Outcomes of Early Risk Stratification and Targeted Implantable Cardioverter-Defibrillator Implantation After ST-Elevation Myocardial Infarction Treated With Primary Percutaneous Coronary Intervention

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Background—Methods to identify high-risk patients and timing of implantable cardioverter-defibrillator (ICD) therapy after ST-elevation myocardial infarction need further optimization.

Methods and Results—We evaluated outcomes of early ICD implantation in patients with inducible ventricular tachycardia. Consecutive patients treated with primary percutaneous coronary intervention for acute ST-elevation myocardial infarction underwent early left ventricular ejection fraction (LVEF) assessment. Patients with LVEF ≤40% were discharged (group 1); patients with LVEF ≤40% underwent risk stratification with electrophysiological study. If no ventricular tachycardia was induced, patients were discharged without an ICD (group 2). If sustained monomorphic ventricular tachycardia (≥200-ms cycle length) was induced, an ICD was implanted before discharge (group 3). Follow-up was obtained up to 30 months in all patients and up to 48 months in a subgroup of patients with LVEF ≤40% without an ICD. The primary end point was total mortality. Group 1 (n=574) had a mean LVEF of 54.8%; group 2 (n=83), 32.6%; and group 3 (n=32), 29.7%. At a median follow-up of 12 months, there was no significant difference in survival between the 3 groups (P=0.879), with mortality rates of 3%, 3%, and 6% for groups 1 through 3, respectively. In the subgroup of group 2 patients with LVEF ≤30% and no ICD (n=25), there was 9% mortality at a median follow-up of 25 months. In group 3, 19% had spontaneous ICD activation resulting from ventricular tachycardia.

Conclusions—Early ICD implantation limited to patients with inducible ventricular tachycardia enables a low overall mortality in patients with impaired LVEF after primary percutaneous coronary intervention for ST-elevation myocardial infarction. (Circulation. 2009;120:194-200.)

Key Words: death, sudden cardiac deaths, implantable cardioverter-defibrillators, electrophysiology, myocardial infarction

Despite advances in percutaneous interventional treatment of acute myocardial infarction (MI), the risk of sudden cardiac death after MI remains high, accounting for 50% of overall mortality.1,2 Although prophylactic implantable cardioverter-defibrillator (ICD) therapy has been shown to produce a significant survival benefit after MI,3-5 the current treatment paradigm centers on how to improve risk stratification tools to maximize benefits, reduce risks, and remain cost-effective in a financially challenging global environment.

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Landmark primary prevention trials have excluded patients with recent MI, enrolling very few patients experiencing an infarct within the previous 2 years.3-5 However, the risk of arrhythmic death is highest soon after MI, particularly during the first 30 days.6-9 This risk is greatest among patients with the lowest left ventricular ejection fraction (LVEF) (≤30%), but even patients with a higher LVEF (31% to 40%) are at a substantially increased risk for sudden death.2 Despite this increased risk, the Defibrillator in Acute Myocardial Infarction Trial (DINAMIT) investigators, who selected patients with a recent MI (6 to 40 days previously), LVEF ≤35%, and impaired cardiac autonomic function, did not find a benefit with early prophylactic ICD implantation.10 A retrospective analysis of the Multicenter Automatic Defibrillator Implantation Trial (MADIT) II data found that patients with an MI that was at least 18 months in the past benefited from prophylactic ICD, whereas those with a more recent MI did not benefit.11

Appropriate risk stratification is key to determining which patients will likely benefit from an ICD in the immediate phase after MI. Although depressed LVEF and low heart rate variability (DINAMIT) identify patients with increased mortality risk, they do not discriminate between arrhythmic and nonarrhythmic.

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causes of death. In contrast, inducible tachyarrhythmia seen at electrophysiological study (EPS) has been shown to identify patients for whom death, if it occurs, is likely to be arrhythmic. Furthermore, a combination of stratification tests appears to be the most satisfactory for predicting risk.

Prophylactic ICD implantation poses a difficult challenge owing to the high cost of the device and the large patient population eligible to receive an ICD. If ICD therapy were to be instigated in all patients in the United States who fulfilled the MADIT II study criteria, it would result in a potential additional annual expenditure in excess of $5 billion. Treatment of ST-elevation MI (STEMI) has advanced significantly in the last 5 years, with primary percutaneous coronary intervention (PPCI) resulting in higher survival, lower incidence of recurrent MI, and improvement in residual left ventricular function. However, trials looking at the possible benefits of ICD therapy after PPCI are lacking. This study aimed to evaluate a new algorithm for risk stratification using a combination of impaired LVEF and inducible ventricular tachycardia (VT) at EPS immediately after PPCI for STEMI, with ICD implantation limited to those with inducible VT.

Methods

Study Design

We prospectively recruited and followed up consecutive patients with STEMI over a 41-month period (April 2004 to September 2007). Patients presented directly to the intervention-capable Westmead Hospital (tertiary center, 957 beds) or were referred by 3 associated district hospitals (combined 685 beds) for PPCI. Patients who had undergone thrombolysis or presented for rescue angioplasty were excluded. Patients also were excluded if death occurred within 5 days or if they underwent urgent cardiothoracic surgery within 6 days of MI. All patients provided written informed consent to participate in the trial.

STEMI Management

All patients in the study were taken to the cardiac catheterization laboratory at Westmead Hospital with the intention to have PPCI and had angiographically confirmed STEMI. All patients with an STEMI diagnosis were given aspirin 300 mg and analgesia (intravenous morphine) as required before cardiac catheterization. For all PCI, a 100-IU/kg bolus of heparin was given immediately after the intervention, followed by a daily dose of 75 mg combined with aspirin 100 to 150 mg daily. All interventionalists were encouraged to use intravenous abciximab before stent deployment unless contraindicated by risk of bleeding. Intraaortic balloon pumps were used in patients with cardiogenic shock. After the intervention, patients were monitored for 24 to 48 hours in the coronary care unit and then transferred to a cardiology ward.

Assessment of Left Ventricular Function

Study protocol required LVEF assessment at >2 days after PPCI with a gated heart pool scan. Measurement of LVEF from transthoracic echocardiogram or left ventriculogram could be used only in situations when a gated heart pool scan could not be performed in a timely manner. Patients with LVEF >40% were discharged; patients with LVEF ≤40% underwent EPS.

Electrophysiological Study

EPS was performed on an inpatient basis with intravenous sedation (intravenous midazolam and fentanyl) in the absence of antiarrhythmic medication when possible. Programmed ventricular stimulation in an attempt to induce VT was performed with a quadripolar catheter deployed in the right ventricular apex. A drive train of 8 beats at 400 ms was followed by up to 4 extrastimuli. Each extrastimulus was introduced at 300 ms and decreased by 10 ms until ventricular refractoriness. The end point for stimulation was sustained monomorphic VT lasting >10 seconds. If sustained monomorphic VT with a cycle length (CL) ≥200 ms was induced by ≤4 extra stimuli, the EPS result was considered positive for inducible VT. Ventricular fibrillation (VF) or flutter with a CL <200 ms was considered a negative result. The programmed ventricular stimulation induction was repeated a second time if the initial induction was negative for VT. Patients with LVEF ≤40% and no inducible VT at EPS were discharged without an ICD. Patients with LVEF ≤40% and inducible VT at EPS had an ICD implanted before discharge.

ICD Implantation

All devices were pectoral ICD systems with the manufacturer and type determined by the implanting physician. At implantation, the defibrillation threshold was tested twice, with 14 J as the first shock, 21 J as the second shock, and then maximum energy (35 J). If 14 J was successful twice during defibrillation threshold testing, the outcome was considered to be satisfactory, and no further testing was necessary. If 20 J was not effective in reverting VF, repeat testing was necessary after lead repositioning or change in polarity. VF was induced by shock (1 J) on the T wave or 50-Hz burst pacing. Programming zones, which have been reported previously, consisted of a VF zone with a CL ≤250 ms with the therapy 1 defibrillation threshold plus a 10-J shock and therapies 2 through 6 with maximum output shocks of 35 J; a fast VT zone with a CL of 200 to 250 ms with therapy 1 of 2× ATP bursts of 8 pulses per burst, therapy 2 of a 5-J shock, therapy 3 of defibrillation threshold plus 10-J shock, and therapies 4 through 6 with maximum output shocks; and a VT zone with CL of 251 to 360 ms with therapy 1 of 3× ATP bursts of 8 pulses, therapy 2 of a 5-J shock, and therapies 4 through 6 with maximum output shocks. Supraventricular tachycardia limit was programmed at 250 ms. The number of intervals detected for each zone consisted of the following: for a VT CL ≤250 ms, detection required 18 of 24 beats, and for VT CL ≥250 ms, detection required 16 beats. Device function was assessed the day after implantation with interrogation of pacing parameters, lead sensing, lead threshold, and lead impedance. A chest x-ray was performed to verify lead position.

Other Treatment

Standard postinfarct medications, including aspirin, β-blockers, angiotensin-converting enzyme inhibitors, and lipid-lowering drugs, were encouraged in all patients.

Follow-Up

Follow-up of all patients was obtained at 30 days and up to 30 months by telephone contact with the patient, family, treating physician or local doctor if indicated, and review of hospital records if necessary. Patients with LVEF ≤30% without an ICD were followed up to 48 months. Patients with an ICD were also followed up at the defibrillator clinic at Westmead Hospital after ICD implantation at 1 and 3 months and then every 6 months thereafter. Each follow-up visit included interrogation of the ICD with analysis of device detections and activations, including electrogram verification, CLs of any arrhythmias, mode of therapy, success of therapies, and patient symptoms or complications.

End Points

The primary end point was death resulting from any cause. Secondary end points included death resulting from cardiac arrhythmia and device activation in patients with an ICD. Cause of death was determined by the local investigator and an independent researcher using information obtained from witnesses, family members, death certificates, hospital records, and autopsy reports. Cause of death was classified as arrhythmic or nonarrhythmic on the basis of a modified Hinkle and Thaler system, with deaths from arrhythmia including witnessed instantaneous deaths, unwitnessed deaths with no clear cause identified, nonsudden deaths caused by incessant tachycardia, deaths considered to be a sequela of cardiac arrest,
deaths resulting from proarrhythmia of antiarrhythmic drugs, and deaths caused by complications of implantable defibrillators.

Study Groups
For analysis, patients were divided into the following 3 groups: group 1, LVEF \( \geq 40\% \) and no EPS; group 2, LVEF \( \leq 40\% \), no inducible VT at EPS, and no ICD; and group 3, LVEF \( \leq 40\% \), inducible VT at EPS, and ICD implanted.

Statistical Analysis
The software package SPSS for Windows (release 15.0, SPSS, Chicago, Ill) was used for analysis. To test for associations between categorical variables, \( \chi^2 \) tests were used. ANOVA with posthoc least-significant-difference tests was used to compare mean values. Mann-Whitney or Kruskal-Wallis tests were used for continuous variables when normal distribution was not present. The cumulative risks of death resulting from any cause over time were estimated separately for each treatment group with use of the Kaplan–Meier procedure and were compared between groups with use of the log-rank (Mantel-Cox) and \( \chi^2 \) tests. A 2-tailed value of \( P < 0.05 \) was considered significant.

Results
Group Numbers
A total of 762 patients were taken to the catheterization laboratory with STEMI (Figure 1). Of these 762 patients, 32 (4%) did not have an LVEF measured by any method and were excluded from analysis. The reasons included inpatient transfer to a hospital that no longer followed the study protocol (18 of 32), significant comorbidity or terminal illness (5 of 32), self-discharge against medical advice (1 of 32), and early discharge with outpatient LVEF assessment (8 of 32). Of these 762 patients, 41 (5%) with an LVEF \( \leq 40\% \) also were excluded from analysis because no EPS was performed. The reasons included significant comorbidities (6 of 41), EPS deemed inappropriate for age (10 of 41) (patients 82 to 94 years of age), death occurring before EPS was performed (2 of 41), patient refusal (5 of 41), inpatient transfer to another hospital (1 of 41), and decision to reassess borderline LVEF at a later stage (17 of 41).

LVEF was assessed at a mean of 4 ± 2 days after infarct during hospital admission by gated heart pool scan in 87% of patients, transthoracic echocardiogram in 11% of patients, and left ventriculogram in 2% of patients. The total number of patients included for analysis was 689, consisting of 574 patients in group 1 (LVEF >40%, no EPS), 83 patients in group 2 (LVEF \( \leq 40\% \), no inducible VT), and 32 patients in group 3 (LVEF \( \leq 40\% \), inducible VT, and an ICD). The mean LVEF for all patients was 50 ± 12%.

Treatment Group Crossover
Nine patients (1%) crossed over to different treatment groups. Two patients from group 1 and 2 patients from group 2 with sustained VT/VF \( > 48 \) hours after infarct received ICD therapy for secondary prevention indications. One patient from group 2 received an ICD because the negative EPS was deemed unreliable as a result of treatment with amiodarone. Four patients in group 3 did not receive an ICD because of patient refusal in 3 cases and contraindication because of intravenous drug use and poor compliance in the other. These patients were placed in their intended groups and included in an intention-to-treat analysis.

Clinical Characteristics
The baseline characteristics of the 3 groups are presented in Table 1. Group 1 had a higher frequency of hypertension (56% versus 39% versus 44%) compared with groups 2 and 3 (\( P = 0.007 \), respectively). STEMI interventional details and outcome are presented in Table 2. There was a significantly higher number of left anterior descending territory infarcts in groups 2 and 3 compared with group 1 (\( P < 0.001 \)). The median duration of symptom-to-reperfusion time, a measure of total ischemic time, was significantly longer in group 3 (\( P = 0.036 \)). The mean LVEFs for groups 1 through 3 were 54%, 32%, and 29%, respectively. The mean difference in LVEF between groups 2 and 3 was significant (\( P = 0.032 \)). Length of hospital stay was significantly longer in group 3 (\( P < 0.001 \)), which was related to inpatient ICD implantation.

EPS Results
EPS was performed in 115 patients at a median of 9 days (interquartile range, 6 to 11 days) after infarct. There were no
major complications and no occurrence of stent thrombosis in the 48 hours after EPS. Minor complications included 1 case of induced atrial fibrillation requiring cardioversion. In group 3, 32 patients had inducible VT with a mean CL of 220 ms, induced on the first induction in 25 of 32 and on the second induction in 7 of 32, with 4, 3, 2, and 1 extrastimuli used in 14, 14, 2, and 2 of the 32 patients. Induced VT was predominantly left bundle-branch block morphology (17 of 32) and required external cardioversion to terminate (21 of 32). In group 2, no arrhythmia was induced (43 of 83) or VF/ventricular flutter was induced (40 of 83) with a mean CL of 173 ms. Four, 3, and 2 extrastimuli were used in 65, 17, and 1 of 83 patients, respectively.

ICD Details

ICDs were implanted at a mean of 6 ± 4 days after EPS in 28 patients in group 3, 3 patients in group 2, and 2 patients in group 1. The majority of patients had single-lead ICD systems consisting of Medtronic Maximo (17 of 33), Medtronic Virtuoso (5 of 33), Medtronic GEM III VR (3 of 33), and Medtronic Entrust (2 of 33) (Medtronic, Minneapolis, Minn). A small number of patients had dual-chamber ICDs, including Medtronic GEM III (2 of 33), Medtronic Intrinsic (2 of 33), and St Jude Medical Atlas HF (1 of 33) (St Jude Medical, Fullerton, Calif). There were no deaths related to ICD implantation. Two patients (6%) had atrial lead dislodgement requiring repositioning. There were no other complications associated with early ICD implantation.

Primary End Point

The median follow-up for all patients was 12 months (interquartile range, 5 to 22 months) with 17, 2, and 1 deaths in groups 1 through 3, respectively. The 30-day death rates were 1%, 1.2%, and 0% for groups 1 through 3, respectively. Kaplan–Meier survival curves for the 3 treatment groups are shown in Figure 2. There was no statistically significant difference in the survival distribution by treatment group (log-rank \( P = 0.879 \)), with estimated 12-month death rates of 3.0 ± 0.8%, 3.0 ± 2.1%, and

### Table 1. Baseline Patient Characteristics by Group*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Group 1 (n=574)</th>
<th>Group 2 (n=83)</th>
<th>Group 3 (n=32)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men, n (%)</td>
<td>453 (79)</td>
<td>62 (75)</td>
<td>30 (94)</td>
<td>0.077</td>
</tr>
<tr>
<td>Age, mean±SD, y</td>
<td>60±13</td>
<td>58±11</td>
<td>57±11</td>
<td>0.224</td>
</tr>
<tr>
<td>Diabetes mellitus, n (%)</td>
<td>149 (26)</td>
<td>13 (16)</td>
<td>11 (34)</td>
<td>0.225</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>320 (56)</td>
<td>32 (39)</td>
<td>14 (44)</td>
<td>0.007</td>
</tr>
<tr>
<td>Hyperlipidemia, n (%)</td>
<td>332 (58)</td>
<td>40 (48)</td>
<td>22 (69)</td>
<td>0.097</td>
</tr>
<tr>
<td>Family history, n (%)</td>
<td>308 (54)</td>
<td>41 (49)</td>
<td>20 (63)</td>
<td>0.482</td>
</tr>
<tr>
<td>History of coronary artery disease, n (%)</td>
<td>130 (23)</td>
<td>16 (19)</td>
<td>10 (31)</td>
<td>0.405</td>
</tr>
<tr>
<td>Previous coronary artery surgery, n (%)</td>
<td>25 (4)</td>
<td>2 (2)</td>
<td>2 (6)</td>
<td>0.598</td>
</tr>
<tr>
<td>Previous PCI, n (%)</td>
<td>54 (9)</td>
<td>5 (7)</td>
<td>6 (19)</td>
<td>0.113</td>
</tr>
<tr>
<td>Current smoker, n (%)</td>
<td>237 (41)</td>
<td>45 (54)</td>
<td>11 (34)</td>
<td>0.089</td>
</tr>
<tr>
<td>Previous stroke, n (%)</td>
<td>24 (4)</td>
<td>4 (5)</td>
<td>1 (3)</td>
<td>0.919</td>
</tr>
<tr>
<td>Q-wave development, n (%)</td>
<td>348 (61)</td>
<td>55 (66)</td>
<td>20 (63)</td>
<td>0.643</td>
</tr>
</tbody>
</table>

*Group 1, LVEF >40% and no EPS; group 2, LVEF ≤40%, no VT, and no ICD; group 3, LVEF ≤40%, VT induced, and ICD.

### Table 2. STEMI Intervention Details by Group*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Group 1 (n=574)</th>
<th>Group 2 (n=83)</th>
<th>Group 3 (n=32)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infarct-related artery, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left anterior descending</td>
<td>197 (34)</td>
<td>70 (84)</td>
<td>24 (75)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Right coronary</td>
<td>271 (47)</td>
<td>5 (6)</td>
<td>4 (13)</td>
<td></td>
</tr>
<tr>
<td>Circumflex</td>
<td>81 (14)</td>
<td>6 (7)</td>
<td>3 (9)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>25 (4)</td>
<td>2 (2)</td>
<td>1 (3)</td>
<td></td>
</tr>
<tr>
<td>STEMI therapy, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>0.372</td>
</tr>
<tr>
<td>PTCA only</td>
<td>24 (4)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>PTCA and stent</td>
<td>519 (90)</td>
<td>79 (95)</td>
<td>30 (94)</td>
<td></td>
</tr>
<tr>
<td>Medical management</td>
<td>26 (5)</td>
<td>2 (2)</td>
<td>1 (3)</td>
<td></td>
</tr>
<tr>
<td>PTCA and CABG</td>
<td>5 (1)</td>
<td>0 (0)</td>
<td>1 (3)</td>
<td></td>
</tr>
<tr>
<td>Symptom-to-reperfusion time, median</td>
<td>220 (168–330)</td>
<td>258 (185–329)</td>
<td>287 (195–380)</td>
<td>0.036</td>
</tr>
<tr>
<td>(interquartile range), min</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LVEF, mean±SD, %</td>
<td>54±8</td>
<td>32±6†</td>
<td>29±7†</td>
<td>0.032†</td>
</tr>
<tr>
<td>Median hospital stay (interquartile range), d</td>
<td>5 (4–7)</td>
<td>9 (7–13)</td>
<td>16 (10–23)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

PTCA indicates percutaneous transluminal coronary angioplasty; CABG, coronary artery bypass graft.

*Group 1, LVEF >40% and no EPS; group 2, LVEF ≤40%, no VT, and no ICD; group 3, LVEF ≤40%, VT induced, and ICD.

†Significant \( p \)-value of 0.032 in relation to LVEF=32% and LVEF=29%.
5.6±5.4% for groups 1 through 3, respectively. In the subgroup of group 2 patients with an LVEF ≤30% and no ICD (n=25), the 2-year mortality was 9±6.2% after a median follow-up of 25 months (interquartile range, 10 to 37 months), with 2 deaths occurring at 1 and 7 months after STEMI.

Secondary End Points

The causes of death are shown in Table 3. The mean LVEF of the 17 patients who died in group 1 was 53%; in group 2, the LVEFs of the 2 patients who died were 18% and 23%; and in group 3, the LVEF of the single patient who died was 37%. The 2 nonsudden deaths that occurred in group 2 were in the group of patients with no arrhythmia induced at EPS. No patients who had inducible VF/flutter at EPS died during follow-up. In group 3, the median follow-up in the defibrillator clinic was 12 months (interquartile range, 5 to 23 months), and 6 of 28 patients (22%) with an ICD experienced a total of 42 appropriate activations during follow-up. All ICD activations were due to VT (CL of 365±78 ms) and terminated with ATP. The mean time to first event was 11±10 months. The relationships between ICD activations and LVEF are presented in Table 4. The 5 patients in groups 1 and 2 who had ICD implantation through treatment group crossover did not have activation of their ICD after follow-up of 1, 3, 14, 23, and 30 months.

Discussion

This is the first study to evaluate a systematic early primary prevention protocol for sudden cardiac death as part of a coordinated regionalized PPCI service. No excess mortality was observed with early ICD implantation, and during follow-up, overall mortality was low compared with previously published trials. An important point is that in patients with LVEF ≤30% without inducible VT and without an ICD, there were no arrhythmic deaths and low mortality after >2 years of follow-up. Early measurement of LVEF after STEMI, combined with targeted EPS, may provide a viable method of selecting patients most likely to benefit from ICD therapy and may have advantages over the current clinical standard of using LVEF ≤30% at >40 days after MI as the sole selection criterion.

The rate of arrhythmic events seen at ICD interrogation in group 3 patients with inducible VT in our study was 22%. Arrhythmic events occur in 14% to 36% of patients with inducible tachyarrhythmia at EPS over a period of 1 to 2 years,27–29 and in the Multicenter Unsustained Tachycardia Trial (MUSTT), which used EPS to guide ICD therapy, the event rate was 18%.3 Of those patients with inducible VF/flutter at EPS who were not eligible for ICD implantation, there were no deaths. This is consistent with previous research that has shown that inducible VF or flutter at EPS is not a marker for an increased risk of sudden death.30,31 In our study, 17% of first ICD activations resulting from VT occurred within the first 2 months after acute MI, and 33% occurred in patients with an LVEF of 31% to 40%. It is possible that these patients would have had adverse outcomes secondary to arrhythmic events if MADIT II criteria had been followed. However, although all ICD activations were appropriate, we cannot equate this to aborted sudden death. ICD therapies, particularly for slow VT, have been shown not to be a surrogate for sudden cardiac death.30,31

There is a lack of definitive data on immediate versus delayed implantation of an ICD after acute MI. DINAMIT found a significant increase in the rate of death from nonarrhythmic causes in the ICD group.10 PPCI has been shown to decrease the rate of reinfarction,22,23 which has been shown at autopsy to account for half of all deaths classified as due to arrhythmia.32 Because only 27% of patients in DINAMIT were treated by PPCI compared with 95% in our cohort of patients, recurrent MI may have had a significant role in the increased number of nonarrhythmic deaths. Furthermore, stratification of patients with autonomic

Table 4. Spontaneous ICD Activation in Group 3*

<table>
<thead>
<tr>
<th>Patient</th>
<th>LVEF, %</th>
<th>ICD Implantation to First Activation, mo</th>
<th>VT CL, ms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>6</td>
<td>340</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>15</td>
<td>350</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td>2</td>
<td>310</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>8</td>
<td>350</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
<td>5</td>
<td>520</td>
</tr>
<tr>
<td>6</td>
<td>33</td>
<td>30</td>
<td>320</td>
</tr>
</tbody>
</table>

Mean±SD 25±8 11±10 365±78

*Group 3, LVEF ≤40%, VT induced, and ICD (n=32).

Table 3. Cause of Death by Group*

<table>
<thead>
<tr>
<th>Deaths</th>
<th>Group 1 (n=574), n</th>
<th>Group 2 (n=83), n</th>
<th>Group 3 (n=32), n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>17</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Cardiac, arrhythmic</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cardiac, nonarrhythmic</td>
<td>8</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Noncardiac</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Group 1, LVEF >40% and no EPS; group 2, LVEF ≤40%, no VT, and no ICD; group 3, LVEF ≤40%, VT induced, and ICD.
dysfunction to the ICD group of DINAMIT may have included more patients with increased mortality from heart failure, not specifically mortality from arrhythmic causes.\textsuperscript{13,33} In our study, there was no observed increase in adverse events with the use of immediate ICD therapy, with no major complications and no significant difference in 1-month mortality rates in patients with and without an ICD.

The Kaplan–Meier 12-month mortality rates in our patients with LVEF \( \leq 40\% \) with and without a defibrillator were low at 5.6\% and 3\%, respectively. Annual mortality rates in DINAMIT in the control and defibrillator groups were 7.5\% and 6.9\%, respectively,\textsuperscript{10} whereas in MADIT I and MUSTT, 1-year mortality among patients with impaired LV who received a defibrillator was \( \approx 10\\%.\textsuperscript{3,4} \)

Our study results are comparable to more recent trials of 1-year mortality of 5.8\% in patients with depressed LV after PCI.\textsuperscript{1}

There was a statistically significant difference in mean LVEF between groups 2 and 3, with a lower overall LVEF seen in group 3 (29\% versus 32\%). This is consistent with lower LVEF after acute STEMI being predictive of inducible VT at EPS.\textsuperscript{27} Depressed LVEF was found to correspond with anterior territory infarction, a relationship that is also well established.\textsuperscript{34} A significant negative correlation was found between total ischemic time and LVEF in patients after STEMI. Total ischemic time continues to play a major role in the determination of LV function, and strategies to reduce this time remain a priority.\textsuperscript{3,35}

In contrast to previous trials, our study involved early LVEF measurement (mean, 4 \( \pm 2 \) days) after MI. LVEF evaluation in this acute phase remains controversial, with studies suggesting that testing in the first month does not reliably identify patients at risk, whereas others maintain that only assessment at day 1 limits the ability to predict recovery of ventricular function.\textsuperscript{36,37}

Use of \( \beta \)-blockers and angiotensin-converting enzyme inhibitors after MI can improve LV function.\textsuperscript{38} However, with the high rate of spontaneous VT observed in our ICD patients and low mortality in non-ICD patients, it appears that an early LVEF dichotomy limit of 40\% was an appropriate cutoff for selecting a high-risk population.\textsuperscript{27} There were no major complications associated with the use of early EPS (mean, 10 days) after infarction, consistent with earlier studies demonstrating that early EPS in the maturing scar after MI is not associated with higher rates of complications.\textsuperscript{27}

Study Limitations

This is not a randomized controlled trial because we believe that having a control group of patients with LVEF \( \leq 40\% \) with inducible VT without an ICD would be unethical owing to the significantly increased risk of sudden death in these patients.\textsuperscript{3,4} However, a uniform protocol was implemented in a consecutive group of patients in the management of acute MI and assessment of LVEF and EPS for risk stratification. All patients included in this trial either presented directly to Westmead Hospital or were referred by its associated peripheral hospitals, so there was no selection bias. The exclusion of 41 patients who were eligible but did not undergo EPS was a limitation of our study. However, the reasons for this were appropriate without representing an exclusion bias. Crossover between groups was minimal, and the results were analyzed as intention to treat. Although this was a moderate-sized trial, to demonstrate a statistically significant equivalence to within 1\% in survival between group 2 patients without an ICD and group 3 patients with an ICD, a total of 3644 patients would be needed in each arm. Confirming the clinical and cost efficacy of this strategy therefore requires a large randomized multicenter trial comparing our protocol with the MADIT II protocol.

Conclusion

Use of LVEF assessment and EPS for risk stratification soon after PCI for MI, with ICD implantation limited to those with inducible VT, produced a uniformly low mortality on follow-up, including those patients with low LVEF.

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Disclosures

None.

References


**CLINICAL PERSPECTIVE**

Selection of myocardial infarction (MI) survivors to receive prophylactic implantable cardioverter-defibrillator (ICD) therapy for primary prevention of sudden death requires further elucidation. Although there is a mortality benefit for patients with significantly depressed left ventricular function when ICDs are implanted late after MI, a recent study found no benefit for patients implanted early after MI, despite studies demonstrating a higher risk of sudden death during the early months after MI that decreases with time. The optimal clinical approach to protecting these patients is not known, and data in the present era of primary percutaneous coronary intervention are limited. Our study recruited consecutive patients treated with primary percutaneous coronary intervention for acute ST-elevation MI. Patients with left ventricular ejection fraction ≤40% underwent electrophysiological study followed by ICD implantation in those with inducible ventricular tachycardia ≥200-ms cycle length. The overall mortality of 3% at 1 year was low compared with previous primary prevention studies, and there was no evidence of excess mortality with ICD implantation early after MI. In addition, patients with inducible ventricular tachycardia selected to receive an ICD had a relatively high rate of spontaneous ICD therapy for ventricular arrhythmias of 22%. Although not randomized, this study suggests favorable outcomes with a uniform, systematic primary prevention protocol integrated within an ST-elevation MI primary percutaneous coronary intervention service. This approach appears to be a rational approach to safely allocate ICD implantation early after ST-elevation MI.
Outcomes of Early Risk Stratification and Targeted Implantable Cardiopace-Defibrillator Implantation After ST-Elevation Myocardial Infarction Treated With Primary Percutaneous Coronary Intervention

Sarah Zaman, Gopal Sivagangabalan, Arun Narayan, Aravinda Thiagalingam, David L. Ross and Pramesh Kovoor

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