Radiofrequency Ablation Therapy in Idiopathic Left Ventricular Tachycardia With No Obvious Structural Heart Disease

Ming-Shien Wen, MD; San-Jou Yeh, MD; Chun-Chieh Wang, MD; Fun-Chung Lin, MD; I-Ching Chen, MD; Delon Wu, MD

Background The feasibility and efficacy of radiofrequency ablation therapy in idiopathic left ventricular tachycardia has not been assessed in a large group of patients.

Methods and Results Twenty consecutive patients with idiopathic left ventricular tachycardia and without structural heart disease underwent electrophysiological study, pharmacological interventions with administration of verapamil and adenosine, and radiofrequency ablation therapy. There were 17 men and 3 women with a mean age of 28±8 years. The QRS configuration during tachycardia was of right bundle branch block and superior axis in 13 patients, indeterminate axis in 6 patients, and right axis in 1 patient. The tachycardia was electrically inducible and responsive to verapamil but not to adenosine. Thirteen patients demonstrated entrainment. Activation and pace-mapping studies disclosed that the tachycardia originated from the inferior apical septum in 15 patients, the midseptum in 4 patients, and the anterior lateral wall of the left ventricle in 1 patient. Radiofrequency ablation was successful in 17 of the 20 patients (85%). The successful ablation sites were characterized by an endocardial activation time 30 milliseconds earlier than the onset of QRS during tachycardia and by a pace-mapping QRS similar to or closely resembling the tachycardia. All patients displayed sharp spikes preceding the local ventricular electrogram at the ablation site. However, these sharp spikes also were noted in 15 control patients and were not specific for this tachycardia; they persisted after ablation. There were no complications. A follow-up of 7±8 months in the 17 successfully ablated patients showed no symptomatic tachyarrhythmias without medications. Six patients underwent repeat electrophysiological study, and no induction of tachycardia was revealed.

Conclusions Radiofrequency ablation therapy is effective and safe in patients with idiopathic left ventricular tachycardia. It should be considered as the primary therapeutic modality in these patients. (Circulation. 1994;89:1690-1696.)

Key Words • electrophysiology • radiofrequency • reentry • tachycardia

Idiopathic ventricular tachycardia with no structural abnormality of the heart is not an uncommon clinical entity.1-7 In these patients, the tachycardia frequently arises from the right ventricular outflow tract, and the QRS morphology is that of left bundle branch block and inferior axis.1-5 In other patients, the tachycardia arises from the inferior apical area of the left ventricular septum, and the QRS is that of right bundle branch block and superior axis.6,7 Transcatheter ablation therapy with either direct current shocks or radiofrequency energy has been successful in patients with idiopathic ventricular tachycardia arising from the right ventricular outflow tract.8,12 In this study, the feasibility and efficacy of radiofrequency ablation therapy are assessed in a large group of consecutive patients with idiopathic ventricular tachycardia having a QRS morphology of right bundle branch block and with no obvious structural heart disease.

Methods

Patients

From July 1991 to September 1993, a total of 42 consecutive patients with idiopathic ventricular tachycardia were referred to Chang Gung Memorial Hospital for consideration of radiofrequency ablation therapy because of troublesome tachycardias. Twenty of these 42 patients exhibited termination of tachycardia after intravenous verapamil; QRS morphology of right bundle branch block suggested that the tachycardia originated from the left ventricle. These 20 patients were included in this study. The procedure was approved by the hospital review board and was in accordance with the local ethical standards. There were 17 men and 3 women with a mean age of 28±8 years (range, 17 to 42). All 20 patients had a complete physical examination, a chest radiograph, and a two-dimensional Doppler echocardiographic examination. None showed evidence of structural heart disease. Two patients presented with syncope and/or presyncope, 7 patients presented with dizziness, and 11 presented with palpitations (Table). The duration of symptoms ranged from 1 month to 21 years. All 20 patients had ECG documentation of ventricular tachycardia, and all received one to four antiarrhythmic drugs with variable effects before referral.

Electrophysiological Study

The electrophysiological study was performed after discontinuation of cardiotoxic drugs for at least five half-lives and obtaining an informed written consent. Three 6F quadripolar electrode catheters (USCI 002943) were introduced percutaneously into the right femoral vein, advanced to the right atrium, and positioned in the high right atrium, across the tricuspid valve, and in the right ventricular apex, respectively, to record the intracardiac electrogram and pacing. ECG leads I, aVF, and V, as well as intracardiac electrograms from different sites were simultaneously displayed and recorded on
Clinical and Electrophysiological Characteristics

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VT indicates ventricular tachycardia; CL, cycle length; ATP, adenosine triphosphate; EAT, endomyocardial activation time; +, inducible or terminable; S, sustained; NS, nonsustained; CRBBB, complete right bundle branch block; LAD, left anterior axis; RAD, right axis deviation; CRBBB, complete right bundle branch block; LAD, left axis deviation; VB, inducible axis; RAD, right axis deviation; ~, not inducible or terminable; LV, left ventricle; inf, inferior; apical, ant, anterior; and sep, septum.

Induction of VT during isoproterenol infusion.

a multichannel oscilloscopic recorder (Electronics for Medicine, VR-16, White Plains, NY) at a paper speed of 100 or 150 mm/s. The pacing stimuli were approximately twice diastolic threshold in strength and 2 milliseconds in duration and were provided by a digital programmable stimulator (Bloom and Associates, DTU-200, Reading, Pa).

Complete anterograde and retrograde electrophysiological studies using incremental pacing and extrastimulus testing were performed in each patient before ablation. The programmed ventricular stimulation was conducted using a maximum of three ventricular extrastimuli at two driven cycle lengths from two right ventricular sites (apex and outflow tract). If tachycardia was not inducible, the programmed stimulation was repeated during isoproterenol infusion (1 to 4 μg/min to achieve a 20% increase in sinus rate). If sustained tachycardia was induced, the entrainment study was conducted using incremental ventricular pacing beginning at a rate slightly faster than the tachycardic rate. The stimuli were delivered from two right ventricular sites (apex and outflow tract) and from the left ventricle.

Catheter Ablation

A 7F steerable quadripolar electrode catheter with a 4-mm tip and a 2-mm interelectrode spacing between the distal two electrodes (Mansfield-Webster, Watertown, Mass) was used for ablation. The radiofrequency current was generated from a commercially available electrosurgical unit (Radionics RFG-3C, Burlington, Mass) that provided a continuous, unmodulated sine wave at 500 kHz. The current was delivered between the distal electrode of the ablation catheter and a large disposable skin electrode pad that was applied to the left posterior chest under continuous digital monitoring of power strength and impedance. Both activation and pace-mapping studies were performed for selection of the ablation site. The ablation catheter was introduced percutaneously through the femoral artery and advanced to the left ventricular cavity. The mapping efforts were initially concentrated at the inferior apical septum of the left ventricle. If an ideal ablation site was not found in this area, the tip of the catheter then was moved to the midseptal area or the left ventricular free wall for mapping. The endocardial activation time relative to the onset of QRS during tachycardia was mapped using the distal two electrodes of the ablation catheter at a filter setting of 30 to 500 Hz. The radiofrequency current was delivered at a site where the endocardial activation was the earliest and preceded the QRS during tachycardia and where the pace-map QRS morphology displayed the closest match to that during tachycardia. A current power of 20 to 35 W for 10 to 20 seconds was delivered initially. If tachycardia was terminated in 10 seconds, booster currents were administered one to three more times at the same site. Incremental ventricular pacing and ventricular extrastimulus testing were performed after each successful ablation to determine whether or not tachycardia was still inducible. A complete electrophysiological study was repeated with isoproterenol infusion to ensure the success of ablation. Successful ablation was defined as no induction of ventricular tachycardia with programmed stimulation with or without isoproterenol infusion.
isoproterenol infusion was given to 5 patients; none had a provocation of tachycardia.

**Catheter Ablation**

The ventricular tachycardia was successfully ablated in 15 of the 20 patients during the initial session; it was successfully ablated during the second session a few days later in 2 patients. Thus, a total of 17 patients (85%) were successfully ablated (Figs 3 and 4). The successful ablation sites were characterized by a recording of high-frequency, sharp spikes that preceded the local ventricular electrogram and occurred 30 to 43 milliseconds before the onset of QRS during tachycardia (Figs 3 and 4) and by a QRS morphology during pace mapping similar to (9 patients) or closely resembling (8 patients) that during tachycardia (Fig 1B). There was no fragmentation of electrograms or continuous activities recorded at these sites. The sharp spikes also were recordable at unsuccessful sites of ablation, and they remained recordable after successful ablation of the tachycardia. The sharp spikes were recordable in 15 patients, 8 men and 7 women with a mean age of 36±11 years (range, 17 to 56), with no structural heart disease and no ventricular tachycardia. They were recordable along the fascicular networks of the left bundle branch system and moved progressively toward the QRS electrogram as the Purkinje networks branched from the base of the interventricular septum toward the apex and the left ventricular wall (Fig 5).

The ablation site in the 17 patients with successful ablation was located at the inferior apical septum in 13 patients, at the midseptal area in 3 patients, and at the anterior lateral free wall in 1 patient (Figs 6 and 7). In the 3 patients with unsuccessful ablation (cases 15, 16, and 17), the earliest endocardial activation was 26, 30, and 26 milliseconds before QRS during tachycardia and was registered from the inferior apical septum in 2 patients and the midseptal area in 1 patient, respectively.

All 20 patients tolerated the procedure well without complications. The total procedure time, the fluoroscopic time, the number of current applications, the power strength, and the duration of current application in the 17 patients with a successful ablation was 173±41 minutes, 48±18 minutes, 6±5, 28±3 W, and 18±5 seconds, respectively. The peak creatinine phosphokinase after ablation was 350±320 IU/L, and the MB fraction was 0.4±1.3%. The two-dimensional Doppler echocardiographic examination and the Tc-99 pyrophosphate myocardial scan after ablation were normal.

**Follow-up**

The mean follow-up duration was 7±8 months (range, 1 to 23). All 17 patients with successful ablation were symptom free without medications. Six patients underwent a late electrophysiological study, and all 6 had no induction of ventricular tachycardia even with isoproterenol infusion, whereas the others had no clinical attacks of episodic palpitation and had no recordable ventricular tachycardia during 24-hour ambulatory ECG monitorings. The 3 patients with unsuccessful ablation were treated with antiarrhythmic agents and continued to have occasional palpitations.
Discussion

Idiopathic Left Ventricular Tachycardia

A unique type of idiopathic ventricular tachycardia characterized by a QRS configuration of right bundle branch block and superior axis was designated as a specific entity by Lin et al in 1983. This tachycardia is inducible and terminable with programmed stimulation. It is responsive to verapamil but not to adenosine and arises from the inferior apical septum of the left ventricle. Reentry is believed to be the underlying mechanism of tachycardia; entrainment is frequently demonstrable by pacing the right ventricular outflow tract. The 20 patients in this study are consistent with this type of tachycardia.

Radiofrequency Ablation Therapy in Idiopathic Ventricular Tachycardia

Transcatheter ablation using direct current shocks or radiofrequency current has been applied in the treatment of idiopathic ventricular tachycardia originating from the right ventricular outflow tract. Stevenson et al applied direct current shocks to the right ventricular outflow tract of a patient with catecholamine-mediated ventricular tachycardia that exhibited a QRS morphology of left bundle branch block and inferior axis, and the tachycardia was eliminated. Morady et al delivered direct shocks to the right ventricular outflow tract and cured all 10 patients with a tachycardia of left bundle branch block and inferior-axis QRS morphology. Using radiofrequency energy, Wilber et al successfully ablated 5 of 6 patients, Klein et al successfully ablated 14 of 15 patients, and Calkins et al successfully ablated all 10 patients with a tachycardia of left bundle branch block and inferior-axis QRS configuration. The high success rate in ablation of these tachycardias probably results from the easy accessibility of the tachycardia focus to the ablation catheter as well as the ability to obtain a stable tissue contact of the catheter during delivery of the current in these patients.

Only a few patients with idiopathic ventricular tachycardia of a QRS configuration showing right bundle branch block and superior axis have been reported. Klein et al, using radiofrequency energy, successfully ablated a patient with idiopathic left ventricular tachycardia that exhibited a QRS pattern of right bundle

Fig 2. Recordings from case 6 showing entrainment of ventricular tachycardia with pacing from the right ventricular outflow tract. The cycle length of the ventricular tachycardia was 430 milliseconds. The ventricular paced cycle length in A was 400 milliseconds and in B, 350 milliseconds. Note that a progressive fusion of the QRS configuration occurred as the ventricular paced cycle length was shortened and the interval between the last paced beat and the first returning beat was identical to the paced cycle length. Note also that the local electrogram recorded from the left ventricle remained unchanged during pacing compared with that during tachycardia. I, AVF, and V1 indicate surface ECG leads I, aVF, and V1; HRA, high right atrial electrogram; LVD and LVP, bipolar left ventricular electrogram recorded from distal and proximal pairs of a quadripolar electrode catheter with 1-cm interelectrode spacing; RVd and RVP, bipolar right ventricular electrogram recorded from distal and proximal pairs of a quadripolar electrode catheter with 1-cm interelectrode spacing; HBE, bipolar electrogram recorded from His bundle electrode catheter; CL, cycle length; and S, stimulus artifact.
branch block and superior axis; the current was delivered to the mid posterior portion of the left ventricular septum. Page et al successfully ablated 2 such patients by delivering the radiofrequency current to a site approximately two thirds from the base to the apex on the inferior margin of the left interventricular septum and the free wall. In these 2 patients, the endocardial activation time was, respectively, 35 and 45 milliseconds earlier than the onset of QRS during tachycardia, and a sharp deflection preceding the local electrogram was observed. However, the pace-map 12-lead ECG at the successful ablation site was not identical to the QRS configuration during tachycardia. The observations of Page et al were confirmed in the patients with a successful ablation in this study. The site of successful ablation is characterized by an endocardial activation time of at least 30 milliseconds earlier than the QRS during tachycardia and is the earliest recorded activation site. Although the pace-map 12-lead ECG displays a perfect match in more than half of the patients at the successful ablation site, a pace-map ECG that closely resembles QRS during tachycardia is also associated with successful ablation. Regarding the sharp spikes that preceded the local electrogram at the successful ablation site, these spikes persisted after ablation and were not specific for patients with idiopathic ventricular

**Fig 3.** Recordings from case 6 showing activation mapping during ventricular tachycardia and radiofrequency ablation. A shows recording of sharp spikes that preceded the local electrogram and occurred 30 milliseconds before the onset of QRS during tachycardia at the ablation site (see Fig 6). B shows delivery of 29 W of radiofrequency current for 10 seconds at this site, resulting in termination of tachycardia in 2.5 seconds. LVd and LVp indicate bipolar electrograms recorded from the distal and the proximal pairs of the quadripolar ablation electrode catheter; RV, bipolar right ventricular electrogram recorded from a quadripolar electrode catheter with 1-cm electrode spacing.

**Fig 4.** Recordings from case 9 showing sharp deflections preceding the local ventricular electrogram (indicated by an arrow) at the ablation site during sinus rhythm (A) or ventricular tachycardia (B) before ablation and during sinus rhythm after ablation (C). The tip of the ablation catheter was located at the inferior apical septum of the left ventricle, where successful ablation was achieved.

**Fig 5.** Recordings from a control patient without ventricular tachycardia and with a normal heart showing recordable sharp spikes along the left bundle branch system. The tip of an ablation catheter was initially positioned at the proximal left bundle at the base of the left interventricular septum (A). The tip of this catheter then was progressively advanced toward the apex along the left interventricular septum (B through F). Note that the sharp spikes were recorded at the upper (A and B), middle (C), lower (D), and apical septum (E), and the interval between the His bundle deflection and the sharp spikes increased progressively. The sharp spikes then merged with the QRS electrogram at the point of the left ventricular apex (F). Dotted line indicates the onset of His bundle potential; intervals between the His deflection and the sharp spikes are shown (in milliseconds). LV Sep indicates bipolar electrogram recorded from the left interventricular septum.
tachycardia that displayed a QRS configuration of right bundle branch block and superior axis. They were also recordable along the fascicular networks of the left bundle branch system in patients with no structural heart disease and no ventricular tachycardia. Thus, these sharp spikes are likely to reflect the fascicular potentials rather than a specific marker of the idiopathic left ventricular tachycardia. Whether or not the presence of these spikes indicates that the reentry circuit of these tachycardias arises from the fascicles could not be ascertained from this study.

Conclusions

Radiofrequency ablation therapy is an effective and safe therapeutic modality for patients with idiopathic ventricular tachycardia arising from the midseptum or the inferior apical septum of the left ventricle. The successful ablation site is where sharp deflections are recorded at least 30 milliseconds before the QRS complex during tachycardia and the endocardial activation is the earliest; a perfect match of pace-map QRS complex to that during tachycardia is not mandatory.

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References

6. Lin FC, Finley CD, Rahimtoola SH, Wu D. Idiopathic paroxysmal ventricular tachycardia with a QRS pattern of right bundle branch
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M S Wen, S J Yeh, C C Wang, F C Lin, I C Chen and D Wu

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