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Ablation of left posterior fascicular ventricular tachycardia during sinus rhythm under guidance of non-contact balloon mapping

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This paper evaluated the effectiveness and safety of patchy ablation for treating left posterior fascicular ventricular tachycardia (LPFVT) using rapid mapping of diastolic potentials and Purkinje potentials during sinus rhythm under the guidance of the Ensite3000 system. Twelve patients suffering from left posterior fascicular ventricular tachycardia were treated at our center. A three-dimensional endocardium geometric model was established under the guidance of the Ensite3000 balloon mapping system during sinus rhythm. The patchy ablation was induced by the diastolic potential (DP) and Purkinje potential (PP) at the top region of the sinus rhythm breakout point (SNR-BO). The conduction block in the left posterior branch was observed on the surface electrocardiograms of 11 patients. Ventricular tachycardia could not be induced in any of these patients by programmed stimulation following ablation. At follow-up, only one patient had relapsed (two months after the operation) and ventricular tachycardia could not be induced after re-ablation. Left posterior fascicular ventricular tachycardia can be treated effectively and safely by marking the left posterior fascicular under the guidance of the Ensite3000 non-contact balloon mapping system. The technique allowed for accurate mapping of the PP and the DP as targets for patchy ablation between the SNR-BO and atroventricular bundle, and the identification of the ablation end point at the time when the conduction block of left posterior branch occurred on the surface electrocardiogram.

Key words: Non-contact mapping, left posterior branch ventricular tachycardia, catheter ablation.

INTRODUCTION

Catheter ablation for treating idiopathic left ventricular tachycardia is an effective treatment that can reduce the pain from ICD implantation and postoperative discharge (Kuck, 2009). Idiopathic left ventricular tachycardia originates from the left posterior branch and its Purkinje fibrous reticulum through formation of micro-reentry (Ohe, 1988). Previous studies suggested that the formation of a reentrant cycle in ILVT is due to an excitable gap and slow conduction in the Purkinje system at the back wall of left ventricle (Okumura, 1988, 1996; Wen 1997; Nogami, 2000; Tsuchiya, 1999). Because the left posterior branch becomes part of reentrant cycle during tachycardia (Ma, 2006) conduction block of this posterior branch can be used as the ablation end point for treatment of ILVT.

Previous studies have proved the methods of radio-frequency ablation guide by activation order mapping, pacing mapping or earliest Purkinje potential (PP) in eliminate ILVT (Wen, 1997, 1994; Tsuchiya, 1999; Nakagawa, 1993). The current catheter ablation strategy is to block the conduction of the left posterior branch by making linear ablation at the proximal end of the sinus rhythm breakout point (SNR-BO) perpendicular to the left.
posterior branch during sinus rhythm, and to identify the conduction block at left posterior branch on surface electrocardiograms as the ablation endpoint.

In our clinical practice, Ensite3000 is used to guide and mark the left posterior branch during sinus rhythm, rapidly mapping the Purkinje potential (PP) and diastolic potential (DP) by non-contact balloon. The PP and DP are used as targets in the top region of SNR-BO to make patchy ablation. The conduction block of the left posterior branch observed on the surface electrocardiogram is considered the ablation endpoint. This method has proved to be safe and effective, with a proven high success rate.

MATERIALS AND METHODS

Characteristics of patients

We treated 12 consecutive patients at our center from March of 2010 to March of 2011 (10 male patients, 2 female patients, with an age range of 16 to 64 years and a mean age of 33.8 ± 14.6 years. They all suffered from paroxysmal palpitations. Their electrocardiograms recorded during tachycardia indicated right bundle branch block together with left axis deviation. The hemodynamics of the remaining patients was steady during tachycardia attack, except that syncope related to ventricular tachycardia occurred in one patient. Ten cases were sensitive to verapamil, 2 cases had organic changes in the heart, namely perinatal cardiomyopathy and right ventricular cardiomyopathy. The other patients showed no signs of organic heart diseases during routine examination. All patients had not received previous treatment by radiofrequency ablation.

Electrocardiogram examination

All patients had spasmodic 12-lead electrocardiograms before or the during operation to measure the beat frequency during ventricular tachycardia, the morphology of the electrocardiogram at each lead, the R/S ratio of V5 and V6, and the frontal plane mean QRS axis.

Electrophysiological study

After withdrawing antiarrhythmic drugs for five half-lives and obtaining informed consent, electrophysiological evaluation was performed on all patients. Seldinger puncture technique was used to feed a coronary sinus venous electrode through the left subclavian vein. Then the electrode for the right ventricle was fed through the right femoral vein. The programmed electrophysiology study involved S1S2 stimulation at the right ventricular apex (RVA) and/or right ventricular outflow tract (RVOT). The S1S2 stimulation was reduced from 330 ms to 250 ms in 10 ms steps. If the ventricular tachycardia could not be induced, lower intensity burst stimulation from 330 to 250 in 10 ms increments was adopted for induction. If tachycardia still could not be induced by either stimulation method, we repeated the above process after isoprenaline infusion.

Non-contact mapping of left ventricular endocardium

The detailed operating instruction of Ensite3000 system was described previously (Schilling et al., 1998; Friedman, 2000). A 10F non-contact balloon catheter was used to insert the balloon into the left ventricle through the left femoral artery and aortic arch in the retrograde direction. The balloon which was inflated with 7.5 ml of contrast and deployed a 64 multielectrode array within the chamber. The balloon was adjusted to make it close to septal surface. The other end of the balloon catheter was fixed outside the body to avoid its displacement. A deflectable catheter with a 4 mm electrode tip ( Biosense Webster) was inserted through the right femoral artery. A 3 dimensional endocardium geometric model along the endocardium of the left ventricle was established. After establishing the ventricle geometric model, the system can analyze the intracardiac electrogram of each sinus cardiac cycle from 3000 endocardium points simultaneously. The filtering adjustment was set to 8 Hz. The pathways of the His bundle, left bundle branch, and sinus rhythm breakout point were mapped under sinus rhythm. Then, ventricular tachycardia was induced again to observe excitation traveling through the endocardium during the attack. When sinus rhythm or ventricular tachycardia was mapped using 12 to 16 Hz filtering, the location of a slow conduction zone was detected. After operation, we analyzed the characteristics of the 3 dimensional intracardiac electrogram and measured the distances from the ablation target to the SNR-BO, VT-BO, and apex.

Catheter ablation

A cold saline ablation catheter was adopted for contact mapping in the area between SNR-BO and the left posterior fascicle to identify a small Purkinje potential before the cardiac ventricle was excited. The ablation catheter was moved slowly in the left posterior spacing or center spacing areas, and PP was marked carefully. The catheter radiofrequency ablation was set to 30 W and 43°C to produce small point by point lesions to form a patch between the point of DP and PP. After patchy ablation was finished, LPFVT was induced by program pacing. For those patients in which tachycardia could still be induced, the areas marking P potential and diastolic potential around the ablation area were lesioned again to extend the ablation area until the ventricular tachycardia could not be induced by programmed stimulations. Heparin was injected into the vein during the operation after artery cannulation to maintain activated coagulation time (ACT) between 250 to 300 s.

Follow-up

Electrocardiograms were recorded immediately after the operation and three days after. After one month, dynamic electrocardiogram examinations were again made. The long term follow-up visit was made by telephone and follow-up clinic to obtain the related information.

RESULTS

Characteristics of electrocardiogram examination

Characteristics of electrocardiogram examination before radiofrequency ablation

The typical electrocardiogram during sinus rhythm was shown in Figure 1a. Regular P waves and normal QRS wave can be observed in all of the patients. The electrocardiograms of all patients during tachycardia showed monomorphic sustained ventricular tachycardia.
with regular ventricular rate. The QRS wave group at the V1 lead of all cases indicated right bundle branch block (RBBB) (Figure 1b). The V1 lead of 8 cases indicated rsR type, and 3 cases were R type. The QRS time ranged from 90 to 140 ms. The limb lead indicated left anterior fascicular block. In the surface electrocardiograms of all patients, the R/S ratios of V5 and V6 leads were less than 1. The frontal plane QRS mean electrical axis of all patients was -86.2° with narrow distribution.

**Figure 1.** Surface electrocardiograms of one LPFVT patient before and after radiofrequency ablation. A refers to the electrocardiogram during sinus rhythm with normal QRS wave width; B refers to the electrocardiogram during ventricular tachycardia and shows increased QRS wave width and right bundle branch block; C refers to the electrocardiogram after treatment by radiofrequency ablation, it shows a deeper q wave for II, III, and avF leads and a larger deep s wave for I and avL.

**Characteristics of electrocardiogram after radiofrequency ablation**

In 11 patients, electrocardiograms after ablation showed a visible emerging graph of the left posterior fascicle (Figure 1c). The q wave was deeper for II, III and AVF leads, and the deep wave was larger at I and AVL leads. The graph of left posterior fascicular block did not appeared during the operation in one patient, but the ventricular tachycardia could not be induced after ablation. One month later, the left posterior fascicular block of one patient had disappeared, as indicated by electrocardiographic examination.

**Electrophysiological study**

In all 12 patients, tachycardia was induced during the operation and showed right bundle branch block together
with left axis deviation. Three patients required intravenous injection of isoproterenol and repeated stimulation to induce tachycardia, and the repeatability was still poor. During ILVT, the duration of the QRS wave group was 125.6 ± 10.2 ms and the RR interval was 356.5 ± 38.6 ms. Ablation was successful during sinus rhythm for all 12 patients. When the ablation was over, the surface electrocardiograms of 11 patients indicated left posterior fascicular block. The ILVT could not be induced after repeated stimulation in any of the patients. The characteristics of three-dimensional electro-anatomical mapping during the operation are shown in Table 1. The follow-up time was 6 to 18 months (13.2 ± 6.05 months). During the post-operative period, 11 patients did not experience an attack of tachycardia and were not taking antiarrhythmic drugs. Only one patient relapsed, at two months after operation. After ablation of the left posterior fascicle, the deeper q wave appeared for II, III and AVF leads, and ventricular tachycardia could not be induced. At follow-up 6 months later, there was no ventricular tachycardia.

Non-contact mapping of the left ventricular conduction system and positioning of ablation target

The sinus rhythm of all patients originated from the His bundle region and transmitted downward along the ventricular septum where it divided into two wavefronts, one going anteriorly to the left free wall and the other going down to the inferobasal part of the ventricle before the entire ventricle was finally activated. The SNR-BO was located in the middle-posterior septal area. The electrocardiogram of this position contained the QS waveform (Figure 2). The virtual monopolar electrograph from the His bundle to the SNR-BO area showed a low-amplitude sharp wave preceding the ventricular potential. This small sharp wave was called the Purkinje potential (PP) and the delay between it and the ventricular potential decreased and eventually merged at the SNR-BO point (Figure 3). During the process of ablation, we mapped the PP in all patients. The ablation regions under the guidance of PP were localized to a patchy area between the SNR-BO and the atrioventricular bundle (Figure 4). The postoperative analyses of the ablation target by three dimensional electro-anatomical mapping are shown in Table 2.

DISCUSSION

Verapamil-sensitive ventricular tachycardia is a common type of idiopathic left ventricular tachycardia. Recent studies have indicated that such ventricular arrhythmias are more common than previously supposed. Radiofrequency ablation can effectively eliminate ventricular tachycardia in patients. Over the past two years, we have used the Ensite3000 system to guide the ablation catheter during the sinus rhythm to detect and localize the Purkinje potential and diastolic potential for local sheet ablation. Here, we describe successful ablation in 12 cases of ILVT generated by a reentrant cycle from left posterior branch. The success of this procedure demonstrates that this ablation method can effectively treat LPFVT.

Verapamil-sensitive ventricular tachycardia is thought to stem from micro-reentry mediated by the left posterior branch (Ramparkash et al., 2008). Wen et al. (1997) found that the reentrant cycle of verapamil-sensitive ventricular tachycardia originated at the middle septal region of the left ventricle, and continued down to the region between lower-order septa. The distance between entry and exit was over 2 cm. Multi-polar electrodes placed on the septal region of the left ventricle were used to further confirm that the reentrant cycle of this ventricular tachycardia occurred near the end of left

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Length of bundle (mm)</th>
<th>Local reentrant location of balloon</th>
<th>PP</th>
<th>DP</th>
<th>Reverse transmission of bundle or not</th>
<th>Bundle block after ablation</th>
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<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>Lower posterior septal</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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</tr>
<tr>
<td>2</td>
<td>43</td>
<td>left posterior fascicle</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
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<td>Y</td>
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<td>Y</td>
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<tr>
<td>5</td>
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<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
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<td>Y</td>
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</tr>
<tr>
<td>12</td>
<td>49</td>
<td>Base of anterior septal</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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</tbody>
</table>
Figure 2. Mapping of the atrioventricular bundle and sinus rhythm break points during sinus rhythm. The sinus rhythm transmits along the atrioventricular bundle down to the bundle branch, and to left posterior fascicle and SNR-BO, where it then spreads to the whole ventricle. The SNR-BO marked in figure is in the middle-posterior septal region. The green line marks the whole conduction wave surface of the sinus rhythm from atrioventricular junction to the SNR-BO.

Figure 3. Mapping of P potential and diastolic potential. A 4-polar ablation catheter is placed along the bundle branch and reveals the DP and PP as marked by the red arrow in the right figure.

posterior branch and its peripheral Purkinje fibrous reticulum (Alba, 2001). By means of non-contact balloon mapping, we observed voltage traveling in a slow conduction area during sinus rhythm. The impulse was conducted to the apex along the left posterior branch following the normal conduction pathway. The slow conduction of the Purkinje fibrous reticulum near the left posterior branch could not trigger ventricular activation. At this time, the virtual electrode placed in the slow conduction area recorded obvious DP (Figure 5). Before ventricular activation is spread, the array indicated an obvious PP preceding the ventricular potential. During the PP, virtual potentials usually spin around LPB. There was an obvious PP on the virtual electrode in this area and it was easy to find the PP and DP if deflectable catheter detection was adopted (Figure 6).
Figure 4. Process of catheter ablation. The temperature-controlled catheter ablates conduction in the area where the diastolic potential and P potential are marked. A marked change in the surface electrocardiogram is observed during the process of ablation. The diastolic potential is reduced, but does not disappear.

Table 2. Analysis of ablation target by non-contact balloon mapping.

<table>
<thead>
<tr>
<th>Ablation area (mm²)</th>
<th>Distance to SNR-BO (mm)</th>
<th>Distance to VT-BO (mm)</th>
<th>Distance to apex (mm)</th>
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<tr>
<td>200</td>
<td>6</td>
<td>35</td>
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<td>33</td>
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<tr>
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<td>9</td>
<td>12</td>
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<td>8</td>
<td>19</td>
<td>32</td>
</tr>
<tr>
<td>228</td>
<td>18</td>
<td>28</td>
<td>26</td>
</tr>
</tbody>
</table>

Due to anterior conduction block in the left posterior branch, the impulse changed its way forward to the Purkinje fibrous reticulum at the base of heart. The earliest DP was recorded in this location, which was the entry point of slow conduction region. After passing through this slow conduction region, the left posterior branch of the back wall septum under the left ventricle generated the earliest PP at the exit of the slow conduction region. The impulse was then conducted to the near and far end along the left posterior branch. That wave conducted in the reverse direction to the near end of the left posterior branch and spread to the Purkinje fibrous reticulum, with ensuing reentry. The resulting impulse conducting through the left anterior branch and His bundle spread to the whole ventricle, forming a ventricular fusion beat with ventricular activation of the apex spreading to the far end of left posterior branch by direct motion.

The routine catheter ablation can stop ILVT effectively, but use of the PP to guide ablation may be less than optimal. The range for the P potential to wide and it is difficult to map the earliest P potential due to many
The virtual electrode is placed in the diastolic slow conduction area to reveal an obvious DP. Based on single pole electrogastrogram, the direction of slow conduction is shown by the red arrow.

The diastolic potential is recorded mostly on the base of the left ventricle or a smaller area of middle septal. Ablation in this area has a very high success rate and shorter ablation times (Tsuchiya, 1999). However, it is...
Conclusions

This study shows that it is feasible to localize the PP and DP by using the local virtual potential at the SNR-BO and accurately guide the ablation catheter to the most suitable area under guidance of non-contact balloon mapping. This operation method, considering the PP and DP as target points for patchy ablation, makes it easy to reach the ablation end point in order to avoid detection everywhere. This ablation method can be performed during sinus rhythm to avoid termination of tachycardia caused by mechanical stimulation of the catheter. In particular, it can be applied to treat patients when ventricular tachycardia cannot easily be induced or the induction is unstable.

Acknowledgement

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References


