Surgical Management of Life-threatening Arrhythmias

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Map-guided direct surgery was performed in 408 patients with various tachyarrhythmias at our institution. Of 355 patients with WPW syndrome, 5 had experienced an episode of ventricular fibrillation (Vf), 180 had atrial fibrillation with a rapid ventricular response, and 76 had other heart diseases. These patients were regarded as being at risk for sudden death. The shortest R-R interval between pre-excitation (215 ± 38 msec) was significantly shorter than the antegrade effective refractory period (270 ± 35 msec) of accessory pathway (ACP) in 126 patients ($p < 0.001$). The shortest R-R interval of the patients with Vf was 200 msec or less. The ACP was successfully interrupted in 334 patients (94%). Simultaneous operations were carried out for other types of heart disease in 58 patients. Surgery was performed in 43 patients with ventricular tachycardia (VT), 39 non-ischemic and 4 ischemic, who were unresponsive to conventional antiarrhythmic therapy. Three patients with non-ischemic VT required emergency operation. The principle of surgery for non-ischemic was excision plus cryocoagulation of right ventricle and incision plus cryocoagulation of left ventricle. Thirty non-ischemic patients (76.9%) were cured of VT, while 7 still take medication prophylactically (3 for sporadic premature beats, and 4 for VT). All 4 patients with ischemic VT were also treated successfully. In conclusion, our results demonstrate the therapeutic value of map-guided direct surgery for life-threatening arrhythmias

MAP-GUIDED direct surgery for tachyarrhythmias was pioneered by Sealy et al¹ in 1969 when he interrupted the accessory pathway (ACP) in a patient with syndrome via an epicardial incision. Subsequently, Iwa et al² succeeded in performing radical correction of WPW syndrome via an endocardial incision. Since then map-guided direct surgery has been used to treat not only WPW syndrome but also other kinds of tachyarrhythmias. Between November 1973 and March 1989, a total of 408 patients with various tachyarrhythmias underwent

map-guided direct surgery at our institution. They included 355 patients with WPW syndrome, 43 with ventricular tachycardia (VT), 4 with ectopic atrial tachycardia, 2 with reentrant atrial tachycardia, 2 with atrial flutter, 1 with atrial flutter-fibrillation, 1 with A-V nodal reentrant tachycardia. In this report, we assess the clinical value of surgery in the management of such potentially life-threatening arrhythmias.

1. WPW Syndrome

1) Clinical material

The 355 patients (254 men and 101 women) came from throughout Japan and 3 patients were from abroad. The age distribution was from 5 months to 74 years, with a mean age of 37.4 years. The major indications for surgery were atrial fibrilla-

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Fig.1. Comparison of antegrade effective refractory period (ERP) of the accessory pathway (ACP) and the shortest R-R interval during atrial fibrillation (af) in 126 patients. The difference in time was significant ($p<0.001$). Double circle = 5 patients with ventricular fibrillation (Vf).

tion (af) with a rapid ventricular response or ventricular fibrillation (Vf) in 123 patients, a short antegrade effective refractory period (ERP) of the ACP in 68, a poor response to medication in 67, the severity of condition in 36, combined heart disease in 28, a poor hemodynamic state during tachycardia in 26, and long duration of medical therapy in 7. Of these indications, Vf, af with a rapid ventricular response, short antegrade ERP of the ACP and combined

heart disease were regarded as potentially life-threatening.

2) Atrial fibrillation with a rapid ventricular response

Atrial fibrillation with a rapid ventricular response was noted in 180 patients (50.7%). Electrophysiological data, including the antegrade ERP of the ACP and the shortest R-R interval between pre-excited beats during af, could be obtained and compared in 126 patients (Fig. 1). The antegrade ERP of the ACP was 270 ± 35 msec (mean $\pm$ S.D.). The shortest R-R interval was 215 ± 38 msec. The shortest R-R interval was significantly shorter than the antegrade ERP of the ACP ($p<0.001$).

3) Ventricular fibrillation

Among the 355 patients operated on for WPW syndrome, Vf was documented by electrocardiogram in 5 patients. The clinical and electrophysiological data of these patients are shown in Table I. Four of the 5 were young adults. It is noteworthy that 2 patients, who belonged to the asymptomatic group without any follow-up by a cardiologist, had Vf as their first episode of tachycardia. In 3 patients Vf developed during strenuous exercise, such as swimming, long-distance running, or baseball training. In 3 patients two different ACPs were identified. An antegrade ERP could be measured for 7 of the 8 ACPs. The shortest R-R interval between pre-excited beats during af in this group was 200 msec or less. Ebstein's anomaly was detected during surgery in 2 of these patients.

4) Combined heart disease

Other types of heart disease were present in 76 patients (21.4%); 53 had congenital and 22 had acquired diseases, while one had the combination of annuloaortic ectasia with Ebstein's anomaly (Table II). In the present series of 53 patients with congenital heart disease, 37 had Ebstein's anomaly, of whom 30 had single and the other 7 had multiple ACPs. Simultaneous operations on other lesions were carried out in 58 patients at the time of interruption of the ACP.

5) Intraoperative mapping

After the introduction of a simple catheter electrode epicardial mapping method we could rapidly identify the earliest pre-excitation site at the atrioventricular groove.

6) Surgical method

TABLE I CLINICAL AND ELECTROPHYSIOLOGICAL CHARACTERISTICS OF 5 PATIENTS WHO DEVELOPED VENTRICULAR FIBRILLATION

No.	age/sex (yrs)	tachy. episode	ant. ERP of ACP (msec)	shortest RR during af (msec)	combined disease
1	18y m	(+)	250(L)+?(R)	200	
*2	30y m	(-)	280(R)+255(L)	200	Ebstein
*3	29y m	(-)	under 280(R)	195	Ebstein
*4	19y m	(+)	280(R)+275(L)	160	
*5	50y m	(+)	under 280(L)	160	

Tachy.=tachycardia, Ant. ERP=antegrade effective refractory period * = developed on exercise
 ACP =accessory pathway, m=male, af=atrial fibrillation, L=left, R=right, Ebstein=Ebstein's anomaly

TABLE II COMBINED HEART DISEASE AND SIMULTANEOUS OPERATION

Congenital	No. of pts.	No. of ops.
<i>Ebstein's anomaly</i>	37	31
<i>Anterior tricuspid annular dysplasia</i>	10	10
<i>Tricuspid atresia</i>	2	2
<i>ASD</i>	1	1
<i>Endocardial cushion defect</i>	1	1
<i>VSD + PDA + mitral regurgitation</i>	1	1
<i>Corrected TGA + PS</i>	1	1
<i>Left SVC</i>	1	0
<i>Total</i>	54	47
<i>Acquired</i>		
<i>Angina pectoris</i>	8	2
<i>Cardiomyopathy</i>	5	0
<i>Mitral stenosis</i>	3	3
<i>Mitral regurgitation</i>	1	1
<i>Aortic stenosis</i>	1	1
<i>Tricuspid regurgitation</i>	1	1
<i>Combined valvular disease</i>	3	3
<i>Annuloaortic ectasia (+Ebstein's anomaly)</i>	1	1
<i>Total</i>	23	12

We have used the same endocardial supraannular atrial incision technique since 1969⁴. In the left cardiac type, interruption was performed under cardiopulmonary bypass with mild hypothermia, cardioplegia, and aortic cross-clamping. In the right cardiac and septal types, interruption was performed under cardiopulmonary bypass with the heart beating. Success could thus be confirmed by disappearance of the delta

waves on the electrocardiogram monitor. Because the normal conduction system is located very near to the ACP, particular care was taken not to create permanent atrioventricular block during interruption of a septal ACP. Since 1982 cryocoagulation has often been employed as an adjunctive procedure to ensure complete ablation⁵.

7) Surgical results

The ACP was successfully interrupted in

TABLE III SURGICAL PROCEDURES FOR NON-ISCHEMIC VT

<i>Procedure</i>	<i>Right ventricle</i>	<i>Left ventricle</i>	<i>Total</i>
<i>Excision + Cryocoagulation</i>	20	3	23
<i>Excision</i>	3	0	3
<i>Incision + Cryocoagulation</i>	2	8	10
<i>Aneurysmectomy + Cryocoagulation</i>	0	2	2
<i>Removal of Tumor</i>	0	1	1
<i>Total</i>	25	14	39

334 out of 355 patients (94%). Of these patients, 323 were completely cured with both normalization of the electrocardiogram and the absence of retrograde conduction postoperatively. These patients no longer required antiarrhythmic drugs, although digitalis was administered for short periods to those who developed atrial fibrillation. After successful interruption of the ACP, 11 patients died from 1 to 22 days postoperatively. Death was due to complications related to other cardiac disease in all cases except one. The ACP was missed in 21 patients; the delta wave reappeared in 17 patients and concealed conduction in 4. However, only in one patient with concealed conduction is tachycardia still a problem, occurring a few times a year. Ten patients have not experienced tachycardia at all, and the other ten had only a few postoperative episodes of tachycardia and no further episodes during a long follow-up period. Therefore, these 20 patients are regarded as being symptomatically cured. None of these 355 patients underwent intentional surgical interruption of the bundle of His. In 13 patients (3.6%), A-V block appeared simultaneously with ACP interruption. The patients required pacemaker implantation, 7 with complete A-V block and 3 with 2nd degree block.

2. Ventricular tachycardia

1) Clinical material

A total of 43 patients with VT, refractory to medical therapy, underwent map-guided

surgery. These patients were classified into two groups: 39 were non-ischemic and 4 were ischemic. The 39 patients with non-ischemic VT (31 men and 8 women) were referred from all over Japan by their cardiologists. The age distribution was from 9 to 66 years, with a mean age of 32.5 years. Their diagnosis at referred hospital was idiopathic VT. According to our histopathological examination of 26 specimens taken from the sites of origin of tachycardia, 17 patients had myocarditis, 6 had arrhythmogenic right ventricular dysplasia (ARVD), 2 had suspected ARVD, and 1 had cardiac fibroma. Emergency surgery was performed in 3 patients for life-threatening non-ischemic VT. These patients were transferred from other university hospitals by airplane or helicopter. The remaining 4 patients (3 men and 1 woman) with ischemic VT had a history of myocardial infarction, and 3 of them also had left ventricular aneurysm. The age distribution was from 42 to 65 years, with a mean age of 54.3 years.

2) Intraoperative mapping

Since 1983, a new automatic activation mapping system using a 15-channel bipolar mat electrode had been employed.⁶

3) Surgical methods

For non-ischemic VT various surgical procedures were performed under cardiopulmonary bypass: excision, simple incision, cryocoagulation, aneurysmectomy, resection of tumor, and a combination of these above. Table III shows the sites of origin of

VT and the surgical procedures employed in the 39 non-ischemic patients. The principle of surgery for non-ischemic VT was to excise the entire thickness of the myocardium in operations on the right ventricle or perform simple incision of the left ventricle, and then to cryocoagulate sites of early excitation or delayed potential in either ventricle. For ischemic VT we performed scarctomy in 1 patient, aneurysmectomy and cryocoagulation in 2, and aneurysmectomy, cryocoagulation and endocardial resection in 1. Aortocoronary bypass was also undertaken in 2 patients.

4) Surgical results

In 30 of the 39 non-ischemic patients (76.9%), VT was cured completely and they returned to normal life without needing any antiarrhythmic drugs. Two patients died during long-term follow-up due to progression of congestive cardiac failure; one with ARVD died after 2 years and 3 months, while the other with dilated cardiomyopathy died 1 year and 5 months after surgery. In 7 patients (17.9%) antiarrhythmic therapy was continued after surgery. In 3 patients it was for sporadic premature beats, and in 4 patients for persistent VT. In this group one patient died 2 years after surgery due to congestive cardiac failure caused by dilated cardiomyopathy. Two patients (5.1%) died due to recurrence of VT. One with ARVD died during the first attack of tachycardia which occurred 5 months after surgery, and the other died one week after surgery. All the patients with ischemic VT became free from tachycardia after surgery. One patient died 6 years after operation from recurrent acute myocardial infarction and another died of pneumonia 2 months after surgery.

DISCUSSION

The prognosis of WPW syndrome was considered to be good until sudden deaths were reported.⁷ Kaplan et al⁸ discovered patients who developed Vf during their clinical course and suggested that WPW syndrome could sometimes be fatal. As the mechanism of sudden death in this syndrome, Dreifus et al⁹ speculated that atrial impulses descend via the ACP with a short antegrade ERP during af, resulting in the

development of Vf. Since then, many patients with WPW syndrome have been reported who developed Vf.

Atrial fibrillation was found in 11.5-39% of the cases corrected by Gallagher et al¹⁰ and in 50.7% of the patients in our series. In patients at risk of Vf (high-risk group), the shortest R-R interval between pre-excitation beats during af has been considered to be important. All patients who developed Vf in the report by Klein et al¹¹ had a shortest R-R interval of 250 msec or less. In our 5 patients, the R-R interval was 200 msec or less, shorter than in Klein's case. Of course, to determine the high-risk group, measurement of the antegrade ERP of the ACP is also important.

It is also clear the shortest R-R interval during af is often even shorter than the antegrade ERP of the ACP. Patients showing the shortest R-R interval of 200 msec or less during af are regarded as a high-risk group who require surgical interruption of the ACP. In 2 patients of our series, Vf developed as the initial attack. Neither patient was receiving medical management because there was no history of reentrant tachycardia or af. The fact that such asymptomatic patients developed Vf is very important. To determine the prognosis of WPW syndrome, even asymptomatic patients should be examined electro-physiologically, and the antegrade ERP of the ACP and the shortest R-R interval during af should be determined.

With stabilization of the surgical results, the indications for interruption of the ACP have been extended to patients with combined heart disease¹² and multiple accessory pathways.¹³ To clarify the cause of sudden death in patients with WPW syndrome complicated by Ebstein's anomaly, Rossi et al¹⁴ histopathologically evaluated 3 such patients at autopsy. He found only mild Ebstein's lesions that may not have affected hemodynamics and suggested that the case of sudden death was tachyarrhythmia via the ACP. Electrophysiological examination of our 37 patients with Ebstein's anomaly revealed a high incidence of af, shortening of the antegrade ERP of the ACP, multiple ACPs. Therefore, we emphasize the necessity of simultaneous operation for WPW syndrome complicated by Ebstein's

anomaly!⁵ In other types of combined heart disease such as tricuspid atresia¹⁶ and valvular disease,¹⁷ tachycardia causes marked deterioration of the hemodynamics. Moreover, the frequency of af increases with age because of the presence of atrial overload. Some problems are encountered in the medical treatment of both WPW syndrome and heart disease. The main problems are: 1) The use of digitalis for congestive heart failure increases the risk of Vf by shortening the antegrade ERP of the ACP. 2) Various antiarrhythmic drugs used for the management of tachycardia can worsen heart failure because of their negative inotropic effects. Simultaneous surgical treatment of both conditions provides a solution. Simultaneous operation tends to be avoided in patients with complications for fear that prolongation of the operating time will increase the risk of surgery. However our study has shown that surgical interruption of the ACP can be successfully performed in patients with combined heart disease. Reports of such simultaneous operations in a series of patients are scarce, with only those by Gallagher et al¹⁸ being available besides ours. We hope that simultaneous surgery for WPW syndrome and other complicating heart conditions will be performed more extensively in the future.

In many instances, ischemic VT is a life-threatening arrhythmia and the administration of antiarrhythmic drugs is not always effective in its control. The reentrant circuit responsible for refractory VT has been shown to occur in the border zone between the fibrosis associated with infarction or an aneurysm and the surrounding normal myocardium. Two map-guided surgical procedures, encircling endocardial ventriculotomy and endocardial resection, have been reported for achieving ablation or isolation of the reentrant circuit. We used endocardial cryocoagulation as both a primary procedure and as an adjunctive measure to be employed with aneurysmectomy. In general, non-ischemic chronic sustained VT has been regarded as having a good prognosis. However, there are some cases in which neither antiarrhythmic drugs, pacing therapy, nor direct counter-shock can control the tachycardia. In such cases, even with non-ischemic VT, tachycardia become life-

threatening and surgery is indicated. In 1974, Fontaine et al¹⁹ reported 3 successful cases of surgery for right ventricular non-ischemic VT based on electrophysiological investigation. They used simple ventriculotomy. In 1978, Gallagher et al²⁰ applied cryocoagulation to the earliest site of occurrence of VT. In 1980, we performed a combination of excision and cryocoagulation for VT arising in the right ventricular outflow tract due to focal myocarditis.²¹ We resected the entire thickness of myocardium at the earliest site and cryocoagulated the region surrounding the resection, leading to complete cure. Since then, our surgical approach has been excision and cryocoagulation for that of right ventricular origin and incision and cryocoagulation for that of left ventricular origin.²² Resection and cryocoagulation of the right ventricular outflow tract was performed in 19 patients, and is particularly useful for ablation of VT without impairing ventricular function. Our treatment for VT of left ventricular origin also prevents narrowing of the ventricular lumen and impairment of cardiac contraction.

Successful surgery for VT requires accurate localization of the areas to be treated using electrophysiological mapping. Surgical therapy for VT has been restricted to the reentrant type which could be induced and terminated reproducibly by electrical stimulation. Difficulties arise in surgical management when tachycardia cannot be induced, when tachycardia is not mappable by the conventional hand-held electrode technique, and when different morphologies are present. Furthermore, epicardial mapping during VT must be completed in a short time because of hemodynamic problems. Both fragmentation mapping in sinus rhythm and pace mapping are safer methods to determine the areas to be operated on than activation mapping during VT. Although they are in use clinically, they give only indirect data. The most striking advantage of our epicardial mapping system is the recording of electrical activity via a 15-channel mat electrode. This shortens the intraoperative mapping time significantly and enables a complete analysis of short episodes on nonsustained VT, and even of ventricular premature beats. Use of this

mapping system together with test anesthesia and more precise preoperative endocardial catheter mapping also allows the use of surgery for non-inducible VT²². Our experience with map-guided surgery for non-ischemic VT shows that it can be efficient and carried out at a low risk. All our patients who died perioperatively or in long-term follow up after surgery had severe preoperative left ventricular dysfunction. Therefore, in patients with ARVD, left ventricular aneurysm, or dilated cardiomyopathy, great care in selecting the operative method is important. When appropriate surgical techniques are used for life-threatening arrhythmias, excellent results can be expected even in these patients.

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