictive value.
However, the similarity between the synthesized and actual right-sided chest leads has been proven in some papers\textsuperscript{14,15} and was also confirmed in some patients in our present study. Therefore, the actual right-sided chest leads can be recorded without special software and we believe that the QRS morphology of the actual VSR is also useful for predicting the origin of OT-VAs.

**Conclusion**

The QRS morphology pattern in the synthesized VSR was simple and a useful parameter for precisely differentiating the origins of OT-VAs.

**Supplementary material**

Supplementary material is available at Europace online.

**Conflict of interest:** none declared.

**Funding**

Akihiko Nogami has received honoraria from St. Jude Medical and Boston Scientific; and an endowment from Medtronic and Johnson & Johnson.

**References**


**Figure 5** (A) Magnetic resonance imaging showing the RVOT and coronary cusps. VSR is placed on the right and lateral side of the chest wall. (B) Magnetic resonance imaging showing the right ventricle and left ventricle. (C) The schema of the relationship between the different origins and QRS morphology patterns in VSR, RVOT, right ventricular outflow tract; TVA, tricuspid valve annulus; LAA, left atrial appendage; LSPV, left superior pulmonary vein; R, right; L, left; NCC, non-coronary cusp; MVA, mitral valve annulus.
Successful ablation of an epicardial ventricular tachycardia by video-assisted thoracoscopy

Tolga Aksu*, Tumer Erdem Guler, and Kivanc Yalin
Kocaeli Derince Education and Research Hospital, Kocaeli, Turkey
*Corresponding author. Tel: +90 505 213 7131; E-mail address: aksutolga@gmail.com

A 19-year-old female was referred to us for monomorphic premature ventricular contraction (PVC) and non-sustained monomorphic ventricular tachycardia. The patient had undergone three endocardial (EN) and two combined EN and epicardial (EP) ablation attempts. The 12-lead ECG showed a PVC with an RBBB morphology (Figure 1A). Echocardiography showed decreased left ventricular function (LVEF 42%). The site of earliest EN activation was localized at the postero-basal-lateral side of the left ventricle on EN mapping (Figure 1A). A fluoroscopically guided pericardial puncture was performed, but the needle was not advanced due to adhesions. Therefore, we decided to attempt minimally invasive approach to facilitate access to the target area. The chest was entered in the third interspace using a non-rib-spreading mini-thoracotomy with thorascopic assistance (Figure 1B and C). Under direct visualization, mapping with a cooled tip catheter was performed near the region of EN ablation catheter (Figure 1C). Pacing at this location produced greater than 90% pace-map match. After ablation and at 6-month follow-up, no further PVC was noted.

Video-assisted thorascopic epicardial access may be feasible for patients with pericardial adhesions and have epicardial ventricular arrhythmias. The technique allows us to reach wide area at epicardium, we think that it may be a useful tool to ablate VTs/PVSs originating from all sites of the epicardium.

The full-length version of this report can be viewed at: http://www.escardio.org/communities/EHRA/publications/ep-case-reports/Documents/Successful-ablation-of-an-epicardial.pdf.