—Review—

Idiopathic Ventricular Premature Contraction and Ventricular Tachycardia: Distribution of the Origin, Diagnostic Algorithm, and Catheter Ablation

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Idiopathic ventricular premature contractions (VPCs), defined as VPCs in the absence of obvious structural heart disease, are one of the common types of arrhythmia in clinical practice. They are sometimes complicated with non-sustained ventricular tachycardia (VT), and/or sustained VT with almost same QRS morphology in 12 leads ECG. Idiopathic VT (IVT) commonly occurs by focal mechanisms and the origins are distributed in a variety of sites in both ventricles.

In this article, the clinical characteristics of IVT/IVPCs, the diagnostic algorithm, and how to ablate them will be reviewed. (J Nippon Med Sch 2018; 85: 87–94)

Key words: idiopathic ventricular tachycardia, idiopathic ventricular premature contractions, classification, origin, mechanism

Introduction

Idiopathic ventricular tachycardia (IVT) is usually defined as ventricular tachycardia (VT) in the absence of obvious structural heart disease. A majority of patients with IVT also experience ventricular premature contractions (VPCs) with a similar QRS morphology. IVT commonly occurs by focal mechanisms, including enhanced automaticity and triggered activity, except with verapamil-sensitive left ventricular tachycardia (so-called Fascicular VT), which has been shown to be caused by a reentrant mechanism. The origins of focal IVTs are distributed in a variety of areas of the right ventricle (RV) and left ventricle (LV). Therefore, the catheter approach to the target of the catheter ablation is also complex. Because the effectiveness of radiofrequency (RF) delivery differs with the different origins of arrhythmias, the suspected origin should be decided in advance of the actual procedure for a better ablation outcome.

IVTs have a characteristic morphology of the QRS complex according to the origin of the tachycardia. Based on this, the diagnostic algorithm of the VT/VPC origin utilizing the ECG morphology has been constructed and has been shown to be useful[1]. In this article, the clinical characteristics of IVT/IVPCs, the diagnostic algorithm, and how to ablate them will be reviewed.

Classification of IVT/IVPC

The origin of IVT is widely distributed in both ventricles and near vascular structures. **Table 1** shows the classification of idiopathic ventricular tachycardia (IVT) according to the mechanism and origin of the tachycardia. Most VTs arise as focal firing from various sites in the right and left ventricles. Of those, with regard to the right ventricle, the common sites of the VT origin are the outflow tract of both the septal and free-wall aspects, the vicinity of the tricuspid annulus and the His bundle, the right papillary muscle, and the muscular sleeve of the pulmonary artery. The left ventricle also has several specific origins of IVTs, including the left endocardial outflow tract and the epicardial outflow tract which sometimes require RF delivery from the coronary cusps and cardiac summit (the area between the great cardiac vein and anterior interventricular vein), posterior and anterior papillary muscles, the vicinity of the mitral annulus, and the crux of the heart (the epicardial origin around the posterior coronary sinus and middle cardiac vein).

A representative IVT with a reentrant mechanism is a fascicular VT, which is usually divided into three categories: a posterior type (most frequent), anterior type, and upper-septal type. These are commonly susceptible to

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Table 1 Classification of idiopathic VT and VPCs according to mechanism and origin of the tachycardia

1) Enhanced automaticity or triggered activity
-origin (successful ablation site)-
(1) Outflow tract
a) RV-Outflow tract (Septum, Free wall, RCC, pulmonary artery)
b) LV-Ourflow tract (LCC, RCC, Sub-aortic valve endocardium, Cardiac summit)
(2) anterior inflow (His bundle area, NCC)
(3) tricuspid annulus (tricuspid annulus)
(4) Crux (Intra-CS, Mid cardiac vein, epicardial approach)
(5) mitral annulus (mitral annulus)
(6) papillary muscle (left side dominant, left posterior PM> left anterior PM)
(7) His-Purkinje system (Purkinje network, bundle branch)
2) Reentrant mechanism
(1) Verapamil sensitive left ventricular tachycardia (Fascicular tachycardia)
a) Posterior type
b) anterior type
c) Upper-septal type

RCC: right coronary cusp, LCC: left coronary cusp, NCC: non-coronary cusp, CS: coronary sinus, PM: papillary muscle

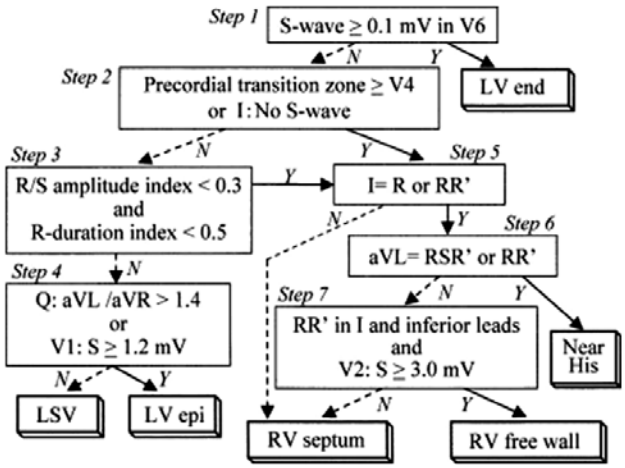

Fig. 1 Electrocardiogram algorithm for identifying the optimal ablation site of idiopathic ventricular outflow tract tachycardias Reproduced with permission from [journal name].

verapamil leading to termination or slowing of the tachycardia.

Clinical characteristics and catheter ablation of IVTs originating from the outflow tract (OT)[2]

As IVTs most commonly originate from the outflow tract (OT), several diagnostic algorithms using surface ECGs during periods of tachycardia have been developed[3,4]. **Figure 1** shows a representative algorithm to search for the target site for catheter ablation[4] and this has been valued as a good tool to obtain a rough estimate. However, there is one shortcoming even with this sophisticated algorithm, namely the differentiation of right or left OT in IVTs, which have a precordial transition of the R/S ratio at V3. Usually, ECGs of typical OT-VTs originating in the RV show R/S transition at or after V3. On the contrary, ECGs of OT-VTs originating in the LV exhibit an R/S transition at or before V3. Thus, the IVTs with a V3 R/S transition may possibly originate from either ventricle. Because approximately 35% of OT-VTs have been shown to have an R/S transition at V3[5], the discrimination between an RV and LV origin is a significant issue in clinical practice. Because the outflow tract area possesses very complex structural features, making it difficult to approach the origin of either ventricle, it is important to estimate the precise origin before the ablation procedure.

The current ECG algorithms do not take into account cardiac rotation, respiratory variation, and the position of the ECG leads on the chest, which is easily influenced by the body habitus, breast size, and technical experience. To eliminate the influence of these factors, Batensky et al.[6] compared the QRS morphology of tachycardia with that during sinus rhythm and proposed an effective good variable to distinguish right from left origins, that is, the V2 transition ratio (**Fig. 2**). A V2 transition ratio >0.6 predicts an LVOT origin with high sensitivity and specificity. Yoshida et al.[7] demonstrated that the V2S/V3R index (**Fig. 2**) using only the ECG during a period of tachycardia is a highly accurate parameter for distinguishing the right and left.

For the electrophysiology (EP) mapping of IVTs, activation mapping of VT/VPCs shows a centrifugal pattern

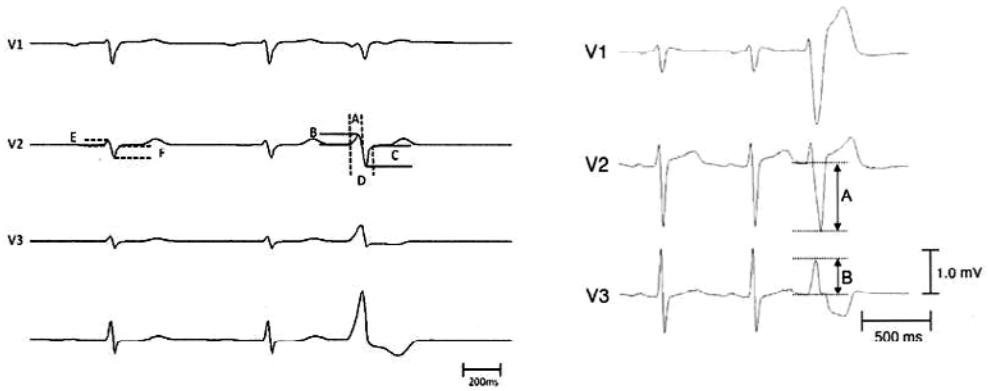

Fig. 2 Novel methods to distinguish RV-OT and LV-OT origins using the surface electrocardiogram.
Left panel: The transition ratio is calculated in each lead with the following formula: B/(B+C) VT÷E/(E+F) SR. If the V2 transitional ratio is more than 0.6 the origin is likely to be in the left ventricle. Reproduced with permission from [journal name].
Right panel: V2S/V3R Index is calculated with the following formula: A/B
If the V2S/V3R index is less than 1.5 the origin is likely to be in the left ventricle. Reproduced with permission from [journal name].

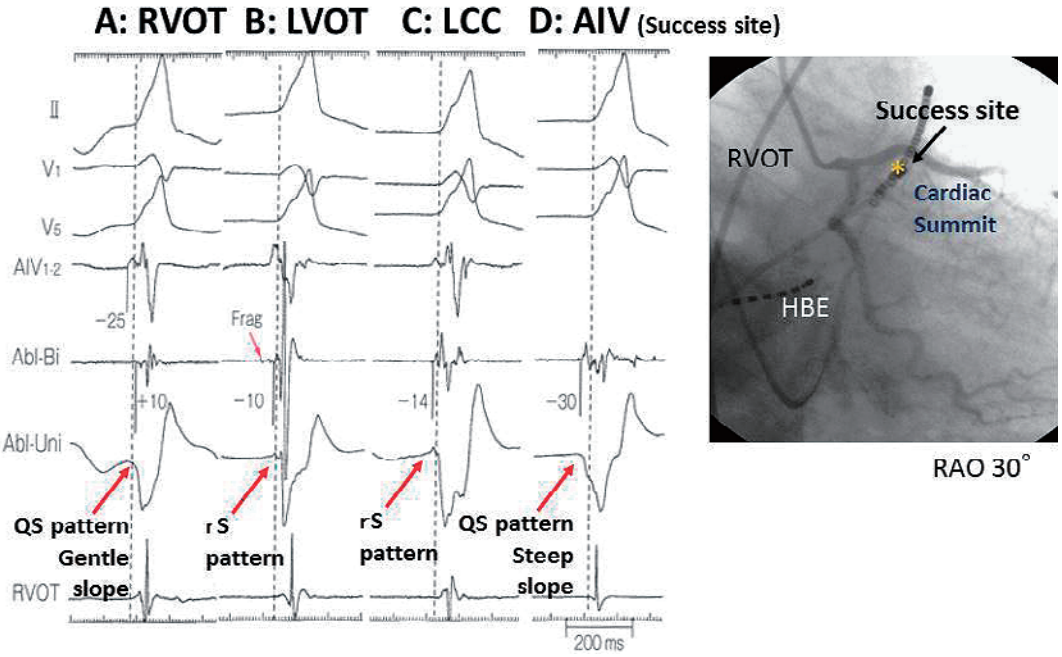

Fig. 3 Local bipolar and unipolar potentials from various sites during VPCs in a case with frequent PVCs from a cardiac summit origin. Panels A through C show the bipolar (Abl-Bi) and unipolar (Abl-Uni) recordings from the earliest site in the RVOT (A), endocardial LVOT (B), and LCC (C), respectively. Panel D shows the recordings from the successful ablation site (anterior interventricular vein: AIV). Note that at the successful ablation site, the local bipolar potential precedes the onset of the QRS complex by 30 ms, and the unipolar recording exhibits a QS pattern with a relatively steep configuration of the initial downslope. Reproduced with permission from [journal name].

reflecting a focal mechanism of that arrhythmia. With the combination of pace mapping, the location of the tachycardia foci can be confirmed. The unipolar recording from the tip electrode is also useful to endorse the ablation target site, where a QS morphology with a relatively steep onset can be recognized[8] (**Fig. 3**). In patients with infrequent VT/VPCs, pace mapping is the only tool currently able to locate the origin. In the majority of patients

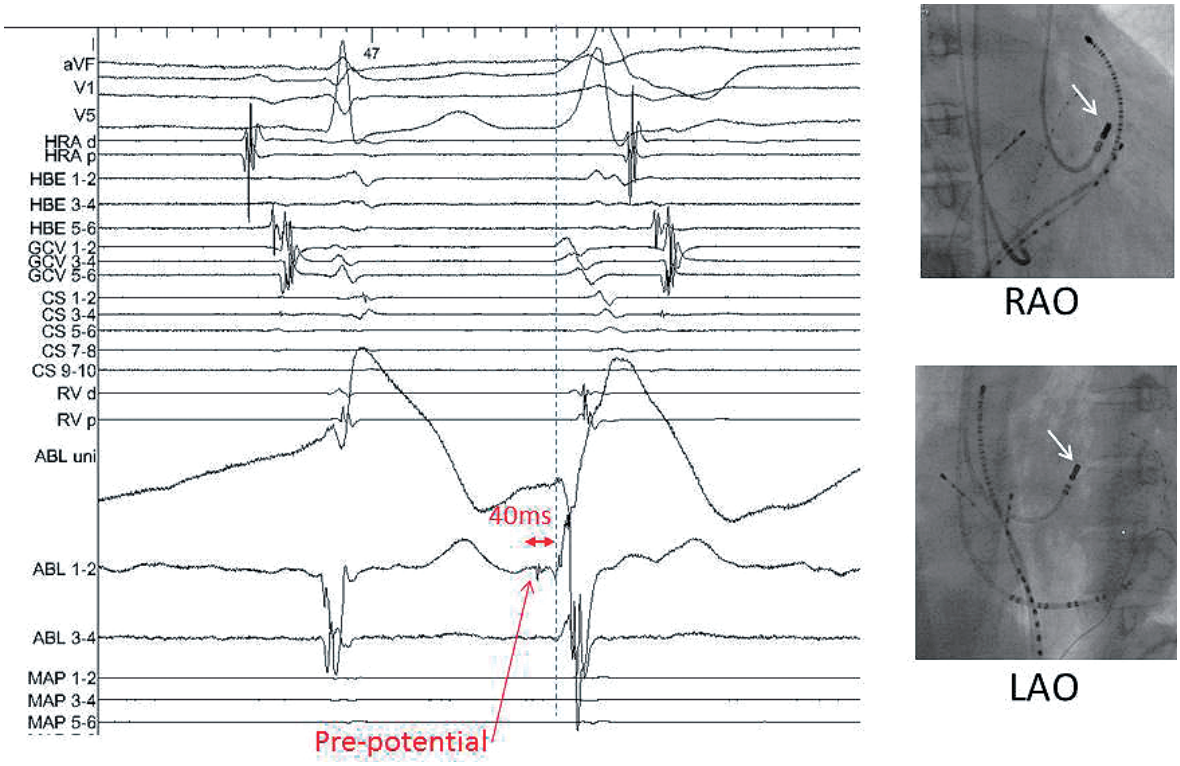

Fig. 4 Discrete pre-potentials recorded at the left coronary cusp (successful site).
The left panel shows the local potentials recorded at the left coronary cusp (successful ablation site). Note that there is a discrete pre-potential preceding the onset of the QRS during the VPC by 40 ms. Right panels: Cine-frames of the RAO 30 and LAO 50 views.
HRA: high right atrium, HBE: His bundle electrogram, GCV: great cardiac vein, ABL uni: uniplar electrogram at the ablation site, Abl: bipolar electrogram at the ablation site, MAP: monophasic action potential, RV-OT: right ventricular outflow tract. Reproduced with permission from [journal name].

with an RV-OT origin, RF deliveries from the septal or free wall of the RV-OT result in successful ablation, however it is sometimes necessary to apply the RF energy in the right coronary cusp or above the pulmonary artery valve.

For LV-OT origins, the ratio of endocardial origins is rather small, and more patients can receive successful ablation by RF applications from the coronary cusp or epicardial side. In the EP mapping inside the coronary cusp, the role of pace mapping is quite scarce and activation mapping is the only tool to access the origin. At the successful ablation site, the local electrogram often demonstrates a discrete potential preceding the onset of the QRS complex during the tachycardia, which may reflect the activation of a dead-end origin[9] (**Fig. 4**). Such discrete potentials have recently been shown to be recorded even at RV-OT below the pulmonary valve and to be a potential guide for successful ablation[10].

When an epicardial origin is suspected, it should be confirmed that the local ventricular activation from the great cardiac vein is preceding the onset of the surface QRS complex during the tachycardia. Because this region corresponds to the top of the cardiac structure, it is commonly called the cardiac summit (**Fig. 3**). For tachycardias arising from the coronary cusps, a relatively high power of the RF (30-50 W) can be delivered due to the rich blood flow. To avoid injury to the coronary arteries, it should be confirmed that the target site is located more than 1 cm from the orifice of the coronary arteries. For a summit origin, it is recommended to use an irrigation catheter and apply a relatively low energy (<20 W) because the blood flow inside the veins is relatively poor.

IVT/IVPCs originating from the pulmonary artery

IVT/IVPCs sometimes originate from the sleeve muscle of the pulmonary artery[11]. One study showed that a smaller ventricular potential, compared with a RV-OT area and a far-field atrial potential, were recorded above the pulmonary valve[11]. Recently, the distribution of the successful ablation site above the pulmonary valve was determined to be 42% for the right cusp, 33% for the left cusp, and 25% for the anterior cusp[12]. The RF deliveries

Table 2 Classification of IVT/IVPC originating in the left ventricle except LV-OT origin

Clinical characteristics	Verapamil sensitive (Fascicular VT)	Mitral annulus origin	Papillary muscle origin	Crux origin
Ratio in the whole IVT/IVPC	10–20%	5%	5%	2%
Origin	LV septum 1) Posterior type: 85% 2) Anterior type: 13% 3) Upper septal type: 2%	Mitral annulus 1) anterior: 60% 2) posteroseptal: 25% 3) posterior: 15%	1) Posterior PM: 2/3 2) Anterior PM: 1/3	1) Vicinity of CS 2) Vicinity of midcardiac vein (MCV)
Mechanism	Macro-reentry involving Purkinje network and false tendon	Enhanced automaticity or triggered activity	Enhanced automaticity or triggered activity	Enhanced automaticity or triggered activity
ECG manifestations during tachycardia	Relatively narrow QRS complex 1) RBBB & sup. axis 2) RBBB & RAD 3) very narrow QRS	Wide QRS complex Relatively narrow QRS in septal origin 1) RBBB & inf axis 2) RBBB & sup axis 3) RBBB & sup axis	Wide QRS complex 1) RBBB & sup axis 2) RBBB & inf axis R/S<1.0 in V6	Wide QRS Epicardial origin high MDI Pseudo delta wave QS pattern in inferior leads
Specific features of the local electrogram at the successful ablation site	a) Late diastolic potential (P1,Pd): reflecting slow conduction b) Presystolic potential (P2, Pp): fascicular or Purkinje potential	a) Far-field atrial potential b) Centrifugal pattern in activation map c) QS pattern in unipolar potential	a) Discrete pre-potential in 40% b) Purkinje potetnail sometimes recorded.	a) Far-field atrial potential b) Centrifugal pattern in activation map c) QS pattern in unipolar potential
Difficulty of ablation	Easy	Relatively easy	Difficult	Difficult

within the cusps resulted in the successful elimination of the arrhythmia without any complications[11,12], although it was recommended to take extra care in order to avoid injury to the vessels due to the close proximity of the ablation sites with the coronary arteries[11].

IVT/IVPCs originating from the tricuspid annulus[13,14]

This tachycardia accounts for approximately 7% of all IVT/IVPCs. The characteristics of the surface QRS complex include a left bundle branch block morphology and monophasic R or RR' pattern in lead I. The R/S transition is seen at or after V4 in the free wall origins, whereas it is recognized at or before V3 in the septal origins. The QRS width is also narrower in the septal origins than free wall origins. The EP mapping is undertaken with a similar method as other focal tachycardias. The emergence of atrioventricular block should be monitored during the ablation for anteroseptal origins starting with a relatively low energy delivery (around 10 W).

Classification, clinical characteristics and catheter ablation of left ventricular origin IVT/IVPCs (ILVTs) (Table 2)

The origin of ILVTs can be classified into 4 categories according to the origin of the tachycardia, except for LV-OT origins. These are fascicular VTs and focal VTs originating from the mitral annulus, papillary muscles, and epicardium near the CS ostium or mid cardiac vein (crux origins).

1) Verapamil sensitive left ventricular tachycardia (fascicular VT)

Fascicular VT accounts for approximately 10% of all the IVT/IVPCs. The mechanism is shown to be a macro-reentry in which the Purkinje network or a false tendon may play a role as a slow conduction area. Fascicular VT is classified into 3 types by the location of the culprit region: the posterior type, anterior type, and upper septal type. The posterior type is dominant, occupying more than 80% of this category of VT. The ECG during the tachycardia shows a right bundle branch block (RBBB) pattern and superior axis in the posterior type, and inferior axis (right axis deviation) in the anterior type. The mid-septal type is a very rare tachycardia showing a narrow QRS complex often with a QRS width <120 ms. The ablation procedure is usually guided by the local electrogram, targeting the late diastolic potentials (Pd potentials), which may reflect slow conduction in the reentry circuit. The Pd potential is shown to be recorded in a relatively wide area located around the middle aspect of the posterior and posteroseptal LV, however, there are some inter-individual variations as shown in **Figure 5**[15]. On the contrary, pre-systolic Purkinje potentials (Pp po-

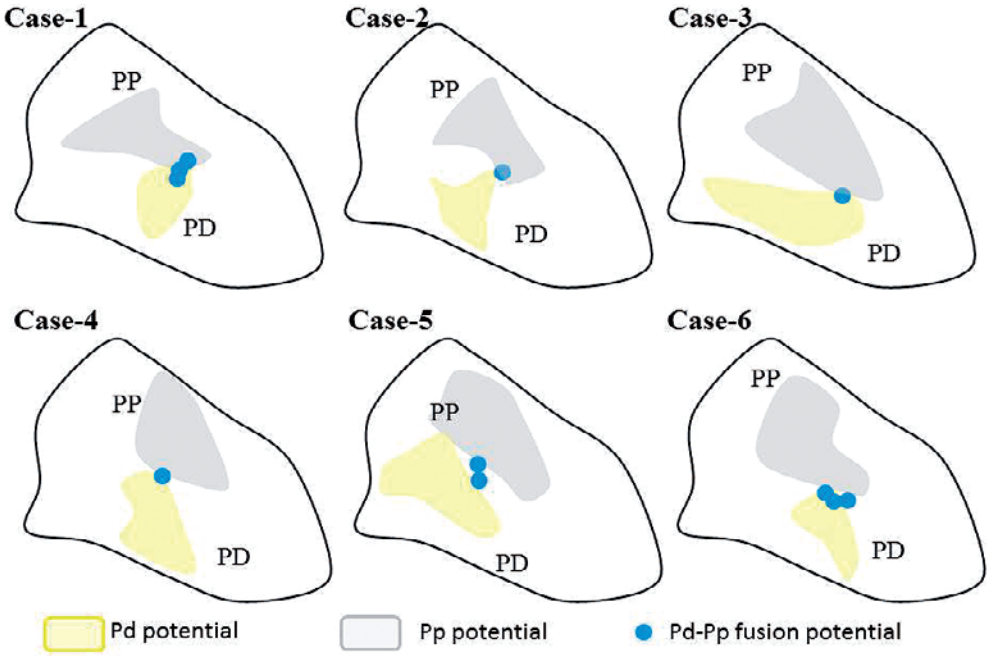

Fig. 5 Spatial distribution of the Pd and Pp potentials in the left ventricular septum. Schematic presentation of the distribution of the Pd and Pp potentials. The gray and yellow areas indicate the respective locations at which the Pp and Pd potentials were recorded in each case. The blue dots indicate the points at which fused Pd and Pp potentials were recorded. Reproduced with permission from [journal name].

tentials) are found in the infero-mid to anterior septal regions and the distribution is exhibited in a similar pattern in all 6 patients with the posterior type of fascicular VT. At the intersection of the Pd (yellow) and Pp (gray) areas, which is located in the mid-posterior septum, both the Pd and Pp potentials can be detected (blue dots) and these potentials are closely spaced or often have a fused configuration. Furthermore, this point corresponds to the latest Pd activation and the earliest Pp activation, suggesting that it is evidently an exit site from the slow conduction connecting to the Purkinje fibers. The RF application at this site has been shown to be effective and safe[15,16].

Recently, one study looked at the long-term outcome of patients undergoing acutely successful ablation of fascicular VT using a large population (120 patients)[17]. After a median of 57 months of follow up, VT of an ECG morphology occurred in 17 patients, and 6 other patients developed new onset of the upper septal fascicular VT. Thus, approximately 80% of the patients were shown to be recurrence-free from the arrhythmia.

2) IVT/IVPCs originating from the vicinity of the mitral annulus

These correspond to approximately 5% of all IVT/IVPCs. The ratio of the tachycardia according to the region of the annulus is 60% for the anterior region, 25% for posteroseptal region, and 15% for posterior region. The ECG during the tachycardia with a free-wall origin shows a wide QRS complex with an RBBB pattern and a small notch in the latter half of the inferior ECG leads. The axis is inferior with anterolateral origins and superior with posterior origins. On the other hand, a relatively narrow QRS complex is detected in tachycardias originating from the posteroseptal region or near the aorto-mitral continuity. **Figure 6** shows a diagnostic algorithm for predicting the site of the origin, constructed by Tada et al.[18].

During the electrogram mapping, both the atrial far-field potentials and near-field ventricular potentials can be detected. At the successful ablation site, the mean of the amplitudes of the atrial and ventricular potentials is approximately 0.2 mV and 1.7 mV, respectively. In 40% of the total patients, a discrete potential preceding the QRS complex is also seen at the success sites. The catheter ablation is relatively easy with a high success rate.

3) IVT/IVPCs originating from papillary muscles (PMs)[19,20]

Tachycardias originating from both posterior and anterior papillary muscles (PPMs and APMs) account for approximately 5% of all IVT/IVPCs. The PPM origins are more frequent than APM origins. The ECG during the tachycardia shows a wide QRS complex with an RBBB

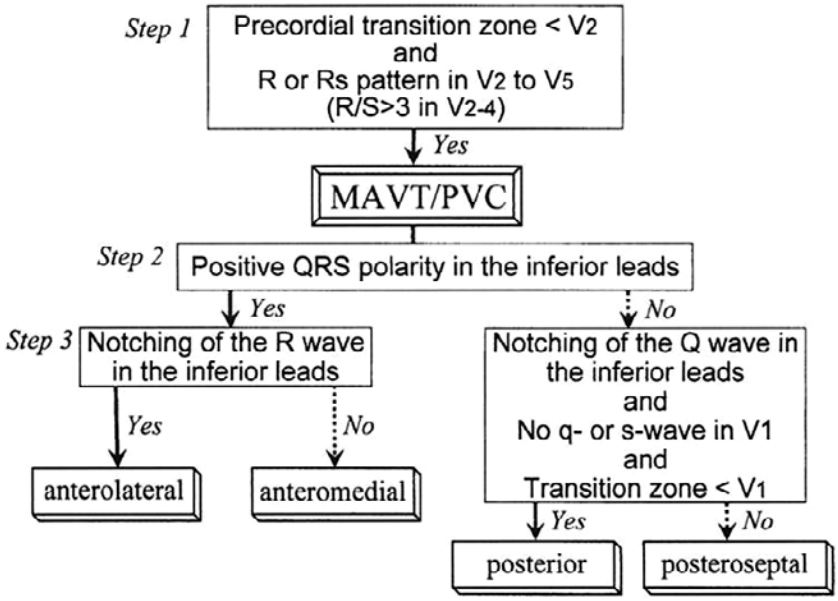

Fig. 6 Proposed ECG algorithm to predict the precise focus of mitral annulus VT/VPCs.
Proposed diagnostic algorithm to predict the precise focus of mitral annulus VT/VPCs based on the 12-lead electrocardiographic recordings. Reproduced with permission from [journal name].

morphology, and superior axis for PPM origins and inferior axis for APM origins, respectively. In most patients with PM origins, the R/S ratio is less than 1.0 in the V6 lead, which is not the case for mitral annulus origins and fascicular VTs. In some patients, there are multiple foci in the PM.

Manipulation of the catheter and stable attachment of the catheter tip on the PM are difficult due to strong pulsations and the anatomical complexity of the PM. Recently, a 3-D mapping system incorporating an intracardiac ultrasound system has become available. Using this, real time navigation and confirmation of the positioning of the catheter tip on the PM are possible and may improve the ablation results. In some patients, the focus exists deep inside the PM. In these patients, at the endocardial surface near the focus, a discrete potential preceding the QRS complex may be detected. The application of an RF current at that site sometimes results in a failed ablation because of the depth of the focus. In about half of the patients, a spiky Purkinje potential can be seen in the local potentials, however it does not clearly precede the QRS and sometimes overlaps with the QRS complex, thus the Purkinje fibers have been thought to be bystanders in this type of tachycardia.

4) IVT/IVPCs originating from the crux of the heart.[21,22]

This tachycardia is a rare clinical entity and arises from the epicardial surface at the crux of the heart, near the junction of the middle cardiac vein (MCV) and the coronary sinus (CS). Most of this category of arrhythmias shows a sustained VT with a short cycle length (<300 ms), sometimes followed by syncopal episodes. This tachycardia has unique ECG manifestations such as a very early R/S transition at the V1 or V2 leads and a QS pattern in the inferior leads. Furthermore, due to the epicardial origin, a wide QRS complex with a pseudo-delta wave is appreciable and the maximum deflection index (MDI) is often >0.55. Ablation is initially attempted from inside of the CS and MCV targeting the earliest activation site during the tachycardia. However, the success rate is shown to be relatively low. The next step is an epicardial approach. In this approach, attention should be paid to the fact that the right coronary artery commonly runs near the ablation target.

In summary, idiopathic VT and VPCs have a variety of origins, which are widely distributed in both the right and left ventricles. To achieve a successful ablation, the RF is applied from a variety of tissues, including the endocardial surface, above the pulmonary valve, at the coronary cusps, inside the CS, MCV, GCV, and finally from the epicardial surface using several specific approaches. It is recommended to predict the precise origin of the tachycardia utilizing algorithms before the ablation procedures to obtain a better ablation outcome and to

shorten the procedure time.

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References

1. Park KM, Kim YH, Marchlinski FE: Using the surface electrocardiogram to localize the origin of idiopathic ventricular tachycardia. PACE 2012; 35: 1516–1527.
2. Heeger CH, Hayashi K, Kuck KH, Ouyang F: Catheter ablation of idiopathic ventricular arrhythmias arising from the cardiac outflow tracts. -Recent insights and techniques for the successful treatment of common and challenging cases- Circ J 2016; 80: 1073–1086.
3. Kamakura S, Shimizu W, Matsuo K, Taguchi A, Suyama K, Kurita T, Aihara N, Ohe T, Shimomura K: Localization of optimal ablation site of idiopathic ventricular tachycardia from right and left ventricular outflow tract by body surface ECG. Circulation 1998; 98: 1525–1533.
4. Ito S, Tada H, Naito S, Kurosaki K, Ueda M, Hoshizaki H, Miyamori I, Oshima S, Taniguchi K, Nogami A: Development and validation of an ECG algorithm for identifying the optimal ablation site for idiopathic ventricular outflow tract tachycardia. J Cardiovasc Electrophysiol 2003; 14: 1280–1286.
5. Yamada T, Yoshida N, Murakami Y, Okada T, Muto M, Murohara T, McElderry HT, Kay GN: Electrocardiographic characteristics of ventricular arrhythmias originating from the junction of the left and right coronary sinuses of Valsalva in the aorta: the activation pattern as a rationale for the electrocardiographic characteristics. Heart Rhythm 2008; 5: 184–192.
6. Betensky BP, Park RE, Marchlinski FE, Hutchinson MD, Garcia FC, Dixit S, Callans DJ, Cooper JM, Bala R, Lin D, Riley MP, Gerstenfeld EP: The V2 transition ratio. J Am Coll Cardiol 2011; 57: 2255–2262.
7. Yoshida N, Yamada T, Mcelderry HT, Inden Y, Shimano M, Murohara T, Kumar V, Doppalapudi H, Plumb VJ, Kay GN: A novel electrocardiographic criterion for differentiating a left from right ventricular outflow tract tachycardia origin: The V2S/V3R Index. J Cardiovasc Electrophysiol 2014; 25: 747–753.
8. Hirasawa Y, Miyauchi Y, Iwasaki Y, Kobayashi Y: Successful radiofrequency catheter ablation of epicardial left ventricular outflow tract tachycardia from the anterior interventricular coronary vein. J Cardiovas Electrophysiol 2005; 16: 1378–1380.
9. Yamada T, McElderry HT, Doppalapudi H, Murakami Y, Yoshida Y, Yoshida N, Okada T, Tsuboi N, Inden Y, Murohara T, Epstein AE, Plumb VJ, Singh SP, Kay GN: Idiopathic ventricular arrhythmias originating from the aortic root prevalence, electrocardiographic and electrophysiologic characteristics, and results of radiofrequency catheter ablation. J Am Coll Cardiol 2008; 52: 139–147.
10. Liu EL, Xu G, Liu T, Ye L, Zhang Q, Zhao Y, Li G: Discrete potentials guided radiogrequency ablation for idiopathic outflow tract ventricular arrhythmias. Europace 2015; 17: 453–460.
11. Sekiguchi Y, Aonuma K, Takahashi A, Yamauchi Y, Hachiya H, Yokoyama Y, Iesaka Y, Isobe M: Electrocardiographic and electrophysiologic characteristics of ventricular tachycardia originating within the pulmonary artery. J Am Coll Cardiol 2005; 45: 887–895.
12. Liao Z, Zhan X, Wu S, Xue Y, Fang X, Liao H, Deng H, Liang Y, Wei W, Liu Y, Ouyang F: Idiopathic ventricular arrhythmias originating from the pulmonary sinus cusp. Prevalence, electrocardiographic / electrophysiological characteristics, and catheter ablation. J Am Coll Cardiol 2015; 66: 2633–2644.
13. Tada H, Tadokoro K, Ito S, Naito S, Hashimoto T, Kaseno K, Miyaji K, Sugiyasu A, Tsuchiya T, Kutsumi Y, Nogami A, Oshima S, Taniguchi K: Idiopathic ventricular arrhythmias originating from the tricuspid annulus: Prevalence, ECG characteristics, and results of radiofrequency catheter ablation. Heart rhythm 2007; 4: 7–16.
14. Li T, Zhan XZ, Xue YM, Fang XH, Liao HT, Deng H, Wei W, Wu SL: Combined approach improves the outcome of catheter ablation of idiopathic ventricular arrhythmias originating from the vicinity of tricuspid annulus. PACE 2014; 37: 624–629.
15. Taniguchi H, Kobayashi Y, Maruyama M, Morita N, Hayashi M, Miyauchi Y, Shimizu W: Electrophysiologocal and anatomical background of the fusion configuration of diastolic and presystolic Purkinje potentials in patients with verapamil-sensitive idiopathic left ventricular tachycardia. J Arrhythmia 2015; 31: 261–267.
16. Chu J, Sun Y, Zhao Y, Wei W, Wang J, Liu X, Jia Y, Mao K, Pu J, Zhang S: Identification of the slow conduction zone in a macroreentry circuit of verapamil-sensitive idiopathic left ventricular tachycardia using electroanatomic mapping. J Cardiovasc Electrophysiol 2012; 23: 840–845.
17. Liu Y, Fang Z, Yang B, Kojodjojo P, Chen H, Ju W, Cao K, Chen M, Zhang F: Catheter ablation of fascicular ventricular tachycardia. Long-term clinical outcomes and mechanisms of recurrence. Circ Arrhythm Electrophysiol 2015; 8: 1443–1451.
18. Tada H, Ito S, Naito S, Kurosaki K, Kubota S, Sugiyasu A, Tsuchiya T, Miyaji K, Yamada M, Kutsumi Y, Oshima S, Nogami A, Taniguchi K: Idiopathic ventricular arrhythmia arising from the mitral annulus. J Am Coll Cardiol 2005; 45: 877–886.
19. Doppalapudi H, Yamada T, McElderry HT, Olumb VJ, Epstein AE, Kay GN: Ventricular tachycardia originating from the posterior papillary muscle in the left ventricle. A distinct clinical syndrome. Circ Arrhythm Electrophysiol 2008; 1: 23–29.
20. Good E, Desjardins B, Jongnarangsin K, Oral H, Chugh A, Ebinger M, Pelosi F, Morady F, Bogun F: Ventricular arrhythmias originating from a papillary muscle in patients without prior infarction. A comparison with fascicular arrhythmias. Heart Rhythm 2008; 5: 1530–1537.
21. Doppalapudi H, Yamada T, Ramaswamy K, Ahn J, Kay GN: Idiopathic focal epicardial ventricular tachycardia originating from the crux of the heart. Heart Rhythm 2009; 6: 44–50.
22. Kawamura M, Gerstenfeld EP, Vedantham V, Rodrigues DM, Burkhardt JD, Kobayashi Y, Hsia HH, Marcus GM, Marchlinski FE, Scheinman MM, Badhwar N: Idiopathic ventricular arrhythmias originating from the cardiac crux or inferior septum. Epicardial idiopathic ventricular arrhythmia. Circ Arrhythm Electrophysiol 2014; 7: 1152–1158.

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