Frequency and Determinants of Implantable Cardioverter Defibrillator Deployment Among Primary Prevention Candidates With Subsequent Sudden Cardiac Arrest in the Community

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Background—The prevalence rates and influencing factors for deployment of primary prevention implantable cardioverter defibrillators (ICDs) among subjects who eventually experience sudden cardiac arrest in the general population have not been evaluated.

Methods and Results—Cases of adult sudden cardiac arrest with echocardiographic evaluation before the event were identified from the ongoing Oregon Sudden Unexpected Death Study (population approximately 1 million). Eligibility for primary ICD implantation was determined from medical records based on established guidelines. The frequency of prior primary ICD implantation in eligible subjects was evaluated, and ICD nonrecipients were characterized. Of 2093 cases (2003–2012), 448 had appropriate pre– sudden cardiac arrest left ventricular ejection fraction information available. Of these, 92 (20.5%) were eligible for primary ICD implantation, 304 (67.9%) were ineligible because of left ventricular ejection fraction >35%, and the remainder (52, 11.6%) had left ventricular ejection fraction ≤35% but were ineligible on the basis of clinical guideline criteria. Among eligible subjects, only 12 (13.0%; 95% confidence interval, 6.1%–19.9%) received a primary ICD. Compared with recipients, primary ICD nonrecipients were older (age at ejection fraction assessment, 67.1±13.6 versus 58.5±14.8 years, P=0.05), with 20% aged ≥80 years (versus 0% among recipients, P=0.11). Additionally, a subgroup (26%) had either a clinical history of dementia or were undergoing chronic dialysis.

Conclusions—Only one fifth of the sudden cardiac arrest cases in the community were eligible for a primary prevention ICD before the event, but among these, a small proportion (13%) were actually implanted. Although older age and comorbidity may explain nondeployment in a subgroup of these cases, other determinants such as socioeconomic factors, health insurance, patient preference, and clinical practice patterns warrant further detailed investigation. **(*Circulation*. 2013;128:1733-1738.)**

Key Words: death, sudden ■ epidemiology ■ heart arrest ■ implantable defibrillators ■ population ■ utilization

Sudden cardiac arrest (SCA) accounts for 50% of cardiovascular mortality.[1] Although patients with severely reduced left ventricular ejection fraction (LVEF) have been shown to be at greater risk, they constitute less than one third of SCA cases.[2,3] In many instances, SCA is the first manifestation of heart disease, and despite impressive advances in the field of resuscitation, overall survival to hospital discharge in the United States remains <5%.[4] Strategies to reduce the burden of SCA include effective treatment of the underlying cardiac pathology (including predisposing risk factors), enhanced risk stratification approaches to identify those at high risk of SCA, and use of the implantable cardioverter defibrillator (ICD) in appropriate candidates. Large randomized clinical trials have established the survival benefit of ICDs when used for primary prevention.[5,6] Although use of the LVEF for SCA risk stratification may have some limitations,[7–10] it remains the major risk assessment criterion for primary prevention of SCA, as laid out in clinical practice guidelines.[11]

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Clinical Perspective on p 1738

The ICD is a potentially life-saving intervention, and it is of considerable importance to understand the extent of its use in the community and the parameters that influence nondeployment of this prevention modality. Since ICD shocks may not be an appropriate surrogate for aborted SCA,[12] it is difficult to assess the overall impact of ICD implantation on SCA in the population. Recent reports have suggested that ICDs may

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be significantly underused in the community for both primary and secondary prevention.[13–15] However, the extent of deployment of the primary ICD among eligible subjects who eventually experience a cardiac arrest in the general population has not been studied previously. We therefore sought to evaluate the frequency and potential determinants of nondeployment of the primary ICD among subjects who experienced SCA in the community.

Methods

The Oregon Sudden Unexpected Death Study (Oregon SUDS) is an ongoing community-based prospective study of out-of-hospital SCA. Detailed methods have been published previously.[3,15,16] Briefly, since February 1, 2002, cases of SCA in the Portland, OR, metropolitan area were identified by use of multiple sources that included the emergency medical response system, the medical examiner's office, and emergency departments of all local hospitals. In the first 3 years, all cases of SCA were identified. From February 2005 onward, identification was limited to the majority subset that had resuscitation attempted by first responders or investigation by the medical examiner. Detailed medical records, including hospital, emergency medical system, and medical examiner records, were analyzed, and cases of SCA were determined by an in-house 3-physician adjudication process. SCA was defined as an unexpected sudden arrest that occurred within 1 hour of symptom onset when witnessed; if unwitnessed, subjects were to have been seen alive and symptom free within 24 hours of their sudden death.[8] Patients with SCA who were successfully resuscitated (survivors) were also included. Noncardiac causes of sudden death were excluded by the adjudication process. In addition, patients with chronic severe illnesses, such as cancer not in remission or severe pulmonary disease (undergoing home oxygen therapy) and those in a hospice facility, were also excluded. All SCA cases aged ≥18 years, from February 1, 2003, to January 31, 2012, with echocardiographic LVEF assessed before arrest were included in the present analysis. Informed consent was obtained from the SCA survivors who participated in the study. The study was approved by the institutional review boards of all participating hospitals.

Echocardiogram and ICD Information

Echocardiographic measurements including the LVEF were collected from existing medical records to identify subjects who would meet criteria for ICD implantation. Echocardiograms performed before but unrelated to the SCA event were used for this purpose. The following strategy was used to obtain information on ejection fraction (EF). For subjects who received an ICD, the EF closest in time to ICD implantation was used. For subjects with history of an acute coronary syndrome event, the EF measured ≥40 days after the event was used, in accordance with guideline recommendations. Additionally, a sensitivity analysis that employed the last echocardiogram before the SCA event was also performed. Information regarding ICD implantation and details of primary versus secondary indication for the device were obtained from the hospital records. Detailed demographic, clinical, and comorbidity data, including data on the diagnosis of heart failure, were obtained through review of records for all subjects.

Assessment of Eligibility for Primary ICD

In identifying subjects who had met eligibility criteria for primary ICD implantation before arrest, and given the extended time frame of SCA ascertainment, consideration was given to prevailing clinical practice standards based on time of publication of the primary ICD trials. An additional period of 1 year was allowed for trial results to influence clinical practice. Hence, the MADIT-II (Multicenter Automatic Defibrillator Implantation Trial II) criteria[5] were applied from 2003 to 2005 and the SCD-HeFT (Sudden Cardiac Death in Heart Failure Trial) criteria[6] were applied from 2006 to 2012. Because an LVEF threshold of 35% has been subject to some criticism,[17] we also performed additional sensitivity analysis using a lower cutoff of 30% to determine primary ICD rates. Subjects who had a secondary prevention ICD (for ventricular tachycardia [VT]) before the SCA event were excluded from the analysis.

Statistical Analysis

Eligible case subjects who received a primary ICD before arrest (ICD recipients) and those who did not (ICD nonrecipients) were analyzed with respect to relevant covariates. Continuous variables, analyzed with the independent-samples Mann-Whitney *U* test, were expressed as mean±SD; categorical variables, analyzed with the χ^2 or Fisher exact test, were expressed as numbers and percentages. $P<0.05$ was considered statistically significant. All analysis was performed with the Statistical Package for the Social Scientist (SPSS, version 20.0; IBM Corporation, Armonk, NY).

Results

Identifying Guideline-Eligible Candidates Among SCA Cases

A total of 2093 cases of SCA were identified over a 9-year period between February 2003 and January 2012. Echocardiographic LVEF information before the SCA event was available for 488 cases (23.3%). Forty cases with echocardiograms within 40 days of an acute coronary syndrome event were excluded from further analysis. Of the remaining 448 cases, 144 (32.1%) had LVEF ≤35%, 127 (28.3%) had LVEF ≤30%, and 304 (67.9%) had LVEF >35%. Between 2003 and 2005, there were 45 cases with a history of myocardial infarction and EF of ≤30% (MADIT-II eligible). From 2006 to 2012, there were 47 cases with EF ≤35%, irrespective of history of myocarial infarction (SCD-HeFT eligible). Thus, a total of 92 cases (20.5%) were identified as being eligible for primary prevention ICDs before the SCA event, with pre-arrest echocardiograms and with application of time-relevant guideline criteria.

Primary ICD Implantation Rates for SCA Cases in the General Population

Figure 1 shows the rate of primary ICD deployment overall, in the subset with EF ≤35%, and among those meeting time-relevant guideline criteria. The frequency of primary ICD implantation in all SCA cases irrespective of the extent of left ventricular dysfunction was 3.3% (15 of 448), and in the subset with EF ≤35%, it was 10.4% (15 of 144). With application of time-specific guideline criteria, there were 12 primary ICD implantations among the 92 eligible candidates (13.0%; 95% confidence interval, 6.1%–19.9%) between 2003 and 2012. Three primary ICDs implanted during 2003 to 2005 did not meet primary prevention criteria based on MADIT II criteria existing at that time. The inclusion of these cases would increase the primary ICD rate to 15 of 95 (15.8%).

Demographic and Clinical Characteristics

The Table shows the demographic and clinical characteristics of primary ICD recipients and nonrecipients among guideline-eligible candidates (n=92). ICD nonrecipients were older than recipients (age at time of EF assessment, 67.1±13.6 versus 58.5±14.8 years; $P=0.05$). Figure 2 shows the proportion of ICD recipients across different age groups, based on age at the time of echocardiography. The y-axis represents the proportion of patients in that age group who received an ICD

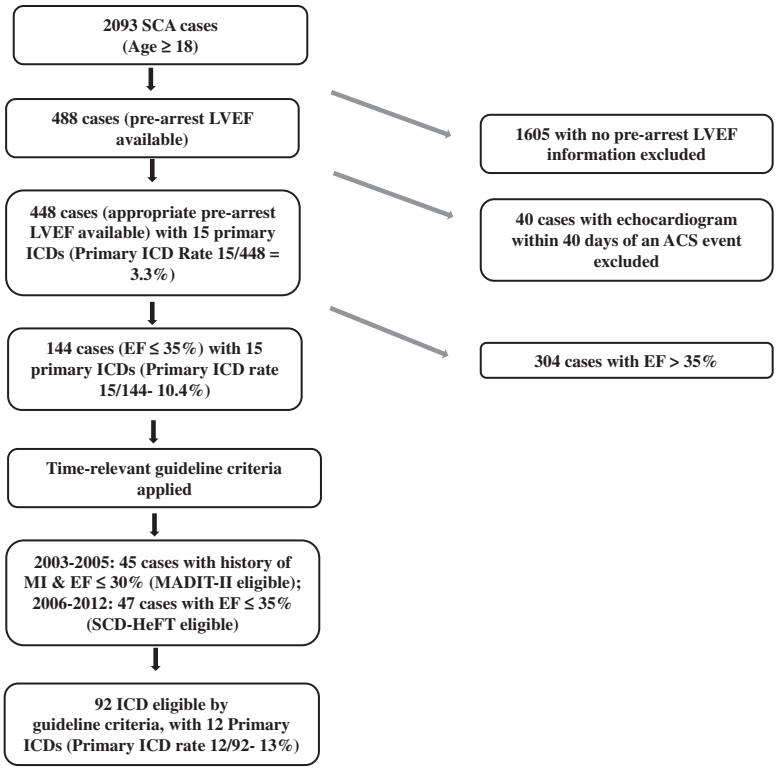

Figure 1. Flow chart showing the process of identifying recipients of implantable cardioverter defibrillators (ICDs) vs nonrecipients among those eligible for primary prevention ICD implantation. ACS indicates acute coronary syndrome; EF, ejection fraction; LVEF, left ventricular ejection fraction; MADIT, Multicenter Automatic Defibrillator Implantation Trial; MI, myocardial infarction; SCA, sudden cardiac arrest; and SCD-HeFT, Sudden Cardiac Death in Heart Failure trial

among all those eligible. The proportion receiving a primary ICD showed a declining trend with increasing age. Although there were no ICD recipients among those aged ≥80 years, 16 (20%) of the nonrecipients were aged ≥80 years (P=0.11).

All recipients and a majority of the nonrecipients had a clinical history of heart failure. Ten (83.3%) and 61 (76.3%) of recipients and nonrecipients, respectively, were on diuretics for symptomatic heart failure. More than two thirds were on heart failure therapy in the form of angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, and β-blockers. There were no significant differences in sex, race, history of myocardial infarction, or revascularization before SCA (percutaneous coronary intervention or bypass). Among ICD nonrecipients, 13.8% had dementia and 12.5% were on chronic dialysis. In addition, 25% had peripheral vascular disease (PVD), and 11.3% had complicated diabetes mellitus. During the SCA event, primary ICD recipients presented less frequently with VT/ventricular fibrillation versus pulseless electric activity or asystole than nonrecipients (VT/ventricular fibrillation, 16.7% versus 54.3%; P=0.02; Table).

Sensitivity Analyses

Last Echocardiogram Before SCA

When the last echocardiogram before the SCA event was used for analysis, of the 448 cases, 129 (28.8%) had an EF ≤35% and 111 (24.8%) had an EF ≤30%. When time-relevant guideline criteria were applied, 78 (17.4%) were eligible for primary ICD, of whom 11 (14.1%) actually had a primary ICD implanted before arrest.

Use of LVEF ≤30%

Among the 92 identified ICD-eligible cases, 87 (95%) had LVEF ≤30%. Of these, 12 (13.8%) received a primary ICD before the SCA event. The proportion of cases implanted was similar in these sensitivity analyses compared with the main analysis.

Discussion

These community-based findings reveal that the rate of prior implantation of primary ICDs among cases of SCA was low (13%). The eligible but nonimplanted cases represent a unique subset in whom SCA may potentially have been preventable. The vast majority (91.4%) did not survive to hospital discharge, which is consistent with low reported rates of SCA survival in the general population.[18,19] Most of the nonrecipients (89%) had a documented history of heart failure. Furthermore, among the nonrecipients, 76% were on diuretics, which indicates heart failure symptoms that necessitated treatment. In an additional 8% of nonrecipients, the echocardiogram had been performed with symptomatic heart failure as the noted indication. Thus, the profile of these subjects suggests that most were likely in symptomatic heart failure and in New York Heart Association functional class II or more, although this finding is inferential because status of symptoms on therapy was not available consistently owing to the community-based design of the study. ICD nonrecipients were older than recipients, which suggests that this may be a potential reason for nondeployment. Although comorbidities were noted in some nonrecipients, several other factors need consideration in evaluating rates of ICD deployment in the community. ICD recipients were less likely to have VT/ventricular fibrillation as the presenting rhythm. Certain previous studies have suggested that the dominant mechanism of fatal SCA among ICD recipients may be through nonshockable rhythms such as pulseless electric activity.[20] Additionally,

Table. Demographic and Clinical Characteristics of ICD Recipients and Nonrecipients

	Primary ICD Recipients (n=12)	Primary ICD Nonrecipients (n=80)	*P* Value*
Age on date of arrest, y	61.4±15.1	69.6±13.6	0.06
Age at time of EF assessment, y	58.5±14.8	67.1±13.6	0.05
Male	7 (58.3)	58 (72.5)	0.32
White	11 (91.7)	64 (83.1)	0.68
Body mass index, kg/m^2	33.3±6.3	29.6±6.3	0.13
Diabetes mellitus	10 (83.3)	47 (58.8)	0.12
Diabetes mellitus with complications	2 (16.7)	9 (11.3)	0.63
History of CHF	12 (100)	71 (88.8)	0.60
History of MI	8 (66.7)	61 (76.3)	0.49
History of PCI/CABG	7 (58.3)	38 (47.5)	0.48
PVD	1 (8.3)	20 (25.0)	0.28
Dialysis	3 (25.0)	10 (12.5)	0.37
Dementia	1 (8.3)	11 (13.8)	1.00
Depression	5 (41.7)	12 (15.0)	0.03
VT/VF as initial rhythm	2 (16.7)	38 (54.3)	0.02
Survival to hospital discharge	1 (8.3)	7 (8.8)	1.00
Diuretics	10 (83.3)	61 (76.3)	0.73
ACEI/ARB	9 (75.0)	52 (66.7)	0.75
β-Blocker	10 (83.3)	51 (65.4)	0.32

Data presented as mean±SD or n (%). Data on age (at echocardiography) and race were available for 77 nonrecipients, whereas data on initial rhythm were available for 70 nonrecipients. Body mass index information was available for 8 recipients and 64 nonrecipients. Data on ACEI/ARB and β-blockers were available for 78 nonrecipients. ACEI/ARB indicates angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; CABG, coronary artery bypass graft; CHF, congestive heart failure; EF, ejection fraction; ICD, implantable cardioverter defibrillator; MI, myocardial infarction; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease; and VT/VF, ventricular tachycardia/ventricular fibrillation.

*Mann-Whitney *U* test for continuous variables; χ^2/Fisher exact test for categorical variables.

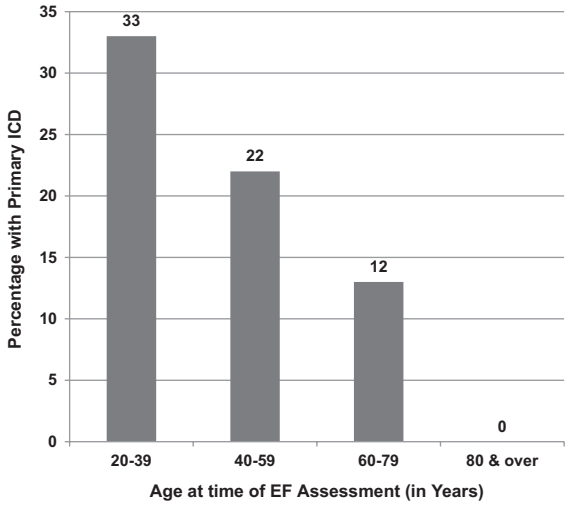

Figure 2. Proportion of recipients of implantable cardioverter defibrillators (ICDs) for primary prevention across different age groups. EF indicates ejection fraction.

because ICD recipients who received appropriate shocks for VT/ventricular fibrillation were not included in the present study, this could have led to potential overrepresentation of non-VT/ventricular fibrillation rhythms among the SCD victims who were ICD recipients.

A few published studies have suggested the possibility of low ICD utilization rates for primary prevention of SCA, but these studies were not conducted in the community. An analysis of the Get With the Guidelines–Heart Failure registry showed a 35% rate of implantation in eligible subjects.[21] Similarly, the IMPROVE-HF registry (Registry to Improve the Use of Evidence-Based Heart Failure Therapies in the Outpatient Setting) showed that ≈33% of eligible patients received an ICD, with an additional 18% receiving cardiac resynchronization therapy with defibrillator.[22] To the best of our knowledge, the present analysis is the first of its kind conducted in the general population, reporting a low rate of primary ICD utilization. First, we have shown that among SCA cases with prior echocardiographic evaluation in the general population, less than a quarter would have been guideline-eligible for primary ICD implantation before the event. This is in agreement with previous studies that have demonstrated that only a minority of SCA cases in the community have severe left ventricular dysfunction.[3,18] Furthermore, among such eligible candidates, only 13% actually had a device implanted. The results were similar when we used the last echocardiogram before SCA and when an EF cutoff of 30% was used for all time periods. This information is new and merits careful consideration.

What are the reasons for the observed low rates of primary ICD implantation in the present study? There is unlikely to be a single explanation, because multiple factors could explain nondeployment of the primary ICD in eligible subjects. Among the nonrecipients in the present study, one fifth were aged ≥80 years at the time of EF assessment. This group may not have received an ICD on the basis of physician-estimated life expectancy or patient preferences. Other studies have also shown that older patients[23,24] and women[25,26] are less likely to receive an ICD, with race also being a determinant.[27] In the present study, we did not observe any sex or race differences.

The presence of significant comorbidities in a subgroup (26%), especially neuropsychiatric comorbidities[23] and chronic dialysis, may have influenced the decision to implant a primary ICD, and most ICD trials have excluded patients with significant comorbidity. This could reflect provider judgment, patient preference, or possibly impairment of the patient's decision-making ability. Current guidelines do not recommend an ICD for those who do not have a reasonable expectation of 1-year survival.[11] However, it is important to recognize that based on the definition of SCD used in the present study, the majority of patients with severe comorbidities with an expected survival of <1 year (such as cancer not in remission) were excluded a priori. Thus, a limited number of patients would have been expected to have significant comorbidities relevant to this specific guideline criterion.

Other patient and physician characteristics may also play a major role in determining appropriate ICD referral. There was no documentation of ICD refusal among subjects in the

present study, although other studies have suggested that refusal among potential primary prevention candidates may play a role. Factors involved in refusal include perceived strength of recommendation by the treating physician, fears about malfunction, and unwillingness to have invasive life-prolonging procedures.[28] Provider practice patterns and type of hospital have also been associated with rates of primary ICD implantation. A single-center study showed that ICD implantation rates were higher when a cardiologist or a heart failure specialist was involved in the care of the patient.[23] Smaller hospital size and lack of a cardiology service have been linked to lower rates of implantation.[29,30] A survey from New Zealand revealed that various physician-related factors could influence ICD referral, including familiarity with guidelines and perceptions of cost-effectiveness.[31] In the present study, we did not have access to detailed information regarding the type of physician or center primarily responsible for individual patient care.

Lack and nature of health insurance is an important potential determinant of the decision to implant the primary ICD.[30] The present study was not designed to collect health insurance information. In general, socioeconomic factors are likely to have a significant influence. Udell et al,[24] from a population-based analysis in Ontario, Canada, reported an association between ICD implantation and residence in more affluent neighborhoods and metropolitan areas. Although we did not have detailed information at the individual level for socioeconomic status, this clearly warrants further evaluation.

Study Limitations

We restricted the present analysis to SCA cases only and did not use information for all ICD implantations in the community for that time period. This was based on the established challenges of using ICD therapies as a surrogate for SCA events.[12] However, we limited analysis to the subset of cases with pre-arrest LVEF information available and incorporated relevant time-specific primary prevention criteria to arrive at the best possible estimates. In addition, these data were obtained from a single community and may not be generalizable to other communities and geographic regions. We did not have direct New York Heart Association functional class assessment for most of the subjects; however, given the overall clinical profile of the cases in the present study, it is likely that the majority were class II or more. The number of ICD recipients analyzed was relatively small, possibly resulting in low power to observe some differences between the 2 groups; however, these were identified from a population of approximately 1 million residents, which highlights the difficulty of identifying and studying such subjects in the community. Because echocardiogram information was obtained from existing medical records, the reading was not standardized. This is an inherent limitation in any population-based study. Furthermore, these data are likely to represent the "real world" scenario for use of the echocardiogram for clinical decision making by referring/implanting physicians.

Conclusions

Only 13% of ICD-eligible community-based SCA cases received a primary ICD before their SCA event. Nonrecipients were characterized by older age than recipients. Although age and comorbidities may explain nondeployment in a subset of cases, other patient factors and clinical practice patterns warrant further detailed study to help optimize primary ICD use in the community.

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CLINICAL PERSPECTIVE

The implantable cardioverter defibrillator (ICD) represents a significant advance for the prevention of sudden cardiac death (SCD). Although clinical guidelines recommend the use of an ICD for primary prevention of SCD among specific patients with low ejection fraction, the extent of its use among those who experience SCD in the community has not been investigated. Using a prospective population-based approach in a large US community, we identified SCD case subjects who would have been eligible for a primary ICD based on echocardiograms performed before the SCD event and using relevant, time-dependent guideline criteria. We found that among cases with assessment of ejection fraction before the occurrence of SCD, 20% would have been eligible for a primary prevention ICD; however, among this eligible subgroup of subjects, only 13% received a primary prevention ICD. The ICD nonrecipients were older than the recipients, and approximately one fourth of them had associated comorbidities such as dementia or advanced renal disease. Further detailed investigations are needed to understand the role of additional factors that affect the decision-making process for primary prevention ICD implantation, such as socioeconomic factors, health insurance, patient preference, and clinical practice patterns.

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