The characteristics of verapamil-sensitive idiopathic left ventricular tachycardia combined with a left accessory pathway and the effect of radiofrequency catheter ablation

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Aims
Verapamil-sensitive idiopathic left ventricular tachycardia (ILVT) combined with a left accessory pathway (AP) is a relatively rare condition. This study examines the characteristics of patients with this condition and the effect of radiofrequency catheter ablation (RFCA).

Methods and results
Catheter ablation was performed on 140 ILVT patients at a single centre from January 2004 to December 2009. A concealed left AP was found in seven patients (5%), all of whom were male, with an average age of 21±9 years. Sustained ILVT and orthodromic atrioventricular reentrant tachycardia (AVRT) were induced in all seven patients. Retrograde activation through a bystander AP occurred concomitantly with ILVT, with an average tachycardia length of 346±29 ms (range 310–400 ms). The location of the APs in four patients was left posterior, two of which showed a slow and decremental property, while in three it was left lateral. Ablation via a retrograde transaortic approach was performed in the seven patients. The left AP was ablated first in six patients, but ILVT was no longer induced in one and became non-sustained in another. In the seventh patient, ILVT was ablated first and this proved successful.

Conclusions
Among patients with ILVT, 5% had a concomitant left AP, most of who were young men. The location of the left AP was mainly posterior and lateral, with 30% showing a slow and decremental property. Idiopathic left ventricular tachycardia and AP should be ablated simultaneously.

Keywords
Idiopathic left ventricular tachycardia • Left accessory pathway • Radiofrequency catheter ablation

Introduction
Verapamil-sensitive idiopathic left ventricular tachycardia (ILVT) is a distinct clinical entity characterized by a right bundle branch block (RBBB) morphology and left-axis deviation. It occurs in young normal hearts, and can be terminated by intravenous administration of verapamil.1–9 Case reports have described the coexistence of ILVT and supraventricular tachycardia (SVT) in the same patient.10–12 However, there has only been one isolated report of ILVT combined with a left accessory pathway (AP),10 and the characteristics of these patients have not been described in detail. This study examines the characteristics of patients with ILVT combined with a left AP and the effect of radiofrequency catheter ablation (RFCA).

Methods
Study population
We analysed 140 patients undergoing RFCA for ILVT at a single centre from January 2004 to December 2009. No structural heart disease was found in any patient. On a surface electrocardiogram (ECG), clinical tachycardia presented as RBBB and left-axis deviation in all cases, and was able to be terminated by intravenous administration of

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After ablation of the AP in these patients by the lack of retrograde atrial activation through the AP.13 Exclusive retrograde AP conduction was identified on the 12-lead ECG.

Recurrence was defined as symptomatic episodes of tachycardia sustained for at least five half-lives. All patients underwent an electrophysiological study and catheter ablation. Under local anaesthesia, two 6-F quadripolar catheters (Biosense-Webster, Diamond Bar, USA) were positioned at the right ventricular apex (RVA) or the right ventricular outflow tract (RVOT), and at the His bundle region via the femoral veins. A 6-F decapolar catheter with 2.5-2.2 mm interelectrode spacing (Biosense-Webster) was inserted into the coronary sinus (CS) via the right internal jugular vein. Twelve-lead surface ECGs and intracardiac electrograms were simultaneously displayed and recorded on a multichannel recorder.

The stimulation protocol consisted of programmed stimulation at two basic cycle lengths with up to two extrastimuli and burst pacing at the RVA and RVOT. When tachycardia could not be induced by programmed ventricular stimulation, atrial pacing was attempted to induce clinical arrhythmia. When sustained tachycardia was not induced during the baseline state, stimulation of the ventricular and atrial site was repeated with an isoproterenol infusion (1–6 μg/min). Orthodromic atrioventricular reentrant tachycardia (AVRT) was diagnosed when ventricular extrastimuli delivered during His refractoriness reproducibly terminated the tachycardia or pre-excited the atrium with an unchanged atrial activation sequence (Figure 1). The para-Hisian pacing manoeuvre was also used to demonstrate retrograde atrial activation through the AP.13 Exclusive retrograde AP conduction beyond the AV node effective refractory period was further confirmed after ablation of the AP in these patients by the lack of retrograde conduction at the same coupling intervals.

Radiofrequency catheter ablation
A 7-F steerable quadripolar electrode catheter with a 4 mm tip (Biosense-Webster) was introduced into the left ventricle (LV) through the femoral artery and used for mapping and ablation. Radiofrequency catheter ablation of ILVT was performed using the following methods: an earliest pre-systolic Purkinje potential (PP) during ILVT, and a sharp PP at the left posterior fascicle (LPH) during sinus rhythm (SR), as documented in a previous report from our centre.14 Radiofrequency energy was delivered from the distal electrode of the mapping catheter for 90 s with an energy of 20–40 W. After every RF pulse, the inducibility of ILVT was again assessed. The endpoints of ablation of ILVT included: (i) non-inducibility of the tachycardia after RF ablation, and (ii) achievement of left posterior hemiblock (LPH) on a surface ECG guided by a sharp PP during SR when ILVT could not be induced.14 Radiofrequency catheter ablation of the AP was targeted at the earliest retrograde atrial activation site using elimination of AP conduction as an endpoint.

Post-ablation care and follow-up
Oral aspirin 150 mg daily was administered for 3 months after the procedure. One day following the procedure, a 12-lead surface ECG, transthoracic echocardiogram, and 24 h Holter monitoring were performed and repeated after 1, 3, 6, and 12 months. Clinical follow-up was carried out every 6 months at the outpatient clinic. Recurrence was defined as symptomatic episodes of tachycardia identified on the 12-lead ECG.

Statistical analysis
All statistical analyses were performed using SPSS 13.0 for Windows. Data are given as mean values ± SD.

Results
Patient characteristics
Among the 140 patients, 9 had a combination of ILVT and SVT. A concealed left AP was found in seven patients (5%), and orthodromic AVRT was induced in all seven. The other two patients had a combination of ILVT and typical anterioventricular nodal reentrant tachycardia (AVNRT) in one, and ILVT and atrial flutter in the other. We did not analyse these two patients due to the study's small sample size. All seven patients with a concealed left AP were male, with an average age of 21 ± 9 years and were without structural heart disease (Table 1). During a symptomatic tachycardia prior to ablation, only one type of tachycardia with RBBB morphology and left-axis deviation was documented in each patient.

Electrophysiological study
Sustained ILVT and orthodromic AVRT were induced in all seven patients. No atrioventricular (AV) conduction through the AP was observed during SR, premature atrial extrastimuli, and atrial pacing studies. Retrograde atrial activation through a bystander left AP was observed in all patients during ILVT, with an average tachycardia length of 346 ± 29 ms (range 310–400 ms). Atrial overdrive pacing showed a completely captured ventricle and introduced narrow QRS wave and a non-terminated tachycardia with an AVVA response in three patients (Figure 2), and ventriculoatrial (VA) dissociation in four patients (Figure 1). Intravenous adenosine administration did not terminate the tachycardia or change the retrograde atrial activation sequence during ILVT.

In four patients, the location of the APs was left posterior. Ventricular extrastimuli delivered during His refractoriness reproducibly terminated the tachycardia or pre-excited the atrium with an unchanged atrial activation sequence during orthodromic AVRT. Two of the four APs showed a slow and decremental retrograde property. During incremental ventricular pacing, a Wenckebach-type VA block over the AP was observed with progressive prolongation of the local VA conduction time in two patients (Figure 2). Also, during premature ventricular extrastimuli, the VA interval was progressively prolonged, with the same sequence of retrograde atrial activation. The location of the APs in the remaining three patients was left lateral (Figure 3). During electrophysiological study, none of these seven patients showed one tachycardia inducing another.

Radiofrequency catheter ablation and outcome
Ablation via a retrograde transaortic approach was successful in all seven patients. The strategy of AP ablation followed by ILVT ablation was adopted in six patients. However, ILVT was no longer induced in one patient, and became non-sustained in another following successful AP ablation due to excessive catheter manipulation which caused trauma in the left ventricle. For this reason, the ablation sequence of ILVT ablation first followed by AP...
Figure 1 Surface electrocardiogram leads I, aVF, and V1 with intracardiac recordings from the high right atrium, His bundle region, proximal (CS5) to distal (CS1) coronary sinus, and right ventricle in Patient 2—orthodromic atrioventricular reentrant tachycardia with retrograde activation (*) through a left posterior accessory pathway. (A) A ventricular extrastimulus delivered during His refractoriness advanced the next atrial activation with an unchanged sequence. (B) Retrograde activation (*) through a bystander left posterior accessory pathway was observed during idiopathic left ventricular tachycardia. (C) Atrial overdrive pacing showed ventriculoatrial dissociation without any change in the tachycardia, confirming the mechanism as ventricular tachycardia. (D) After successful ablation of accessory pathway, ventriculoatrial dissociation was observed during idiopathic left ventricular tachycardia. HRA, high right atrium; HBE, His bundle region; RV, right ventricle; SR, sinus rhythm.
Ablation was performed in the remaining patient and was successful. Successful ablation of the earliest PP electric potential was detected during ILVT in five patients. Lineament ablation in LPF was adopted, and LPH achievement was considered as the endpoint of ablation in two other patients as ILVT was no longer able to be induced or sustained. No ILVT or AVRT occurred during an average post-ablation follow-up of 3.7 ± 1.5 years.

**Discussion**

This study retrospectively analysed 140 patients with ILVT confirmed by electrophysiological study, and found that a concealed left AP existed in seven patients (5%). This probability cannot be occasional when compared with the incidence of SVT in the general population. In an epidemiological study of SVT in the USA general population (based on 1990 census data), Orejarena et al. estimated that the incidence of SVT was 36 of 100 000 person-years, and the prevalence was 2.29 of 1000 persons. Recent studies have demonstrated that the pathological substrate of ILVT is superficially located within left posterior Purkinje network and is amenable to RFCA. Thakur et al. identified a false tendon extending from the posteroinferior left ventricular free wall to the left ventricular septum in all of 15 patients with ILVT. In comparison, only 5% of 671 control patients demonstrated a false tendon. It was hypothesized that this false tendon is interweaved with and stretches the Purkinje fibre network, resulting in an abnormal conduction pathway.

**Table 1** Clinical and electrophysiological characteristics of the seven patients with idiopathic left ventricular tachycardia and a left accessory pathway

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Age (years)/gender</th>
<th>Duration of symptoms (years)</th>
<th>Mode of ILVT initiation</th>
<th>ILVT-TCL (ms)</th>
<th>AP location</th>
<th>Characteristic of AP conduction</th>
<th>Reaction to adenosine during ILVT</th>
<th>Structural heart disease</th>
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<tr>
<td>1</td>
<td>17/M</td>
<td>3</td>
<td>VBP</td>
<td>310</td>
<td>Lateral</td>
<td>Normal</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>16/M</td>
<td>3</td>
<td>VES</td>
<td>320</td>
<td>Posterior</td>
<td>Normal</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>15/M</td>
<td>2</td>
<td>ABP</td>
<td>360</td>
<td>Posterior</td>
<td>Decremental</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>41/M</td>
<td>8</td>
<td>VBP</td>
<td>340</td>
<td>Lateral</td>
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<td>No</td>
<td>No</td>
</tr>
<tr>
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<td>3</td>
<td>VBP</td>
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</tr>
<tr>
<td>6</td>
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<td>4</td>
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<td>350</td>
<td>Lateral</td>
<td>Normal</td>
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<td>No</td>
</tr>
<tr>
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<td>Posterior</td>
<td>Decremental</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

ABP, atrial burst pacing; AP, accessory pathway; ILVT, idiopathic left ventricular tachycardia; TCL, tachycardia cycle length; VBP, ventricular burst pacing; VES, ventricular extrastimulation.

**Figure 2** Surface electrocardiogram leads I, aVF, and V1 with intracardiac recordings from the high right atrium, proximal (HBEp) to distal (HBEd) His bundle region, proximal (CS5) to distal (CS1) coronary sinus, and right ventricle in Patient 3. (A) During incremental ventricular pacing in this patient, a Wenckebach-type ventriculoatrial block over the accessory pathway (*) was observed, with progressive prolongation of the local ventriculoatrial conduction time. (B) Atrial overdrive pacing (CS5) showed a completely captured ventricle and introduced narrow QRS wave and a non-terminated tachycardia during idiopathic left ventricular tachycardia with retrograde activation (*) through a bystander left posterior accessory pathway. The response to pacing was AVVA, confirming the mechanism of ventricular tachycardia. HRA, high right atrium; HBE, His bundle region; SR, sinus rhythm. RV, right ventricle.
in a local conduction delay and further occurrences of ILVT. In the present study, a transthoracic echocardiogram demonstrated a false tendon in six of the seven patients. Thus, we speculate that ILVT combined with a left AP is not occasional but is due to the formation of a left ventricular false tendon and AV AP induced by an aberration in the early stage of cardiac embryogenesis. All of the seven patients in this study were young males, which might be the reason that ILVT is more likely to occur in young men. Previous studies have suggested that the average age of patients with ILVT is 15–40 years, and that 60–80% of patients are male.1,2,4,17– 20

In this study, VA conduction through a bystander AP was observed in all seven patients during ILVT. The location of the left APs was posterior in four cases and lateral in three, and two (30%) of the seven APs showed a slow and decremental property. Several techniques have been described to differentiate various types of wide QRS tachycardia. However, a false diagnosis of SVT combined with bundle branch block or intraventricular aberrant conduction rather than true ventricular tachycardia (VT) is likely to be made due to the eccentric atrial activation that appears when VA conduction is through a bystander AP, especially under the conditions one tachycardia inducing another or non-clarity of the His potential. Generally, we recommend using atrial overdrive pacing to clarify the mechanism of wide QRS tachycardia. In this study, atrial overdrive pacing showed a captured ventricle accompanied by QRS change or AV dissociation during wide QRS tachycardia, and adenosine was not able to terminate the tachycardia or change the atrial activation sequence in all seven patients. Thus, a diagnosis of ILVT combined with a bystander left AP was able to be made.

Idiopathic left ventricular tachycardia and orthodromic AVRT were induced without inducing another type of tachycardia in all of the seven patients, suggesting that the two conditions can be eradicated by one procedure. Both the retrograde transaortic and transseptal approach can be used for catheter ablation of ILVT and a left AP. As far as we are aware, no studies have determined which ablation sequence should be adopted when VT is combined with SVT, but the ablation sequence in most reports has been from SVT to VT. A retrograde transaortic approach was utilized in the seven patients in this study. The left AP was ablated first in six patients, but ILVT was no longer induced in one patient and became non-sustained in another, probably because catheter manipulation in the LV injured the Purkinje fibre network in the LPF area, such that ILVT was no longer able to be induced or sustained. For this reason, ILVT was ablated first in the seventh patient and this proved successful. Thus, VT followed by SVT in patients with ILVT combined with a left AP might be advisable.

**Conclusion**

Among patients with ILVT, 5% had a concomitant left AP, most of who were young men. The location of the left AP was mainly posterior and lateral, with 30% showing a slow and decremental property. Idiopathic left ventricular tachycardia and AP should be ablated simultaneously.
Author contributions: J.-Q.H. was involved in concept/design, data analysis/interpretation, drafting the article, statistics, and data collection. J.M. was involved in concept/design, critical revision of the article, approval of the article statistics, and secured funding. Q.Y., Z.-L.L., Y.H., and S.Z. involved in data collection, approval of the article, and statistics.

Conflict of interest: none declared.

References