EARLY EXPERIENCES OF ENDOCARDIAL CATHETER MAPPING OF THE LEFT VENTRICLE IN PATIENTS WITH SUSTAINED VENTRICULAR TACHYCARDIA—Efficacy, safety and complications—

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In 23 patients with recurrent sustained ventricular tachycardia (VT) which originated from the left ventricle, endocardial catheter mapping has performed. In an additional 14 patients we also stimulated their left ventricle for non-sustained VT. Multiple sites could be mapped for the recording of local electrical activity, for pacing and for the induction of VT. These procedures could be done without complication. A careful, reasonable, and safe method of endocardial mapping will facilitate clinical electrophysiologic study.

For refractory ventricular tachycardia (VT), it is essential to induce VT to see drug efficacy1-3 and also to determine the origin of VT. Endocardial pace-mapping is another important tool to determine the origin of VT.

Safe and thorough endocardial catheter mapping is required for these purposes.

Since 1984, we have seen 45 patients with recurrent sustained VT? Of these about half had a focus or foci of VT in the left ventricle and we had to perform endocardial mapping of the left ventricle. We employed the technique of Josephson, using his multipurpose quadripolar catheter.4,5 This paper describes our early experiences.

SUBJECTS AND METHODS
Among 45 patients with sustained ventricular tachycardia (VT) which lasted until it was ended by drugs or DC shock at the hospital, the origin (focus) of VT was found in the left ventricle in 23 patients. Local electrical activities from multiple sites in the right ventricle were found after the onset of the QRS complex during VT. Seven patients had had previous myocardial infarction and two of them had another focus in the right ventricle with a different QRS configuration of VT. Ten patients had either an aneurysm of the left ventricle or a regional wall motion abnormality (WMA) and some of these cases have been reported elsewhere? These 10 patients had no episode of chest pain or history of myocardial infarction and their coronary angiograms were entirely normal. The other

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6 patients had so-called idiopathic VT. The QRS configuration showed right bundle branch block (RBBB) pattern and left axis deviation (LAD) and their VTs characteristically responded to verapamil. Of the 23 patients, nine had received electrophysiologic studies two to six times for the evaluation of drug efficacy or the effect of surgical therapy. In additional 14 patients, programmed stimulations were done from the left ventricle for non-sustained VT to see whether they had electrically inducible VT or not. The results of the introduction of a catheter into the left ventricle were included in the present study to see the efficacy and the safety on the technique. Seven patients had old myocardial infarction (n = 5) or angina pectoris (n = 2) and other five had frequent non-sustained VT (= three or more consecutive ventricular beats not lasting for 15 sec or more). The latter had no underlying organic heart disease. Two patients with hypertrophic cardiomyopathy were included because of a history of syncope and nonsustained VT. Table I summarizes the profiles of 37 patients. Endocardial mapping was performed according to Josephson’s technique, using a multipurpose quadripolar catheter (USCI Josephson’s multipurpose catheter) in 12 standard sites within the left ventricle (Fig. 1A)\(^4,5\). The earliest activation site was then determined by careful and repeated mapping and it was thought to be the site of origin of VT. In 8 patients who had undergone surgical therapy for VT of left ventricular origin, the results of the preoperative endocardial mapping studies were compared with those of intraoperative epicardial mapping. During the electrophysiologic study, the standard 12 lead electrocardiogram (ECG) was recorded in a routine manner to identify whether the induced VT or the pace-mapped QRS configuration has

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**TABLE I CLINICAL PROFILES OF PATIENTS**

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>No. of pts (sex ratio)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustained VT</td>
<td>23 (M : F = 16 : 7)</td>
<td>48–71 years</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>7 (5 : 2)</td>
<td></td>
</tr>
<tr>
<td>(old myocardial infarction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ischemic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV aneurysm or WMA*</td>
<td>10 (8 : 2)</td>
<td>34–62 years</td>
</tr>
<tr>
<td>idiopathic VT</td>
<td>6 (4 : 2)</td>
<td>19–54 years</td>
</tr>
<tr>
<td>Nonsustained VT</td>
<td>14 (12 : 2)</td>
<td>36–71 years</td>
</tr>
<tr>
<td>With ischemic heart disease</td>
<td>7 (7 : 0)</td>
<td></td>
</tr>
<tr>
<td>Primary non-sustained VT</td>
<td>5 (3 : 2)</td>
<td></td>
</tr>
<tr>
<td>Hypertrophic cardiomyopathy</td>
<td>2 (1 : 1)</td>
<td></td>
</tr>
</tbody>
</table>

LV aneurysm or WMA; Left ventricular aneurysm or regional wall motion abnormality. pts; patients

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Fig.1. A: A scheme of standard sites of mapping. B: Introduction of an electrode catheter into the left ventricle. The site to be mapped is chosen while the catheter is within the aortic root (AO). After introduction into the left ventricle (LV), only pulling out is to map from the base to the apex as schematically shown. Ao; aorta, LA; left atrium.
Endocardial Catheter Mapping of Ventricular Tachycardia

Fig. 2. The endocardial mapping for the earliest activation site. Among multiple sites, the earliest activation site was obtained from the mid-lateral free wall of the left ventricle in a 58 year old male. I, II, V1; surface ECG leads. HRA; high right atrium. HBE; record from His bundle region. RV apex; right ventricular apex. LV; left ventricle. A; atrial activity.

Fig. 3. Endocardial and epicardial mapping in a case with sustained ventricular tachycardia (VT). The interval between the local electrical activity and the onset of QRS complex of VT was shown in milliseconds. The earliest activation site at the lower interventricular septum determined by endocardial mapping was far from the earliest site determined by the epicardial mapping (as shown as asteriks).

the same QRS configuration as the clinical VT. This paper described mainly the technical aspects of the endocardial mapping procedure.

RESULTS

Introduction of catheter into the left ventricle
A six French sized quadripolar electrode catheter was used and a J-shaped loop could be made at the aortic root in all patients. Since multiple sites were mapped for pacing, for the recording of local electrical activity, or for induction of VT in the left ventricle, the catheter was introduced into the left ventricle a hundred times or more in all. Fig. 1A shows a scheme of standard sites of mapping. The direction of the loop was adjusted for the desired mapping sites at the aortic root as schematically shown in Fig. 1B.

Electrophysiological findings
The earliest local electrical activity determined by endocardial mapping preceded QRS of VT by 10 to 95 msec (Fig. 2) and these sites were related to the border of an aneurysm or the region of abnormal wall motion. Such sites seemed to be very close to the site determined during the intraoperative endocardial mapping of

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### Table II
Comparision of Results of Endo- and Epicardial Mapping

<table>
<thead>
<tr>
<th>Case</th>
<th>Time before QRS of VT msec (endo/epi)</th>
<th>Site of the earliest activation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>endocardial map</td>
</tr>
<tr>
<td>1</td>
<td>-20/0</td>
<td>lower IVS*</td>
</tr>
<tr>
<td>2</td>
<td>-20/-10</td>
<td>FW</td>
</tr>
<tr>
<td>3</td>
<td>-15/-10</td>
<td>FW</td>
</tr>
<tr>
<td>4</td>
<td>-20/nd</td>
<td>FW</td>
</tr>
<tr>
<td>5</td>
<td>-30/-10</td>
<td>FW</td>
</tr>
<tr>
<td>6</td>
<td>-70/nd</td>
<td>apex</td>
</tr>
<tr>
<td>7</td>
<td>nd/-20</td>
<td>FW</td>
</tr>
<tr>
<td>8</td>
<td>-50/nd</td>
<td>apex</td>
</tr>
</tbody>
</table>

VT: ventricular tachycardia. endo/epi: endocardial and epicardial mapping. map: mapping. IVS: interventricular septum. FW: free wall. nd; VT not induced during intraoperative electrophysiologic study. In case 7, only reproducibility was checked preoperatively. Except for case 5, other patients had aneurym of the left ventricle. Right bundle branch block pattern of VT was found in case 1 to 6, and 8. Case 7 showed rS pattern in VT with left axis deviation during VT. VT of left bundle branch block pattern (pleomorphism) was also observed in 2, 4, 7, and 8 of which the earliest activation site was found in the right ventricle.

**H.I.** 57 year-old male OMI-VT

![ECG Diagram](image)

Fig.4. Fragmented or continuous local electrical activities. This record was obtained from a 57 year old male with ventricular tachycardia and old myocardial infarction. The mapping site was 7 (close to 1 and 5). When the catheter was moved to a site between 1 and 11, such continuous activities were not recorded (right side). I, II, V1; surface ECG leads. RV apex; right ventricular apex. HBE; Record from His bundle region. LV; left ventricle.

VTs in patients who had undergone surgical therapy for refractory VT. However, the biggest discrepancy between the earliest activation site which was determined by endocardial preoperative mapping, and that determined by intraoperative epicardial mapping, was found in VT which originated from the interventricular septum. In this case, the breakthrough point (= the earliest activation site in the epicardial mapping) was found in the posterior wall and confirmed the reports of inefficacy of epicardial mapping for VT which originates from the septum (Fig. 3). Table II summarizes the results of the preoperative endocardial mapping and the intraoperative epicardial mapping study.

Fragmented local electrical activities were obtained from two patients; both had old myocardial infarction with ventricular aneurysm (Fig. 4). Such fragmented activities were confined to a small area in both cases (Fig. 4) and they were observed only during VT. In one case, the duration of fractionation of local electrical

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activities extended to 170 msec just before the initiation of VT. In the other, catheter mapping was done during VT. VTs of these two cases showed acceleration by rapid pacing of VT and degenerated into fibrillation. If the fragmented activities were recorded from the catheter placed on the reentrant circuit, or not was not fully studied.

Pace-mapping was performed when VT could not be induced by programmed stimulations or when hemodynamic deterioration was expected upon induction of VT, because of rapid rate. The pacing sites which resulted in a similar configuration of QRS complexes as clinically documented VT were determined. The QRS configuration was checked by a 12 lead surface ECG (Fig. 5).

Complication
No complication occurred in this study. As a possible minor complication, the catheter may be introduced into coronary ostium while making a J-shaped loop at the aortic root. A knot was made on one occasion but was soon untied. These complications should be avoided by a technical improvement.

DISCUSSION
The use of electrical stimulation has been established as a method for understanding the mechanism of VT, or the evaluation of medical or surgical therapeutic interventions. For drug-refractory VT, it is essential to determine the origin of VT. Though a precise determination can be done by the intraoperative mapping study, some VT may not be inducible during surgery. Therefore, a preoperative catheter mapping is required and this procedure must be done safely as well as effectively. Any electrode catheter could be introduced into either ventricle, but it is difficult or even dangerous to manipulate an electrode catheter within the left ventricle to map multiple sites. For this reason, we have employed the technique reported by Josephson. The method is quite reasonable as is schematically shown in Fig. 1B; the catheter tip will not cause any damage by penetrating into the ventricular wall since the electrode catheter lies upon the endocardium on its side (Fig. 1B). Recording of the electrical activity and stimulation of the left ventricle is done from two pairs of electrodes simultaneously. Mapping is done from the base toward the apex very safely and effectively (Fig. 1B). We have had no problem with complications with this technique. Sometimes however, the J-shaped loop appeared to be too small and we needed to make the loop larger for mapping. This phenomenon may be due to the small size of the aortic root in Japanese people or may reflect a merely technical inadequacy. Introduction of the catheter into the coronary artery or making a knot can be avoided by cautious manipulation.

However, after introducing the electrode catheter into the left ventricle more than a hundred times the present method seems to be very safe and good for endocardial mapping of
the left ventricle. The precise determination of the origin of VT is essential for the success of surgical therapy\textsuperscript{13-16} as well as for other aggressive therapies such as electrical ablation or coagulation\textsuperscript{17-18}.

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