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Nonsurgical Transthoracic Epicardial Radiofrequency Ablation

An Alternative in Incessant Ventricular Tachycardia

Josep Brugada, MD, Antonio Berruezo, MD, Alejandro Cuesta, MD, Joaquin Osca, MD, Enrique Chueca, MD, Xavier Fosch, MD, Luis Wayar, MD, Lluis Mont, MD

Barcelona, Spain

OBJECTIVES The purpose of this study was to analyze the feasibility, efficacy, and safety of epicardial radiofrequency (RF) ablation in patients with incessant ventricular tachycardia (VT).

BACKGROUND Management of patients with incessant VT is a difficult clinical problem. Drugs and RF catheter ablation are not always effective. A nonsurgical transthoracic epicardial RF ablation can be an alternative in patients refractory to conventional therapy.

METHODS Epicardial RF ablation was performed in 10 patients who presented with incessant VT despite the use of two or more intravenous antiarrhythmic drugs.

RESULTS In eight patients, endocardial ablation (EdA) failed to control the tachycardia. In the remaining two patients, epicardial ablation (EpA) was first attempted because of left ventricular thrombus and severe artery disease, respectively. Eight patients had a diagnosis of coronary artery disease with healed myocardial infarction. One patient had dilated cardiomyopathy, and one patient had idiopathic, incessant VT. In patients with structural heart disease, the mean ejection fraction was 0.28 ± 0.10%. Four patients previously received an implantable defibrillator. The EpA effectively terminated the incessant tachycardia in eight patients, which represents a success rate of 80%. In them, after a follow-up of 18 ± 18 months, a single episode of a different VT was documented in one patient. No significant complications occurred related to the procedure.

CONCLUSIONS In patients with incessant VT despite the use of drugs or standard EdA, the epicardial approach was very effective and should be considered as an alternative in this life-threatening situation. (J Am Coll Cardiol 2003;41:2036–43) © 2003 by the American College of Cardiology Foundation

Patients with incessant ventricular tachycardia (VT) represent a life-threatening situation, with great morbidity and mortality, and often a difficult clinical problem. Radiofrequency (RF) catheter ablation is the therapy of choice when intravenous drugs have failed. However, endocardial ablation (EdA) of VT due to a previous myocardial infarction (MI) or in patients with structural heart disease continues to be one of the most challenging procedures in clinical electrophysiology, with a success rate ranging from 45% to 75% (1,2).

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The reasons for unsuccessful EdA are often difficult to ascertain. One reason thus far exposed is that the re-entry circuits may be located deep in the subendocardium or in the epicardium, inaccessible to present mapping and ablation techniques (3,4). Mapping of arrhythmia foci or circuits that are deep within the myocardium or in the epicardium has been attempted in open-chest heart surgery (5,6) and with RF ablation catheters in two ways. Small, 2F electrode catheters have been introduced into the coronary sinus and advanced into the cardiac veins. With this technique, epicardial circuits can sometimes be identified, but only when veins cross the region of the circuit (7). In 1996, Sosa et al. (8–11) introduced a new transthoracic epicardial method for the electrophysiologic study of patients with VT and, two years later, for the ablation of the arrhythmia. The method is based on the hypothesis that some crucial parts of the re-entry circuit in VT might be located near the epicardial site of the ventricle. The technique is performed by introducing a standard ablation catheter into the pericardial space, using a transthoracic puncture in the subxiphoid region. The new technique was first described in patients with Chagas' disease (8–10). More recently, they have also shown their experience in a group of patients with an inferiorly healed MI with preserved left ventricular function (11).

In patients with incessant VT in whom the classic EdA procedure has failed, the epicardial approach can be an alternative. The aim of this study was to analyze the efficacy and safety of epicardial ablation (EpA) in patients with incessant VT.

From the Arrhythmia Section, Cardiovascular Institute, Hospital Clinic, University of Barcelona, Barcelona, Spain.

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Abbreviations and Acronyms

CAD = coronary artery disease
ECG = electrocardiogram
EdA = endocardial ablation
EpA = epicardial ablation
LBBB = left bundle branch block
MI = myocardial infarction
RF = radiofrequency
SVT = supraventricular tachycardia
VT = ventricular tachycardia

METHODS

Study patients. Since 1998, ablation was attempted in 150 patients with VT. Epicardial ablation was performed in 10 of 19 patients with incessant VT. We considered VT to be incessant when, despite the use of at least two intravenous antiarrhythmic drugs, electrical cadioversion, and/or overdrive stimulation, the patient presented with persistent, recurrent, sustained VT for at least a 24-h period.

In eight patients, the usual endocardial approach had failed to terminate VT, despite the use of standard and special catheters (8-mm tip in five patients and endocardial irrigated tip in three patients). In the remaining two patients, the endocardial approach was not tried because of the presence of a left ventricular thrombus and severe arterial disease, respectively.

No patient was excluded from ablation on the basis of infarct location, left ventricular function, presence or absence of an aneurysm, number of ventricular configurations, or characteristics of VT.

In the whole group, a coronary artery and left ventricular angiogram was obtained before the procedure. Analysis of the angiogram was used to establish the proximity between the catheter tip and a coronary vessel before ablation.

Echocardiography was performed immediately after the procedure and before hospital discharge. Likewise, we monitored creatine kinase and its MB fraction during the first 36 h after EpA.

All patients signed informed consent, approved by the local ethics committee, to participate in the study.

Technique. After written, informed consent was obtained, the patient was taken to the electrophysiology laboratory in a fasting state and was mildly sedated with 10 mg diazepam. During the procedure, intravenous fentanyl was given to prevent pain during the applications or earlier if needed. The technique used was the same as already described (8). After asepsis of the subxiphoid region, local anesthesia was attained with 10 ml of 2% mepivacaine. An epidural needle was used for the pericardial puncture (Perican, 18G × 3¼; effective size 1.3 × 80 mm; Braun, Melsungen, Germany) (12). Using a 10-ml syringe with contrast media (Omnitrast 350, Schering, Berlin, Germany), the needle was advanced toward the left scapula, guided by fluoroscopy. When the pericardial space was thought to be reached, a small bolus of <1 ml of contrast agent was injected. If the tip of the needle was outside the pericardial space, a contrast bottom was seen. When the tip was inside the pericardial space, the cardiac silhouette was drawn (Fig. 1). A soft, floppy tipped guidewire was then introduced into the pericardial space while it was seen easily moving inside the pericardial sac. The same 7F sheath used for standard ablation was then advanced over the guidewire. A quadripolar, deflectable, 4-mm (n = 7) or 8-mm (n = 3) tipped catheter with

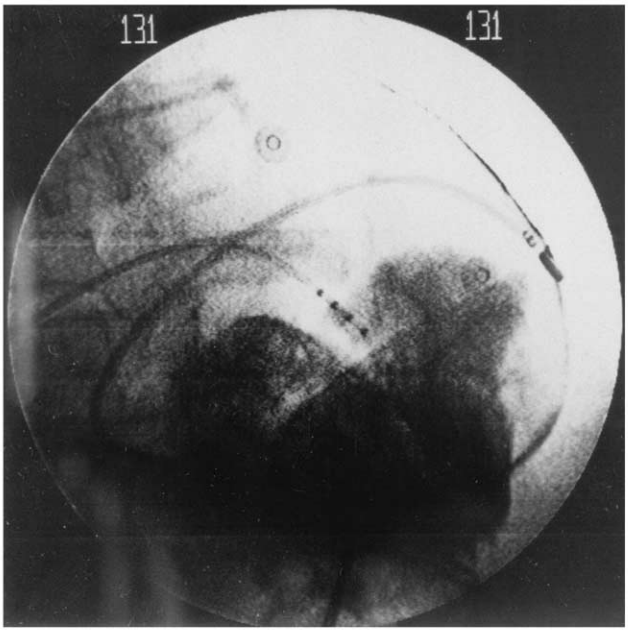

Figure 1. Radioscopic anteroposterior view showing a quadripolar diagnostic catheter in the right ventricle and an 8-mm tip ablation catheter in the pericardial space. Note the contrast in the pericardial sac.

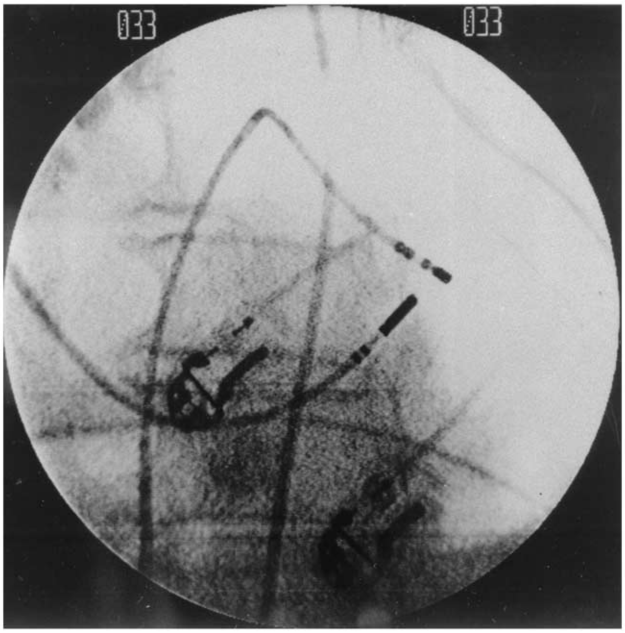

Figure 2. Radioscopic anteroposterior view showing an 8-mm tip ablation catheter in the left ventricle and a 4-mm tip ablation catheter in the pericardial space at the site of failed endocardial ablation and successful epicardial ablation.

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Table 1. Clinical Characteristics of the Patients

Patient No.	Gender (M/F)	Age (yrs)	FC (NYHA)	Cardiopathy	EF (%)	MI (Localization)	Endocardial Attempt	VT Morphology	Cycle Length (ms)
1	M	78	II	Ischemic	20	Inferior	Yes	LBBB	405
2	F	77	I	Ischemic	40	Inferior	Yes	LBBB	415
3	M	60	II	Dilated	20	—	Yes	RBBB	380
4	M	74	II	Ischemic	27	Anterior	No	RBBB	325
5	M	75	I	Ischemic	30	Inferior	Yes	RBBB	480
6	M	55	II	Ischemic	46	Inferior	Yes	RBBB	520
7	M	70	II	Ischemic	15	Posterolateral	Yes	RBBB	480
8	M	57	I	None	60	—	Yes	RBBB	420
9	M	69	II	Ischemic	23	Unlocated	No	RBBB	430
10	M	61	II	Ischemic	32	Inferior	Yes	RBBB	320

EF = ejection fraction; FC = functional class; LBBB = left bundle branch block; MI = myocardial infarction; NYHA = New York Heart Association; RBBB = right bundle branch block; VT = ventricular tachycardia.

temperature control (Cordis-Webster Inc., Johnson & Johnson, Diamond Bar, California) was introduced through the sheath in the pericardial sac (Figs. 1 and 2).

The equipment used for recording was an EP-TRACER (Cardio Tek bv, Maastricht, the Netherlands). The 12-lead surface electrocardiogram (ECG), distal and proximal bipolar electrograms of the EpA catheter, and endocardial signals from a diagnostic catheter were displayed. The stimulation protocol consisted of up to three extrastimuli down to the refractory period or a coupling interval of 200 ms in sinus rhythm and at three different cycle lengths.

Selection of ablation site. Similar criteria to those used during EdA were used to identify the site of VT origin in the epicardium: earliest electrogram during tachycardia, presence of mid-diastolic potentials or continuous diastolic activity during tachycardia, entrainment mapping, and exact pace mapping on the 12-lead ECG. Generally, the presence of isolated mid-diastolic potentials was the first mapping technique used. Potential target sites identified were evaluated for entrainment mapping. Pace mapping was used if presystolic activity was seen and VT was stopped. No other cartographic system was used.

Radiofrequency pulses were applied between the tip of the epicardial catheter and a patch electrode located behind the left scapula (Stockert EP Shuttle, Cordis Webster Inc.). Energy was delivered in all cases during VT. The temperature limit was adjusted to 65° and power to 40 W. At the chosen site, energy was applied for 20 s and, only if the VT stopped, continued for up to 60 s. The clinical, incessant VT was the target for ablation. In addition, other hemodynamically stable VTs that occurred during the procedure were targeted for ablation, as well. The ablation was considered effective when VT terminated during the application and no sustained VT could be induced.

Statistics. Continuous data are expressed as the mean value ± SD. Mean values were compared with the Student *t* test. Statistical analyses were performed using the statistical package SPSS version 10 for Windows (SPSS Inc., Chicago, Illinois). A p value of <0.05 was considered significant.

RESULTS

Radiofrequency epicardial catheter ablation was attempted in 10 patients. The clinical characteristics are shown in Table 1. The patients included nine men and one woman, with a mean age of 68 ± 9 years (range 55 to 78 years). All patients were in New York Heart Association functional class I or II before incessant VT. Eight patients (80%) had coronary artery disease (CAD), with a previous MI in all of them. One patient had been diagnosed with dilated cardiomyopathy. Finally, the remaining patient had an idiopathic VT. Myocardial infarction was located in the inferoposterior wall in six cases and in the anterior wall in one case and was unallocated in the remaining patient. The mean left ventricular ejection fraction in the patients with structural heart disease was 0.28 ± 0.10% (range 0.15% to 0.46%) and 0.60% in the patient with idiopathic VT. At coronary angiography, one-vessel disease was observed in three patients with total occlusion of the right, left anterior descending, and circumflex coronary arteries, respectively. One patient had two-vessel disease and two patients had three-vessel disease. Finally, four patients presented with nonsignificant CAD. On angiography, four patients showed a ventricular aneurysm.

A cardioverter-defibrillator was implanted in four patients before ablation therapy. The antiarrhythmic drugs used before ablation were amiodarone (n = 9), procainamide (n = 8), lidocaine (n = 3), sotalol (n = 2), and mexiletine (n = 1). In ischemic patients, the interval between MI and incessant VT presentation was a mean of 53 ± 76 months (range 1 to 200 months). Due to incessant VT, five patients had signs of heart failure decompensation.

Catheter mapping and ablation. The clinical VT had a right bundle branch block pattern in eight patients (80%) and a left bundle branch block (LBBB) pattern in two patients (20%). The mean cycle length was 417 ± 65 ms (range 320 to 520 ms).

Eleven EpA sessions were performed in 10 patients. In one patient, a second procedure was performed on the next day, and no pericardial effusion nor adhesions were encoun-

Table 2. Technical Characteristics of Epicardial Ablation Procedures

Patient No.	Procedure Time (min)	X-Ray Time (min)	Application Time (s)	No. of Applications	Energy (W)	Catheter (mm)	Maximum Temperature (°C)	Result
1	150	65	256	7	40	8	63	Effective
2	157	77	120	2	26	4	65	Effective
3	120	42	358	15	50	8	60	Not effective
4	105	35	250	6	50	4	65	Effective
5	60	42	72	2	70	4	63	Effective
6	120	35	196	9	50	8	50	Not effective
7	180	36	271	7	20	4	60	Effective
8	115	40	718	13	16	4	65	Effective
9	56	35	346	11	50	4	54	Effective
10	59	18	206	4	50	4	60	Effective
Mean ± SD	112 ± 43	43 ± 17	279 ± 178	9 ± 5	42 ± 17		60 ± 5	8/10

tered. The mean duration of the procedure was 112 ± 43 min (range 56 to 180 min), and the mean fluoroscopy time for the entire procedure was 43 ± 17 min (range 18 to 78 min). Table 2 shows the main technical characteristics of the procedures.

Target sites were identified by activation mapping, with isolated mid-diastolic or presystolic potentials, during the VT in 10 patients (example of tracings are reflected in Figs. 3 to 5). In the two cases with LBBB, the target site of successful ablation was identified by isolated mid-diastolic potentials. These potential sites were confirmed by entrainment mapping in only four patients, because the stimulation threshold was too high in the other patients (Fig. 5 depicts an example of concealed entrainment). The mean activation time of the epicardial electrogram preceding the QRS complex of the surface ECG at the ablation site was 111 ± 36 ms (range 35 to 165 ms), an average of 27% of the tachycardia cycle length.

Initial and long-term effects of ablation. The incessant VT was effectively ablated from the epicardium in eight patients, which gives a success rate of 80%. In two patients, EpA failed to terminate the clinical tachycardia. In one patient with a diagnosis of CAD, in which the epicardial access failed to ablate the tachycardia, the VT was finally ablated through standard endocardial access that had failed previously. In the remaining patient with a diagnosis of dilated cardiomyopathy, none of the ablations could terminate the tachycardia, and urgent heart transplantation was necessary because of hemodynamic instability and refractory heart failure.

Primary success was achieved in eight patients in whom VT was not inducible by programmed ventricular stimulation 30 min after the procedure, using the same stimulation protocol. In seven of these patients, the VT was successfully ablated from the epicardium at the first attempt, including the patient with anterior MI. In the remaining patient, two epicardial sessions were necessary to ablate the tachycardia due to early recurrence after an apparently effective first procedure. The second session effectively ablated the tachycardia without recurrences, and the post-procedure recovery was not different from that of the other patients. Interestingly, in both patients in whom endocardial access was not attempted, EpA terminated the tachycardia effectively.

Together with the 10 incessant VTs, another seven morphologies of VT were induced in six patients during the procedure; four of them were hemodynamically stable and targeted for ablation from the epicardium, as well, with effective ablation in all of them, which gives a total success rate of 85.7% (12 of 14 stable VTs). In four patients, two VTs were ablated from the epicardium. The other poorly tolerated VTs, although inducible after ablation, were not targeted. The average number of applications per patient, including those that failed to ablate the clinical VT, was 9 ± 5 (range 2 to 17; median 8). During EpA, the energy delivered had a mean power of 42 ± 17 W (range 16 to 70 W) and a mean temperature of 60 ± 5°C (range 50 to 65°C).

No patient was lost to follow-up. All patients were followed for at least two months, with a mean of 18 ± 18 months (range 2 to 46 months). After ablation, oral amiodarone was continued in three patients (33%). After discharge, arrhythmia recurrence occurred in 1 (10%) of 10 patients while on amiodarone (Patient #1). It occurred two years after the EpA, and the morphology and rate of the tachycardia were completely different. He was referred again for electrophysiologic study and the VT was successfully ablated from the endocardial site, in a different location from the previous one. After discharge, no patient had any episode of syncope. All patients were alive at the end of follow-up. Only two patients were readmitted to the hospital. In one case (Patient #1), the reasons were VT recurrence and ablation and heart failure decompensation. In the other case (Patient #3), the reasons were heart transplantation evaluation and biopsies.

Complications. The pericardial space was reached and the catheter was freely moved in all patients, despite the presence of transmural MI in seven patients (including four cases of ventricular aneurysm) and one episode of acute pericarditis, occurring two months before the procedure in Patient #8. All RF applications were delivered in the left

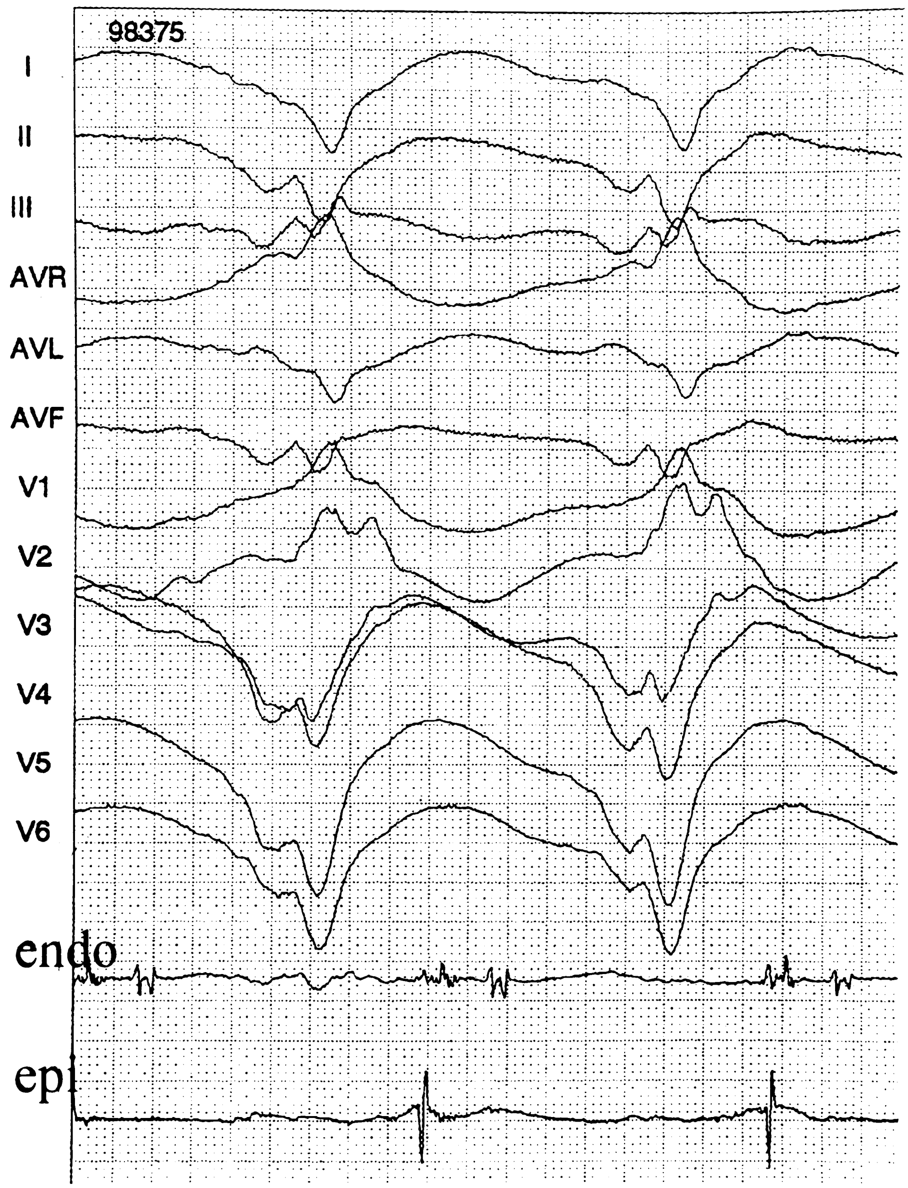

Figure 3. **(Top to bottom)** 12-lead surface electrocardiograms and two electrograms from the endocardium and epicardium. The signal from the endocardium shows a split potential. Ablation at this site was unsuccessful. From the epicardium, the electrical signal was discrete and had a similar precocity. At this site, ablation was effective.

ventricle. In none of them was a major coronary vessel located near the application site. One patient had a calcified apical aneurysm, and the catheter was positioned near its base (Fig. 2).

No significant complications were observed. Two patients had thoracic pain for three days after the procedure, which needed analgesia with acetaminophen. The control echocardiogram did not show significant pericardial effusion, and cardiac enzymes were not significantly raised. Five patients were in heart failure during the procedure. In four of them with effective ablation, the hemodynamic state compensated immediately after the ablation. The fifth patient underwent urgent heart transplantation. No heart failure decompensation was observed immediately after the procedure, nor in the following days. Moreover, the readmission of Patient #1 occurred one year later and was not related to the ablation.

DISCUSSION

Endocardial ablation of VT is often more difficult than ablation of supraventricular tachycardia (SVT) and continues to be a challenging procedure. With the former, the reported rates of success, ranging from 45% to75%, are clearly lower than those for SVT, and furthermore, ablation of VT has higher rates of recurrence (13–16). The presence of critical parts of the VT circuit in the epicardium far away from the endocardium has been suggested as one of the reasons for these unsatisfactory results. In fact, it has been

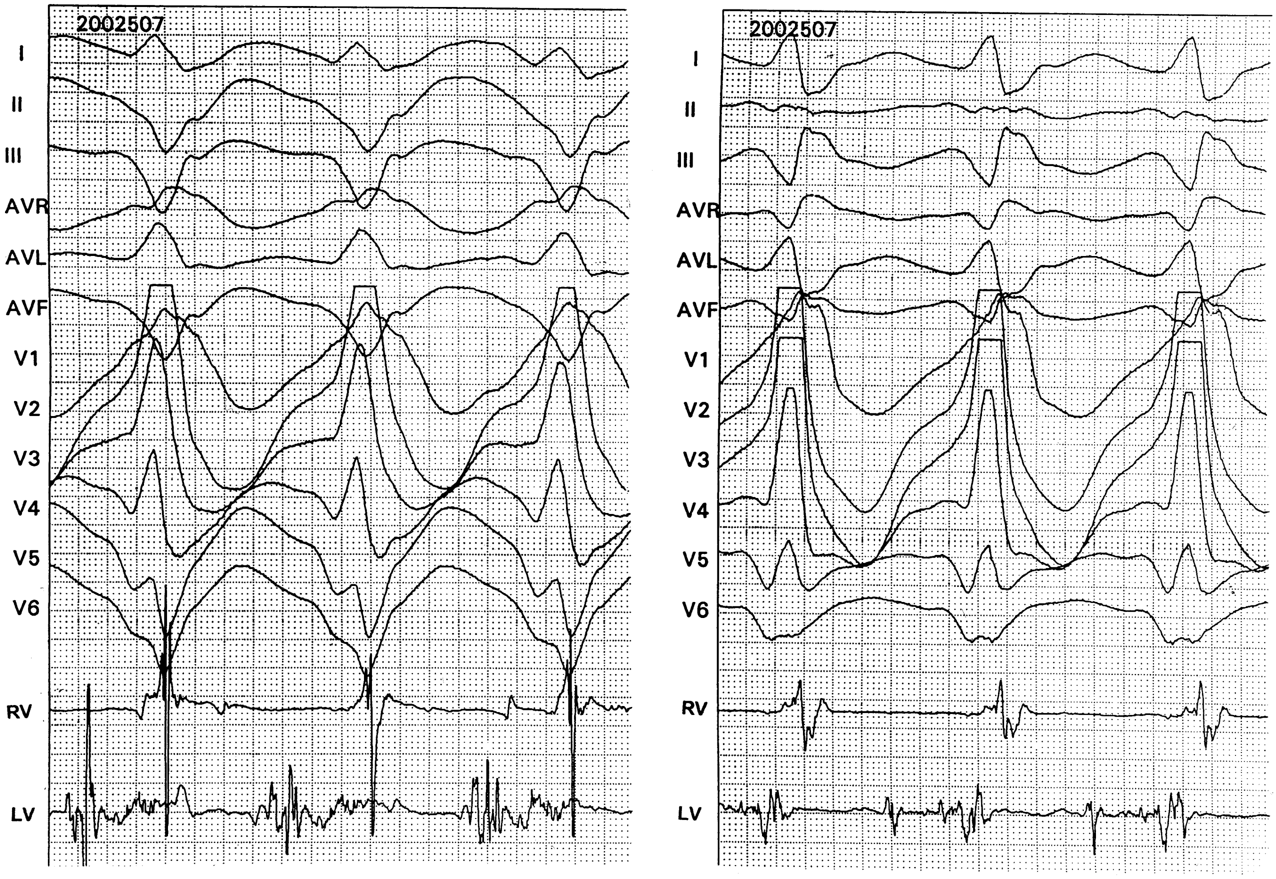

Figure 4. **(Top to bottom)** 12-lead surface electrocardiograms, endocardial signals from the right ventricle, and epicardial signals from the left ventricle corresponding to two different ventricular tachycardias in the same patient. **(Left)** Epicardial signals show fractionated electrograms of high voltage present during the diastole preceding the QRS complex. **(Right)** Epicardium signals show an isolated diastolic potential followed by a fractionated electrogram preceding the QRS complex. In these sites, radiofrequency ablation effectively terminated the tachycardia depicted in the 12-lead electrocardiogram.

reported that some VTs can be eliminated only by therapy applied to intramural or epicardial sites, implying a noncritical role of the endocardium in such tachycardias (17). This entails two problems: 1) how to locate these circuits; and 2) how to ablate them.

Initial reports. Epicardial ablation was first performed through open-chest heart surgery (5,6). The initial attempts of EpA in the surgical suite were performed through the coronary veins. Nevertheless, the technique has several limits. The proximity of the coronary arteries has raised major concerns; moreover, this procedure is limited by the veins' anatomy and localization of the tachycardia circuit (7,18).

In 1996, Sosa et al. (8–11) introduced a new method to perform both epicardial mapping in the electrophysiology laboratory and posterior EpA. The results reported were impressive because of the simplicity and effectiveness of the technique. Initially, the procedure (previously described) was used in patients with Chagas' disease in South America, exceptional in other countries (19,20). Afterward, it was applied in the treatment of VTs in patients with chronic, inferior MI (11). However, there is still a lack of information on the risk of complications and efficacy in other profiles of patients.

The present study confirms the feasibility, efficacy, and safety of epicardial RF ablation in a nonselected population of patients with incessant VT refractory to standard EdA.

Study population. We performed EpA in patients who presented with incessant VT, in whom pharmacologic and EdA have failed anteriorly. All but one of the patients included in our series presented with a low ejection fraction. Besides, three patients (33%) were diagnosed with multivessel disease. Finally, in four cases, a ventricular aneurysm was identified. These characteristics are different from those of the series reported by Sosa et al. (11) and similar to most published series of EdA of VT (13–16).

Interestingly, in our patients, the MI was mainly located in the inferoposterior wall. This is in accordance with previous reports in which re-entrant circuits present in the epicardium were more common in inferior wall infarction (6,21).

Technical aspects and efficacy of epicardial access. Despite the initial concerns of pericardial puncture in a dry or normal pericardial space, it was possible to enter into this space in all patients. Although most of them had a transmural infarction, no anatomic obstacles inside the pericardial sac were found to move the ablation catheter freely up

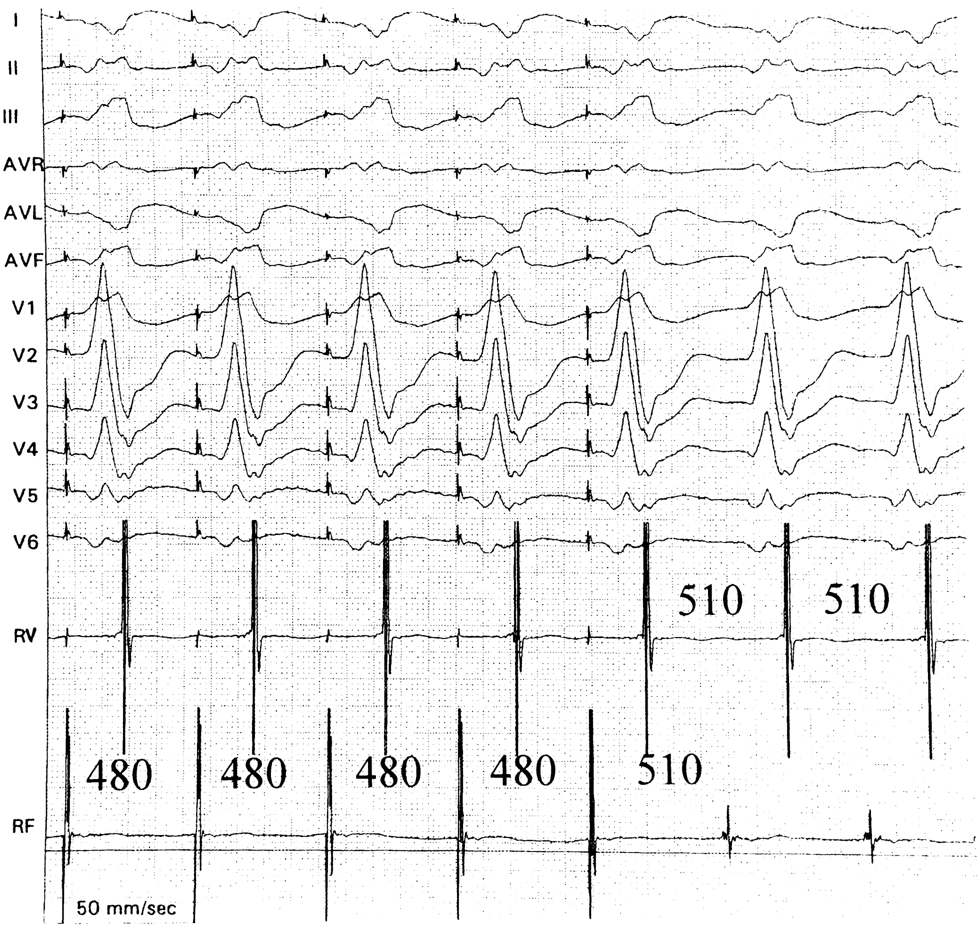

Figure 5. **(Top to bottom)** 12-lead surface electrocardiogram, endocardial signals from the right ventricle, and epicardial signals from the left ventricle. The cycle length of the ventricular tachycardia was 510 ms. Pacing from the epicardium shows concealed entrainment and a return cycle identical to the tachycardia cycle length. Ablation was effective at this site.

to the appropriate position. It was possible even in patients with a ventricular aneurysm, as well as in the patient with a previous acute pericarditis. Furthermore, the stability and contact of the catheter tip were good, accordingly with the absence of cardiac structures interfering with it. It is possible that this might have been different if the patient had been previously submitted to heart surgery.

During tachycardia, we used a standard mapping approach with the detection of diastolic potentials in all the cases and performance of entrainment mapping in four patients (Fig. 4). This represents a standard approach to VT in this case from the epicardium.

The duration of the procedure, fluoroscopy time, number of applications, as well as the rest of the technical characteristics of the ablation in terms of energy and temperature, were similar to those published previously for EdA and the results reported by Sosa et al. (11) and others (13–16).

With this approach, we successfully ablated the clinical, incessant VT in 80% of cases. These results reveal how EpA of VTs could be an effective complement to EdA and the first choice for those patients with contraindications to endocardial access. The combination of EdA and EpA may improve the success rates of VT ablation. Further studies are required in a wider spectrum of patients to demonstrate that VT ablation with both approaches, in a stepwise fashion, would increase the effectiveness of the procedure.

Safety. Several concerning issues have been raised in EpA. The potential for tamponade and perforation of the heart, risk of coronary occlusion due to RF application in proximity to coronary vessels, or mediastinitis and other complications of extravascular radiocontrast material have limited the utilization of this technique.

It is certain that there is a risk of pericardial effusion caused by bleeding from the thoracic wall, coronary arteries, or myocardial puncture. This could be higher with EpA than with pericardiocentesis, as the former attempts to enter in a virtual pericardial sac without a previous effusion. Advancing the needle tip with small contrast infusions could partially prevent this. In the series reported by Sosa et al. (11), accidental right ventricular perforation occurred in four patients of a total of 53 EpA procedures, even though hemopericardium drainage was necessary only in three patients in whom a small quantity (50 ml) was drained. In the present study, we did not detect any pericardial effusion either immediately after the procedure or on the day of hospital discharge.

All the manipulation maneuvers inside the pericardium may also cause an inflammatory response in the days after the procedure. In the present series, only two patients presented with thoracic pain for three days afterward. No other pericardial complications were found.

Additionally, the potential for coronary lesions, MI, and further deterioration of heart function represents a great concern. The precise relationship between the ablation catheter tip and the coronary arteries is very difficult to define. Furthermore, no safety distance has been established. On the other hand, applications in infarct-related areas have more chance to be near occluded or previously severely damaged arteries, as it has been already said (19). Moreover, voluntary damage in the coronary arteries has been used as an option in some patients with incessant or recurrent VT, using transcoronary chemical ablation (22–24). Even assuming that a coronary lesion can be caused, the risk must be balanced with the benefits in the different populations. Our patients were in a situation (incessant VT) in which we thought that the risk of complications had to be assumed and so the patients were informed. Finally, none of our patients had ischemic accidents, which reinforces the idea of the safety of the procedure.

CONCLUSIONS

In patients with incessant VT not controlled with pharmacologic therapy or by standard EdA, the EpA was very effective and no severe complications occurred. This technique should be considered as an alternative for these patients who are at very high risk. Further studies are warranted to define the usefulness of epicardial access for VT ablation.

Reprint requests and correspondence: Dr. Josep Brugada, Arrhythmia Section, Cardiovascular Institute, Hospital Clinic, Villarroel 170, 08036, Barcelona, Spain. E-mail: jbrugada@clinic.ub.es.

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