Surgical alternatives in the treatment of life-threatening ventricular arrhythmias


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Abstract. We present our experience in the treatment of life-threatening ventricular tachycardia using electrophysiologically guided surgery (97 patients), automatic implantable cardioverter defibrillator (AICD) (42 patients), and orthotopic heart transplantation (15 patients). Eighty-three percent of these patients had ischemic and 17%, nonischemic heart disease. Our results of electrophysiologically directed surgery show an early mortality of 10% and a recurrence of 5% in the ischemic group. In the nonischemic group, the recurrence was 45%. The AICD was implanted in 31 patients with ischemic heart disease, in 5 with ventricular dysplasia, and in 6 with dilative cardiomyopathy, the ejection fractions ranging from 12% to 65%, with a mean of 30%. Early and late mortalities were 5% and 19%, respectively. The AICD was effective in all patients. Survival rate at 1 year was 83% ± 6.4%. Thirteen of 15 patients have survived heart transplantation for 3–20 months (mean: 11 months). Ejection fractions prior to transplantation ranged from less than 10% to 34% (mean: 16%). We conclude that electrophysiologically guided surgery is highly effective in most cases of ischemia-related ventricular tachycardia. The AICD is considered a palliative alternative in patients with either poor ventricular function, no electrophysiological substrate, or multimorphological tachycardia. Heart transplantation has to be considered especially in young patients in whom progression of the underlying disease can be anticipated. Bridging by AICD is possible when transplantation is not immediately available or recommendable.

Key words: Ventricular arrhythmias – Electrophysiologically guided surgery – Automatic defibrillator – Heart transplantation

Since the introduction of antiarrhythmic, electrophysiologically guided surgery for re-entrant ventricular tachycardia [7, 11, 34, 44], this new method of treatment has undergone considerable development and now can be offered as a reasonable alternative for patients who are refractory to conventional pharmacological treatment. In 1978, Guiraudon [12] suggested endocardial encircling ventriculotomy, and in 1979, Harken [14] published the first results of endocardial resection. Subsequently, various ablative techniques using cryosurgery [16], electrocoagulation [9], and laser irradiation [32] or modifications thereof have been described [10, 26, 27]. However, the current surgical approaches do not encompass all patients suffering from life-threatening arrhythmias for at least three reasons:

1. Ventricular tachyarrhythmia may occur in the presence of end-stage ventricular failure.
2. The anatomic substrate may not be found during preoperative electrophysiological study.
3. Endocardial surgery for tachycardia not related to ischemic heart disease has been disappointing.

In our effort to extend the group of treatable patients, especially to those with impaired ventricular function, two additional therapeutic principles were integrated in our concept of antiarrhythmic surgery: first, the implantation of an automatic implantable cardioverter/defibrillator...
(AICD) [23] as a palliative measure, and second, heart transplantation (HTx) as a definitive therapeutic approach. This paper describes the development of our policy in the treatment of life-threatening ventricular tachyarrhythmia with respect to cause, manifestation, and stage of the underlying disease.

Patients

Since May 1980, antiarrhythmic surgery for pharmacologically refractory ventricular tachycardia (VT) has been performed at the Hannover Medical School on a total of 154 patients (Fig. 1). Our analysis comprises three major groups of patients treated surgically on the basis of electrophysiological studies (Table 1).

**Group I: Electrophysiologically directed surgery**

The first population of 97 patients was operated upon by electrophysiologically directed surgery between May 1980 and September 1987. In the majority (86 patients, 89%) VT was related to coronary heart disease, whereas 11 patients (11%) suffered from other myocardial abnormalities. In the following, the two subgroups are described. All but 2 of the 86 patients with ischemic heart disease (77 male, 9 female; aged 27–71; mean: 53 years) had had at least one myocardial infarction 1 month–25 years (mean: 32 months) prior to surgery. The average left ventricular ejection fraction (LVEF) was 35% (range: 19%–68%).

In the initial phase of electrophysiologically guided surgery, 14 patients (16%) were treated by endocardial incision only. Since 1981, our approach has changed to endocardial resection for the subsequent 72 patients (84%). Starting in 1983, we employed a combination of endocardial resection and endocardial cryoablation on 26 patients. In addition to antiarrhythmic surgery, coronary artery bypass grafting (CABG) was performed on 12 (14%), aneurysmectomy on 39 (45%), and combined CABG and aneurysmectomy on 20 patients (23%).

Eleven patients (8 male, 3 female; aged 10–67; mean: 44 years) underwent antiarrhythmic surgery for VT in the presence of nonischemic heart disease. Four patients were found to have right ventricular dysplasia, 4 had left ventricular dysplasia, and in 1, both ventricles were involved. One patient was diagnosed to have an aneurysm (presumably related to sarcoid), and 1 had a right ventricular scar after previous operation for tetralogy of Fallot. The first 2 patients were treated by ventriculotomy only. When cryothermia became available, it was used on the 9 subsequent cases. The preoperative mean LVEF in these patients was 52% (range: 31%–69%).

**Group II: Automatic implantable cardioverter/defibrillator**

Patients were considered as candidates for implantation of an AICD if they had suffered at least one episode of cardiac arrest due to ventricular fibrillation (VF) or flutter or recurrent episodes of sustained VT of more than 200 beats per minute under maximal antiarrhythmic medication, including amiodarone. Starting in January 1984, 42 patients (39 male, 3 female, aged 22–77; mean: 55 years) underwent implantation of an AICD (Table 1). The insertion technique comprised median sternotomy in all patients; the defibrillation electrodes were attached to the epicardium with fibrin adhesive in a patch-patch configuration. There were one or more recurrent episodes of cardiac arrest due to VF in 21 patients, VT in 17 patients, or both conditions in 4 patients. Thirty-one patients had ischemic heart disease with at least one previous myocardial infarction. Of the remaining 11 patients, 6 suffered from nonischemic cardiomyopathy, 2 had right ventricular dysplasia, 1 had left ventricular dysplasia, and 1 had right ventricular dysplasia and an aneurysm. The first 9 patients were treated by endocardial resection, and the 27 subsequent patients were treated by endocardial incision. The operative mean LVEF in these patients was 30% (range: 19%–69%).

Table 1. Patients (n=154) operated upon for pharmacologically refractory ventricular tachyarrhythmias from May 1980 to September 1987 by different modes of surgical intervention

<table>
<thead>
<tr>
<th>EDS</th>
<th>AICD</th>
<th>HTx</th>
<th>Total</th>
</tr>
</thead>
</table>

| Patients (n) | 97 | 42 | 15 | 154 |
| Male/female | 85/12 | 39/3 | 12/3 | 136/18 |
| Ischemic | 86 (89%) | 31 (71%) | 11 (73%) | 128 (83%) |
| Nonischemic | 11 (11%) | 11 (29%) | 4 (27%) | 26 (17%) |
| RVD | 4 | 2 | – | 6 |
| LVD | 4 | 1 | – | 5 |
| BVD | 1 | 2 | 1 | 4 |
| Sarcoïd | 1 | – | – | 1 |
| Fallot | 1 | – | – | 1 |
| COCM | – | 5 | 3 | 8 |
| HOCM | – | 1 | – | 1 |
| Age, mean | 50 ± 11 | 55 ± 10 | 47 ± 6 |
| Range (years) | 10–71 | 22–77 | 37–56 |
| EF, mean | 36 ± 11 | 30 ± 13 | 16 ± 7 |
| Range (%) | 19–69 | 12–65 | <10–34 |

EDS = electrophysiologically directed surgery; AICD = automatic implantable cardioverter/defibrillator; HTX = heart transplantation; RVD = right ventricular dysplasia; LVD = left ventricular dysplasia; BVD = biventricular dysplasia; COCM = congestive cardiomyopathy; HOCM = hypertrophic obstructive cardiomyopathy; EF = ejection fraction; sd = standard deviation.
Fig. 2. Actuarial survival curve for 72 patients after endocardial resection for postinfarct ventricular tachycardia (upper curve) compared to all patients who underwent electrophysiologically directed surgery (97 patients). Actuarial survival after 3 years was 80% ± 5% and 78% ± 4%, respectively.

Table 2. Group I: 97 patients operated by electrophysiologically guided surgery (endocardial incision, endocardial resection, ventriculotomy, cryosurgery). Results of patients with coronary artery disease versus various myocardial abnormalities

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>VTIS</th>
<th>VTNI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients (n)</td>
<td>97</td>
<td>86</td>
<td>11</td>
</tr>
<tr>
<td>Follow-up, mean ± sd</td>
<td>38 ± 28</td>
<td>38 ± 29</td>
<td>36 ± 24</td>
</tr>
<tr>
<td>Range (months)</td>
<td>1 - 87</td>
<td>1 - 87</td>
<td>1 - 75</td>
</tr>
<tr>
<td>Operative mortality n (%)</td>
<td>10 (10.3)</td>
<td>9 (10.5)</td>
<td>1 (9)</td>
</tr>
<tr>
<td>Late mortality n (%)</td>
<td>12 (12.4)</td>
<td>12 (16)</td>
<td>-</td>
</tr>
<tr>
<td>Actuarial survival (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 year</td>
<td>-</td>
<td>77 ± 4.6</td>
<td>-</td>
</tr>
<tr>
<td>2 years</td>
<td>-</td>
<td>75 ± 4.8</td>
<td>-</td>
</tr>
<tr>
<td>3 years</td>
<td>-</td>
<td>74 ± 5.0</td>
<td>-</td>
</tr>
<tr>
<td>Recurrences n (%)</td>
<td>9 (9)</td>
<td>4 (5)</td>
<td>5 (45)</td>
</tr>
<tr>
<td>Change of therapy</td>
<td>3 to HTx</td>
<td>3 to AICD</td>
<td></td>
</tr>
</tbody>
</table>

VTIS = coronary artery disease; VTNI = various myocardial abnormalities; HTx = heart transplantation; AICD = automatic implantable cardioverter defibrillator

ventricular dysplasia, and 2 had biventricular disease. Prior to AICD implantation, 9 patients had undergone open heart surgery (6 CABG, 1 aneurysmectomy, 1 electrophysiologically guided surgery, 1 mitral valve replacement). In 2 patients, catheter ablation had been performed previously. All patients underwent extended electrophysiological studies. In 10 patients, open heart procedures were performed concomitantly with defibrillator insertion. Coronary bypass surgery was performed in 8 patients, and antiarrhythmic surgery on 2 patients. The preoperative LVEF varied from 12% to 65% (mean: 30%).

Group III: Heart transplantation

The third group operated upon since January 1986 comprises 15 patients (12 male, 3 female; aged 37–56; mean: 47 years), who underwent orthotopic heart transplantation (HTx) in the presence of life-threatening ventricular arrhythmia, corresponding to 9% of the 176 patients with heart transplantations performed at the Hannover Medical School since July 1983. In these cases, VT was combined with end-stage left ventricular failure with a mean LVEF of 16% (range: less than 10%–34%) (Table 1).

Eleven patients who underwent heart transplantation suffered from ischemic heart disease; 3 had dilative cardiomyopathy (1 after mitral valve replacement), and one had biventricular dysplasia. All presented with malignant forms of VT or VF, which had been observed for 1.93 ± 1.33 years prior to HTx. Seven patients had suffered recurrent circulatory arrest and had been resuscitated successfully.

Three patients in the ischemic HTx group had undergone endocardial resection 1–3 years prior to heart transplantation; 1 had undergone CABG and aneurysmectomy 1 year previously. Of the 4 patients in the non-ischemic group, 2 had an AICD implanted prior to HTx. In all cases in this group, myocardial function had become borderline. The patients had been scheduled for HTx 1.1 ± 0.5 months in advance.

Results

Group I: Electrophysiologically guided surgery

Nine of the 86 patients (10.5%) in the ischemic subgroup died early due to cardiac or respiratory failure (Table 2). The mean preoperative EF of these patients was 33% ± 6%. During a mean follow-up period of 38 ± 29 months (1–86 months), 12 patients (16%) died later – 9 during the first year, 2 less than 2 years after the operation, and one 5 years postoperatively. Sudden cardiac death, probably related to recurrent VT, occurred in 3 patients. Four patients died of heart failure, while 2 fatalities were due to reinfarction. One patient succumbed to a cerebral infarct, and 2 additional cases to pulmonary embolism. Sixty-five of the 86 patients are still alive (a 3-year actuarial survival of 74% ± 5%) (Table 2). Recurrences of VT occurred in 4 survivors (4.6%), 1 after endocardial incision and 3 after endocardial resection, but none of them died. One underwent another successful antiarrhythmic procedure, 1 received an antitachycardia pacemaker, and 2 patients are under good pharmacological control. Seventeen patients (26%) are under antiarrhythmic therapy for unipolar or multifocal, premature ventricular beats.

Ten of 11 patients with nonischemic heart disease survived for a mean follow-up period of

2 In this presentation, continuous data will be presented as mean ± standard deviation or as mean and range. Data were analyzed by using chi-square analysis or Student's t-Test to analyze intergroup differences. Cumulative incidence of survival or of patients free of arrhythmic events or of sudden death were calculated using actuarial methods. A p-level of less than 0.05 was considered as significant.
36 ± 24 months (1–75 months). One patient died of heart failure 1 month after the operation. Five patients have suffered recurrences of VT. Three received an AICD and are included in the patient group with defibrillators. In 2 patients, VT could not be abolished in the operating room, in the third patient, the AICD was implanted 30 months later. The remaining patients with recurrences were successfully treated by catheter ablation and antiarrhythmic medication, respectively. An additional patient received defibrillator patches only following directed surgery, since slow VT was still inducible in the operating room. Ventricular tachycardia has not recurred in this patient since. Therefore, only 5 patients have remained free of recurrences.

**Group II: Automatic implantable cardioverter/defibrillator**

After AICD implantation, 2 patients died early of ventricular fibrillation and low cardiac output (1 after previous CABG, 1 with concomitant CABG) (Table 3). The preoperative LVEF of these patients was 20% and 25%, respectively.

During a mean follow-up period of 16 ± 12 months (1–44 months), there were 8 late fatalities due to noncardiac (1), cardiac (4), sudden death (2), and unknown cause (1). In 2 patients, catheter ablation had to be performed after AICD implantation because of excessive shock deliveries. Both patients died subsequently of sudden cardiac events, 1 probably due to generator depletion. The 1-year actuarial survival of our AICD patients, therefore, was 83% ± 6.4% (Fig. 3). One patient underwent His-bundle ablation because of supraventricular tachyarrhythmia, another received an antitachycardia pacemaker in the presence of a slower form of VT, and 2 patients received a demand pacemaker because of inter-

**Group III: Heart transplantation**

After a mean follow-up of 10 ± 6 months (1–20 months), 13 of the 15 patients with heart trans-
Table 4. Patients changing groups during follow-up: 3 heart transplants (HTx) after endocardial resection, 2 HTx after automatic implantable cardioverter defibrillator (AICD) implantation, and 3 AICD after ventriculotomy and cryosurgery

<table>
<thead>
<tr>
<th>Time between surgical interventions (months)</th>
<th>EDS-IS → HTx</th>
<th>EDS-NI → AICD</th>
<th>AICD → HTx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients (n = 8)</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Underlying disease</td>
<td>3 ICM</td>
<td>2 RVD/</td>
<td>1 BVD/</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 BVD/</td>
<td>1 COCM</td>
</tr>
<tr>
<td>Age (years)</td>
<td>52/51/53</td>
<td>70/52/43</td>
<td>54/42</td>
</tr>
<tr>
<td>EF before first operation</td>
<td>55/30/30</td>
<td>69/50/50</td>
<td>30/15</td>
</tr>
<tr>
<td>EF before second operation</td>
<td>15/20/15</td>
<td>45/50/50</td>
<td>15/12</td>
</tr>
</tbody>
</table>

EDS-IS = electrophysiologically directed surgery – ischemic disease; EDS-NI = EDS non-ischemic disease; HTx = heart transplantation; ICM = ischemic cardiomyopathy; COCM = congestive cardiomyopathy; BVD = biventricular dysplasia; RVD = right ventricular dysplasia; EF = ejection fraction

Plants (87%) have survived. One patient with biventricular dysplasia and previous AICD implantation died 2 weeks after transplantation because of multiple cerebral infarction. The second patient, who was transplanted because of ischemic cardiomyopathy, succumbed to septic shock 12 months postoperatively.

Modifications of the therapeutic concept

In 8 patients, our original surgical therapeutic concept had to be changed (Table 4). In 3 patients with ischemic heart disease, who were in stable rhythm after endocardial resection, heart transplantation had to be performed because of left ventricular deterioration. Their LVEF had been 55%, 30%, and 30% prior to endocardial resection but had declined to 15%, 20%, and 15%, respectively, over the intervening period of 23 ± 7 months. Ten months after HTx, all 3 patients were alive. Three patients with either left or right ventricular dysplasia received an AICD after electrophysiologically directed ventriculotomy and additional cryoablation because of recurrence of VT, which had been recognized in the operating room. The third patient received an AICD 30 months after the initial antiarrhythmic operation; within the following 12 months, he received 16 shocks. Two patients, who primarily had an AICD implanted for biventricular dysplasia and dilative cardiomyopathy after mitral valve replacement, underwent heart transplantation 24 months subsequently. In both, the AICD had delivered 4 shocks each. Their LVEF was 30% and 15%, respectively, prior to AICD implantation and had deteriorated to 15% and 12% prior to heart transplantation. One of them died early after HTx due to cerebral complications.

Discussion

Modern electrophysiological techniques have facilitated the identification of a large number of patients at high risk of sudden death from ventricular arrhythmias [11, 34, 41, 43]. The probability of a recurrent episode of sudden cardiac arrest exceeds 70% in patients who have survived one such event unrelated to acute myocardial infarction but with a history of congestive heart failure, previous myocardial infarction, and complex ventricular ectopy [4, 36, 41]. Since conventional treatment of ventricular tachycardia by means of antiarrhythmic drugs or indirect surgery have often been disappointing, new electrical and surgical modes of therapy, including catheter ablation [8, 18, 33], antitachycardia pacemakers [1, 6], automatic implantable defibrillators [23, 45], and endocardial surgery [14, 26, 32] have been introduced.

Of the variety of surgical techniques applied to isolate or ablate the arrhythmogenic area, localized endocardial resection has become the most commonly used approach. It was performed in 49% of all patients collected in the multicenter Surgical Ablative Registry [3], with 16% of the cases undergoing additional cryoablation. An alternative new therapeutic concept was realized in 1980, when Mirowski et al. [23] first inserted an automatic defibrillator in a human. During recent years, more than 2000 units have been implanted worldwide. In Europe, however, the supply of generators sometimes has been limited. None of these therapeutic modes can save or improve myocardial function in patients with terminal heart disease. Therefore, cardiac transplantation may offer an ultimate resort for such patients with untreatable, life-threatening ventricular arrhythmias [35].

Presently there are only a few teams experienced in all the therapeutic modalities mentioned. Therefore, criteria for patient selection may only be evaluated objectively if conservative therapy as well as the various surgical techniques can be offered at one center. The picture is further confused by the facts that these methods have evolved in succession (Fig. 1) and various underlying diseases had to be treated (Table 1).
Finally, systematic and comparable postoperative hemodynamic and electrophysiological studies are lacking. The aim of this study is to compare the various therapeutic alternatives applied in one center in an attempt to clarify which approach is the most effective, involves the lowest risk, and provides for the optimal quality of life in a given patient.

**Electrophysiologically directed surgery**

Endocardial incision according to Guiraudon [12] was performed on our first 14 patients, irrespective of left ventricular function. However, because of the considerable early mortality of 29%, this technique was abandoned and replaced by localized endocardial resection in the succeeding 72 patients. The early mortality decreased thereafter to 7%, which compares well with the results of the originators of this method [13, 15, 19, 21].

Actuarial survival of these 72 patients after endocardial resection was calculated at 82% after 1 year and 71% after 3 years. Similar results were reported by the multicenter Surgical Ablation Registry, with a 72% survival after 2 years and 57% after 5 years, which also showed the worst long-term results in patients with poor preoperative LVEF [3]. Ostermeyer et al. reported an actuarial survival of 89% after 1 year and 70% after 5 years in their population and demonstrated the extent of the underlying coronary heart disease to be the most important predictor of long-term survival [28]. Our data also show that preoperative left ventricular function was considerably impaired in all patients with ischemic heart disease, as demonstrated by a mean LVEF of 36% ± 11%.

The value of subendocardial resection is that it is a potentially curative procedure. This is emphasized by the fact that, in our series of 72 patients, only 4 suffered recurrences of spontaneous ventricular tachycardia. None of these patients died from VT, one could be reoperated successfully, and the others could be well controlled pharmacologically or by electrical stimulation. In the Surgical Ablation Registry, the overall recurrence was 16%, but no distinction was made among the different surgical methods [3]. Miller et al. reported an overall clinical relapse after endocardial resection in 11% despite the postoperative inducibility of VT by ventricular stimulation in 28% of the patients studied [22]. Postoperative electrophysiological stimulation as a predictor of the efficacy of electrophysiologically directed antiarrhythmic surgery is controversial [2, 19, 29, 31, 37, 40]. We rely mainly on clinical follow-up data and consider postoperative stimulation to be undesirable, at least shortly after the operation, because of an elevated myocardial irritability [17].

Our results demonstrate that electrophysiologically directed surgery offers a relatively safe and efficacious surgical option for patients with coronary artery disease, as long as they present with sufficient myocardial contractility. Since some myocardial damage, if only transient, is likely to be induced by the operation, we believe patients with a LVEF of more than 30% to be suitable candidates for direct antiarrhythmic surgery.

Despite a low perioperative mortality in our nonischemic group, the high percentage of recurrences in 5 out of 12 patients indicates that surgical ablation is no satisfactory approach for such patients. We consider patients with ventricular tachycardia in the presence of dysplastic or dilative cardiomyopathy to be candidates for primary AICD implantation or—in the presence of terminal heart failure—of cardiac transplantation.

**Automatic implantable defibrillator**

Although the optimal approach for application of the AICD electrodes is still debatable [5, 20, 25, 39, 42], we prefer a median sternotomy, which must be used in patients with concomitant open heart surgery. The indications for implantation of the automatic defibrillator (AICD) seem to be clear in a patient whose recurrent ventricular arrhythmia is not accessible to conventional pharmacological therapy or electrophysiologically directed surgery [24, 38]. In 25 of our 42 patients, ventricular fibrillation was the indication for primary AICD implantation; in 17 patients, it was ventricular tachycardia. Five patients suffered from nonischemic heart disease, whereas 12 with coronary heart disease were selected for this mode of treatment because the risk of endocardial resection was considered too high in view of poor left ventricular function, the LVEF in this group being less than 30% (20%–29%).

None of the 23 patients with simple AICD implantation in our series died early, demonstrating the minimal risk of this procedure [25, 30]. However, 1 of 10 patients who had had previous open heart surgery and 1 of 9 patients undergoing a concomitant open heart procedure died early. The mean LVEF was 21% and 25% and these patients had not been considered amen-
able to endocardial resection for fear of a further reduction of the remaining contractility by ventriculotomy. The actuarial 1-year survival of our 42 AICD patients was 83%. Four of the 8 late fatalities were not due to arrhythmias but to cardiac failure caused by the underlying heart disease. It should be mentioned that 2 patients died because the device was not readily available at the time it should have been replaced. This experience shows that patients with an implanted AICD require close out-patient monitoring to detect early device exhaustion. More than 50% of our patients have been saved by multiple shocks delivered by the device during follow-up (Table 3). Most of our patients, of course, feel discomfort at the moment of AICD discharge, but none of them complained of pain. Although the device causes considerable psychological stress [5, 30] in patients utterly dependent on AICD, all felt tremendous relief after its implantation. Our experience demonstrates AICD to be a most suitable method for treating patients not amenable to endocardial resection.

**Heart transplantation**

Ventricular tachycardia was the exclusive indication for heart transplantation in only 1 of our 15 patients. All others presented with VT or VF complicating surgically incorrectable cardiac disease, with 11 patients suffering from ischemic heart disease and 4 from nonischemic conditions. Five patients had deterioration of left ventricular function after previous antiarrhythmic intervention. In 3 patients with ischemic ventricular tachycardia, endocardial resection had been curative, but myocardial function subsequently deteriorated, so that heart transplantation was considered according to conventional indications. In two patients suffering from VT and VF in the presence of congestive obstructive cardiomyopathy and right ventricular dysplasia who were treated by AICD, heart transplantation was not discussed at the time of implantation. Further deterioration of ventricular function, however, made transplantation necessary after an interval of 2 years. These examples demonstrate that, in some cases, AICD may provide a useful bridging mode to transplantation. The 2 deaths occurring among the 15 patients with heart transplants due to VT associated with end-stage left ventricular failure compare well with the experience gained at the Hannover Medical School (184 transplantations in 176 patients). There were 20 early fatalities (10.8%), and the actuarial survival was 77% at 1 year and 76% at 2 years for the whole transplantation population (Fig. 5).

In conclusion, patients with end-stage ischemic heart disease and life-threatening cardiac arrhythmias are considered good candidates for transplantation to eliminate ventricular tachycardia and restore function of both ventricles, especially in younger patients when progression of their underlying disease can be anticipated. The question arises whether these patients should have had heart transplantation earlier or if directed antiarrhythmic surgery and AICD should have preceded transplantation. In view of the donor problem, we presently feel that every effort to treat ventricular tachycardia by other means should be undertaken first in order to gain time.

**Conclusion**

The prerequisite for any curative treatment of ventricular tachycardia is the localization of the morphological substrate by pre- and intraoperative electrophysiological mapping. Endocardial resection is a curative operation in patients with ventricular tachycardia related to ischemic heart disease and can be performed with a low operative risk and a low incidence of recurrence. Survival after surgery is determined by the progression of the underlying coronary disease. The limits of electrophysiologically directed surgery are closely related to left ventricular function. Early and late survival is similar to that achieved by left ventricular aneurysmectomy. Alternative modes of treatment, such as the
implanted defibrillator or heart transplantation, may be considered, especially in patients with either diffuse hypokinesia of the left ventricle or those with aneurysms and poor function of the remaining myocardium.

In the group with nonischemic heart disease, no curative surgical method exists. The operative risk of ventriculotomy in combination with cryosurgery is low, but we experienced a high incidence of recurrence. Therefore, for this group of patients alternative methods, such as the implantable defibrillator or heart transplantation, have to be considered early. Implantation of AICD is a palliative, alternative procedure for patients with poor left ventricular function, no electrophysiological substrate, or multimorphological VT and should also be considered when contraindications to heart transplantation exist in patients with end-stage left ventricular function. Furthermore, an AICD may be inserted to gain time when heart transplantation is not immediately possible. The AICD improves survival remarkably in patients considered at high risk for sudden cardiac death who are refractory to all other therapeutic approaches.

The indications and contraindications for heart transplantation in patients with ventricular tachycardia do not differ from the average transplant population. Ventricular tachycardia in nonischemic heart diseases patients with dilative cardiomyopathy and with ventricular dysplasia, however, have to be distinguished. In young patients with dilative cardiomyopathy and progressive deterioration of left ventricular function, heart transplantation may be considered early, and AICD implantation can only be regarded as a bridging therapy, since transplantation ultimately becomes inevitable. Since the clinical course of patients with ventricular dysplasias remains unclear, their optimal therapeutic mode must be individualized. Presently, we regard treatment by AICD as the definitive form in cases with sufficient left ventricular function and heart transplantation only as the ultimate resort in a severely failing heart. A longer follow-up of survival and of the life quality attained is necessary for the definitive evaluation of current indications and strategy in the treatment of ventricular tachycardia.

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## Discussion

**Gerard M. Guiraudon, M.D., London, Ontario, Canada**

Dr. Frank is to be commended for his very informative presentation, which summarizes the experience of one of the leading teams in this field. More than 1500 patients have received an automatic implantable defibrillator. Worldwide experience shows that the life expectancy of patients with pharmacologically refractory, life-threatening ventricular arrhythmia has been dramatically improved. The advent of an efficient, reliable implantable defibrillator and the progress in cardiac transplantation have introduced a new trend in intervention for ventricular arrhythmias. We reviewed the therapy given to the last hundred consecutive patients referred to our institution for malignant ventricular arrhythmias. Twenty-two patients had an automatic implantable defibrillator (AICD) implanted. Nineteen had an AICD (CPI) and 3, a pacemaker cardioverter defibrillator (PCD Medtronic). Six patients had map-guided, direct surgery using encircling endocardial cryoablation. Four patients had map-guided, direct surgery using encircling endocardial cryoablation. Sixty-eight patients were discharged on drug therapy. No patient had direct surgery combined with defibrillator implantation. The Hannover experience shows an identical trend toward less map-guided surgery, more implantation of automatic defibrillators, and better selection of drugs. I wish to ask Dr. Frank two questions. One, what is his policy regarding catheter ablation? Two, what are his current indications for map-guided surgery? We tend to reserve direct surgery for patients with low risk and anatomy that suggests good efficacy.

**Juro Wada, M.D., Tokyo, Japan**

Thank you, Mr. President, for the privilege of being on the podium. As the first Asian heart transplant surgeon, I congratulate the Hannover group for opening up new indications for heart transplantation. I would like to know your definition of malignancy in arrhythmia, the underlying diseases you encountered, and your criteria or indications for heart transplantation.

**Günter Frank, M.D., Hannover, FRG**

I want to thank Dr. Guiraudon and Dr. Wada for their kind remarks. Dr. Guiraudon underscored the importance of the implantable defibrillator (AICD), which has changed our indications for surgery for ventricular tachycardia (VT) in the past. In our experience, implantation of the AICD via sternotomy has involved low risk and morbidity, but we also hope for the development of new nonsurgical devices. We, too, feel that a routine combination of surgical ablation and AICD implantation is not logical. With regard to catheter ablation, we had success in 20 of 42 patients; 17 patients had to be operated, and 3 received an AICD after ablation. Our indication for endocardial resection is the monomorphic, sustained and drug-resistant VT related to ischemic heart disease. In the last series of 30 patients, there was no failure and only one early death due to postoperatively low output. Dr. Wada, the underlying disease of the patients who underwent heart transplantation for VT was ischemic cardiomyopathy in 11 patients, dilative cardiomyopathy in 3, and biventricular dysplasia in 1 patient. All patients presented with life-threatening, sustained and multiple drug resistant VT in combination with end-stage ventricular function (ejection fraction: 16% ± 7%). Seven of them had been successfully resuscitated. In closing, various surgical concepts are available at present; the decision of the most suitable mode has to be made individually for each patient, and a longer follow-up is necessary for definitive evaluation of our current indications.