Implantable cardioverter-defibrillators (ICDs) are one of the few interventions where we can be reasonably confident that a patient did or did not benefit from the treatment. If one is to benefit from an ICD, then the person must survive long enough to have an arrhythmic event and receive therapy from the device. Thus, the patients who benefit the most are those with a high rate of arrhythmic death and a low rate of nonarrhythmic death. Indeed, the enrollment criteria for clinical trials of ICDs were designed to optimize these 2 rates. Accordingly, the patients enrolled in the primary prevention ICD trials were much younger and had less comorbidity than the community heart failure population.1

On the basis of trial results, we now have guidelines for ICDs that limit them to patients with an ejection fraction below 35% if symptomatic (New York Heart Association Class II or III) or <30% if asymptomatic (New York Heart Association Class I) and expected survival of at least one year.2 However, the clinician is frequently confronted with a patient who meets the primary prevention ICD criteria yet has other characteristics (advanced age or multiple comorbidities) that create legitimate concern that the patient will not benefit from the device. Payers, policy makers, and society warn that even if symptomatic (New York Heart Association Class II or III) or asymptomatic (New York Heart Association Class I) the person must survive long enough to have an arrhythmic event and receive therapy from an ICD. If the annual risk of death is less than 5%, then an ICD is very expensive for the gain in benefit (ie, not worth it). If total mortality is at least 5% per year, we then examine the ratio of arrhythmic to nonarrhythmic mortality. We see that if the annual risk of death is less than 5%, then an ICD is very expensive for the gain in benefit (ie, not worth it). If total mortality is at least 5% per year, we then examine the ratio of arrhythmic to nonarrhythmic mortality.

But how can we predict who will and will not have an arrhythmic death? A recent study examined the relationship between arrhythmic death rate and age. If total mortality is at least 5% per year, we then examine the ratio of arrhythmic to nonarrhythmic mortality. We see that if this ratio is at least 50:50 then ICDs have value even at extremely high mortality rates. Indeed, the model indicates that among patients with an expected median survival of less than 1 year (median 1 year mortality >50% and currently excluded from receiving an ICD by guidelines) an ICD would still be of value if arrhythmic deaths were at least as likely as nonarrhythmic deaths.

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Is Anyone Too Old for an Implantable Cardioverter-Defibrillator?

Paul A. Heidenreich, MD, MS; Vivian Tsai, MD

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ICDs for patients in their 70s appears to be a reasonable value, though we project that beyond 80 years of age that is less likely to be the case. Most of these patients in the >80 years group from the Krahn analysis (Table) were in their early 80s, and the value of an ICD in those 85 years and higher is likely to be much smaller.

Although age is clearly important, including other variables such as comorbidities may improve the estimates of arrhythmic death. The Seattle Heart Failure Model is a validated prediction tool of total mortality using clinical, laboratory, medication, and device variables. The model was used to predict cause of death (arrhythmic and pump failure or other) in a cohort of over 10,000 patients with heart failure from 6 clinical trials (Table). One year mortality for those with a score of 0 was less than 5% so ICDs are unlikely to be of value in these patients. Similarly, the ICDs do not appear to be a good value in the sickest patients who have a relative low rate of arrhythmic death compared to nonarrhythmic death.

The purpose of this exercise was to show the importance of both total mortality and the ratio of arrhythmic to nonarrhythmic death in determining the value of an ICD. The estimates of cost-effectiveness for an individual patient will depend on many factors not considered here including preference for length and quality of life which has been show to be highly variable and often changes markedly following an acute episode of heart failure.

What can we conclude from this? First, it is not simple to predict the relative rates of arrhythmic and nonarrhythmic causes of death with currently available data. Perhaps future markers will help. Second, as patients with heart failure age the increase in total mortality is somewhat offset by a slower increase in arrhythmic death rate making the

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**Table.** Mortality and Cause of Death Estimates Using Different Patient Groups and the Impact on Cost-Effectiveness of ICDs

<table>
<thead>
<tr>
<th>Patient Group</th>
<th>Total Annual Mortality</th>
<th>Arrhythmic/Nonarrhythmic Ratio</th>
<th>Cost-Effectiveness, $/Quality-Adjusted Life Year*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;50</td>
<td>11</td>
<td>1.1</td>
<td>$55,000</td>
</tr>
<tr>
<td>51–60</td>
<td>13</td>
<td>0.9</td>
<td>$60,000</td>
</tr>
<tr>
<td>61–70</td>
<td>18</td>
<td>0.65</td>
<td>$65,000</td>
</tr>
<tr>
<td>71–80</td>
<td>22</td>
<td>0.65</td>
<td>$65,000</td>
</tr>
<tr>
<td>&gt;80</td>
<td>25</td>
<td>0.34</td>
<td>$85,000</td>
</tr>
<tr>
<td>Seattle Heart Failure Model score‡</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 (healthiest 38%)</td>
<td>4</td>
<td>4</td>
<td>$100,000</td>
</tr>
<tr>
<td>1 (41% of patients)</td>
<td>11</td>
<td>1.3</td>
<td>$50,000</td>
</tr>
<tr>
<td>2 (16% of patients)</td>
<td>24</td>
<td>0.72</td>
<td>$65,000</td>
</tr>
<tr>
<td>3 (3% of patients)</td>
<td>55</td>
<td>0.67</td>
<td>$85,000</td>
</tr>
<tr>
<td>4 (sickest 0.5%)</td>
<td>82</td>
<td>0.46</td>
<td>&gt;$150,000</td>
</tr>
</tbody>
</table>

*Cost effectiveness estimates from the Figure adapted from *Am Heart J.* 2002;144:440–448.
†Adapted from *Am Heart J.* 2004;147:837–840.
‡Adapted from *Circulation.* 2007;116:392–398.

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**Figure.** This graph shows the impact of the ratio of sudden to non-sudden death and of total mortality on incremental cost-effectiveness of the ICD. Data are adapted from Owens et al (*Am Heart J.* 2002;144:440–448) assuming that 80% of total mortality is cardiac. Note the U-shape relationship with total mortality and cost-effectiveness for patient populations with different proportions of deaths that are sudden.
cost-effectiveness of ICDs relatively stable until patients are into their mid 80s. Is there an age limit beyond which there is poor value from an ICD? Yes, but we will need additional well-designed outcome studies like Chan’s to determine what age this might be and to fill in the many other knowledge gaps not addressed by clinical trials.

Disclosures
Dr. Heidenreich has the following potential conflict of interest: Consultant to the ALTITUDE Clinical Science Initiative, Sponsored by Boston Scientific, less than $5000.

References
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