Mechanisms Underlying the Lack of Effect of Implantable Cardioverter-Defibrillator Therapy on Mortality in High-Risk Patients With Recent Myocardial Infarction: Insights from the Defibrillation in Acute Myocardial Infarction Trial (DINAMIT)

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Background—Although implantable cardioverter-defibrillators (ICDs) lower mortality in stable patients with low ejection fraction late after myocardial infarction, randomized trials of ICD versus control subjects implanted early after myocardial infarction do not show mortality benefit. Our objective was to investigate possible mechanisms underlying the lack of mortality benefit in the Defibrillation in Acute Myocardial Infarction Trial (DINAMIT).

Methods and Results—This is a secondary analysis of the prospective randomized clinical trial. Outpatients with recent (6 to 40 days) acute myocardial infarction, left ventricular dysfunction (ejection fraction <35%), and low heart rate variability were randomized to ICD (n=311) or to standard medical therapy (n=342). In a competing-risks analysis, those factors that increased the risk of arrhythmic death also increased the risk of nonarrhythmic deaths. After adjustment for these factors, receiving an ICD was associated with a decreased risk of arrhythmic death (hazard ratio, 0.33; 95% confidence interval, 0.15 to 0.71) but an increase in nonarrhythmic death (hazard ratio, 1.70; 95% confidence interval, 1.00 to 2.80). In an adjusted time-dependent analysis, patients receiving an ICD and having appropriate ICD therapy had a 15.1% yearly hazard of mortality compared with 5.2% in ICD patients with no appropriate therapy (P<0.001). The reduction in sudden death in ICD patients was completely offset by increased nonarrhythmic deaths, which were greatest in patients receiving ICD shock therapy (hazard ratio, 6.0; 95% confidence interval, 2.8 to 12.7).

Conclusions—In patients receiving ICDs early after myocardial infarction, those factors that are associated with arrhythmia requiring ICD therapy are also associated with a high risk of nonsudden death, negating the benefit of ICDs in this setting. (Circulation. 2010;122:2645-2652.)

Key Words: death, sudden ■ defibrillation ■ implantable cardioverter-defibrillators ■ myocardial infarction

Implantable cardioverter-defibrillators (ICDs) in appropriately selected patients reduce all-cause mortality by reducing sudden death resulting from ventricular tachyarrhythmias. In some studies of ICDs in patients with no prior history of sustained arrhythmias (primary prophylaxis), a relative risk reduction of 20% to 30% in mortality compared with control subjects has been reported, resulting in an absolute reduction in mortality of 1.5% to 3% per year. However, not all ICD studies show a reduction in all-cause mortality. In 2 studies of patients with dilated cardiomyopathy and in 1 study in which patients were randomized immediately after aortocoronary bypass surgery, ICD implantation was not associated with a significant reduction in mortality. In high-risk patients randomized to ICD or to no ICD implantation shortly after an acute myocardial infarction (MI) (Defibrillator in Acute Myocardial Infarction Trial [DINAMIT]), there was no effect of the ICD on all-cause mortality. The hazard ratio (HR) for all-cause death in the ICD versus the control group was 1.08 (95% confidence interval [CI], 0.76 to 1.55). In DINAMIT, the ICD significantly reduced arrhythmic death; the HR for death adjudicated to be due to arrhythmia for the ICD group compared with the control group was 0.42 (95% CI, 0.22 to 0.83; P=0.009). In contrast, the HR for death from nonarrhythmic causes was 1.75 (95% CI, 1.11 to 2.76; P=0.02),
with the increase in nonarrhythmic deaths completely offsetting the decrease in arrhythmic deaths. Similar results were seen in the recent Immediate Risk Stratification Improves Survival (IRIS) study of ICD implantation in high risk past MI survivors.9

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The objective of this substudy of DINAMIT was to assess in detail the risk factors for arrhythmic and nonarrhythmic death in patients enrolled in the trial in an attempt to explain the lack of an effect of ICD therapy on all-cause mortality. Our hypothesis was that ICD therapy did not reduce death because the patients destined to receive ICD therapy were also at high baseline risk of nonsudden death and because arrhythmic events treated by an ICD in patients with recent MI are often associated with intercurrent cardiac events such as heart failure or ischemic events, resulting in poor prognosis after ICD therapy.

Methods

Patient Population

The methods and the main results of the DINAMIT study have been described in detail.8 In brief, patients 18 to 80 years of age were eligible for enrollment if they had had an MI 6 to 40 days before randomization, a left ventricular ejection fraction (LVEF) of ≤35%, and evidence of impaired cardiac autonomic function (SD of N-N intervals ≤70 ms or average heart rate >80 bpm on a 24-hour Holter monitor performed ≥3 days after the index MI).

Patients were excluded if they had New York Heart Association class IV heart failure symptoms at the time of randomization, coronary bypass grafting, 3-vessel percutaneous coronary intervention immediately after the acute MI (or planned at the time of randomization), or prior ICD therapy.

Three hundred thirty-two patients were randomized to the ICD group and 342 to a control group at an average of 18 days after MI. Follow-up ranged from 15 months to 4 years (and averaged 30±13 months).

Because this analysis is primarily mechanistic, patients who were randomized to receive an ICD but were not implanted within 3 months were excluded. Among those randomized to ICD, 20 never received an implant, and 1 patient received the implant at 1293 days. Control patients (assigned to no ICD) who went on to receive an ICD were censored at the date of implantation.

Substudy Outcomes

The primary outcome in DINAMIT was death resulting from any cause. Deaths resulting from cardiac arrhythmia and cardiac causes were classified by a blinded (with respect to therapy assignment) central validation committee using criteria developed by Hinkle and Thaler10 and validated in the Multicenter Automatic Defibrillator Implantation Trial-II (MADIT-II) trial.11 Defibrillator therapies were assessed at regular follow-up visits in each center by interrogation of the ICD data logs. All ICD therapies were adjudicated by 1 of 3 investigators blinded to ultimate patient outcome, and arrhythmia events were classified as appropriate (resulting from a ventricular tachyarrhythmia) or inappropriate (resulting from other causes) therapy. Events for each patient were adjudicated in chronological order until an appropriate ICD therapy was identified for every patient or until the last follow-up, whichever came first. Ventricular fibrillation (VF) was defined from the intracardiac electrogram as a polymorphic arrhythmia with ventricular cycle length <210 ms.

For the purpose of this analysis, patients were classified into 3 groups: patients not receiving an ICD (control), patients randomized to and receiving an ICD and not receiving appropriate ICD therapy at any time (no appropriate ICD therapy), and patients randomized to and receiving an ICD and receiving appropriate ICD therapy (antitachycardia pacing [ATP], high-energy shocks, or both; appropriate ICD therapy).

Statistical Analysis

The relationships between clinical factors at baseline and outcomes and between postrandomization events and outcomes were analyzed in 2 sequential steps. The relationship between baseline clinical factors and presumed arrhythmic deaths and nonarrhythmic deaths was investigated with the use of “competing-risks” proportional hazards analysis and displayed as cumulative incidence over time (otherwise known as actual probability).12,13

As a second step, outcomes were analyzed with a time-dependent analysis, which incorporates postrandomization events (appropriate ICD therapy in this case) into the model and seeks to assess whether such events alter subsequent risk of death, controlling for those baseline factors identified to alter risk in the first step.

Competing-Risks Analysis

Death resulting from an arrhythmia excludes the possibility of death resulting from another cause. This results in an “opportunity” for patients to be at risk of nonsudden death (the conversion hypothesis).14 It is also possible that patients with an ICD who are saved from arrhythmic death (and thus have longer time period at risk for nonarrhythmic death) have clinical characteristics different from patients having nonarrhythmic deaths in the absence of an ICD. Proportional hazards models can be extended to accommodate this competing-risk framework.15 The analysis adjusted for treatment effect by taking into account potentially differential effects of the risk factors for the different causes of death. The analysis uses all patients but excludes the randomized treatment allocation from the model. A backward elimination variable selection method was bootstrapped to identify those variables that were consistently identified as important predictors. Baseline variables considered for the model are given in Table 1. A final multivariable competing-risks model was fit, incorporating the variables identified as potentially important and treatment allocation.

Time-Dependent Analysis

As a subsequent step, the contribution of defibrillator therapy (any device therapy, appropriate therapy, and shock therapy) to mortality was analyzed with a time-dependent Cox proportional hazards model after adjustment for those baseline prognostic factors identified in the competing-risks model. In the time-dependent analysis, the outcome is considered to belong to the no therapy group until one of the therapy events occurred, after which the outcome is assigned to the therapy group.16

Cumulative probability of mortality after the first appropriate therapy for ventricular tachycardia (VT) and VF was calculated, as well as mortality in patients not having any appropriate therapy during follow-up. To illustrate the time-dependent effect of defibrillator therapy, the final Cox model was used to estimate survival curves for hypothetical low-risk (having none of the risk factors associated with mortality) and high-risk (having all the risk factors associated with mortality) patients. Survival curves were generated from the Cox model assuming that a therapy was delivered at 30 days, 6 months, 1 year, or never.

Results

Patient Characteristics

There were 674 patients in the DINAMIT study; 332 were randomized to an ICD. Among the 21 patients excluded because they did not receive an ICD within 90 days, 8 died, including 2 patients with arrhythmic deaths. Among 342 patients randomized to no ICD, 17 received an ICD at some time during follow-up and were censored at that time. Four of these patients
died subsequently, all of nonarrhythmic causes. Of the ICD patients, 18% (n=59) received appropriate ICD therapy.

Baseline demographics for the 3 groups—no ICD, ICD without appropriate ICD therapy, and ICD with appropriate ICD therapy—are illustrated in Table 1. Patients with appropriate ICD therapy were more likely to have had an infarct before the index infarct, more likely to have nonsustained VT on the Holter monitor performed after MI, and slightly less likely to have a β-blocker at initial hospital discharge.

The LVEF at randomization was very similar in the 3 groups. The majority of patients in all groups received some form of acute reperfusion (thrombolysis or percutaneous coronary intervention). There were no differences in the percentages of patients showing new Q waves with their index MI versus non-Q-wave MI.

### Table 1. Baseline Variables for the Defibrillation in Acute Myocardial Infarction Trial (DINAMIT)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control Group (n=342)</th>
<th>Appropriate ICD Therapy (n=59)</th>
<th>No Appropriate ICD Therapy (n=252)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD) follow-up, mo</td>
<td>28 (14)</td>
<td>28 (14)</td>
<td>30 (14)</td>
</tr>
<tr>
<td>Age, y</td>
<td>62 (11)</td>
<td>61 (11)</td>
<td>61 (11)</td>
</tr>
<tr>
<td>Male sex, %</td>
<td>77</td>
<td>85</td>
<td>74</td>
</tr>
<tr>
<td>Baseline LVEF, % (% patients)*</td>
<td>29 (5)</td>
<td>28 (6)</td>
<td>28 (5)</td>
</tr>
<tr>
<td>6-wk LVEF, % (n patients)</td>
<td>30 (11)</td>
<td>29 (10)</td>
<td>32 (10)</td>
</tr>
<tr>
<td>ΔLVEF (6 wk to baseline), % (% patients)</td>
<td>1.3 (10)</td>
<td>−1.8 (10)</td>
<td>3.4 (11)</td>
</tr>
<tr>
<td>n patients</td>
<td>166</td>
<td>31</td>
<td>119</td>
</tr>
<tr>
<td>CHF at randomization, NYHA class III, %</td>
<td>14</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>SDNN, n (%)</td>
<td>61 (22)</td>
<td>61 (20)</td>
<td>60 (20)</td>
</tr>
<tr>
<td>n patients</td>
<td>330</td>
<td>58</td>
<td>245</td>
</tr>
<tr>
<td>Thrombolysis, %</td>
<td>38</td>
<td>43</td>
<td>37</td>
</tr>
<tr>
<td>PTCA, %</td>
<td>42</td>
<td>32</td>
<td>39</td>
</tr>
<tr>
<td>VT on Holter, %</td>
<td>16</td>
<td>34</td>
<td>14</td>
</tr>
<tr>
<td>Any reperfusion, %</td>
<td>66</td>
<td>64</td>
<td>68</td>
</tr>
<tr>
<td>MI preceding the index MI, %</td>
<td>32</td>
<td>51</td>
<td>33</td>
</tr>
<tr>
<td>CHF with index MI, %</td>
<td>49</td>
<td>61</td>
<td>50</td>
</tr>
<tr>
<td>BB at randomization, %</td>
<td>87</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>Diabetes Rx within 1 y of index MI, %</td>
<td>29</td>
<td>20</td>
<td>33</td>
</tr>
<tr>
<td>Hypertension Rx within 1 y of index MI, %</td>
<td>45</td>
<td>58</td>
<td>43</td>
</tr>
<tr>
<td>Lipid-lowering Rx at D/C, %</td>
<td>80</td>
<td>69</td>
<td>79</td>
</tr>
</tbody>
</table>

*CHF indicates congestive heart failure; NYHA, New York Heart Association; SDNN, SD of the N-N interval; PTCA, percutaneous transluminal coronary angioplasty; BB, β-blocker; Rx, therapy; and D/C, discontinuation. Variables are expressed as mean (SD) when appropriate.

**Table 2. Events During Follow-Up**

<table>
<thead>
<tr>
<th>Event</th>
<th>Control Group (n=342)</th>
<th>Appropriate ICD Therapy (n=59)</th>
<th>No Appropriate ICD Therapy (n=252)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospitalization, %</td>
<td>67</td>
<td>76</td>
<td>63</td>
<td>0.07</td>
</tr>
<tr>
<td>Mean (SD) hospitalizations, n</td>
<td>1.7 (2.0)</td>
<td>2.9 (2.9)</td>
<td>1.5 (1.6)</td>
<td>0.0004</td>
</tr>
<tr>
<td>Any MI, %</td>
<td>7</td>
<td>24</td>
<td>9</td>
<td>0.003</td>
</tr>
<tr>
<td>Unstable angina, %</td>
<td>18</td>
<td>19</td>
<td>10</td>
<td>0.06</td>
</tr>
<tr>
<td>CABG and/or PCI, %</td>
<td>15</td>
<td>12</td>
<td>9</td>
<td>0.50</td>
</tr>
<tr>
<td>CHF event, %</td>
<td>26</td>
<td>44</td>
<td>21</td>
<td>0.0008</td>
</tr>
<tr>
<td>Any inappropriate shock, %†</td>
<td>7</td>
<td>8</td>
<td>&gt;0.9</td>
<td></td>
</tr>
</tbody>
</table>

*CABG indicates coronary artery bypass graft; PCI, percutaneous coronary intervention; and CHF, congestive heart failure.

**Table 2. Events During Follow-Up**

*ICD therapy versus no ICD therapy groups. The Fisher exact test was used for all outcomes except mean number of hospitalizations, which used a Wilcoxon rank sum test.

†Inappropriate therapy was not measured after the first appropriate therapy.

### ICD Programming and Defibrillation

#### Threshold Testing

All patients received a single-chamber ICD. Approximately 99% of the patients were programmed according to protocol (backup bradycardia pacing rate, ≥50 bpm). The mean programmed detection rate for ventricular arrhythmias was 175±7 bpm, with 15±8 beats to detect VT. The VF detect was programmed at 203±8 bpm (n=310).

In total, 294 of 311 patients had ATP programmed. There were 81 appropriate therapy events in 59 patients: 18 patients had ATP only, 26 patients had shock therapy only, and 15 patients had shocks and ATP events. A total of 33 VT events were treated with ATP, 17 VT events with shock, and 31 VF events with shock (not every event in every patient was fully adjudicated).

All patients had defibrillation threshold testing (DFT) at implantation, and 92% had an adequate defibrillation threshold testing (defined as less than one-half maximal device output).

#### Clinical Course

Among patients destined to have appropriate ICD therapy, 63% received this therapy within 1 year of randomization and 95% within 3 years.

After randomization, more patients in the appropriate ICD therapy group had intercurrent clinical events: 32% had an episode of unstable angina or MI versus 16% in the group with no appropriate ICD therapy and 23% in the control group, and 44% had new heart failure compared with 21% in the no appropriate therapy group (P=0.0008) and 26% in the control group (Table 2). Among the 59 patients with appropriate ICD therapy, 32 had an intercurrent adverse event after implantation, and 50% died. Among 27 patients with ICD therapy and no intercurrent event, 18.5% (5 of 27) died (Table 3). Among 18 patients who received ATP therapy only, 9 had ATP and an intercurrent event and 5 died; 9 had ATP and no
intercurrent event, and none died. Among 28 patients who had inappropriate therapy only (19 had shocks), 5 died.

**Mortality After Appropriate ICD Therapy**
Patients with appropriate ICD therapy had a >2-fold increase in all-cause mortality compared with either the control or the no appropriate therapy group (Table 4). Of 59 patients with appropriate ICD therapy, 21 (36%) died after the therapy compared with 33 of 252 patients with no appropriate ICD therapy (13%; \( P = 0.0001 \) between ICD groups) and 54 of 342 (16%) in the control group.

In the control group, \( \approx 54\% \) of the deaths were sudden and presumed arrhythmic, and 31% were cardiac nonarrhythmic. In contrast, in both the ICD groups (with and without appropriate therapy), most of the deaths (67% and 61%, respectively) were cardiac nonarrhythmic (Table 4).

Similar to the “any appropriate therapy” analysis, patients receiving appropriate shocks from their ICD (n = 41) were at greater risk of death resulting from any cause and greater risk of nonarrhythmic death than either patients in the ICD no shock group (n = 291) or those in the control group (all-cause death, 39%, 16%, and 17%, respectively; nonarrhythmic death, 32%, 15%, and 9%, respectively).

Figure 1 illustrates outcomes in the 3 groups of patients: those who were assigned to no ICD therapy (Figure 1A), those who received an ICD but received no appropriate device therapy (Figure 1B), and those who received an ICD and appropriate ICD therapy (Figure 1C). In patients receiving an ICD, the cumulative incidence of arrhythmic mortality was low, whereas nonarrhythmic mortality was high in ICD recipients receiving appropriate therapy.

### Table 3. Mortality in the 59 Patients With Implantable Cardioverter-Defibrillator Therapy, With and Without Intercurrent Events*

<table>
<thead>
<tr>
<th>Event before ICD Rx (n=18)</th>
<th>345 ± 334 d before Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event occurrence</td>
<td>230 ± 262 d after Rx</td>
</tr>
<tr>
<td>Mortality (50.0%)</td>
<td></td>
</tr>
<tr>
<td>Event after ICD Rx (n=11)</td>
<td>272 ± 297 d after Rx</td>
</tr>
<tr>
<td>Event occurrence</td>
<td>285 ± 193 d after Rx</td>
</tr>
<tr>
<td>Mortality (45.5%)</td>
<td></td>
</tr>
<tr>
<td>Event with ICD Rx† (n=3)</td>
<td>0 ± 0 d before/after Rx</td>
</tr>
<tr>
<td>Event occurrence</td>
<td>62 ± 88 d after Rx</td>
</tr>
<tr>
<td>Mortality (45.5%)</td>
<td></td>
</tr>
</tbody>
</table>

Mortality in patients with intercurrent events (n=32)

**Table 4. Death**

<table>
<thead>
<tr>
<th></th>
<th>Control Group (n=342)</th>
<th>ICD Group* (n=311)</th>
<th>ICD Group† (n=291)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appropriate ICD Therapy (n=59)</td>
<td>No Appropriate ICD Therapy (n=252)</td>
<td></td>
</tr>
<tr>
<td>Total deaths, n (%)</td>
<td>54 (16)†</td>
<td>21 (36)</td>
<td>33 (13)</td>
</tr>
<tr>
<td>Crude hazard of mortality, (%)‡</td>
<td>6.7</td>
<td>15.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Type of deaths, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sudden, presumed arrhythmic</td>
<td>29 (54)</td>
<td>5 (24)</td>
<td>5 (15)</td>
</tr>
<tr>
<td>Cardiac, nonarrhythmic</td>
<td>17 (31)</td>
<td>14 (67)</td>
<td>16 (48)</td>
</tr>
<tr>
<td>Noncardiac</td>
<td>8 (15)</td>
<td>2 (9)</td>
<td>12 (36)</td>
</tr>
</tbody>
</table>

ICD indicates implantable cardioverter-defibrillator.

*After adjustment for the other covariates included in the model, there was a time-dependent effect of appropriate therapy on mortality (\( P = 0.000005 \)).

†Crude hazard of mortality is the number of events per patient-year of follow-up expressed as a percentage.

Figure 1. Cumulative incidence for arrhythmic mortality (solid line) and nonarrhythmic mortality (dashed line). A, Patients who were randomized to no implantable cardioverter-defibrillator (ICD); B, patients who were randomized to an ICD and received an ICD but received no appropriate device therapy; C, patients who were randomized to ICD, received an ICD, and received appropriate ICD therapy.
Figure 2 illustrates outcomes after the first appropriate therapy (ie, time 0 is the day of the first appropriate therapy, whenever it occurs). All-cause mortality is high in the period after the first appropriate therapy, with an ≈30% mortality at 1 year and 40% mortality at 2 years after appropriate therapy administered for VT or VF. Outcomes after therapy for VF appear worse than after therapy for VT.

**Competing-Risk Analysis**

All baseline clinical factors associated with increased risk of death from any cause except for diabetes mellitus had a similar effect (increase in risk) for both presumed arrhythmic death and nonarrhythmic death. The risk associated with these factors is thus considered for all-cause mortality.

Factors associated with significant risk from any cause (both arrhythmic and nonarrhythmic) included age >60 years (HR, 1.7; 95% CI, 1.0 to 2.9), QRS duration ≥120 ms on the baseline ECG (HR, 1.5; 95% CI, 1.0 to 2.3), nonsustained VT on the baseline Holter monitor (HR, 1.9; 95% CI, 1.2 to 3.0), treatment for hypertension (HR, 1.9; 95% CI, 1.2 to 2.9), and MI preceding the index MI (HR, 1.7; 95% CI, 1.1 to 2.5). Higher LVEF (LVEF, 30% to 35% versus <25%; HR, 0.42; 95% CI, 0.24 to 0.75) and β-blocker therapy (HR, 0.6; 95% CI, 0.4 to 1.0) were associated with a lower risk of death. Treated diabetes mellitus was associated with an increase in risk of arrhythmic death (HR, 2.6; 95% CI, 1.3 to 5.2) but not nonarrhythmic death (HR, 1.1; 95% CI, 0.7 to 1.8). After adjustment for these factors, assignment to an ICD was associated with a decreased risk of arrhythmic death (HR, 1.70; 95% CI, 1.00 to 2.80) and any shock therapy were all associated with an increase in risk of ≈5-fold for mortality from both all-cause and nonarrhythmic death.

Figure 3 illustrates the estimated risk of death in patients with no or many high-risk features and as a function of the time after the first appropriate therapy by the ICD. After an appropriate therapy, the risk of death increases markedly very soon after the event, with a much higher absolute risk in high-risk patients and progressively higher risk the sooner after implant the first event occurs.

**Antiarrhythmic Drugs**

Of the 59 patients who received appropriate ICD therapy, 23 were placed on an antiarrhythmic (primarily amiodarone), and 11 of these 23 died. Among the 252 patients who received an ICD and had no appropriate therapy, 27 received an antiarrhythmic drug, and 6 of them died. Among the 342 patients with no ICD, 75 patients received an antiarrhythmic drug, and 14 of them died.

**Discussion**

**Main Study Findings**

The results of this substudy of the DINAMIT trial show that patients expected to be at high risk of sudden death after an...
acute MI who receive an ICD by random assignment and subsequently receive appropriate ICD therapy have a high risk of death in the 6 months to 1 year after such appropriate therapy. Most of these deaths are cardiac nonarrhythmic in nature, presumably resulting from heart failure, recurrent ischemia, or both. Given the relatively small proportion of patients with an ICD who receive appropriate therapy (19% of ICD recipients after a follow-up of 28 months), this high mortality (40% at 2 years by the Kaplan-Meier method) completely offsets the observed sudden death reduction in the ICD group as a whole. The competing-risks analysis shows that even after adjustment for high-risk clinical features, patients with an ICD are at lower risk of arrhythmic but are at higher risk of nonarrhythmic death than patients without an ICD. Second, the time-dependent proportional hazards analysis shows that after adjustment for baseline clinical differences, patients who receive appropriate ICD therapy have a greater risk of death after therapy than they did before the therapy. In other words, although the device probably saved their lives at the time of therapy, it simply postponed their deaths for a short period of time.  

Both the competing-risks model and the time-dependent analysis suggest that defibrillators do not reduce all-cause mortality early after MI because patients “saved” by their defibrillator have a relatively high burden of ischemic and heart failure risk, both at baseline and during follow-up, and have a high likelihood of dying in the weeks to months after such effective ICD therapy. For patients implanted with an ICD soon after MI, these observations suggest a fundamental limitation of the treatment paradigm: The patients at highest risk of receiving appropriate therapy (who might most “need” the ICD) are the ones at highest risk of dying of nonarrhythmic causes soon after the therapy; those at lowest risk of nonarrhythmic death (in whom the device can “do the most good”) are the ones at much lower risk of ever receiving appropriate therapy in the first instance. Figure 3 illustrates this conundrum: “Lower-risk” patients have a low likelihood of receiving ICD shocks, and their mortality is low whether they receive ICD shocks or not, and higher-risk patients have a greater chance of receiving ICD shocks, but their subsequent mortality rate is very high, offsetting the potential benefit from the ICD therapy. It also merits emphasis that 38% of the events treated by the ICD were VF, a proportion that is higher than in prior trials of ICDs for primary prevention of sudden death. Having VF, in contrast to VT alone, may be a further risk marker for a poor outcome, particularly since it always requires a shock for successful treatment.

**ICD Studies in Coronary Patients**

Prior studies of the ICD in post-MI patients have randomized patients late after MI. In a substudy of the MADIT II study, the mortality benefit of the ICD after MI seemed to be confined to the subgroup with a >18-month window between the index MI and ICD implantation.

The Coronary Artery Bypass Graft Patch study randomized patients immediately after bypass graft surgery. A Cox regression model revealed a significant interaction between treatment group and mechanism of cardiac death ($P=0.03$).
For arrhythmic deaths, the HR (ICD versus control) was 0.55 (95% CI, 0.3 to 1.0). However, for nonarrhythmic cardiac deaths, the HR was 1.2 (95% CI, 0.8, 1.8). As a consequence, the overall mortality was very similar in patients randomized to ICD and no ICD.\textsuperscript{16}

Moss et al.\textsuperscript{19} in their subanalysis of the MADIT-II study, showed an $\approx$3-fold increased risk of death in patients with appropriate ICD therapy compared with those with no therapy and a 90% increase in the risk of a first HF hospitalization after appropriate ICD shocks.\textsuperscript{20} In the Sudden Cardiac Death in Heart Failure (SCD-HeFT) study, Poole et al.\textsuperscript{16} using a time-dependent analysis similar to that in the present study, showed that appropriate shock (versus no appropriate shock) was associated with an HR for all-cause death of 5.7 (95% CI, 4.0 to 8.1; $P<0.001$). These observations suggest that increased mortality after ICD therapy may not entirely explain the lack of ICD benefit in the DINAMIT study because both the MADIT and SCD-HeFT studies were able to show a reduction in mortality with ICD treatment.

In the recent IRIS study,\textsuperscript{7} patients within 5 to 31 days of a MI were enrolled if they had both an LVEF $\leq$40% and heart rate $\geq$90 bpm or nonsustained VT at $\geq$150 bpm during Holter monitoring. Randomization to therapy with an ICD (or no ICD) on top of optimal medical therapy had no significant overall impact on survival at 12, 24, or 36 months. Similar to the DINAMIT study, assignment to an ICD was associated with a significant reduction in sudden death ($P=0.049$) and a significant increase in nonsudden death ($P=0.001$) compared with the optimal medical therapy only group.

**Cause-Specific Mortality After Appropriate ICD Therapy**

In patients receiving appropriate device therapy in DINAMIT, several baseline clinical features were associated with a high risk of nonarrhythmic death. In these patients (compared with the no ICD therapy group and the control group), there was a higher incidence of an MI preceding the index infarct, heart failure before randomization, and absence of percutaneous coronary intervention with the index infarct. The same baseline factors that were associated with sudden death (except for diabetes mellitus) were also associated with an increased risk of nonarrhythmic death. Even after adjustment for baseline clinical features observed to be associated with increased mortality, being assigned to the ICD was still associated with a greater risk of nonarrhythmic death.

The adjusted time-dependent analysis suggests that the excess of nonsudden deaths in the ICD group receiving therapy is not due entirely to a higher burden of disease at the baseline evaluation. There were substantially more episodes of heart failure, MI, and unstable angina during follow-up in the group with ICD therapy compared with the group without therapy. However, this study is not able to distinguish between ventricular arrhythmias themselves causing cardiac deterioration and then an increased risk of death; an intercurrent cardiac event causing cardiac arrhythmia, treatment, and a subsequent increase in mortality rates; or the therapy (shocks) themselves directly or indirectly leading to increased mortality. The small number of deaths in the subgroups limits the inferences that can be drawn from these secondary analyses. The increase in risk of death soon after receiving ICD shocks suggests that VT or VF in these patients is associated with a "step" change in the course of the underlying cardiac disease and thus the prognosis for nonarrhythmic mortality.

Although the mechanisms responsible for the excess nonarrhythmic deaths in the ICD appropriate therapy group cannot be established with certainty, this study highlights the fact that appropriate ICD therapies in some patient populations do not necessarily lead to a meaningful overall mortality reduction, and it is not appropriate to equate ICD therapies with "deaths averted."

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**References**


**CLINICAL PERSPECTIVE**

In the Defibrillation in Acute Myocardial Infarction Trial (DINAMIT) study, implanted defibrillators did not reduce mortality in high-risk patients if implanted early after myocardial infarction. In patients randomized to an implantable cardioverter-defibrillator (ICD), sudden deaths were reduced but nonarrhythmic mortality was increased. In an analysis of the potential causes of this finding, patients who are destined to receive therapy from their ICD (compared with those destined not to receive therapy) have clinical features that also increase their risk of nonsudden death, including risks related to heart failure and recurrent ischemic events. During follow-up, patients who receive therapy from their ICD are more likely to have recurrent cardiac clinical adverse events both before and after ICD therapy compared with patients who receive no therapy or do not have an ICD. In an early post–myocardial infarction setting, the same clinical circumstances that increase the risk of ventricular arrhythmias also increase the risk of nonsudden death; in addition, ICD therapies themselves may increase the risk of subsequent death. These findings underscore the limitations of a strategy of ICD implantation in certain high-risk groups, especially early after acute myocardial infarction.

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