Background: The Multicenter Automatic Defibrillator Implantation Trial (MADIT)-II demonstrated that implantable cardioverter defibrillators (ICDs) save lives when used in patients with a history of myocardial infarction (MI) and an ejection fraction of 0.3 or less.

Objective: To investigate the cost-effectiveness of implanting ICDs in patients who met MADIT-II eligibility criteria and were enrolled in the Duke Cardiovascular Database between 1 January 1986 and 31 December 2001.

Design: Cost-effectiveness analysis.

Data Sources: Published literature, databases owned by Duke University Medical Center, and Medicare data.

Target Population: Adults with a history of MI and an ejection fraction of 0.3 or less.

Time Horizon: Lifetime.

Perspective: Societal.

Interventions: ICD therapy versus conventional medical therapy.

Outcomes Measures: Cost per life-year gained and incremental cost-effectiveness.

Results: Compared with conventional medical therapy, ICDs are projected to result in an increase of 1.80 discounted years in life expectancy and an incremental cost-effectiveness ratio of $50 500 per life-year gained. Cost-effectiveness varied dramatically with changes in time horizon: The cost-effectiveness ratio increased to $67 800 per life-year gained, $79 900 per life-year gained, $100 000 per life-year gained, $167 900 per life-year gained, and $367 200 per life-year gained for 15-year, 12-year, 9-year, 6-year, and 3-year time horizons, respectively. Changing the frequency of follow-up visits, complication rates, and battery replacements had less of an effect on the cost-effectiveness ratios than reducing the cost of ICD placement and leads.

Limitations: The study was limited by the completeness of the data, referral bias, difference in medical therapy between the Duke cohort and the MADIT-II cohort, and not addressing potential upgrades to biventricular devices.

Conclusions: The economic expense of defibrillator implantation in all patients who meet MADIT-II eligibility criteria is substantial. However, in the range of survival benefit observed in MADIT-II, ICD therapy for these patients is economically attractive by conventional standards.

Clinical and Economic Implications of the Multicenter Automatic Defibrillator Implantation Trial-II

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We assessed the long-term clinical and economic implications of implanting ICDs in all patients who meet the eligibility criteria for MADIT-II.

METHODS

Study Sample

Our study sample consisted of patients at least 21 years of age who had a history of MI and an ejection fraction of 0.3 or less and underwent cardiac catheterization at Duke University Medical Center between 1 January 1986 and 31 December 2001. Patients who had had an MI within 30 days of catheterization were included only if they...
Implications of MADIT-II

The Multicenter Automatic Defibrillator Implantation Trial (MADIT-II) has shown that implantable cardioverter defibrillators (ICDs), compared with conventional therapy, appreciably improve survival in patients who have had a myocardial infarction and have an ejection fraction of 0.3 or less. However, the cost of following these recommendations has not been adequately assessed.

Contribution

Implantable cardioverter defibrillators are projected to improve survival by 1.80 discounted years, with an incremental cost-effectiveness ratio of $50,500 per life-year gained. Sensitivity analysis shows that the cost of replacing ICD batteries and leads exerts greater effect on cost-effectiveness ratios than other factors.

Implications

The large number of patients eligible for ICDs under MADIT-II criteria may strain societal ability to perform and pay for these procedures.

—The Editors

had more than 1 month of follow-up data available. Patients who underwent a revascularization procedure within 3 months of catheterization were included only if they had more than 3 months of follow-up data available. The study start date for these patients corresponds to either 1 month after MI or 3 months after the revascularization procedure, respectively. The start date for all other patients is the date of catheterization.

Patients were excluded from this analysis if they had New York Heart Association class IV symptoms, advanced cerebrovascular disease, any condition other than cardiac disease associated with a high likelihood of death within 1 year, or no ejection fraction data. Patients who had a previously implanted ICD or who received an ICD after catheterization were also excluded. Criteria for implantation of ICDs at our institution over the years have been in accordance with guidelines on implantation of antiarrhythmia devices from the American College of Cardiology, the American Heart Association, and the Heart Rhythm Society. As a result of our exclusion criteria, none of the patients in our study received an ICD for a MADIT-II indication. We obtained the approval of our institutional review board before the inception of the study.

Data Collection

Data for the study were collected by using the Duke Cardiovascular Database. This database systematically compiles the clinical experience of all cardiology patients who had cardiac catheterization at Duke University Medical Center (6, 7). Patient information available through the system includes symptoms at time of cardiac procedures, diagnoses, electrocardiographic findings, medica-

tions, severity of coronary artery disease, and measures of left ventricular function. The database incorporates posthospital follow-up at 6 months, 1 year, and annually thereafter; follow-up is complete in 95% of patients (8–10). The National Death Index is periodically searched to monitor the survival of patients lost to follow-up.

Statistical Analysis

Baseline Characteristics

Baseline characteristics for the Duke cohort are presented as means (±SD) for continuous variables and as percentages for categorical variables. Statistical tests comparing the baseline characteristics of the Duke cohort with MADIT-II patients were based on the sufficient statistics (mean, frequency, and standard deviation) from the MADIT-II published data and the Duke cohort. Chi-square tests were applied for discrete variables, and 2-sample t-tests were used for continuous variables. Statistical significance was determined at the 2-sided 0.05 level.

Survival Comparisons

We compared survival distributions within 3 years to assess whether the short-term survival for the Duke cohort was similar to that of the MADIT-II population. To produce the MADIT-II survival curves, we scanned and plotted the published survival curves using digitization software (UnGraph 4.0, Biosoft, Ferguson, Missouri). Estimates of the area under the survival curves and the 3-year survival rate were used to quantify differences in survival between the MADIT-II and Duke populations.

We constructed a Cox regression model with adjustments for the severity of coronary artery disease, age, sex, and indicator variables based on a patient’s study start date (11). To mirror ischemic heart disease and heart failure management in the MADIT-II era, the survival model was averaged over all patients, with the study start date adjusted to the most recent era (between 1998 and 2001).

Lifetime Survival Models

Patients in the Duke cohort had a maximum of 15 years of follow-up. To extrapolate from these data for a lifetime cost-effectiveness analysis, we constructed treatment-specific survival curves. The right-hand tail of the survival curves was created by estimating a log-hazard ratio comparable to the survival of an age- and sex-matched cohort from the U.S. population (12, 13). In this analysis, we assumed that this hazard ratio remained constant after 15 years.

The lifetime survival model for the hypothetical Duke ICD group was constructed by assuming a constant hazard ratio of 0.69, as observed in the ICD arm of MADIT-II. To test the importance of this assumption, we performed a sensitivity analysis that assumed that the benefit of an ICD remained at a hazard ratio of 0.69 for the 3 years following the study start date and increased to a hazard ratio of 1.00 thereafter.
Clinical Events

The Duke Information System for Clinical Computing (DISCC) database was used to obtain data on the following clinical events: MI, percutaneous coronary intervention, coronary artery bypass graft surgery, rehospitalization, and death. To adjust for censored data due to staggered entry, we calculated estimates for mean number of clinical events using a nonparametric partitioned estimator (14). We selected 5 evenly spaced time partitions: 0 to 3 years, 3 to 6 years, 6 to 9 years, 9 to 12 years, and 12 to 15 years. Within each time partition, we calculated the average number of events per year.

Medical Costs

Total in-hospital costs were estimated by using a series of regression models derived from the Global Use of Strategies To Open Occluded Coronary Arteries (GUSTO)-IIb Economic and Quality of Life Substudy (14, 15). The perspective of the analyses was societal, although some societal costs (nonmedical costs, outpatient care, and productivity costs) were omitted. All costs were converted to 2002 U.S. dollars.

Lifetime Medical Costs

To extrapolate medical costs beyond 15 years, we multiplied the average in-hospital medical cost per year alive by the remaining life expectancy. To calculate the lifetime cost for the Duke medical therapy group, we modeled the observed clinical events data for the initial 15 years and then extrapolated the clinical events for an entire lifetime. The clinical events data were then converted to costs by using a series of regression models from previously conducted clinical trials (15, 16).

Lifetime ICD Costs

Lifetime costs for the Duke ICD arm were separated into 2 categories: 1) in-hospital costs not directly related to ICD therapy and 2) costs directly related to ICD therapy. Medical costs not related to ICD therapy were estimated by multiplying the average cost per year alive for the medical therapy arm (as described earlier) by the projected survival for the ICD arm. This assumption reflects our understanding that ICDs reduce the risk for sudden cardiac death but not the other risks associated with having coronary artery disease and low ejection fraction.

To determine ICD-related costs, we developed a template for ICD placement, follow-up visits, and battery replacement based on practice standards at Duke University Medical Center. In our primary or base-case analysis, follow-up visits were scheduled at 3-month intervals and batteries were replaced every 5 years following the implantation. Rates of complications were based on a publication by Kennergren (17) and the Medtronic product performance report for the first quarter in 2003 (18). Professional fees for ICD placement were estimated by using North Carolina Medicare reimbursement rates. Hospital costs for ICD placement and common ICD complications (lead fractures, lead dislodgement, pocket hematoma, infection, cardiac perforation, and pneumothorax) were estimated by using cost data from Duke University Medical Center for patients with diagnosis-related groups (DRGs) of 514 or 515 (placement) and 110, 111, 144, or 145 (complications).

Cost-Effectiveness Analysis

We calculated the incremental cost-effectiveness ratio for ICD therapy versus medical therapy by dividing the incremental discounted costs by the incremental discounted survival. Discounting is the process of converting future dollars and future health outcomes to their present value. The survival benefit was estimated by calculating the area between the survival curves. Conventionally, therapies with a cost-effectiveness ratio of $50,000 per life-year gained or lower are considered economically attractive and those costing $150,000 per life-year gained or greater are considered economically unattractive (19). Costs and survival benefits were discounted at a rate of 3% per year according to the recommendations of the Panel on Cost-Effectiveness in Health and Medicine (20, 21).

Sensitivity Analyses

Our base-case analysis assessed the cost-effectiveness of ICD therapy given current expectations of costs and outcomes. Sensitivity analyses were conducted by varying the therapeutic effectiveness and cost of ICDs, rates of complications, and MI risk in the medical therapy group.

| Table 1. Comparison of Baseline Clinical Characteristics of the Duke Medical Therapy Group and Patients in the Multicenter Automatic Defibrillator Implantation Trial-II* |
|---------------------------------|-----------------|-----------------|-----------------|
| Characteristic                  | Duke Medical Therapy Group (n = 1285) | MADIT-II Medical Therapy Group (n = 490) | MADIT-II ICD Group (n = 742) |
| Mean age ± SD, y                | 63 ± 11         | 65 ± 10†        | 64 ± 10†        |
| Men, %                         | 73              | 85‡             | 84†             |
| CAD, %                         |                 |                 |                 |
| Interval of >6 mo between previous MI and enrollment | 29              | 87‡             | 88‡             |
| Previous CABG                  | 28              | 56†             | 58†             |
| Previous angioplasty           | 19              | 42†             | 45†             |
| Comorbid conditions, %         |                 |                 |                 |
| Diabetes mellitus              | 32              | 38§             | 33§             |
| Hypertension                   | 55              | 53§             | 53§             |
| Current or former smoker       | 68              | 82‡             | 80†             |
| Cardiac function               |                 |                 |                 |
| Mean ejection fraction ± SD    | 24 ± 5          | 23 ± 6†         | 23 ± 5†         |

* CABG = coronary artery bypass grafting; CAD = coronary artery disease; ICD = implantable cardioverter defibrillator; MADIT = Multicenter Automatic Defibrillator Implantation Trial; MI = myocardial infarction.
† P < 0.05 compared with the Duke medical therapy group.
‡ P < 0.001 compared with the Duke medical therapy group.
§ P > 0.2 compared with the Duke medical therapy group.
cations, frequency of follow-up visits and battery replacements, and the time horizon. In a 1-way sensitivity analysis (that is, an analysis in which one factor was varied at a time), ICD-related costs (professional and technical) were estimated by using North Carolina Medicare reimbursement rates rather than the Duke University Medical Center cost data. An additional sensitivity analysis was conducted by using quality-adjusted survival as the measure of effectiveness. In this analysis, the utility values assumed for both treatments that 1 year of life in the MADIT-II health state is equivalent to 0.88 year in optimal health (22, 23).

Role of the Funding Source
This study was funded in part by Guidant Corporation. All of the analyses were done independently by Duke investigators. Representatives of Guidant had no input into the design of the study, the acquisition and analysis of data, or the wording of the manuscript.

RESULTS
Baseline Characteristics
From 1986 through 2001, 51,001 patients underwent at least 1 cardiac catheterization at our institution. Of these, 1,285 (2.5%) met our study’s inclusion criteria. The primary reasons for exclusion were no history of MI (n = 39,255); ejection fraction greater than 0.3 (n = 15,292); or cardiac catheterization for primary valvular disease, congenital heart disease, restrictive or obstructive cardiomyopathy, or pericardial disease (n = 16,970). In Table 1 the baseline characteristics of the Duke cohort are compared with the baseline characteristics of the MADIT-II patients (medical therapy and ICD groups). Compared with patients enrolled in MADIT-II, patients in the Duke cohort were younger, underwent revascularization less frequently, had a higher mean ejection fraction, and had a shorter time between MI and enrollment.

Clinical Outcomes
Short-Term Survival
Overall, survival of patients in the medical therapy group was similar in the Duke and MADIT-II populations (3-year survival probability of 71% and 69%, respectively) (Figure 1). For the initial 3 years following study enrollment, the Duke cohort averaged slightly less survival time (2.46 years vs. 2.52 years). The Duke ICD group’s 3-year survival probability and cumulative survival time were similar to those in the MADIT-II ICD group (79% and 2.62 years vs. 78% and 2.65 years, respectively).

Extrapolated Survival
At 15 years, the adjusted survival estimate was 33.8% for the Duke ICD group versus 20.8% for the Duke medical therapy group. Beyond the 15th year, the ICD group was estimated to have an average of 1.00 additional year of survival compared with the medical therapy group (1.81 years vs. 0.81 year). As shown in Figure 2 the projected life expectancy for the ICD therapy group was 10.88 years compared with 8.26 years for the medical therapy group. Under our base-case assumption, ICDs were projected to result in an increase of 2.62 years undiscounted years in life expectancy versus conventional medical therapy.

Clinical Events
In the Duke medical therapy group, most hospitalizations and coronary artery bypass graft surgery occurred in the initial 3 years. Coronary artery bypass graft surgery was 2.6 times more likely to occur in years 0 to 3 than in years 3 to 15 combined (Table 2). Approximately half of percutaneous coronary interventions occurred in the first 3 years.
Table 2. Clinical Events, Survival, and Medical Costs for the Duke Medical Therapy Group*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Years 0–3</th>
<th>Years 3–6</th>
<th>Years 6–9</th>
<th>Years 9–12</th>
<th>Years 12–15</th>
<th>Total (Years 0–15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of clinical events</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MI</td>
<td>0.054</td>
<td>0.036</td>
<td>0.020</td>
<td>0.019</td>
<td>0.016</td>
<td>0.144</td>
</tr>
<tr>
<td>CABG</td>
<td>0.159</td>
<td>0.016</td>
<td>0.013</td>
<td>0.015</td>
<td>0.016</td>
<td>0.219</td>
</tr>
<tr>
<td>PCI</td>
<td>0.071</td>
<td>0.027</td>
<td>0.026</td>
<td>0.017</td>
<td>0.009</td>
<td>0.150</td>
</tr>
<tr>
<td>Hospitalizations</td>
<td>0.692</td>
<td>0.268</td>
<td>0.165</td>
<td>0.092</td>
<td>0.031</td>
<td>1.247</td>
</tr>
<tr>
<td>Death</td>
<td>0.291</td>
<td>0.157</td>
<td>0.162</td>
<td>0.100</td>
<td>0.081</td>
<td>0.792</td>
</tr>
<tr>
<td>Survival, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undiscounted</td>
<td>2.46</td>
<td>1.90</td>
<td>1.37</td>
<td>1.00</td>
<td>0.72</td>
<td>7.45</td>
</tr>
<tr>
<td>Discounted†</td>
<td>2.36</td>
<td>1.66</td>
<td>1.10</td>
<td>0.73</td>
<td>0.48</td>
<td>6.33</td>
</tr>
<tr>
<td>Medical costs, $</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undiscounted in-hospital</td>
<td>20 463</td>
<td>8526</td>
<td>5942</td>
<td>5022</td>
<td>2568</td>
<td>42 552</td>
</tr>
<tr>
<td>Discounted in-hospital</td>
<td>19 972</td>
<td>7461</td>
<td>4776</td>
<td>3702</td>
<td>1750</td>
<td>37 661</td>
</tr>
</tbody>
</table>

* CABG = coronary artery bypass grafting; MI = myocardial infarction; PCI = percutaneous coronary intervention.
† Discounting is the process of converting future dollars and future health outcomes to their present value. A discount rate of 3% per year was used.

Economic Outcomes

The base-case costs of ICD placement, follow-up, and maintenance are provided in Table 3. During fiscal year 2003, we observed that 77% of ICDs were implanted after cardiac catheterization (DRG 514) and 23% were implanted without cardiac catheterization (DRG 515). According to the practice standards of Duke University Medical Center, the average costs for DRG 514 and 515 were $42 416 and $32 914, respectively. Average costs for ICD follow-up visits ranged from $70 to $89, depending on ICD type and reprogramming. The average cost for ICD battery replacement was $17 493.

Over 15 years, the average undiscounted and discounted in-hospital costs were $42 552 and $37 661, respectively, for the Duke medical therapy group (Table 2). Total projected survival and medical costs for both Duke cohorts are presented in Table 4. In the medical therapy group, the estimated lifetime undiscounted medical costs were $47 721. For the ICD group, the combined undiscounted estimation of ICD-related and in-hospital (non-ICD) costs was $152 893 ($84 680 and $68 213, respectively).

Cost-Effectiveness

Tables 5 and 6 show the results of the cost-effectiveness analyses. In the base-case analysis, we estimated that ICD therapy would result in 1.80 discounted life-years gained at a cost of $90 829 (discounted). The incremental cost-effectiveness ratio is $50 500 per life-year gained. In the sensitivity analyses, cost-effectiveness varied dramatically with changes in time horizon: The cost-effectiveness ratio increased to $67 800 per life-year gained, $79 900 per life-year gained, $100 000 per life-year gained, $167 900 per life-year gained, and $367 200 per life-year gained for 15-year, 12-year, 9-year, 6-year, and 3-year time horizons, respectively.

The average cost for ICD and leads placement was $19 870 in the base-case analysis. If these costs were reduced to $10 000, the incremental cost-effectiveness ratio would be $45 200 per life-year gained. Changing the frequency of follow-up visits, complication rates, and battery replacements had less of an effect on the cost-effectiveness ratios than reducing the cost of ICD placement and leads. When Medicare rates were used, the incremental cost-effectiveness ratio decreased slightly to $49 400 per life-year gained. If the efficacy of the ICD ended after 3 years,
Our results imply that approximately 32,000 (2.5% of 1,318,000) of these patients meet MADIT-II criteria. The overall number of ICDs implanted in 2000 was 34,000 (24). Thus, implanting ICDs in all MADIT-II–eligible patients would at least double the annual number of ICD implants in the United States (32,000 plus 34,000).

On the basis of the MADIT-II findings, ICDs are projected to result in an estimated 1.81 discounted life-years gained if the effect of ICDs remains constant over time. Not surprisingly, the incremental cost-effectiveness ratio associated with that survival benefit is reasonably favorable ($50,500 per life-year gained). This ratio becomes more favorable ($45,200 per life-year gained) if the cost of the ICD system is reduced to $10,000. Although the cost-effectiveness ratio did not significantly change with a 1-year increase or decrease in battery longevity, the ratio becomes significantly more favorable ($42,200 per life-year gained) if the longevity doubles to 10 years. However, if the efficacy of the ICD ends after 3 years of follow-up, the incremental cost-effectiveness ratio ($123,400 per life-year gained) would be unfavorable. Under the 3-year survival benefit scenario, if the mortality hazard ratio is less than 0.61, the incremental cost-effectiveness ratio would be less than $100,000 per life-year gained.

Our study showed that patients seen in clinical practice who meet MADIT-II entry criteria are clinically different from patients enrolled in MADIT-II. Patients in the Duke cohort were younger, had a shorter time between MI and enrollment, had a higher mean ejection fraction, and underwent revascularization less frequently. The survival of the Duke cohort was slightly worse than that of patients randomly assigned to conventional therapy in MADIT-II. If sicker patients are more likely to derive survival benefit from an ICD, the resulting cost-effectiveness ratio would be more favorable than the one obtained for the base case in our study.

Comparing our results with those from other ICD cost-effectiveness analyses requires careful consideration of design features, including the time horizon (25). Among

### Table 4. Projected Survival and Medical Costs for the Duke Medical Therapy Group and the Duke Implantable Cardioverter Defibrillator Group

<table>
<thead>
<tr>
<th>Variable</th>
<th>Duke medical therapy group</th>
<th>Duke ICD group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Years 0–3</td>
<td>Years 3–15</td>
</tr>
<tr>
<td>Survival, y</td>
<td>2.46</td>
<td>4.99</td>
</tr>
<tr>
<td>Discounted survival, y†</td>
<td>2.36</td>
<td>3.97</td>
</tr>
<tr>
<td>In-hospital medical costs, $</td>
<td>20,463</td>
<td>22,059</td>
</tr>
<tr>
<td>Discounted in-hospital medical costs, $†</td>
<td>19,972</td>
<td>17,688</td>
</tr>
</tbody>
</table>

* ICD = implantable cardioverter defibrillator.
† Discounting is the process of converting future dollars and future health outcomes to their present value. A discount rate of 3% per year was used.
‡ Including costs for possible complications. Assumed complication rates were as follows: ICD lead fractures, 4.2%; lead dislodgement, 10%; pocket hematoma, 16%; infection, 7.2%; cardiac perforation, 1.4%; and pneumothorax, 3.8%.

### Table 5. Results of Base-Case Analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Undiscounted Costs</th>
<th>Discounted Costs†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duke medical therapy group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life expectancy, y</td>
<td>8.26</td>
<td>6.79</td>
</tr>
<tr>
<td>In-hospital costs, $</td>
<td>47,721</td>
<td>40,661</td>
</tr>
<tr>
<td>Duke ICD group‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life expectancy, y</td>
<td>10.88</td>
<td>8.59</td>
</tr>
<tr>
<td>In-hospital and ICD costs, $</td>
<td>152,894</td>
<td>131,490</td>
</tr>
<tr>
<td>Incremental cost-effectiveness ratio, $/life-year gained</td>
<td>50,500</td>
<td></td>
</tr>
</tbody>
</table>

* Base-case assumptions include costs and survival discounted at 3% per year and use of a lifetime horizon. ICD = implantable cardioverter defibrillator.
† Discounting is the process of converting future dollars and future health outcomes to their present value.
‡ Assumed complication rates were as follows: ICD lead fractures, 4.2%; lead dislodgement, 10%; pocket hematoma, 16%; infection, 7.2%; cardiac perforation, 1.4%; and pneumothorax, 3.8%.

### Discussion

This study showed that, among an unselected population of patients receiving cardiac catheterization, the number of patients meeting MADIT-II eligibility criteria is not small. In 2000, about 1,318,000 inpatient cardiac catheterizations were performed in the United States (24). If the Duke cardiac catheterization experience were generalized, our results imply that approximately 32,000 (2.5% of

The relationship between cost-effectiveness and the mortality hazard ratio is illustrated. For our base case, hazard ratios below 0.69 and 0.84 resulted, with cost-effectiveness ratios below 50,000 per life-year gained and $100,000 per life-year gained, respectively. If ICD placement costs were reduced to $10,000, hazard ratios below 0.69 and 0.72 and 0.86 resulted in incremental cost-effectiveness ratios below $50,000 per life-year gained and $100,000 per life-year gained, respectively.

Applying a utility of 0.88 to patients receiving ICDs and those receiving medical therapy resulted in a discounted quality-of-life–adjusted survival benefit of 1.58 years and an incremental cost-effectiveness ratio of $57,300 per quality-adjusted life-year gained.

The estimated survival benefit would be 0.64 discounted life-year gained at an additional cost of $79,536, and the incremental cost-effectiveness ratio would be $123,400 per life-year gained (Table 6).

We examined the sensitivity of our analyses to variations in the mortality hazard ratio. In Figure 3 the relationship between cost-effectiveness and the mortality hazard ratio for ICD versus conventional medical therapy is illustrated. For our base case, hazard ratios below 0.69 and 0.84 resulted, with cost-effectiveness ratios below 50,000 per life-year gained and $100,000 per life-year gained, respectively. If ICD placement costs were reduced to $10,000, hazard ratios below 0.69 and 0.72 and 0.86 resulted in incremental cost-effectiveness ratios below $50,000 per life-year gained and $100,000 per life-year gained, respectively.

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Discounting is the process of converting future dollars and future health outcomes to their present value. A discount rate of 3% per year was used.

The base-case cost-effectiveness analyses from MADIT-I, the Antiarrhythmics Versus Implantable Defibrillator (AVI) trial, and the Canadian Implantable Defibrillator Study (CIDS) considered time horizons ranging from 3 to 6 years (29–31). Our cost-effectiveness results are less favorable than results obtained from MADIT-I and the AVID trial. However, the results of our analysis with a 6-year time horizon ($166 000 per life-year gained) are similar to results obtained from CIDS ($138 800 per life-year gained in 1999 U.S. dollars). The main difference among these analyses is the time horizon. Although there is no standard time horizon for such analyses, the Panel on Cost-Effectiveness in Health and Medicine recommends that a lifetime horizon be used (20, 21).

Whether the health care system can afford to implant ICDs in all MADIT-II–eligible patients is not determined only by the monetary costs. Having enough personnel to implant and maintain these devices is equally important. While data on the number of ICDs implanted by each electrophysiologist in the United States are unavailable, it is safe to assume that the current number of electrophysiologists who can implant ICDs is far below the number required to meet the anticipated demand. National cardiology associations need to orchestrate their efforts in developing a plan to address the increasing need for personnel able to implant and follow ICDs.

Study Limitations

The degree of completeness of our data may limit our conclusions. The entire ICD group was extrapolated. Indeed, the most direct evidence relating to the cost-effectiveness of ICD therapy in patients who meet MADIT-II criteria will be provided by the cost-effectiveness analysis of the actual data gathered in MADIT-II. In addition, this analysis was based on patients referred for a cardiac catheterization. Because this involves referral bias, the findings of this analysis may not apply to other patients who meet MADIT-II criteria and are seen in other settings. The difference in the onset of enrollment between the Duke cohort and the MADIT-II cohort probably resulted in a significant difference in medical therapy between the 2 groups. Adjusting for this difference, however, did not alter our findings. Finally, we did not address potential upgrades to biventricular devices. However, because of the uncertain effect of biventricular pacing on survival and on heart failure hospitalizations, doing so would have required a new model with many assumptions and permutations.

Study Implications

Among an unselected cardiac catheterization population, the annual number of patients meeting MADIT-II criteria in the United States appears to be at least as large as the entire population who received ICDs for any indication in 2000. Thus, the resource implications of ICD implantation in all patients who meet MADIT-II criteria are substantial. Our study provides necessary assessment of the potential impact of implanting ICDs in all MADIT-II–eligible patients. In the range of survival benefit observed in MADIT-II, ICD therapy in these patients is economically attractive by conventional standards. This therapy would be even more attractive if its cost is reduced and its longevity is extended.

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