LARGE ENCIRCLING CRYOABLATION WITHOUT MAPPING FOR VENTRICULAR TACHYCARDIA AFTER ANTERIOR MYOCARDIAL INFARCTION: LONG-TERM OUTCOME

Jean M. Frapier, MD^a
Jean J. Hubaut, MD^a
Jean L. Pasquié, MD^b
Paul A. Chaptal, MD^a

Objective: Map-guided procedures have been the accepted standard for ventricular tachycardia surgery. However, promising results of visually guided resections without mapping have been reported. The goal of this study was to evaluate the efficacy of large encircling cryoablation without mapping for ventricular tachycardia after anterior myocardial infarction. **Methods:** Between 1985 and 1996, this procedure, along with aneurysmectomy, was performed on 38 patients for malignant ventricular tachycardia. The mean interval between the operation and myocardial infarction was 59.2 months; 7 patients (18.4%) were operated on within 1 month of myocardial infarction. The mean patient age was 62.1 ± 7.3 years and the mean left ventricular ejection fraction was $29.0\% \pm 7.2\%$. **Results:** Hospital mortality was 2.6% (1 patient). The electrical success rate based on postoperative electrophysiologic studies was 94.5%. Overall electrical success rate was 89.1%. Freedom from ventricular tachycardia was 77% (95% CI 61%-94%) at both 5 and 7 years. Freedom from sudden cardiac death was 91% (95% CI 80%-100%) at both 5 and 7 years, with overall actuarial survivals at 5 and 7 years of 63% (95% CI 47%-80%) and 42% (95% CI 22%-63%), respectively. The main cause of late death was congestive heart failure in 62.6% of these patients. **Conclusions:** One can achieve good results without intraoperative mapping in the treatment of patients with ventricular tachycardia after anterior myocardial infarction by using large encircling cryoablation. (J Thorac Cardiovasc Surg 1998;116:578-83)

Percutaneous catheter ablation¹ and nonthoracotomy implantation of automatic implantable cardioverter defibrillators (AICDs)² have decreased the number of direct operations performed for life-threatening ventricular tachycardia (VT) after myocardial infarction (MI). However, for these patients direct surgical ablation combined with aneurysm resection and myocardial revascularization remains the most powerful curative tool. Among several direct surgical procedures, two major approaches have become prevalent: (1) elective procedures, with ablation of arrhythmogenic foci after precise localization by intraoperative mapping³; (2) extensive procedures such as the total removal of the

endocardial scar,⁴ isolation of this tissue by encircling endocardial ventriculotomy,⁵ encircling endocardial cryoablation,⁶ or laser irradiation.⁷ In contrast to previous reports detailing the importance of intraoperative mapping,⁸⁻¹⁰ series of visually guided resections without mapping achieved results similar to those obtained with map-guided procedures.^{11,12} The goal of this study was to evaluate, by retrospective analysis, the outcomes of patients who underwent large encircling cryoablations without mapping for refractory VT after anterior MI. This is the largest reported series of patients treated by this method in which follow-up was continued up to 10 years.

Patients and methods

Patients. Between 1985 and 1996, 38 patients (34 male, 4 female) underwent surgery for spontaneous, sustained VT after MI. The mean patient age was 62.1 ± 7.3 years (range 41-72 years). The mean interval between the operation and MI was 59.2 months (range 3 weeks-24 years); 7 patients (18.4%) underwent surgery within 1 month of MI. The mean left ventricular ejection fraction (LVEF) was $29.0\% \pm 7.2\%$

From the Departments of Cardiovascular Surgery^a and Cardiology,^b Arnaud de Villeneuve Hospital, Montpellier, France.

Received for publication Nov 14, 1997; revisions requested Feb 6, 1998; revisions received March 26, 1998; accepted for publication June 16, 1998.

Address for reprints: Jean-Marc Frapier, MD, Chirurgie Cardiovasculaire Service du Pr Chaptal, Hôpital Arnaud de Villeneuve, 34059 Montpellier Cedex, France.

Copyright © 1998 by Mosby, Inc.

0022-5223/98 \$5.00 + 0 12/1/92607

(range 15%-45%) and the mean left ventricular end-diastolic pressure was 14.8 ± 7.3 mm Hg (range 4-35 mm Hg). On coronary angiogram, 21 (55%) had 1-vessel disease, 11 (29%) had 2-vessel disease, and 6 (16%) had 3-vessel disease. The VT was monomorphic in 28 (74%) patients and polymorphic in 10 (26%). Twelve patients (31.5%) had more than 5 episodes of malignant arrhythmias and 25 patients (65.7%) had repeated VT that could be stopped only by cardioversion, with an average of 3 cardioversions per patient. The mean number of antiarrhythmic drug trials was 2.5 per patient (range 1-6), with amiodarone (200-400 mg daily) administered to all 38 patients (100%).

Methods.

Indications. All patients had an anterior MI. They were referred for surgical treatment (1) if their VT was unresponsive to medical treatment or the antiarrhythmic medications had to be stopped because of major side effects or (2) if there was an indication of associated disease, such as congestive heart failure over an anteroapical aneurysm or angina with graftable coronary arteries.

Low ejection fraction was not considered a contraindication, especially in the presence of a large anteroapical aneurysm. However, patients with poor contraction of the other segments on the right or left anterior oblique projection of the ventriculogram, or on the echocardiogram, and/or diffuse coronary disease with target vessels less than 1.5 mm, were not selected for this type of operation and were referred for AICD implantation.

Preoperative study protocol. The preoperative study protocol included a Holter electrocardiogram (ECG), echocardiogram, cardiac catheterization, coronary arteriogram, and electrophysiologic studies (EPS). EPS were performed 24 to 48 hours after antiarrhythmic drug cessation in 28 (73.6%) patients who were in stable condition. The stimulation protocol consisted in apical ventricular premature beats (1, 2, and up to 3 extrastimuli) with increasing prematurity on a 500-ms basic cycle length. A sustained VT was the end point of the EPS protocol. Ten (26.3%) patients who were in unstable condition were deemed unsuitable for preoperative EPS.

Operative technique. During cardiopulmonary bypass, when cooling to moderate hypothermia (28°C) when necessary, the proximal saphenous vein graft anastomosis was performed first. With the aid of cardioplegic arrest, the ablative procedure was carried out by way of a left ventriculotomy through the scar, as first described by Guiraudon and associates,¹³ without mapping. Points of cryolesion were either edge to edge or overlapping and applied 1.5 cm outside the area of the visible scar in all patients. In the septum, where the exact delimitation of the scar is less easy, this distance of 1.5 cm was increased so that a second row could be applied. Care was taken to avoid ablation in the upper part of the septum near its membranous portion, which can cause a His bundle block (which happened twice at the beginning of our experience). Cryoablation was performed with a Frigitorics cryosurgical system CCS 100 with a 15-mm diameter flat face curved probe (CooperSurgical Inc, Shelton, Conn). A

mean of 11.4 ± 2.2 cryolesions (range 8-15) was realized at a mean temperature of -61°C (range -50°C to -74°C) for 2 minutes per point. The principal associated procedures were aneurysmectomy and coronary artery bypass surgery. Thirty-eight (100%) patients underwent aneurysmectomy, with a Jatene procedure in 12 (31.5%). The 12 (31.5%) patients who required coronary artery bypass received a total of 18 grafts (mean 1.5 grafts per patient). The mean cardiopulmonary bypass time was 109 ± 45 minutes (range 48-251 minutes), and the average crossclamp time was 37 ± 24 minutes (range 25-94 minutes).

Postoperative protocol. At postoperative day 14, the patients were subjected to EPS with the same protocol as used before the operation, by way of the temporary right ventricular epicardial leads, as well as a Holter ECG, and echocardiogram. After EPS, patients were maintained on a program of amiodarone (200 mg daily) for 6 months, which was subsequently discontinued except in the presence of abnormal EPS or Holter ECG findings during the postoperative period or in the presence of atrial fibrillation.

Evaluation and definitions. Results of EPS were considered abnormal only if a sustained VT (>30 seconds) was inducible, irrespective of its morphology. Electrical success was defined by abnormal EPS and Holter ECG results during the postoperative period. Clinical success was defined by the absence of spontaneous VT with or without antiarrhythmic medication after surgery (corresponding to freedom from VT). Sudden cardiac death, defined as death occurring within 1 hour of onset of symptoms in an otherwise clinically stable patient, was considered as recurrent VT. Heart transplantation during the follow-up was counted as death from congestive heart failure.

Follow-up. Patients were traced for a mean follow-up of 61.9 ± 38.5 months (range 3-124 months). One Portuguese patient was lost to follow-up at 3 months. He was included in the in-hospital results but was eliminated from rough long-term results. He was included in the actuarial results as censored data. Data were obtained via questionnaires to the patient's referring physician and cardiologist or by consultation in the outpatient clinic of the Cardiology Unit of Arnaud de Villeneuve Hospital.

Statistical analysis. Preoperative and perioperative data were obtained by reviewing the patients' hospital records. All data were entered into a computer for statistical analysis with SAS statistical software (SAS Institute, Inc, Cary, NC) at the medical statistics department of the hospital. Data are expressed as a mean $\pm$ standard deviation. Statistical analysis was performed by Wilcoxon paired *t* test for comparison between 2 periods. Actuarial survival and freedom-from-events curves were prepared according to the Kaplan-Meier method.

Results

Mortality. Early mortality (within 30 days) after large encircling cryoablation was 2.6% (1 patient). This 67-year-old male patient died of congestive heart failure on postoperative day 17 and had been operated on for recurrent VT within the first month after anterior MI.

Fig 1. Solid line, Overall actuarial survival (operative mortality included) at 7 years (Kaplan-Meier method, 95% CI 22%-63%). Broken line, Freedom from sudden cardiac death at 7 years (Kaplan-Meier method, 95% CI 80%-100%).

Fig 2. Actuarial rate of freedom from VT at 7 years (Kaplan-Meier method, 95% CI 61%-94%).

His preoperative LVEF was 25%; hypokinesia of the inferior wall was associated with a previous inferior MI. The encircling cryoablative procedure was addressed only to the anterior scar.

Late mortality after surgery was 44.4% (16/36 patients): 38.8% (14 patients) died, and 5.5% (2

patients) underwent heart transplantation. The main cause of death was congestive heart failure (62.6% of late mortality), but sudden cardiac death occurred in 5.5% (2 patients). At 5 and 7 years, the overall actuarial survivals (Fig 1) were 63% (95% CI 47%-80%) and 42% (95% CI 22%-63%), respectively. Freedom from

sudden cardiac death was 91% (95% CI 80%-100%) at both 5 and 7 years.

Morbidity. Early morbidity included 8 patients (21.6%) with low cardiac output (1 of 8 had an intra-aortic balloon insertion) and 2 patients (5.4%) with complete heart block had a pacemaker insertion. Late morbidity included AICD implantation for malignant recurrent VT in 1 (2.7%) patient and residual angina in 2 patients (5.5% of survivors).

Rhythm. The electrical success rate based on postoperative EPS was 94.5% (35/37 survivors). One patient had polymorphic sustained VT, but VT did not develop during follow-up. Another patient had monomorphic sustained VT comparable with the preoperative VT; this patient had a nonfatal recurrent VT during follow-up. In a third patient with polymorphic nonsustained VT, the procedure was not considered to have been a failure according to the aforementioned definition. Two patients had a VT recorded on Holter ECG or on intensive care unit monitoring. They had nonfatal recurrent VT during follow-up. The overall electrical success rate was 89.1% (33/37 survivors).

The clinical success rate was 83.3% (30/36 survivors). Six patients (16.7%) had arrhythmias that could not be controlled. Two of these 6 patients died of sudden cardiac death at 21 and 48 months, and 4 patients had nonfatal recurrent VT. Freedom from VT was 77% (95% CI 61%-94%) at both 5 and 7 years (Fig 2).

Ventricular function. After the operation, LVEF improved significantly, from $29.0\% \pm 7.2\%$ to $36.6\% \pm 11.2\%$ ($P = .0106$).

Discussion

Progress in understanding the origin of ischemic VT, whose mechanisms were described by Josephson and associates,¹⁴ led to the first direct approach to its treatment: subendocardial resection, limited and guided by intraoperative mapping.³ With this procedure, the best electrical success rates improved from 66%¹⁵ to 91%.¹⁶ Subsequent developments in the direct treatment of ischemic VT further increased success rates. The introduction of computerized mapping, sequential endocardial resection, and the combined use of these procedures increased this success rate consistently to more than 90%.^{8,17,18} In attempts to avoid the limitations of intraoperative mapping, Moran and colleagues⁴ described a technique of large endocardial resection without mapping for which the electrical success rate was 92%. In contrast, Guiraudon and colleagues abandoned encircling endocardial ventriculotomy⁵ and later described encircling endocardial cryoablation, with success rates up to 93%⁶ without the deleterious effects of the circular endoventricular incision.

After initial experiences with map-guided subendocardial resection and localized cryolesions, we turned to large encircling cryoablation without mapping. This decision was influenced by our observations that, especially with quadripolar hand-held electrodes, mapping was not successful in all patients after ventriculotomy (mapping success rate of 63%, unpublished data). Moreover, in the majority of patients with anterior MI, the earliest activation or cryotermination site was located within the area of the visible scar tissue. Although large blind endocardectomy has produced consistently high success rates,^{4,11} the arduous nature of this procedure—particularly when performed on mitral papillary muscle or interventricular septum—compelled us to perform large encircling cryoablation.

Although unsuccessful mapping or “no mapping” has been documented as a prominent risk factor for failure by several authors,^{9,10,23} it was not a significant factor of failure in some series.¹⁹⁻²² Even with computerized mapping, with which one can achieve a 100% rate of successful mapping, the highest electrical success rates ranged from 72% to 87%.^{23,24} Results from our large encircling cryoablations were similar to those obtained by Guiraudon and associates,¹³ with an electrical success rate of 94.5%. Furthermore, although mapping was used in their series, they saw no difference in electrical success rates between patients with successful or unsuccessful intraoperative mapping.²⁰ In addition, as argued by Guiraudon and colleagues,¹³ map-guided surgical procedures were often regional or large procedures rather than truly localized, as assessed by the surgical protocols described in various reports.^{4,9,17,18} Finally, Cox,⁸ in his collaborative report, revealed no significant difference in the postoperative rate of VT inducibility between 179 patients treated by localized procedures versus 342 patients treated by generalized techniques.

We report a post-cryoablation freedom from sudden cardiac death of 91% (95% CI 80%-100%) at both 5 and 7 years. However, our results concerning overall survival were far from ideal, with overall actuarial survivals of 63% (95% CI 47%-80%) and 42% (95% CI 22%-63%) at 5 and 7 years, respectively. This lower survivorship could be explained, in part, by the mean length of our postoperative follow-up (61.9 ± 38.5 months), which is significantly longer than is reported in other studies. Furthermore, unlike other series,²³ patients over 65 years old were not rejected from our series. Moreover, despite an improvement in the postoperative LVEF, the preoperative LVEF of our series was 29%. It has been demonstrated that an LVEF of less than 31% is a strong predictor of late postoperative mortality.²⁵ Undoubtedly, our revascularization rate of

31% had been too weak. Mickleborough and associates,²³ in their series, had an 85% rate of coronary artery bypass, and in many other reports this rate was about 70%.^{24,25}

Death after operation for ischemic VT is rarely due to recurrent VT.²³ The main cause of late postoperative death remains congestive heart failure. We believe that sustained improvements in left ventricular function, by ventricular remodeling and extensive revascularization,²³ should improve overall long-term survivals. Adding a more drastic selection of patients, by using the quality of the residual left ventricular function as a criterion for operability,²⁶ in the era of other alternatives^{1,2} should lead to excellent outcome.

Study limitations. In this series, only 65.7% (25/38) of patients who underwent large encircling cryoablation had intractable VT (eg, uncured by preoperative antiarrhythmic drug treatment). Indications for surgery in the other 34.3% (13/38) were primarily congestive heart failure, myocardial ischemia, or both. Amiodarone was used before the operation and was stopped the day of the operation in all responsive patients. Because of the long-lasting half-life of amiodarone, it is likely that the electrical success rate based on postoperative EPS would have been lower if all patients had been nonresponsive. Moreover, amiodarone treatment was continued for 6 months after cryoablation, irrespective of postoperative EPS results. It is possible that our clinical success rate would have been lower if all 38 patients had been nonresponsive to medical therapy.

Conclusion

We believe that one can achieve good results without intraoperative mapping in the treatment of VT developing after anterior MI by using large encircling cryoablation according to Guiraudon's technique. All attempts should be made to improve left ventricular function to achieve better long-term survival.

We thank Vergnes Christine, MD, and Marie-Christine Picot, MD, PhD, Medical Statistics Department, Lapeyronie Hospital Montpellier, for help with the statistical analysis.

REFERENCES

1. Trappe HJ, Pfitzner P, Fieguth HG, Wenzlaff P, Kieblock B, Klein H. Nonpharmacological therapy of ventricular tachyarrhythmias: observations in 554 patients. *PACE* 1994;17(Pt 2): 2172-7.
2. Ferguson TB, Smith JM, Cox JL, Cain ME, Lindsay BD. Direct operation versus ICD therapy for ischemic ventricular tachycardia. *Ann Thorac Surg* 1994;58:1291-6.
3. Harken AH, Josephson ME, Horowitz LN. Surgical endocardial resection for the treatment of malignant ventricular tachycardia. *Ann Surg* 1979;190:456-60.
4. Moran JM, Kehoe RF, Loeb JM, Lichtenthal PR, Sanders JH, Michaelis IL. Extended endocardial resection for the treatment of ventricular tachycardia and ventricular fibrillation. *Ann Thorac Surg* 1982;34:538-52.
5. Guiraudon G, Fontaine G, Franck R, Escande G, Etievent P, Cabrol C. Encircling endocardial ventriculotomy: a new surgical treatment for life-threatening ventricular tachycardias resistant to medical treatment following myocardial infarction. *Ann Thorac Surg* 1978;26:438-43.
6. Guiraudon G, Klein GJ, Vermeulen FE, Yee R, Van Hemel NM. Encircling endocardial cryoablation: a technique for surgical treatment of ventricular tachycardias after myocardial infarction. *Circulation* 1983;68(Suppl):III176.
7. Menilsdrey P, Laborde F, Beloucif S, Mayolini P, Pivnicka A. Tachycardies ventriculaires d'origine ischémique. Traitement par thermo-exclusion circonférentielle au laser Nd-YAG. *Presse Med* 1985;15:531-4.
8. Cox JL. Patient selection criteria and results of surgery for refractory ischemic ventricular tachycardia. *Circulation* 1989;79(Suppl):I163-77.
9. Swerdlow CD, Mason JW, Stinson EB, Oyer PE, Windle RA, Derby GC. Results of operations for ventricular tachycardia in 105 patients. *J Thorac Cardiovasc Surg* 1986;92:105-13.
10. Ostermeyer J, Kirklin JK, Borggreffe M, Cox JL, Breithardt G, Bircks W. Ten years electrophysiologically guided direct operations for malignant ischemic ventricular tachycardia—results. *Thorac Cardiovasc Surg* 1989;37:20-7.
11. Landymore RW, Gardner MA, McIntyre AJ, Barker RA. Surgical intervention for drug-resistant ventricular tachycardia. *J Am Coll Cardiol* 1990;16:37-41.
12. Kron IL, Lerman BB, DiMarco JP. Extended subendocardial resection: a surgical approach to ventricular tachyarrhythmias that cannot be mapped intraoperatively. *J Thorac Cardiovasc Surg* 1985;90:586-91.
13. Guiraudon GM, Thakur RK, Klein GJ, Yee R, Guiraudon CM, Sharma A. Encircling endocardial cryoablation for ventricular tachycardia after myocardial infarction: experience with 33 patients. *Am Heart J* 1994;128:982-9.
14. Josephson ME, Horowitz LN, Farshidi A, Kastor JA. Recurrent sustained ventricular tachycardia. 1. Mechanisms. *Circulation* 1977;57:431-40.
15. Miller JM, Kienzle MG, Harken AH, Josephson ME. Subendocardial resection for ventricular tachycardia: predictors of surgical success. *Circulation* 1984;70:624-31.
16. Haines DE, Lerman BB, DiMarco JP, Kron IL. Improved surgical outcome in patients with ventricular tachycardia with repeat endocardial mapping after initial subendocardial resection during normothermic bypass [abstract]. *J Am Coll Cardiol* 1986;7:141A.
17. Kron IL, Lerman BB, Nolan SP, Flanagan TL, Haines DE, DiMarco JP. Sequential endocardial resection for the surgical treatment of refractory ventricular tachycardia. *J Thorac Cardiovasc Surg* 1987;94:843-7.
18. Krafchek J, Lawrie GM, Roberts R, Magro SA, Wyndham CR. Surgical ablation of ventricular tachycardia: improved results with a map-directed regional approach. *Circulation* 1986;73: 1239-47.
19. Hobson CE, DiMarco JP, Haines DE, Flanagan TL, Kron IL. The influence of preoperative shock on outcome in sequential endocardial resection for ventricular tachycardia. *J Thorac Cardiovasc Surg* 1991;102:348-54.
20. Thakur RK, Guiraudon GM, Klein GJ, Yee R, Guiraudon CM. Intraoperative mapping is not necessary for VT surgery. *PACE* 1994;17(Pt 2):2156-62.

21. Nath S, Haines DE, Kron IL, DiMarco JP. The long-term outcome of visually directed subendocardial resection in patients without inducible or mappable ventricular tachycardia at the time of surgery. *J Cardiovasc Electrophysiol* 1994;5:399-407.
22. Lee R, Mitchell JD, Garan H, Ruskin JN, McGovern BA, Buckley MJ, et al. Operation for recurrent ventricular tachycardia: predictors of short- and long-term efficacy. *J Thorac Cardiovasc Surg* 1994;107:732-42.
23. Mickleborough LL, Mizuno SI, Downar E, Gray GC. Late results of operation for ventricular tachycardia. *Ann Thorac Surg* 1992;54:832-9.
24. Pagé PL. Surgical treatment of ventricular tachycardia. *Arch Mal Coeur* 1996;89:115-21.
25. Lawrie GM, Pacifico A, Kaushik R, Nahas C, Earle N. Factors predictive of results of direct ablative operations for drug-refractory ventricular tachycardia. *J Thorac Cardiovasc Surg* 1991;101:44-5.
26. Van Hemel NM, Kingma JH, Defauw JA, Vermeulen FE, Mast EG, Ernst JM, et al. Left ventricular segmental wall motion score as a criterion for selecting patients for direct surgery in the treatment of postinfarction ventricular tachycardia. *Eur Heart J* 1989;10:304-15.

ON THE MOVE?

Send us your new address at least six weeks ahead

Don't miss a single issue of the journal! To ensure prompt service when you change your address, please photocopy and complete the form below.

Please send your change of address notification at least six weeks before your move to ensure continued service. We regret we cannot guarantee replacement of issues missed due to late notification.

JOURNAL TITLE:

Fill in the title of the journal here. _____

OLD ADDRESS:

Affix the address label from a recent issue of the journal here.

NEW ADDRESS:

Clearly print your new address here.

Name _____

Address _____

City/State/ZIP _____

COPY AND MAIL THIS FORM TO:

Periodical Subscription Services
Mosby, Inc.
11830 Westline Industrial Dr.
St. Louis, MO 63146-3318

OR FAX TO:

314-432-1158

OR PHONE:

1-800-453-4351
Outside the U.S., call
314-453-4351