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Outcome of endocardial resection in 33 patients with coronary artery disease: Correlation with ventricular tachycardia morphology

The results in 33 patients with ventricular tachycardia (VT) treated by endocardial resection were reviewed, with special emphasis on the presence of single or multiple morphologies preoperatively and intraoperatively. Multiple VT morphologies were induced in 16 patients and a single VT morphology was induced in the remaining 17. Intraoperative programmed stimulation failed to induce VT in eight patients and visually-directed endocardial resection was performed. The remaining patients underwent map-guided resection. The surgical success rate did not correlate with any morphologic characteristics of the VT, such as bundle branch block pattern or axis. In addition, concordance of VT morphologies preoperatively and intraoperatively before resection did not correlate with the surgical success rate. However, patients in whom multiple morphologies of VT were induced intraoperatively had a significantly higher success rate (100%) compared with those patients in whom only a single morphology was induced intraoperatively (50%, $p < 0.05$). Long-term follow-up was maintained in 26 patients. Ventricular tachycardia recurred in two patients and VF recurred in two others who did not have inducible VT 1 week after endocardial resection. In conclusion, neither the preoperative morphologic characteristics of VT nor discordance between the morphologies of VT induced preoperatively and in the operating room influenced the outcome of endocardial resection. However, the surgical success rate is higher when multiple morphologies of VT are inducible in the operating room than when only one VT morphology is inducible. (AM HEART J 1992;124:1500.)

Mark J. Niebauer, MD, Marvin Kirsh, MD, Alan Kadish, MD, Hugh Calkins, MD, and Fred Morady, MD *Ann Arbor, Mich.*

From the Division of Cardiology, Department of Internal Medicine and Division of Thoracic Surgery, Department of General Surgery, University of Michigan Medical Center.

Received for publication May 15, 1992; accepted July 15, 1992.

Reprint requests: Fred Morady, MD, University of Michigan Medical Center, 1500 East Medical Center Drive, B1 F245, Ann Arbor, MI 48109-0022.

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Surgical treatment of intractable ventricular tachycardia (VT) has been performed, with various modifications in technique, since 1959.[1] One approach involves endocardial resection (ER) guided by intraoperative mapping.[2, 3] The presence of multiple morphologic forms of VT has been associated with inefficacy of ER.[4] However, the concordance between the preoperative and intraoperative VT morphologies to date has not been examined in detail. In this retrospective study, the results of ER in 33 patients are reported, with particular attention to the preoperative and intraoperative morphologies of VT induced by programmed stimulation.

METHODS

Patient characteristics. Thirty-three patients (26 men and 7 women) underwent ER between 1984 and 1990 at the University of Michigan and Ann Arbor Veterans Administration Medical Centers. The patients ranged in age from 28 to 74 years (mean ± standard deviation, 58 ± 12) at the time of surgery. Each patient had coronary artery disease and a history of myocardial infarction, and was referred for management of sustained monomorphic VT refractory to pharmacologic therapy with a mean of 2.5 ± 1.2 antiarrhythmic agents. The mean left ventricular ejection fraction as determined by contrast ventriculography was 0.30 ± 0.11. Each patient had angiographic evidence of an anterior, apical, or inferior wall aneurysm.

Electrophysiologic testing. Electrophysiology tests were performed at least 5 half-lives after antiarrhythmic drug therapy was discontinued and after informed consent was obtained. Each patient underwent programmed ventricular stimulation 1 to 7 days preoperatively, intraoperatively, and 1 week postoperatively. During the preoperative and postoperative electrophysiology tests, three 6F quadripolar electrode catheters were inserted into a femoral vein and were positioned in the right atrium, His bundle position, and right ventricle. For VT mapping in the left ventricle, a 6F quadripolar electrode catheter was inserted into a femoral or brachial artery and was passed retrogradely across the aortic valve into the left ventricle. Leads V_1, I, III, and the intracardiac electrograms were recorded at a paper speed of 100 mm/sec on a Siemens-Elema Mingograf-7 recorder (Siemens Medical Instrumentation, Inc., Iselin, N.J.). Programmed stimulation was performed with a programmable stimulator (Bloom Associates, Ltd., Reading, Pa.) using stimuli 2 msec in duration and at least twice the diastolic threshold. To induce VT, one to three ventricular extrastimuli were delivered following eight-beat basic drive trains at cycle lengths of 400 to 600 msec, first at the right ventricular apex, then at the outflow tract or septum. Unless the VT required immediate termination, a 12-lead electrocardiogram was recorded. In some cases, more than one morphology of VT was induced in a given patient. Sustained VT was defined as VT lasting longer than 30 seconds and nonsustained VT was defined as VT lasting from 6 to 30 seconds. Whenever possible, the site of origin of the VT was localized by endocardial activation mapping or pace mapping.

Intraoperative mapping and ER. Each patient was taken to the operating room and was anesthetized with fentanyl before the intraoperative testing. Programmed stimulation was performed after initiation of cardiopulmonary bypass and after ventriculotomy, with the same stimulation protocol used during preoperative testing. When induced, VT was characterized according to its morphology. The patient underwent endocardial activation mapping using a hand-held electrode, and then underwent resection of the reentrant circuit by previously described means.[5] A cryogenic probe was used in seven patients, alone or as an adjunct to surgical resection, because of the location of the mapped focus or endocardial scar. Once the focus was resected or ablated, programmed stimulation was repeated in an attempt to reinduce VT. This process was repeated until VT was not inducible, or until mapping was no longer possible. When VT was not inducible intraoperatively, a visually-directed ER, in which all identifiable endocardial scar tissue is resected, was performed.[6] Five patients also underwent coronary artery bypass grafting after ER.

Postoperative testing. Programmed ventricular stimulation was performed in each patient 7 days after the operation, using the same stimulation protocol used in the preoperative test. If VT was induced, it was characterized according to its morphology and cycle length.

Long-term follow-up. Long-term follow-up was maintained in 26 of the 28 patients discharged after the postoperative electrophysiologic (EP) study. Information regarding the patient's health status and details of his or her medical treatment was obtained from either the referring physicians, by review of the patient's medical record, or by direct contact with the patient or his or her immediate family.

Analysis of data. Data were compared using the chi square test or the Student's paired t test. A p value <0.05 level was considered statistically significant.

RESULTS

Short-term results of surgery. Five of the 33 patients (15%) died within 1 week of surgery of either sepsis, pneumonia, or shock caused by severe left ventricular dysfunction. These five patients did not survive to undergo the postoperative EP test, and therefore the short-term surgical results could not be determined. The remaining 28 patients underwent a postoperative EP test, and VT could not be induced in 24 (86%).

Morphologic characteristics of induced VT. Sustained monomorphic VT was inducible in each of the 33 patients preoperatively, but in only 22 of the 33 patients (67%) intraoperatively ($p < 0.05$). The morphologies of VT induced by programmed stimulation preoperatively, intraoperatively, and postoperatively are described in Table I.

Among the 28 patients who survived the operation, VT induced during the preoperative EP test had a right bundle branch block configuration in 22 patients and a left bundle branch block configuration in 18 patients. The number of VTs exceeds the number of patients because more than one morphology of VT could be induced in 16 patients.

Table I. Morphologies of ventricular tachycardia induced preoperatively, intraoperatively, and postoperatively

Patient No.	*Preop*	*Intraop before SER*	*Intraop after SER*	*Postop*
1	LBSA	LBSA	None	None
	LBIA	RBIA		
	RBIA			
2	LBSA	LBSA	LBSA	ND
		RBIA		
3	RBSA	RBIA	None	None
		LBSA		
		IND		
4	RBSA	RBSA	None	None
		LBSA		
5	RBIA	None	None	None
	LBSA			
6	RBIA	RBIA	None	None
	RBSA	LBSA		
7	LBSA	None	None	None
	RBSA			
8	LBSA	LBSA	None	None
	RBIA	RBIA		
9	RBIA	LBSA	LBIA	None
10	RBSA	RBSA	None	ND
	LBSA	RBIA		
11	RBSA	RBSA	RBSA	RBSA
12	IND	None	None	None
13	LBSA	None	None	None
	RBIA			
	LBIA			
14	LBIA	None	None	None
15	RBSA	LBSA	None	None
16	LBSA	None	None	LBSA
17	LBSA	LBSA	None	None
		RBIA		
18	RBSA	RBIA	None	None
		LBSA		
		LBIA		
19	RBSA	RBSA	None	None
		LBIA		
20	LBSA	None	None	None
	RBSA			
21	RBSA	UNK	LBSA	LBSA
22	RBSA	None	None	None
	RBSA			
	RBIA			
23	RBSA	RBSA	None	None
	RBIA	RBIA		
	LBSA	LBSA		
24	RBIA	RBSA	None	None
	LBSA	LBIA		
25	RBSA	UNK	UNK	ND
26	LBSA	UNK	None	None
	RBIA			
27	LBSA	RBSA	None	None
		IND		
28	LBSA	LBSA	RBIA	None
29	LBSA	IND	None	LBSA
	RBSA			
30	UNK	RBIA	IND	ND
31	LBSA	LBSA	None	None
	RBIA	RBSA		
32	RBIA	RB?A	None	ND

Table I. —*Continued*

Patient No.	Preop	Intraop before SER	Intraop after SER	Postop
	RBSA			
33	RBIA	IND	None	None
	LBIA	IND		
	LBSA	IND		

LB/RB, Left/right bundle branch morphology; *SA/IA*, superior/inferior axis; *UNK*, unknown; *None*, no inducible VT; *IND*, indeterminate morphology; *ND*, not determined because of perioperative death before postoperative electrophysiology test; *SER*, subendocardial resection.

Table II. Morphology of ventricular tachycardia and outcome of surgery

	Bundle branch block		Axis	
Number of VT forms*	Right	Left	Superior	Inferior
Preoperative	22	18	26	13
Successful outcome	15 (68%)	13 (72%)	19 (73%)	10 (77%) N.S.
Intra-Op A	14	14	17	10
Successful outcome	12 (86%)	13 (93%)	15 (88%)	10 (100%)N.S.

Intra-Op A, Intraoperative preresection.
*Sum of morphologies exceeds patient numbers because some patients had more than one VT morphology.

Concordance between preoperative and intraoperative VT morphologies was defined as the presence of at least one VT morphology that was identical during the preoperative and intraoperative EP tests. Concordance was present in 12 of 28 patients (43%). Among these patients, the mean cycle lengths of the VTs induced during the two tests were not significantly different (337 ± 81 msec versus 297 ± 75 msec, respectively).

Correlation between VT morphology and surgical result. Neither the morphology nor the axis of the VT induced either preoperatively or intraoperatively was associated with a successful outcome of endocardial resection (Table II). The presence of concordance between the VTs induced preoperatively and intraoperatively also did not correlate with the surgical results. VT was no longer inducible 1 week postoperatively in 10 of 11 patients (91%) who had identical preoperative and intraoperative VT morphologies, compared with five of five patients (100%) who had different morphologies preoperatively and intraoperatively ($p > 0.05$).

The presence of multiple VT morphologies induced intraoperatively was associated with a successful outcome of endocardial resection. The outcome was successful in 100% of the 13 patients in whom more than one VT morphology was induced in the operating room, as compared with three of six (50%) patients who exhibited a single VT morphology intraoperatively ($p < 0.05$).

Map-guided versus visually-directed endocardial resection. Among the 28 patients who survived the operation, the 20 patients in whom VT could be induced intraoperatively underwent map-guided endocardial resection and the other eight patients underwent a visually-directed resection. A similar percentage of these two groups (85% and 88%, respectively) did not have inducible VT 1 week after the operation ($p > 0.05$).

VT morphologies in patients with inducible VT postoperatively. Among the four patients in whom sustained monomorphic VT was inducible 1 week after surgery, the VT morphology was the same as the preoperative VT morphology in three patients and was different in the other patient.

Long-term results. Complete follow-up information was obtained in 26 of the 28 patients who underwent preoperative, intraoperative, and postoperative electrophysiologic testing (Table III). Two of the four patients who still had inducible VT 1 week after surgery were treated with quinidine, while the others received an implantable cardioverter-defibrillator (ICD). During a mean of 49.5 months of follow-up, the two patients treated with quinidine have not had symptomatic VT and one of the patients who underwent implantation of the ICD has experienced discharges from the device and encainide was therefore added to her therapy. She is otherwise without complaints. The other patient who received an ICD died suddenly 3 months later.

Among 24 patients who did not have inducible VT 1 week postoperatively, 14 have remained asymp-

Table III. Long-term patient follow-up

Patient No.	Follow-up (mo)	VT	Treatment	Status
1	30	None		Alive
2	0	—		Died, postop
3	—	Unknown		Unknown
4	24	None		Alive, Txp
5	60	RBSA	Amiodarone + Mexilitene	Alive
6	24	None		Alive, Txp
7	24	None		Alive
8	48	None		Alive
9	24	None		Alive
10	0	—		Died, postop
11	84	RBSA	Quinidine	Alive
12	41	None		Alive
13	24	None		Alive
14	7	None		Died, VF
15	74	None		Alive
16	51	LBSA	ICD	Alive
17	—	Unknown		Unknown
18	18	None		Died, VF
19	1	None		Died, CHF
20	22	LBIA	ICD, Encainide	Alive
21	3	LBSA	ICD	Died
22	24	None		Alive
23	39	None		Alive
24	8	None		Died, MI
25	0	—		Died, postop
26	57	None		Alive
27	36	None		Died, CHF
28	18	None		Alive
29	60	LBSA	Quinidine	Alive
30	0	—		Died, postop
31	33	None		Alive
32	0	—		Died, postop
33	6	None		Died, septicemia

ICD, Implantable cardioverter-defibrillator; *CHF*, congestive heart failure; *MI*, myocardial infarction; *VF*, ventricular fibrillation; *Txp*, heart transplant; other abbreviations as in Table I.

tomatic and are currently not receiving antiarrhythmic therapy after a mean of 34.6 months. Two of these patients have received heart transplantation 1 and 2 years after ER for end-stage ischemic cardiomyopathy.

Two patients who did not have inducible VT postoperatively experienced episodes of sustained VT during follow-up. In each case, the VT morphology was different from that in the preoperative or intraoperative EP tests. One of these patients received an ICD and the other has been successfully treated with amiodarone and mexiletene. Six patients who did not have inducible VT 1 week postoperatively have died since discharge. Two had sudden deaths attributed to ventricular fibrillation 7 and 18 months postoperatively. Two patients died of complications of congestive heart failure at 1 and 36 months of follow-up. Among the remaining patients, one died of a myocardial infarction at 8 months of follow-up and the other died of sepsis at 6 months of follow-up.

DISCUSSION

Long-term results. In this series there was a perioperative mortality of 15%, which is similar to the results of others,[2, 6-8] including the findings of a multicenter registry.[12] Eighty-six percent of the remaining patients underwent successful ER and no significant difference in success rate could be discerned between patients who underwent a map-guided ER and those who underwent a visually-directed resection. Although all patients had inducible, sustained VT preoperatively, VT was inducible intraoperatively in only 22 of the 33 patients (67%). No morphologic characteristic of the VT was associated with the outcome of surgery. Concordance of VT morphologies preoperatively and intraoperatively was present in only 43% of patients and was not significantly associated with operative success or failure in eradicating VT. However, patients who had multiple intraoperative VT morphologies had a higher rate of operative success than the patients who had a single intraoperative VT morphology.

Intraoperative induction of VT. The finding that intraoperative success in inducing VT was only 67% in this study was surprising in that the programmed stimulation protocol was identical to that used preoperatively. Conceivably, the use of anesthetic agents may have influenced the inducibility of VT in the operating room, although the agent used (fentanyl) produces few electrophysiologic effects.[9]

The issue of preoperative and intraoperative concordance of VT morphologies has not been addressed previously. We found that VT concordance was present in less than half of our patients and that it was not predictive of surgical outcome. Therefore although the morphology of VT induced in the operating room may be different from the morphology of the VT induced preoperatively, the outcome of ER does not appear to be adversely affected by this difference. Factors that may have accounted for the absence of VT concordance preoperatively and intraoperatively include the effects of anesthetic agents, cardiopulmonary bypass, and ventriculotomy.

Multiple VT morphologies. Miller et al.[4] reported that certain morphologic variables are predictive of failure in ER, including multiple spontaneous (but not induced) morphologies, disparate sites of VT morphologies, right bundle branch block (RBBB) morphology, and certain locations of VT foci (inferior wall, papillary muscles, and septum). Others[10, 11] found no significant effect of multiple or single VT morphologies, mapping, or inferior wall origin on surgical success. In the present study, the presence of multiple VT morphologies intraoperatively correlated with a higher surgical success rate. It may be that the higher success rate in patients who have multiple VT morphologies is attributable to a more widespread ER than in patients who had only one VT morphology.

Long-term follow-up. We found that two patients who did not have inducible VT 1 week postoperatively experienced recurrences of VT at a later time. Of note is that in both patients the morphology was different from that of any of the VTs before ER. The possibility of a false negative 1 week postoperative EP study exists, but it is also possible that the patients developed recurrent VT because of a new VT focus that was not present at the time of the operation. Additionally, two patients who also did not have inducible VT postoperatively experienced VF arrests and died in the follow-up period, along with three others who died of cardiac causes and another who died of sepsis.

Map-guided versus visually-directed ER. Map-directed ER and visually-directed ER have been reported to have comparable success rates. This was also the case in the present study. However, in the present study, visually-directed ER was performed only in patients in whom VT was not inducible in the operating room. A randomized comparison of the two techniques will be needed to determine if their success rates are significantly different.

Clinical implications. In conclusion, the outcome of ER is not adversely affected by discordance between the morphologies of VTs induced in the EP laboratory and in the operating room. However, every effort should be made to induce as many different types of monomorphic VT as possible, because the surgical success rate may be lower if only one type of VT is induced intraoperatively than if multiple morphologies of VT are induced.

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Irregular ventricular tachycardia: A possible manifestation of longitudinal dissociation within the reentry pathway

Sustained monomorphic ventricular tachycardia is usually regular; that is, it is associated with constant R-R intervals. In several cases, however, the cycles of ventricular tachycardia are more or less variable. Fifty-four cases of sustained monomorphic ventricular tachycardia were evaluated in order to assess whether tachycardia was regular. Nine cases were defined as irregular (i.e., the R-R cycles varied by more than 40 msec throughout a 1-minute recording). In five cases tachycardia was "regularly irregular," since the R-R cycles could be divided into two separate groups: the group of long cycles and that of short cycles. In these cases the variability manifested according to a defined and constant pattern: bigeminal pattern (alternation of short and long cycles), trigeminal pattern (two short cycles followed by a long cycle), and so on. The regular variability of tachycardia cycle length suggests one of the following possibilities. (1) There are two alternative circuits (a short circuit and a long circuit) that share the same exit pathway. Whenever the reciprocating impulse runs through the short circuit, the R-R cycle is short; but if a block in the short circuit occurs, the impulse runs through the long circuit, resulting in a long R-R cycle. (2) There is a longitudinal dissociation within the reentry circuit; two separate pathways with different inherent conduction velocities are present. When the impulse runs through the fast pathway, the R-R cycle is short; whereas when a block in the fast pathway occurs, the impulse traverses the slow pathway, resulting in a long R-R cycle. (Am Heart J 1992;124:1506.)

Giuseppe Oreto, MD, Gaetano Satullo, MD, Francesco Luzza, MD, Antonino Donato, MD, Ignazio M. Scimone, MD, and Alfredo Cavalli, MD
Messina, Italy

Sustained monomorphic ventricular tachycardia (VT) is usually regular; that is, the R-R cycles are constant. Polymorphic and nonsustained VT, in contrast, are often associated with variable R-R intervals. In some instances, however, sustained monomorphic VT reflects irregular R-R intervals. This has been observed particularly before spontaneous termination of VT.[1] This study is focused on the incidence and the mechanism of R-R cycle variability in sustained VT.

From Istituto Pluridisciplinare di Clinica Medica, Cattedra di Malattie Cardiovascolari, Università di Messina, Messina, Italy.

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Reprint requests: Giuseppe Oreto, MD, Via Terranova, 9, 98122 Messina, Italy.

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METHODS

Fifty-four patients with sustained monomorphic VT were selected. All of them had had a previous myocardial infarction and had been admitted to the hospital for treatment of an arrhythmia. VT was diagnosed on the basis of results of a surface ECG according to current criteria.[2-4] For each patient, a 12-lead ECG was available, as well as a con-