Radiofrequency ablation for post infarction ventricular tachycardia

Report of a single centre experience of 112 cases


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Objectives This report presents the largest consecutive series to date of radiofrequency ablation in the treatment of post infarction ventricular tachycardia.

Methods One hundred and twelve consecutive patients were studied, with an average of 12 documented episodes of ventricular tachycardia in the month preceding the radiofrequency ablation. Seventy-four percent of the subjects had an ejection fraction of less than 35%; 84% had more than one morphology of ventricular tachycardia and 30% had haemodynamically unstable ventricular tachycardia. The mean follow-up period was 61 months.

Results Complete success defined as no inducible sustained monomorphic ventricular tachycardia was achieved in 38%. Modified result, defined as ventricular tachycardia only inducible by two stimuli more aggressive than at baseline was achieved in 34%. During follow-up, ventricular tachycardia recurred in 25 patients: 22 after a failed procedure, two following a modified result and one following a complete success. Twenty-five patients died: 13 of progressive cardiac failure and four of presumed arrhythmic causes, three after a failed procedure and one following a modified result. There were no procedure-related deaths. Procedural complications occurred in seven patients.

Conclusions In this report, radiofrequency ablation of post infarction ventricular tachycardia is a successful procedure with a low complication rate. Acute procedural success accurately predicts long-term freedom from recurrent ventricular tachycardia.


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Key Words: Ventricular tachycardia, myocardial infarction, radiofrequency catheter ablation, outcome study.

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Introduction

Ventricular tachycardia (VT) is a common complication of ischaemic heart disease, with significant associated morbidity and mortality[1,2]. Traditionally, antiarrhythmic medications formed the mainstay of treatment, despite the low efficacy, the risk of pro-arrhythmia and long-term adverse effects[3]. Antiarrhythmic surgery is successful in abolishing VT; however, the operative mortality in most series was unacceptably high[4].

Over the past 10 years, internal cardioverter defibrillators (ICDs) have become the treatment of choice for all but incessant VT. This treatment is based on the evidence of a number of studies which have shown that ICDs reduce overall mortality in certain specific subgroups of patients with VT[5,6]. However, ICDs do not reduce the frequency of episodes and are contraindicated in patients with frequent arrhythmic episodes and contribute to pathological anxiety and depression in some patients[7]. Furthermore, ICD therapy is relatively expensive, when considered over the expected lifetime of particularly younger patients.

Radiofrequency ablation is the treatment of choice in the management of patients VT in the absence of structural heart disease[8]. The role of radiofrequency ablation in patients with post infarction VT is less well defined. In the post infarction setting, radiofrequency ablation has predominantly been used in patients with incessant or highly symptomatic, haemodynamically well tolerated drug refractory VT. A number of series have shown the procedure to be well tolerated with a reasonable procedural success rate[9–14].
This analysis reports the results of a single centre experience in radiofrequency catheter ablation of post infarction VT in 112 consecutive patients.

**Methods**

**Subjects**

This report reviewed consecutive patients from a single tertiary referral cardiology centre. Records of all patients who had undergone radiofrequency ablation for VT were reviewed, and all patients whose VT was scar related and consequent on a previous myocardial infarction were included. Patients were not enrolled within 21 days of a myocardial infarction. Prior to radiofrequency ablation all patients were investigated to exclude dynamic ischaemic contributors to their arrhythmias including coronary angiography in 100%, echocardiogram in 100% and functional assessments of ischaemia in 53%. Nineteen percent underwent percutaneous (17) or surgical (five) revascularization prior to VT ablation. Following revascularization, patients were only enrolled following further documentation of spontaneous or inducible VT.

**Electrophysiological study**

All patients gave informed consent and electrophysiology study and ablation was performed in a uniform way under local anaesthesia and sedation unless haemodynamic indications or patient request necessitated general anaesthesia. In all cases femoral arterial pressure, oxygen saturation and ECG were continuously monitored throughout. A dobutamine infusion was used routinely to improve haemodynamics during mapping in sustained VT. Heparin was administered once catheters were inserted into the left ventricle to maintain an activated clotting time of greater then 250 ms. Given the urgent nature of the cases, anti-arrhythmic drugs were often continued up to the time of the procedure. During the procedure no antiarrhythmic drugs were administered.

Prior to ablation, a standardized stimulation protocol was conducted from a 6 Fr quadrapolar Josephson’s catheter situated in the right ventricular apex. Stimulus duration was 2 ms through a 10 mA amplitude custom-built stimulator. The stimulation protocol comprised an 8-beat drive of ventricular stimuli from the right ventricular apex at a cycle length of 400–600 ms; followed by extrastimuli introduced at decreasing cycle lengths until refractoriness was reached. The stimulation protocol allowed for up to five extrastimuli to be introduced, as required until sustained VT was induced.

**Ablation protocol**

The sites for ablation were determined using a combination of endocardial mapping techniques previously described. Initial mapping was performed in sinus rhythm to locate areas with low voltage fragmented or delayed electrograms suggestive of scar with abnormal conduction properties. Pace mapping at the cycle length of the target VT was performed at these sites to identify a prolonged stimulus-to-QRS interval and a close QRS morphology match. When haemodynamically tolerated, mapping was then performed during VT to identify sites with (1) isolated diastolic potentials, (2) entrainment with concealed fusion (3) pre-systolic activity. Information from electroanatomical (CARTO) and non contact (Ensite 3000) mapping systems was used when appropriate.

When VT was terminated during radiofrequency delivery, a series of radiofrequency lesions was created to consolidate the initial lesion or alternatively to create a linear extension along the scar edge that included the presumed exit site. Ablation was performed using standard 4 mm and 8 mm tip catheters with a temperature limit of 60 °C or irrigated tip catheters with a power limit of 50 watts. Ablation was performed for a maximum of 120 s at one site.

Following the ablation procedure the standardized stimulation protocol was repeated to assess inducibility. The stimulation protocol was completed if the refractory period of five extrastimuli was reached without induction of sustained tachycardia. No further ablation took place after the final stimulation protocol.

**Definitions of procedural success**

Acute success — no sustained monomorphic VT induced at refractoriness of five extra stimuli.
Modified result — sustained monomorphic VT only inducible by two extra stimuli more aggressive than at baseline.
Failed procedure — sustained monomorphic VT inducible by less than two extra stimuli more aggressive than at baseline.

The induction of polymorphic VT, ventricular fibrillation or VT with a cycle length less than 230 ms was considered a non-specific response of no clinical relevance.

**Follow-up**

Data on all patients was initially collected at the time of ablation procedure, and additional information added throughout the course of the study. Patients local to the hospital were followed-up by one of the study investigators. Patients referred from other cardiologists were reviewed by their local hospital. Details of arrhythmia follow-up from these remote assessments were obtained from outpatient visits, defibrillator interrogations, ambulatory ECG monitors, hospital admissions and emergency department presentations.

In addition all patients were contacted at specified intervals of 1 month, 6 months, 12 months and 24 months. Final follow-up information was collected on all patients in February and March 2001.
Statistics

Continuous data are expressed as mean ± standard deviation. Individual group comparisons were made using paired t-tests. Dichotomous variables were assessed with Chi-square tests. P<0·05 was considered significant.

Results

Clinical characteristics (Table 1)

This analysis is comprised of details from 109 patients and 112 consecutive admissions, who underwent radiofrequency ablation for VT consequent on previous infarction. If two or more ablation procedures were conducted during the same admission they were analysed as a single procedure.

The group consisted of 95 males, mean age 56 (range 37–86). Ten percent of the patients were in incessant VT, a further 67% had the ablation performed in the context of a ‘VT storm’ defined as >3 episodes of sustained VT in a 24-h period and 23% were admitted or transferred from other hospitals on a semi-elective basis. The group had an average of 12·1 (range 0–150) symptomatic documented episodes of VT in the month prior to the procedure. All subjects had failed at least one antiarrhythmic medication (range 1–6): amiodarone (91%), sotalol (73%), mexiletene (23%). The majority of the subjects had significant left ventricular dysfunction and 42% New York Heart Association class 3 or 4 symptoms.

Electrophysiological study and radiofrequency ablation procedure (Table 2)

Eighty-one percent of the cases were performed using only conventional catheters and mapping techniques. In 11% the ‘Carto’ electroanatomical (Biosense Webster, Diamond Bar, CA, U.S.A.) and in 5% the ‘Ensite 3000’ non-contact (Endocardial Solutions, St Paul, Mn, U.S.A.) mapping systems were used. One-hundred and six (96%) of cases were performed under local anaesthesia and continuous sedation with midazolam and fentanyl. The other six cases were performed under general anaesthesia. Two left ventricular catheters were used in 84% of cases, with a retrograde catheter in 96% and a trans-septal catheter in 88%. Coronary venous access was used in 3%. In a single case an additional percutaneously inserted epicardial catheter was used.

All patients had VT induced with three or fewer extrastimuli at the start of the procedure (Fig. 1).

Ablation site was selected using a combination of pace mapping, entrainment mapping, fragmented or delayed potentials, diastolic potentials or early pre-systolic activation as described in the Methods section. Table 2 gives the percentage of cases in which one of these was either the predominant mode of mapping or the mapping tool that identified successful ablation sites. Ablation was performed with standard-tip 4 mm catheters in 60%, 8 mm tip catheters in 30% and with irrigated tip

<table>
<thead>
<tr>
<th>Table 1 Clinical characteristics</th>
<th>Mean</th>
<th>Range</th>
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<tbody>
<tr>
<td>Age</td>
<td>64</td>
<td>37–88</td>
</tr>
<tr>
<td>Male/female</td>
<td>95/17</td>
<td></td>
</tr>
<tr>
<td>LVEF &gt;35%</td>
<td>26 (23%)</td>
<td></td>
</tr>
<tr>
<td>LVEF 20–35%</td>
<td>47 (42%)</td>
<td></td>
</tr>
<tr>
<td>LVEF &lt;20%</td>
<td>39 (35%)</td>
<td></td>
</tr>
<tr>
<td>NYHA class 1</td>
<td>25 (22%)</td>
<td></td>
</tr>
<tr>
<td>NYHA class 2 or 3</td>
<td>81 (72%)</td>
<td></td>
</tr>
<tr>
<td>NYHA class 4</td>
<td>7 (6%)</td>
<td></td>
</tr>
<tr>
<td>Number of VT episodes in last month</td>
<td>12.1</td>
<td>0–150</td>
</tr>
<tr>
<td>Number of VT episodes in last 6 months</td>
<td>15.2</td>
<td>1–200</td>
</tr>
<tr>
<td>Anterior scar</td>
<td>46 (41%)</td>
<td></td>
</tr>
<tr>
<td>Inferior scar</td>
<td>39 (35%)</td>
<td></td>
</tr>
<tr>
<td>Number of failed antiarrhythmic medications</td>
<td>2.1</td>
<td>1–6</td>
</tr>
</tbody>
</table>

LVEF=left ventricular ejection fraction, NYHA=New York Heart Association functional class, VT=ventricular tachycardia.

<table>
<thead>
<tr>
<th>Table 2 Electrophysiological and ablation characteristics</th>
<th>Number</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than one VT morphology</td>
<td>93 (83%)</td>
<td></td>
</tr>
<tr>
<td>Number of VT morphologies</td>
<td>2–4</td>
<td>1–6</td>
</tr>
<tr>
<td>Haemodynamically unstable VT</td>
<td>32 (29%)</td>
<td></td>
</tr>
<tr>
<td>Pacemapping</td>
<td>49 (44%)</td>
<td></td>
</tr>
<tr>
<td>Entrainment mapping</td>
<td>43 (38%)</td>
<td></td>
</tr>
<tr>
<td>Diastolic potentials</td>
<td>91 (81%)</td>
<td></td>
</tr>
<tr>
<td>Fragmented electrograms</td>
<td>72 (64%)</td>
<td></td>
</tr>
<tr>
<td>Pre-systolic activation</td>
<td>49 (44%)</td>
<td></td>
</tr>
<tr>
<td>Procedure duration</td>
<td>240 min</td>
<td>110–560</td>
</tr>
<tr>
<td>Fluoroscopy time</td>
<td>240 min</td>
<td>110–560</td>
</tr>
<tr>
<td>RFA applications</td>
<td>21</td>
<td>3–78</td>
</tr>
</tbody>
</table>

VT=ventricular tachycardia, RFA=radiofrequency ablation.

Figure 1 Number of extrastimuli required to induce ventricular tachycardia. All patients had either spontaneous ventricular tachycardia (VT) or had VT induced at the start of the procedure prior to any ablation. The number of extrastimuli required to induce VT at the start of the procedure is shown.
catheters in 10%. Here was no difference in outcome with different ablation catheters.

**Procedural success — Table 3**

The final stimulation protocol was conducted in 110 of the 112 procedures. In the remaining two cases the procedure was curtailed urgently because of cardiac tamponade in one and progressive unexplained hypotension in the other. For the purpose of this analysis both were considered to be failed ablation procedures.

According to our original classifications, acute success was achieved in 38%, a modified result in 34% and acute failure in 28% (Table 3).

**Implantable cardioverter defibrillators**

Twelve patients had ICDs at the time of initial procedure. All patients with a failed procedure were offered an ICD, and 14 patients subsequently had an ICD inserted. In addition two patients with a modified result had an ICD inserted by external cardiologists. Neither of these patients had any documented recurrence of VT before or after ICD insertion.

**Predictors of success — Table 4**

Acute ablation success and failure were not predicted by the size or site of the infarct or the degree of left ventricular dysfunction. On univariate analysis, increased number of VT morphologies and haemodynamically unstable VT were predictors of ablation failure; whilst on multivariate analysis, only the number of VT morphologies was statistically associated with procedural failure.

**Complications**

Significant complications occurred in seven patients (6%) and minor complications in a further eight
patients. One patient required surgical repair of the femoral artery and another eight required ultrasound compression of a false aneurysm of the femoral artery. Cardiac tamponade occurred in three patients requiring immediate drainage in each case. One patient had a focal neurological deficit following the procedure which recovered within 48 h. Two patients required permanent pacing following damage to the conducting system. None of these patients with procedural complications suffered any significant long-term disability. No patient died during or as a consequence of the procedure.

Medications

At the time of hospital discharge 95% of the patients enrolled were taking either an angiotensin-converting enzyme inhibitor or an angiotensin II receptor antagonist, 98% of patients were taking an antiplatelet agent or warfarin, 73% were taking beta-blockers and 54% were taking a HMG CoA reductase inhibitor. Fifty-eight percent of patients were discharged on an antiarrhythmic drug: 97% after a failed procedure, 43% after a modified result and 39% following a complete success. The choice of antiarrhythmic was amiodarone in 42%, sotalol in 18% and others in 5%. If the ablation procedure was performed on amiodarone, it was routinely continued after the procedure. When standardized for procedural success, the use of antiarrhythmic drugs had no effect on long-term outcome.

Follow-up — Table 3

Follow-up was available on all patients enrolled in the study for a mean of 61 months. At the time of this analysis all patients had been followed for at least 9 months and 96% for more than 12 months following ablation.

VT recurred spontaneously during follow-up in 25 patients. Of these 25 recurrences, 22 occurred after a failed ablation procedure, two following a modified result and one following a complete procedural success. The mean time to VT recurrence was 6 weeks (range of 1 h–9 months). The mean time to recurrence following a failed procedure was 17 days and following a successful procedure was 7 months (Fig. 2). The VT recurrence rates were significantly different between the complete successor or modified groups and the procedural failure group ($P<0.001$).

During the same follow-up, 25 patients died, 13 of progressive cardiac failure and eight of non-cardiac causes. Two patients died suddenly of arrhythmic causes despite having an ICD inserted following a failed procedure. The remaining two patients died of unknown cause; neither of these had any documented episodes of VT following the ablation. One followed a failed procedure and the other a modified successful procedure. For the purpose of analysis both of these patients were considered to have died from arrhythmic recurrence (Fig. 3). There was a trend to worsening 5 year survival in the failed procedure group; however, this did not reach statistical significance.

Discussion

The main results of this analysis are that radiofrequency ablation of patients with highly symptomatic, sustained VT can be done with high success rate and low procedural complication rate; and that long-term recurrence of VT can be accurately predicted from the procedural end-point.
Results

This analysis reviewed 112 consecutive patients undergoing radiofrequency ablation for post infarction VT. Procedural success was achieved in 72%; this is a similar success rate to previously reported series. Suggested contraindications to VT ablation include (1) multiple inducible VT morphologies, (2) large areas of scar, (3) haemodynamically unstable VT. This report confirms that an increased number of VT morphologies and haemodynamically unstable VT were predictors of an unsuccessful procedure. Despite the statistical differences, procedural success was still achieved in 60% of patients with more than three VT morphologies or with haemodynamically unstable VT. This supports our previous work suggesting that even in patients with relative contraindications; radiofrequency ablation can have a high success rate.

The majority of the patients in this series underwent electrophysiological study and radiofrequency ablation using conventional mapping techniques. Success rates are likely to improve with the use of computer assisted mapping tools and catheters capable of creating deeper lesions.

Recurrence

The major new finding of this study is the ability to predict the longer term recurrence of VT from the procedural analysis.

In other series, the recurrence of VT following an initially successful procedure has been as high as 50% [14]. Even series that have targeted ablation to all morphologies of inducible sustained stable VT have reported 15–30% subsequent recurrence of VT following a successful procedure [15,16]. This analysis differs from other series in both the method of programmed stimulation and the definitions of success. The Westmead stimulation protocol used in this report has been extensively validated [15,19,20]. It uses a single site of stimulation from the right ventricular apex with up to five extrastimuli. In large scale randomized trials the Westmead protocol has been shown to be more sensitive and specific than the dual site protocol in predicting the risk of ventricular arrhythmias following myocardial infarction [15]. The variability of VT induction requirements with the Westmead protocol has also been defined [19,20]; a change in induction requirements of two or more extrastimuli has been demonstrated to be beyond the range of chance variability [19,20]. These data dictated the definitions of procedural success used in this study as such a change in induction requirements could be considered to be due to the antiarrhythmic effects of the ablation.

The long-term follow-up data presented in this report has shown that using this stimulation protocol and definitions of success it is possible to accurately predict which patients will remain free from recurrence of VT. According to the definitions used, a modified result is similar to a total procedural success in predicting long-term freedom from VT. In these patients the rate of recurrent VT is less than 4%.

Mortality

Published reports of patients with post infarction VT have shown that progressive heart failure is the major cause of mortality [15,16]. This report confirms these findings. Regardless of procedural success or failure, the majority of deaths in each group were due to cardiac failure.

In this report, the overall mortality varied according to the procedural outcome, with the highest 5 year mortality amongst those with a failed procedure (Fig. 3). In part, the increased mortality rates can be explained by the higher rates of arrhythmic deaths in the group with a procedural failure. The Kaplan–Meier survival curves demonstrate that much of the increased mortality in the procedural failure group occurred within 1 year of the ablation procedure, when arrhythmia recurrences and arrhythmic deaths were highest.

The presence of multiple morphologies of VT and haemodynamically unstable VT was associated with a higher rate of procedural failure; the increased mortality in this group may relate to these baseline differences in electrophysiological parameters.

Role of radiofrequency ablation

At present radiofrequency ablation for ischaemic VT is considered by many only as an adjunct to an ICD in patients with intractable or highly symptomatic VT. With the accuracy of prediction demonstrated in this series, procedural success at the time of ablation could obviate the need for ICD implantation. These findings may expand the role of radiofrequency ablation, making it the therapy of first choice in a growing proportion of patients; with ICDs reserved as the treatment for failed ablation procedures or for prophylactic indications. Even if ICDs remain justified on the basis of residual uncertainty, the quality of life is likely to be improved by the reduction in discharges resulting from catheter ablation.

This study has demonstrated the success and safety of catheter ablation for post infarction VT as well as the accuracy of the stimulation protocol in predicting recurrence of VT. At this stage a randomized study is warranted to address the safety, cost effectiveness and patient acceptance of a catheter ablation strategy using standardized programmed stimulation following the ablation procedure to determine the need for implantation of ICDs.

Limitations

As with most series, this report is from a single institution. The interest in catheter ablation of VT at this
centre is an important source of both patient referral and patient selection bias. Catheter ablation requires its own evidence base from a range of centres to allow these results to be generalized.

A significant number of patients in this series were revascularized and were only included in the analysis if they had further VT after revascularization. The delayed effect of revascularization on long-term recurrence has not been assessed. Medications were also not standardized in this series, Angiotensin-converting enzyme inhibitor, beta-blocker, HMG CoA reductase inhibitor and antiarrhythmic medication usage was high. No significant difference in acute procedural success or VT recurrence was seen for any of these medications; however, this was not independently assessed.

Whilst the results are encouraging, there was no randomization and no direct comparison with alternative therapies such as antiarrhythmic surgery or pharmacotherapy.

Conclusions

Radiofrequency catheter ablation of patients with highly symptomatic, sustained, monomorphic post infarction VT can be performed with high success rate and low procedural complication rate.

The procedure can be successfully applied to a wide spectrum of patients including multiple morphologies of VT and haemodynamically unstable VT. Using a standardized stimulation protocol at the time of ablation, the long-term recurrence of VT can be accurately predicted from the procedural end-point.

References