Catheter Ablation of Fascicular Ventricular Tachycardia
Long-Term Clinical Outcomes and Mechanisms of Recurrence

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Background—Fascicular ventricular tachycardia (FVT) is a common form of sustained idiopathic left ventricular tachycardia with an Asian preponderance. This study aimed to prospectively investigate long-term clinical outcomes of patients undergoing ablation of FVT and identify predictors of arrhythmia recurrence.

Methods and Results—Consecutive patients undergoing FVT ablation at a single tertiary center were enrolled. Activation mapping was performed to identify the earliest presystolic Purkinje potential during FVT that was targeted by radiofrequency ablation. Follow-up with clinic visits, ECG, and Holter monitoring was performed at least every 6 months. A total of 120 consecutive patients (mean age, 29.3±12.7 years; 82% men; all patients with normal ejection fraction) were enrolled. FVT involved left posterior fascicle and left anterior fascicle in 118 and 2 subjects, respectively. VT was noninducible in 3 patients, and ablation was acutely successful in 117 patients. With a median follow-up of 55.7 months, VT of a similar ECG morphology recurred in 17 patients, and repeat procedure confirmed FVT recurrence involving the same fascicle. Shorter VT cycle length was the only significant predictor of FVT recurrence (P=0.03). Six other patients developed new-onset upper septal FVT that was successfully ablated.

Conclusions—Ablation of FVT guided by activation mapping is associated with a single procedural success rate without the use of antiarrhythmic drugs of 80.3%. Arrhythmia recurrences after an initially successful ablation were caused by recurrent FVT involving the same fascicle in two thirds of patients or new onset of upper septal FVT in the remainder.

Key Words: bundle of His • catheter ablation • follow-up studies • recurrence • tachycardia, ventricular

Since the first description of fascicular ventricular tachycardia (FVT) involving the left posterior fascicle (LPF) in 3 patients by Zipes et al1 in 1979, our understanding of this common form of idiopathic left ventricular (LV) tachycardia has expanded particularly during the past 2 decades. Through detailed electrophysiological studies (EPS), FVT has been determined to be reentrant in mechanism, can be responsive to verapamil, involves various branches of Purkinje network emanating from left fascicles with differential conduction properties participating in the tachycardia, and can be successfully treated by localized ablation in the LV septum.2–14 On the basis of reports of small single-center cohorts undergoing ablation, acute success rates are generally high although limited data exist about electrophysiological findings and clinical outcomes in the few patients who do develop arrhythmia recurrence. More recently, case reports have described patients with FVT representing years after ablation with different variants of FVT.15,16 This study aimed to prospectively investigate long-term clinical outcomes of a large cohort of patients undergoing catheter ablation of FVT in a regional referral center in China, analyze mechanisms of arrhythmia recurrence, and identify electrophysiological or clinical predictors of FVT recurrence.

Methods

Population
This study was approved by an institutional ethics committee, and all subjects gave informed consent. From January 2008 to December 2012, consecutive patients undergoing clinically indicated EPS and ablation for FVT at the Affiliated Hospital of Nanjing Medical University, China, were enrolled into a prospective clinical database. All patients fulfilled all of the following criteria:

1. Symptomatic sustained VT
2. Documented clinical VT with right bundle branch block–like morphology

The Data Supplement is available at http://circep.ahajournals.org/lookup/suppl/doi:10.1161/CIRCEP.115.003080/-/DC1. The Authors. Circulation: Arrhythmia and Electrophysiology is published on behalf of the American Heart Association, Inc., by Wolters Kluwer. This is an open access article under the terms of the Creative Commons Attribution Non-Commercial-NoDerivs License, which permits use, distribution, and reproduction in any medium, provided that the original work is properly cited, the use is noncommercial, and no modifications or adaptations are made.
WHAT IS KNOWN
- Fascicular ventricular tachycardia (FVT) is an idio- 
apathic left ventricular tachycardia with an Asian 
preponderance.
- On the basis of small single-center series of patients 
undergoing catheter ablation of FVT, acute success 
rates are generally high although limited data exist 
on long-term outcomes.

WHAT THE STUDY ADDS
- This study reports long-term clinical outcomes of 
a large cohort of 120 patients with FVT with a me-
dian follow-up in excess of 4.5 years. Activation 
mapping–guided FVT ablation is associated with 
high acute procedural success (100%) when 
FVT is inducible. Approximately 15% (17/117) 
of patients subsequently developed arrhythmia 
recurrence.
- Two thirds of FVT recurrence were caused by FVT 
involving the same fascicle that was targeted dur-
ing the index ablation, whereas the rest was caused 
by new-onset upper septal VT. Shorter tachycardia 
cycle length was the sole independent predictor of 
left posterior FVT recurrence.
- The development of new left posterior fascicular 
block after FVT ablation was associated with more 
basal ablations and did not protect against left poste-
rior FVT recurrence.

Electrophysiological Study
Antiarrhythmic medications were withdrawn for at least a period of 5 
half-lives. After written informed consent was obtained, the EPS was 
performed in the lasting state under conscious sedation. Six French 
quadri-polar catheters were positioned at the bundle of His and right 
ventricular (RV) apex. AH and HV intervals and ECG frontal axis 
during sinus rhythm were recorded at baseline and at the end of the 
procedure. Particular attention was paid to the development of fas-
cicular block after ablation. Specifically, LPF block was defined as 
frontal axis between 90° and 180°, rS pattern in leads I and aVL, qR 
pattern in leads III and aVF, and QRS duration of <120 ms as per the 
most recent international guidelines.17

In patients without spontaneous VT, programmed stimulation was 
performed from the RV apex, RV outflow tract, and right atrium at drive 
trains of 2 different cycle lengths (500 or 400 ms and 330 ms), with ≤3 
extra stimuli, with and without the use of isoproterenol (1–3 μg/min).
If necessary, incremental burst pacing up to cycle lengths of 280 and 
200 ms in the RV and atrium, respectively, was performed for VT in-
duction. The filter setting for the bipolar intracardiac electrogroams was 
30 to 500 Hz. Differential diagnoses, such as a typical atrioventricular 
reentrant tachycardia and bundle branch reentry, were excluded by es-
tablished deductive criteria during EPS in combination with diagnostic 
maneuvers, activation mapping, and entrainment.

Activation Mapping
A 7-French deflectable, nonirrigated, quadri-polar catheter with 
a 4-mm distal electrode, an embedded thermistor, and 2-5-2 mm 
temperature-controlled radiofrequency energy was delivered at the 
site with the earliest PP during VT. The power output was titrated to 
as high as 35 W to achieve a target temperature of 40°C to 60°C for 
≤120 s. The ablation procedure was considered successful if FVT 
terminated during ablation or if any VT was not inducible 30 minutes 
after ablation despite repeat programmed stimulation and isoproter-
enol infusion.

Follow-Up
After the procedure, continuous ECG monitoring was performed for 
24 hours. All antiarrhythmic agents were not restarted in the absence 
of postoperative arrhythmia recurrence. All patients were reviewed in 
clinic monthly after the procedure for the first 3 months and then fol-
lowed up every 6 months. A 12-lead ECG and 24-hour Holter moni-
toring were performed at every clinic visit. Arrhythmia recurrence 
was defined as symptomatic recurrence with ECG documentation of 
recurrent VT either on the 12-lead ECG or Holter monitoring.

Statistical Analysis
Continuous variables and categorical variables were described by 
means±SD and percentages, respectively. An independent samples 
t test and paired samples t test were performed for comparisons 
of the corresponding parameters and paired data. χ2 test was used 
for comparison of categorical data. To determine the association 
between procedural parameters and VT recurrence, univariable 
and multivariable Cox proportional regression analyses were per-
formed, and results were expressed as hazard ratios with 95% con-
fidence intervals. P value of <0.05 was considered as statistically 
significant.

Results
Patient Characteristics
From January 2008 to December 2012, 120 consecutive 
patients underwent EPS and ablation for FVT, refractory to 
a mean of 1.3±0.9 antiarrhythmic medications (Figure 3). 
Fifty-six patients received intravenous verapamil during epi-
isodes of VT, before EPS that terminated VT in all patients. 
Two patients had previously undergone unsuccessful abla-
tion attempts at their referring hospitals. The mean age was 
29.3±12.7 (range, 7–69) years, and they were predominantly 
men (81.7%). The median duration of symptoms before EPS 
was 14 (25th to 75th percentile, 3–63 months) months. All 
but 3 patients reported palpitations, whereas the remaining 3 
experienced presyncope or syncope. Echocardiography con-
firmed structurally normal hearts in all cases with a mean LV 
ejection fraction of 65.3±4.5%.
Electrophysiological Studies

In all patients, preprocedural ECGs demonstrated sinus rhythm with normal axes and QRS durations. AH (80.4±15.6 ms) and HV (44.4±8.2 ms) intervals were within normal limits before ablation. VT was not inducible in 3 patients whom therefore did not proceed to catheter ablation. In the remaining 117 patients, monomorphic VT involved the LPF (LPFVT; right bundle branch block–like morphology with superior axis; mean VT cycle length, 362.1±79.4 ms; mean QRS duration, 123.9±14.0 ms; HV intervals during VT, −11.9±13.0 ms), and the left anterior fascicle (LAFVT; right bundle branch block–like morphology with right inferior axis; mean VT cycle length, 364.0±26.9 ms; mean QRS duration, 124.6±12.0 ms; HV intervals during VT, −7.5±2.1 ms) in 115

Figure 1. Activation map using the NavX system was created during fascicular ventricular tachycardia (FVT). Septal sites with His or Purkinje potentials, extending from most basal septal sites with bundle of His recordings to most apical sites with presystolic Purkinje potentials (apical PP), were marked on the left ventricular geometry. The site with the earliest presystolic Purkinje potential (earliest PP) during FVT was targeted by catheter ablation. The distance between the most basal His recording to the earliest PP was expressed as a ratio of the distance between the His bundle and apical PP, as an objective measure to indicate the position of ablation sites along the course of the left fascicles.

Figure 2. Intracardiac electrograms during electrophysiological studies of left posterior fascicular ventricular tachycardia (LPFVT). Note the more rounded diastolic potential (DP) of the anterograde limb and sharper presystolic Purkinje potential (PP) of the retrograde limb of LPFVT recorded on the ablation catheter (ABL). Radiofrequency ablation delivered at this site with the earliest PP-terminated LPFVT. CS indicates coronary sinus; and His, His bundle.
and 2 patients, respectively. In all patients, bundle of His was activated retrogradely during VT (often with VA dissociation), ruling out alternative diagnosis, such as bundle branch re-entry and supra–VT with aberrancy.

**Mapping and Ablation**

The mean earliest PP preceded the onset of QRS during VT by 30.1±9.3 ms (Figure 2). A 3D mapping system was used in 71.6% of cases. In LPFVT subjects, the earliest PP was located 61.3±23.7 (range, 40–116) mm from the most basal septal LV site where a His potential could be measured or 69.0±10.8% of the course that extended along the septum from the bundle of His to the end of the LPF (His-RF/His-apical PP; Figure 1).

Similarly for patients with LAFVT, the earliest PP was located 61.0±8.5 (55–67) mm from the most basal LV site where a His potential could be measured and 68.5±5.4% of the course that extended along the septum from the bundle of His to the end of the LPF (His-RF/His-apical PP; Figure 1).

**Figure 3.** Flowchart of consecutive patients with fascicular ventricular tachycardia enrolled in this study. LAF indicates left anterior fascicle; LPF, left posterior fascicle; ILVT, idiopathic left ventricular tachycardia; and VT, ventricular tachycardia.

### Table 1. Procedural Details According to Changes in ECG Frontal Axis After Successful Left Posterior Fascicular Ventricular Tachycardia Ablation

<table>
<thead>
<tr>
<th>Condition</th>
<th>New Onset LPFB (n=23)</th>
<th>Rightward Shift in Frontal Axis (n=67)</th>
<th>Axis Unchanged (n=25)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedural time, min</td>
<td>138.4±54.8</td>
<td>138.4±54.8</td>
<td>122.4±57.3</td>
<td>0.66</td>
</tr>
<tr>
<td>Fluoroscopy time, min</td>
<td>12.9±5.5</td>
<td>15.9±8.3</td>
<td>11.0±4.5</td>
<td>0.83</td>
</tr>
<tr>
<td>Fluoroscopy dose, cym²</td>
<td>63.5±62.9</td>
<td>90.0±24.5</td>
<td>53.4±21.8</td>
<td>0.37</td>
</tr>
<tr>
<td>Axis before ablation, °</td>
<td>59.4±21.8</td>
<td>53.8±20.7</td>
<td>47.3±24.5</td>
<td>0.33</td>
</tr>
<tr>
<td>Axis after ablation, °</td>
<td>101.8±13.5</td>
<td>64.1±16.1</td>
<td>44.9±26.8</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>AH during SR, ms</td>
<td>75.0±32.5</td>
<td>77.0±15.0</td>
<td>83.6±12.2</td>
<td>0.75</td>
</tr>
<tr>
<td>HV during SR, ms</td>
<td>46.0±14.1</td>
<td>44.8±7.9</td>
<td>45±9.8</td>
<td>0.98</td>
</tr>
<tr>
<td>VT cycle length, ms</td>
<td>382.0±70.7</td>
<td>347.3±84.3</td>
<td>379.2±77.1</td>
<td>0.72</td>
</tr>
<tr>
<td>HV interval during VT, ms</td>
<td>−10.7±9.3</td>
<td>−13.5±9.4</td>
<td>−14.6±3.9</td>
<td>0.31</td>
</tr>
<tr>
<td>His-RF site/His-apical PP, %</td>
<td>0.57±0.13</td>
<td>0.61±0.16</td>
<td>0.77±0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>Earliest PP-QRS interval during VT, ms</td>
<td>31.4±5.4</td>
<td>30.5±8.3</td>
<td>30.7±9.2</td>
<td>0.87</td>
</tr>
<tr>
<td>RF energy, W</td>
<td>30.0±4.4</td>
<td>31.1±5.3</td>
<td>29.7±6.0</td>
<td>0.65</td>
</tr>
<tr>
<td>Temperature achieved, °C</td>
<td>52.2±3.5</td>
<td>51.5±6.1</td>
<td>49.0±4.5</td>
<td>0.26</td>
</tr>
<tr>
<td>VT recurrence during follow-up, %</td>
<td>9 (39.1)</td>
<td>10 (14.9)</td>
<td>4 (16.0)</td>
<td>0.04</td>
</tr>
<tr>
<td>VT recurrence during follow-up (per 100 person-years)</td>
<td>0.62</td>
<td>0.06</td>
<td>0.19</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

His-RF/His-apical PP is the linear distance between the most basal left-sided His potential to the site of successful RF ablation expressed as a percentage of the distance between the most basal left-sided His potential and the most apically recorded PP during left posterior fascicular VT. LPFB indicates left posterior fascicular block; PP, presystolic Purkinje potential; RF, radiofrequency; SR, sinus rhythm; and VT, ventricular tachycardia.
extended along the septum from the bundle of His to the end of the LAF. Entrainment was performed successfully in 20% of cases, demonstrating concealed fusion and participation of the ablation site in FVT.

Ablation was acutely successful by targeting the earliest PP in all 117 patients with inducible FVT, with noninducibility of any VT despite programmed stimulation and isoproterenol infusion achieved as the electrophysiological end point. At the end of the procedure, HV intervals during sinus rhythm remained unchanged in all patients.

ECG changes during sinus rhythm were seen in the majority of patients who underwent ablation of LPFVT. Twenty-three (20%) subjects developed new onset LPF block, whereas 67 patients (58.3%) exhibited rightward shift in their frontal axis compared with baseline (frontal axis, 31º–84º). The axis remained unchanged in the remaining 25 patients (21.7%).

**Table 2. Characteristics of Recurrent VT**

<table>
<thead>
<tr>
<th></th>
<th>Recurrence With LPFVT (n=17)</th>
<th>Recurrence With Upper Septal VT (n=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Index Ablation</td>
<td>Repeat Ablation</td>
</tr>
<tr>
<td>Left posterior fascicular block during sinus rhythm preablation</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>VT cycle length, ms</td>
<td>337.7±98.9</td>
<td>369.8±104.4</td>
</tr>
<tr>
<td>VT Frontal axis, a</td>
<td>−98.3±17.2</td>
<td>−76.2±73.3</td>
</tr>
<tr>
<td>VT QRS duration, ms</td>
<td>121.8±7.6</td>
<td>121.8±13.2</td>
</tr>
<tr>
<td>HV interval, ms</td>
<td>−10.5±10.7</td>
<td>−6.2±10.2</td>
</tr>
<tr>
<td>Earliest PP-QRS/DP-QRS interval, ms*</td>
<td>34.0±8.4</td>
<td>34.7±10.2</td>
</tr>
<tr>
<td>His-RF site/His-apical PP, %</td>
<td>62.3±6.4</td>
<td>61.1±1.7</td>
</tr>
</tbody>
</table>

His-RF/His-apical PP is the linear distance between the most basal left-sided His potential to the site of successful RF ablation expressed as a percentage of the distance between the most basal left-sided His potential and the most apically recorded PP during LPFVT. DP indicates diastolic potential; LPFVT, left posterior fascicular VT; PP, presystolic Purkinje potential; RF, radiofrequency; and VT, ventricular tachycardia.

* indicates the number is DP-QRS interval.

**Figure 4.** A, Activation map in patient 1 recorded during the first ablation procedure for left posterior fascicular ventricular tachycardia (LPFVT). B, Activation map in patient 1 recorded during the second ablation procedure after presenting with recurrent LPFVT. C, Activation map in patient 2 recorded during the first ablation procedure with LPFVT. D, Activation map in patient 2 recorded during the second ablation procedure after presenting with upper septal VT. Note in patient 1 the earliest presystolic Purkinje potential (PP) during the first and second procedure was similar in location, strongly suggestive that the index LPFVT had recurred. In comparison, the site of successful ablation during upper septal VT in patient 2 is much more basal compared with the original site of ablation during LPFVT. A-C, Ablation catheter was recording the site with the earliest PP (white arrow), whereas during mapping of upper septal VT (D), the earliest diastolic potential (DP) is targeted (white arrow). The local activation at each site was measured by annotating the local His/PP, rather than the ventricular electrogram.
Development of LPF block was associated with more proximal ablations (His-RF/His-apical PP ratio of 0.57±0.13 versus 0.77±0.10 in patients whose frontal axis remained unchanged; P=0.03; Table 1). ECG remained unchanged in the 2 patients with LAFVT after ablation. No complications occurred during the index procedure.

Arrhythmia Recurrences During Follow-Up and Repeat Ablation

With a median follow-up of 55.7 months (25th to 75th percentile, 38.9 to 71.7 months), VT recurred in 23 patients with LPFVT. There was no recurrence of LAFVT. The median time to recurrence was 2.5 months (25th to 75th percentile, 1.5 to 17 months) after the index ablation. In 17 patients, the recurrent VT had ECG morphology similar to the clinical

### Table 3. Predictors for Successful Left Posterior Fascicular Ventricular Tachycardia Recurrence

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Univariable HR (95% CI)</th>
<th>P Value</th>
<th>Multivariable HR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.99 (0.92–1.01)</td>
<td>0.72</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Sex</td>
<td>0.99 (0.99–1.01)</td>
<td>0.99</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Earliest PP-QRS interval</td>
<td>0.99 (0.94–1.05)</td>
<td>0.82</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>New onset LPFB after first ablation</td>
<td>2.57 (0.58–11.38)</td>
<td>0.21</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>His-RF site/His-apical PP</td>
<td>0.10 (0.01–17.98)</td>
<td>0.39</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>VH interval during VT</td>
<td>1.04 (0.98–1.12)</td>
<td>0.21</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>VT cycle length</td>
<td>0.98 (0.97–0.99)</td>
<td>0.02</td>
<td>0.98 (0.97–0.99)</td>
<td>0.03</td>
</tr>
<tr>
<td>VT QRS duration</td>
<td>0.91 (0.84–0.99)</td>
<td>0.04</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

His-RF/His-apical PP is the linear distance between the most basal left-sided His potential to the site of successful RF ablation expressed as a percentage of the distance between the most basal left-sided His potential and the most apically recorded PP during left posterior fascicular VT. HR indicates hazard ratio; LPFB, left posterior fascicular block; PP, presystolic Purkinje potential; SR, sinus rhythm; and VT, ventricular tachycardia.

All consented to repeat ablation. The VT induced during the repeat procedure had similar electrophysiological parameters, including cycle length, HV intervals, and prematurity of the earliest PP in relation to QRS onset. The earliest PP during FVT was again mapped to the vicinity of the LPF, to a location in close proximity, and to the ablation site of the index procedure (Figure 4A and 4B). Ablation was acutely successful again in all 17 patients, and FVT has not recurred during a median follow-up of 40.3 months (25th to 75th percentile, 25.9 to 55.4 months). The development of LPF block did not confer any protection from recurrent FVT (Tables 1 and 3).

Interestingly, in the remaining 6 patients, recurrent VT exhibited a different ECG morphology, with narrower QRS...
ablation during ongoing FVT is associated with high acute

Major Findings

Electrophysiological End Points of FVT Ablation

Predictors of Idiopathic LV Tachycardia Recurrence

Discussion

and variable inferior axis (Figure 5; Figure II in the Data Supplement; Table 2). Five of these 6 patients had developed new-onset LPF block after the first ablation. Only 3 patients agreed to undergo a repeat EPS. During the second ablation procedure, the LPF was activated in an anterograde direction with a resultant positive HV interval that was shorter during VT compared with sinus rhythm. EPS and activation mapping confirmed the diagnosis of upper septal VT. Concealed entrainment was only successful in 1 patient with a post-pacing interval (320 ms) minus tachycardia cycle length (315 ms) of 5 ms (Figure III in the Data Supplement). The lower turnaround of the upper septal VT circuit, as marked by the site with the most premature diastolic potential, was targeted. The ablation site was significantly more basal compared with the index ablation (Table 2; Figures 4C, 4D, and 6). Radiofrequency ablation was initiated cautiously at 10 W, gradually increased to a maximum of 20 W, and was acutely successful in all 3 patients without any atrioventricular nodal injury or ECG changes. All 3 patients remain free from recurrent arrhythmias after a median follow-up of 46.1 months.

Three patients in whom VT was not inducible at the first procedure did not return for repeat EPS. Therefore, the single procedural success rate of FVT ablation without the need for antiarrhythmic agents in an unselected cohort of patients is 80.3% (94/117). Allowing for repeat procedures, 97.4% (114/117) of patients were free from recurrent VT during a median follow-up of 55.7 months.

Electrophysiological End Points of FVT Ablation

Locating the optimal site for ablation becomes more difficult when FVT is difficult to induce or is nonsustained. Numerous ablation strategies performed during sinus rhythm to overcome this hurdle have been reported. Purkinje potentials visible after the QRS complex, which may be characteristic of delayed retrograde activation of abnormal Purkinje fibers
that act as the anterograde limb of LPFVT, have been targeted during sinus rhythm. Although these potentials seem unique to patients with FVT compared with a small group of control patients without FVT, such electrograms are recordable over a sizeable area of the septum and can be detected remotely in the LAF Purkinje network in patients presenting with LPFVT. Thus, undertaking such a strategy would result in a substantial septal area being ablated with the risk of injury to the conducting system. A more anatomically guided approach of placing 7 to 15 ablation lesions in a linear pattern, perpendicular to the long axis of the ventricle approximately midway from the base to the apex in the region of the mid to midinferior septum, guided by the presence of Purkinje potentials and pace mapping was reported to be effective in 6 patients with nonsustained LPFVT. Consistent with our results that the successful ablation site is located on average 69% of the septal course extending from the bundle of His to the end of the left fascicle, it is highly plausible that such lesion sets could transact the lower turnaround of the LPFVT circuit, preventing arrhythmia recurrence. Finally, a few groups have suggested the creation of partial or complete LPF block as a reproducible, easily demonstrable electrophysiological end point for LPFVT ablation. In our study, the development of complete LPF block was associated with more basally located ablations. Furthermore, the formation of LPF block did not reduce the risk of LPFVT recurrence. These findings, in conjunction with other observations that selective capture of the LPF during LPFVT did not affect tachycardia cycle length, LPFVT can still develop in patients with preexisting LPF block, and the vast majority of patients remained arrhythmia free after LPFVT ablation without developing new-onset LPF block, would suggest that the LPF does not participate in LPFVT circuit. Hence, rightward shift in the ECG axis is most likely because of inadvertent collateral damage to the LPF, particularly when ablation is delivered more basally. Therefore, our results would imply that creation of LPF block is unlikely to be an effective electrophysiological end point for FVT ablation, although this hypothesis was not tested directly in the experimental design. It is also noteworthy that 5 of 6 patients who developed arrhythmia recurrence with upper septal VT developed LPF block after their first index. It is speculative but plausible that the inadvertent creation of sites of slow conduction within the Purkinje network could be proarrhythmic, promoting reentry amongst different septal circuits.

**Predictors of FVT Recurrence**

In a previous study of 79 patients whom underwent ablation of idiopathic VT, which included 40 FVT patients, 9 patients (5 FVT subjects) developed VT recurrence. The only significant predictor of arrhythmia recurrence was the endocardial activation time at the successful ablation. In our study with a larger sample size, only faster tachycardia cycle length but not prematurity of the local PP potential predicted FVT recurrence. More rapid ventricular contractions may lead to reduced catheter stability and tissue contact, impairing ablation lesion size and quality. Subsequent recovery of conduction between the anterograde and retrograde limbs of the LPFVT circuit allowed for VT recurrence. Hence, during the repeat procedure, the successful ablation site was once again mapped to a similar location and additional ablation rendered once again FVT noninducible.

**Potential for Multifascicular VT**

Upper septal VT is the most uncommon variant of fascicular VT, characterized by a tachycardia circuit that uses parts of the LPF as the anterograde limb (with simultaneous bystander activation of the right bundle and LAF to produce a narrow QRS) and septal Purkinje fiber or auxiliary fascicle as the retrograde limb. Such VT has also been described as fast–slow fascicular VT, whereby the slower conducting septal fascicle serves as the retrograde limb as opposed to the fast–slow fascicular VT seen in LAFVT and LPFVT, whereby anterograde limb is the slower conducting abnormal Purkinje fiber. It has been reported by Nishiuchi et al recently that upper septal VT was responsible for arrhythmia recurrence in a patient who had previously undergone successful ablation of LPFVT, similar to 6 patients in our cohort. However, upper septal VT can also present as the de novo arrhythmia. Unlike LPFVT, it is important to target the earliest diastolic potential originating from the septal fascicle, which marks the lower turnaround of the upper septal VT circuit. Ablating the earliest PPs around the anterograde limb, where concealed entrainment can be achieved, could result in fascicular or bundle branch block. Moreover, VT can remain ininducible with the tachycardia switching to revolve around the LAF as upper septal VT with a different ECG morphology or around the right bundle branch to form bundle branch reentrant VT.

**Limitations**

Only patients with inducible FVT underwent ablation, and therefore, our findings during activation mapping would not be applicable for patients with noninducible VT. Intravenous verapamil was not administered during EPS to avoid rendering FVT noninducible. Therefore, the possibility of focal Purkinje VT being the diagnosis in a few cases cannot be excluded.

**Conclusions**

Ablation of FVT guided by activation mapping is associated with a single procedural success rate without the use of antiarrhythmic drugs of 80.3% that increases to 97.4% with repeated ablations. Only faster tachycardia cycle length but not the development of new LPF block predicted LPFVT recurrence. Arrhythmia recurrences after an initially successful ablation were caused by recurrent FVT involving the same fascicle in two thirds of patients and new onset of upper septal VT in the remainder.

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Disclosures

None.

References


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SUPPLEMENTAL MATERIAL

Supplemental Figure Legends

Supplemental Figure 1. The pre-systolic potential (PP) occurs typically pre-QRS and the diastolic potential (DP) were recorded by twenty-polar catheter extends from left basal septal sites to most apical sites during fascicular ventricular tachycardia.

Supplemental Figure 2. The ECGs of upper septal VT were printed on paper from 3 patients. The ECGs from the remaining 3 patients were too faint to be seen clearly. Left panel shows 12 lead ECG during sinus rhythm after the first radiofrequency ablation and right panel shows upper septal VT which was inducible during the second ablation procedure.

Supplemental Figure 3. Entrainment mapping was performed in a patient with upper septal VT with a tachycardia cycle length of 315 ms. Concealed entrainment was achieved at the left basal septal site (A) with a post-pacing interval (PPI) of 320 ms. In comparison, manifest fusion was achieved at the middle anterior septum (B) and the LV apex (C) with PPIs of 378 ms and 392 ms, respectively.
Supplemental Figure 1
Supplemental Figure 3