Outflow Tract Tachycardia With R/S Transition in Lead V₃
Six Different Anatomic Approaches for Successful Ablation

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OBJECTIVES
The aim of this study was to analyze different anatomic mapping approaches for successful ablation of outflow tract tachycardia with R/S transition in lead V₃.

BACKGROUND
Idiopathic ventricular tachycardia can originate from different areas in the outflow tract, including the right and left ventricular endocardium, the epicardium, the pulmonary artery, and the aortic sinus of Valsalva. Although electrocardiographic criteria may be helpful in predicting the area of origin, sometimes the focus is complex to determine, especially when QRS transition in precordial leads is in V₃.

METHODS
We analyzed surface electrocardiograms of 33 successfully ablated patients with outflow tract tachycardia: 20 from the right ventricular outflow tract (RVOT) and 13 from different sites. The R/S transition was determined, and the different anatomic approaches needed for successful catheter ablation were studied.

RESULTS
Overall, R/S transition in lead V₃ was present in 19 (58%) of all patients. In these patients, mapping was started and successfully completed in the RVOT in 11 of 19 (58%) patients. The remaining eight patients with R/S transition in lead V₃ needed five additional anatomic accesses for successful ablation: from the left ventricular outflow tract (n = 2), aortic sinus of Valsalva (n = 2), coronary sinus (n = 1), the epicardium via pericardial puncture (n = 1), and the trunk of the pulmonary artery (n = 1), respectively.

CONCLUSIONS
A R/S transition in lead V₃ is common. In patients with outflow tract tachycardia with R/S transition in lead V₃, a stepwise endocardial and epicardial mapping through up to six anatomic approaches can lead to successful radiofrequency catheter ablation. (J Am Coll Cardiol 2005;45:418–23) © 2005 by the American College of Cardiology Foundation

Radiofrequency (RF) catheter ablation is an effective and curative therapy for patients without structural heart disease presenting with idiopathic ventricular tachycardia (VT) or frequent ectopic beats originating from the outflow tract area (1–3). Most of idiopathic outflow tract VT originates from the septal aspect of the right ventricular outflow tract (RVOT) (2,4), but some originate from the free wall of the RVOT (4,5) or the endocardium of the left ventricular outflow tract (LVOT) (4,6–8). In patients with failed endocardial RF catheter ablation of outflow tract VT, successful ablation from the aortic sinus of Valsalva has been described recently (9–12). The RF catheter ablation of outflow tract VT from an origin in the pulmonary trunk or through a percutaneous access to the pericardial space was rarely described (13,14).

Although electrocardiographic criteria may be helpful in predicting the area of origin, sometimes the focus is complex to determine, especially when QRS transition in precordial leads is in V₃.

The aim of this study was to analyze the prevalence of R/S transition in precordial lead V₃ in patients with successful ablation of outflow tract tachycardia and to study the different anatomic approaches needed for successful ablation of outflow tract tachycardia with R/S transition in lead V₃.

METHODS

Study population. The subjects of this study were 33 consecutive patients (13 male, 20 female, mean age 41 ± 16 years) with symptomatic idiopathic outflow tract VT, who underwent successful RF catheter ablation. Paroxysmal sustained idiopathic VT was present in 20 patients (61%), and 13 patients (31%) presented with frequent ventricular ectopy. At least one 12-lead electrocardiogram (ECG) with the arrhythmia was available for all patients. Twenty-six patients (79%) had at least one failed antiarrhythmic drug treatment (range 1 to 6) before catheter ablation. All patients gave written informed consent before the procedure.

Electrophysiologic study. Antiarrhythmic drugs were discontinued at least five half-lives before the procedure. Attention was paid to correct lead placement. Standard multielectrode catheters were inserted under fluoroscopic guidance through both femoral veins in the right ventricular apex and the RVOT. If activation mapping and pace mapping were thought to indicate a focus outside the RVOT, a multielectrode catheter was positioned in the coronary sinus, LVOT mapping via the retrograde aortic approach was done, and heparinization with a bolus of 5,000 IU intravenous heparin was started. If activation
mapping and pace mapping did not indicate a focus inside the LVOT, the mapping catheter was withdrawn from the left ventricle to the aortic sinus of Valsalva and positioned just above the coronary cusps. If endocardial RF catheter ablation failed and an epicardial origin remote from the aortic sinus of Valsalva and the coronary sinus with its branches was suspected, a percutaneous pericardial approach was chosen. Details of percutaneous pericardial access have been described in detail elsewhere (15). In one patient with unsuccessful RF ablation from the RVOT, the LVOT, and the epicardium, endocardial mapping was extended from the RVOT to the pulmonary trunk moving the mapping catheter through the pulmonary valve.

Both bipolar and unipolar electrograms were recorded by a Prucka system (filter at 30 to 500 Hz and 0.05 to 500 Hz, respectively).

**MAPPING TECHNIQUES AND RF CATHETER ABLATION.** The successful ablation site was determined by activation mapping using both bipolar and unipolar recordings during the arrhythmia. In 22 patients (66%), sufficient spontaneous activity of the arrhythmia was present allowing activation mapping. The other patients needed isoproterenol infusion to facilitate the inducibility or the spontaneous occurrence of the arrhythmia. In one patient, mapping was based on pace mapping alone, because of very low ectopic activity at the time of the procedure.

The electroanatomic mapping system (Carto; Biosense-Webster, Diamond Bar, California) was used for reconstruction of the area of interest and navigation of the ablation catheter in cases when ectopic activity was low, stability of the ablation catheter was difficult, and/or when the focus was in close proximity to vulnerable structures such as the coronary arteries.

The RF catheter ablation was performed using a steerable quadripolar ablation catheter with a 4-mm distal tip electrode (Celsius or Navistar; Biosense-Webster, Diamond Bar, California). The RF energy was delivered using a maximum power of 50 W and a maximum electrode–tissue interface temperature of 70°C. The applications of RF energy were 60 to 90 s in duration. If the origin of the arrhythmia was in the aortic sinus of Valsalva or an epicardial origin remote from the aortic sinus was present, a coronary angiography was performed before ablation to assess the anatomic relationship, and repeated after ablation, if a close relationship existed.

**DEFINITION OF SUCCESS.** Successful catheter ablation was defined as: 1) the absence of spontaneous or induced outflow tract VT or premature ventricular beats from the outflow tract, both in the absence and presence of isoproterenol, at the end of the procedure; 2) the absence of clinical arrhythmia during 24-h ECG monitoring after the ablation procedure; and 3) no recurrences of symptomatic arrhythmia >3 months of follow-up.

**Statistical analysis.** Continuous variables were expressed as mean ± SD. Categorical variables were compared by chi-square analysis. Sensitivity, specificity, positive and negative predictive values of different R/S transition zones for successful RF catheter ablation inside or outside the RVOT were given. A p value of <0.05 was considered statistically significant.

**RESULTS**

**ECG analysis.** The ECG analysis of the 33 successfully ablated patients showed left bundle-branch block morphology and an inferior axis in 31 patients and monophasic R-wave in lead V1 with inferior axis in 2 patients.

The R/S transition (first precordial lead with R/S ratio > 1) in precordial lead V3 was present in 19 patients (58%), R/S transition in V4 to V6 was present in 9 patients (27%), and R/S transition in V1 to V3 was present in the remaining 5 patients (15%), respectively.

**Site of origin in all patients.** Successful RF ablation was performed in the RVOT in 20 patients (61%), in the LVOT in 5 patients (15%), through an access in the coronary sinus in 3 patients (9%), in the aortic sinus in 2 patients (6%), epicardial via pericardial access in 2 patients (6%), and in the trunk of the pulmonary artery in 1 patient (3%), respectively.

**Site of origin of outflow tract tachycardia when R/S transition is in V3.** Nineteen patients presented with outflow tract tachycardia with R/S transition in V3. Successful RF catheter ablation in the RVOT was performed in 11 patients (58%) and outside the RVOT in 8 patients (42%) (p = 0.71). Therefore, the sensitivity of a R/S transition in V3 for successful ablation in the RVOT was low (55%), and the specificity was even lower (38%). The positive and negative predictive values of a R/S transition in V3 for successful ablation in the RVOT were 58% and 36%, respectively. In patients with R/S transition in V3 and late local activation or unsuccessful RF catheter ablation in the RVOT, successful ablation could be performed in the LVOT (n = 3; 16%, all just below the left coronary cusp of the aortic valve in the region of the aortomitral continuity), aortic sinus of Valsalva (n = 2; 11%, 1 in the left coronary cusp and 1 in the non-coronary cusp near the commissure to the left coronary cusp), coronary sinus (n = 1; 5%), pulmonary artery (n = 1; 5%), and the epicardium via pericardial puncture (n = 1; 5%), respectively. An overview of surface ECG morphologies with successful RF catheter ablation from six different anatomic approaches is given in Figure 1.

Figures 2 through 6 illustrate in detail the five anatomic approaches outside the RVOT for successful ablation of idiopathic VT with R/S transition in V3.
Site of origin of outflow tract tachycardia in all other patients. Nine patients presented with outflow tract tachycardia with R/S transition in leads V4 to V6. Successful RF catheter ablation in the RVOT was performed in all. Therefore, the specificity of a R/S transition in V4 or later for successful ablation in the RVOT was high (100%), but the sensitivity was low (45%) because 11 patients with successful RF catheter ablation in the RVOT had R/S transition in lead V3. Accordingly, the positive predictive value of a R/S transition in V4 to V6 for successful ablation in the RVOT was excellent (100%), but the negative predictive value was low (54%).

Five patients presented with outflow tract tachycardia with R/S transition in leads V1 and V2. All had successful RF catheter ablation outside the RVOT: in the LVOT (n = 2), epicardial through an access from the coronary sinus (CS), in the main pulmonary artery (PA), and in the epicardial space via percutaneous pericardial access (EPI), respectively. Note that all ECGs present with left bundle-branch block morphology, inferior axis, R/S transitional zone in the precordial leads V3, and negative QRS complex in lead I.

DISCUSSION

Main findings. The results of our study indicate that a R/S transition zone in precordial lead V3 is common in patients with idiopathic outflow tract tachycardia, with a prevalence of 58% in our study group. Although surface ECG criteria may be helpful to predict the area of origin in many patients, this was not the case in our subgroup of patients with R/S transition in precordial lead V3. The prevalence of R/S transition in V3 in RVOT tachycardia was not statistically different from outflow tract tachycardia originating outside the RVOT; therefore, the predictive value for this ECG criterion was low. Approximately 50% of outflow tract tachycardia with R/S transition in V3 could be successfully ablated from the RVOT, whereas our study showed for the first time that a relevant proportion of patients needed different anatomic approaches for successful RF catheter ablation using up to six different anatomic accesses including the LVOT, the aortic sinus of Valsalva, the coronary sinus, the pulmonary artery, and the epicardium via percutaneous pericardial puncture.

Electrocardiographic algorithms to predict the site of origin. Electrocardiographic characteristics to differentiate between a RVOT and a LVOT origin have been described.

Figure 1. Twelve-lead surface ECG from six different patients with idiopathic ventricular tachycardia that was successfully ablated in the right ventricular outflow tract (RVOT), in the left ventricular outflow tract (LVOT), in the aortic sinus of Valsalva (AO), in the coronary sinus (CS), in the main pulmonary artery (PA), and in the epicardial space via percutaneous pericardial access (EPI), respectively. Note that all ECGs present with left bundle-branch block morphology, inferior axis, R/S transitional zone in the precordial leads V3, and negative QRS complex in lead I.

Figure 2. Example of a successful ablation of frequent premature ventricular complexes from the left ventricular outflow tract (LVOT). (A) Shown are both unipolar (Abl uni) and bipolar (Abl bi) electrograms from the ablation catheter positioned at the LVOT. (B and C) Radiograms obtained in the right anterior oblique (RAO 30°) view (B) and left anterior oblique (LAO 60°) view (C) show the successful ablation site. The distal electrodes of the ablation catheter (ABL) are positioned in the LVOT just below the left coronary cusp of the aortic valve in the region of the aortomitral continuity. Schematic drawings present the position of the aortic valve area (AV) and the mitral annulus (MA). CS = coronary sinus; RVA = right ventricular apex.
The presence of an S-wave in lead I was helpful to identify a left ventricular origin; however, this ECG characteristic was present in all six anatomic approaches of our study group. Moreover, a R/S transition in lead V1 or V2 was found to be predictive of an origin in the LVOT, which is confirmed by our results. However, in these studies, the sensitivity and specificity of these ECG patterns were not given because of the limited number of patients studied. Another study reported that if the R/S ratio was >1 in lead V3, the origin was likely to be in the RVOT (4). The positive predictive value of this criterion was described as 100%, and the negative predictive value was low (50%), which is in accordance with our results. Conversely, if the R/S ratio in their study was <1 and the initial R-wave amplitude in leads V1 and V2 was high, the origin was likely to be in the LVOT. However, this algorithm could not identify an origin remote from the RVOT and LVOT.

Ouyang et al. described that QRS morphology of idiopathic VT from the aortic sinus of Valsalva is similar to that of RVOT arrhythmia, and that a longer R-wave duration and a higher R/S wave amplitude in lead V1 and V2 was present in VT originating in the aortic sinus of Valsalva (12). Several more complex ECG algorithms have been developed to classify idiopathic outflow tract VT according to the site of origin, allowing localization of VT origin in up to six different outflow tract sites using up to seven analysis steps (16,17). However, a limitation of these studies was that an epicardial origin remote from the aortic sinus was assumed when ablation had failed.

The value of surface ECG criteria in outflow tract tachycardia with R/S transition in V3 is limited.
the definite localization of VT origin has to be determined by invasive electrophysiologic mapping techniques.

**Mapping and ablation strategy for outflow tract VT with R/S transition in V3.** The prediction of the precise origin of outflow tract tachycardia may still be challenging because of the close anatomic relationship of the different anatomic compartments of the outflow tract area. Therefore, we propose a stepwise mapping procedure in patients with R/S transition in V3. Because one-half of VT with R/S transition in V3 originate in the RVOT, mapping should be started there. If this anatomic access fails to identify the origin of idiopathic VT, mapping of the pulmonary artery should be done, although this site of origin is rare, but no additional anatomic access is needed (13). We present another case in our series with successful ablation from the trunk of the pulmonary artery (Fig. 5). If activation mapping and pace mapping were thought to indicate a focus outside the RVOT and the pulmonary artery, mapping of the coronary sinus may add useful information as to whether a left-sided epicardial origin is present (18). Successful RF catheter ablation through a coronary sinus access has been described in patients with ischemic VT (19), and is possible in patients with idiopathic VT as described for the first time in this study (Fig. 4). However, the possibility of a close relationship with the coronary arteries should be considered, and coronary angiography should be performed before and after RF catheter ablation. If a transvenous access is not successful, mapping of the LVOT and the aortic sinus of Valsalva via retrograde transaortic access are the next steps. Idiopathic VT arising from the LVOT and the aortic sinus are less common. They can be found particularly around the superior mitral annulus near the aortomitral continuity, or the aortic sinus of Valsalva, where extensions of myocardium are often found (20). A navigation system is useful to monitor the exact positioning and stability of the ablation catheter during energy delivery. Coronary angiography adds additional information and real-time visualization of the relationship between the ablation site and the ostia of the coronary arteries. Finally, if all previous anatomic accesses...
were unsuccessful, epicardial mapping via percutaneous pericardial access should be considered.

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REFERENCES


