*Kidney International, Vol. 68 (2005), pp. 818–825*

# Survival of dialysis patients after cardiac arrest and the impact of implantable cardioverter defibrillators

**Charles A. Herzog, Shuling Li, Eric D. Weinhandl, Jeremy W. Strief, Allan J. Collins, and David T. Gilbertson**

*Chronic Disease Research Group, Minneapolis Medical Research Foundation, Minneapolis, Minnesota; and Department of Medicine, Hennepin County Medical Center, University of Minnesota, Minneapolis, Minnesota*

**Survival of dialysis patients after cardiac arrest and the impact of implantable cardioverter defibrillators.**

*Background.* Sudden cardiac death is the single largest cause of mortality in dialysis patients. There are no published data on the use or survival impact of implantable cardioverter defibrillators (ICDs) in dialysis patients. The objective of this retrospective cohort study was to determine ICD use in dialysis patients and impact on survival.

*Methods.* Dialysis patients hospitalized from 1996 to 2001 for ventricular fibrillation/cardiac arrest, having ICD implantation within 30 days of admission, discharged alive, and surviving at least 30 days from admission were identified from the 100% end-stage renal disease (ESRD) sample of the Medicare database. Long-term survival was estimated by life-table method. Impact of independent predictors on survival was examined in a comorbidity-adjusted Cox model and a propensity model.

*Results.* There were 460 patients (7.6%) with ICD and 5582 patients (92.4%) without ICD. Estimated 1-, 2-, 3-, 4-, and 5-year survivals after day 30 of admission in the ICD group were 71%, 53%, 36%, 25%, and 22%, respectively; in the no-ICD group, 49%, 33%, 23%, 16%, and 12% ($P < 0.0001$). ICD implantation was independently associated with a 42% reduction in death risk [relative risk 0.58 (95% CI 0.50, 0.66)]. In the propensity model, the relative risks of death for the lower, middle, and upper third propensity groups were 0.45 (0.26, 0.81), 0.61 (0.45, 0.84), and 0.65 (0.55, 0.76), respectively. The C statistic for the propensity model equaled 0.81.

*Conclusion.* In dialysis patients, ICD therapy is apparently underused. ICD implantation in cardiac arrest survivors on dialysis is associated with greater survival.

The risk of death in dialysis patients is extraordinarily high. The rate of all-cause mortality for United States dialysis patients in 1999 to 2001 was 235 deaths/1000 patient-years [1]. Cardiac disease is the major cause of death, accounting for 43% of all-cause mortality [1]. Dialysis patients have poor long-term survival after acute myocardial infarction (AMI) [2]; 20% of cardiac deaths are attributed to AMI [1]. The single largest cause of death in dialysis patients, however, is linked to arrhythmic mechanisms, as 61% of all cardiac deaths are ascribed to cardiac arrest/arrhythmia [1].

Dialysis patients are at high risk for sudden cardiac death. As reported in the 2004 Annual Data Report of the United States Renal Data System (USRDS), the rate of cardiac arrest has decreased over the last decade. In the prevalent United States dialysis patient population the cardiac arrest rate (adjusted for age, gender, race, and diabetic status) has declined from 75 events per 1000 patient years in 1994 to 62 events per 1000 patient years in 2002 [3]. The hazard of cardiac arrest, however, is not uniform over time for dialysis vintage, as the rate of cardiac arrest progressively rises in relation to duration of dialysis therapy [4]. Several factors contribute to the vulnerability of dialysis patients to sudden cardiac death: obstructive coronary artery disease, left ventricular hypertrophy, rapid electrolyte shifts in hemodialysis patients (and hyperkalemia), and abnormalities in myocardial ultrastructure and function, including endothelial dysfunction, interstitial fibrosis, decreased perfusion reserve, and diminished ischemia tolerance [5–8].

Dialysis patients suffer abysmal outcome after cardiac arrest, having an 85% 1-year mortality [4]. In the general population, implantable cardioverter defibrillators (ICDs) have been shown to be superior to medical therapy for improving the outcome of survivors of cardiac arrest and life-threatening ventricular tachycardia [9]. Although a nonsignificant survival advantage for ICDs was reported in two other comparable trials [10, 11], a meta-analysis of all three trials does suggest better survival with ICDs, with a statistically significant ($P = 0.0006$) 28% reduction in death risk [12]. There are no published data on ICD use and effect on survival in dialysis patients.

**Key words:** cardiac arrest, defibrillation, dialysis, survival.

Received for publication October 29, 2004
and in revised form January 26, 2005, and March 16, 2005
Accepted for publication March 30, 2005

## METHODS

We performed a retrospective cohort study using the 100% end-stage renal disease (ESRD) sample of the Medicare database (administrative data derived predominantly from Medicare claims and identical to the source of the United States Renal Data System database) ($N$ = 1,408,250 patients). We studied period-prevalent dialysis patients (1996 through 2001) who survived at least 90 days after dialysis initiation ($N$ = 472,443), were hospitalized during the period January 1, 1996, to December 31, 2001, with an index event of cardiac arrest [*International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) code 427.5] or ventricular fibrillation/flutter (ICD-9-CM code 427.4) ($N$ = 30,518), were discharged alive from the hospital, and survived at least 30 days from the index admission ($N$ = 6,173). ICD implantation within 30 days of hospital admission was identified from ICD-9-CM procedure code 37.94. Patients with a prior ICD implant were excluded, yielding a final study population of 6042 patients (identified from sequential subsets as described above and further enumerated in the **Results** section). Patients were followed from day 30 after admission to the earliest of death, renal transplantation, loss to follow-up, or December 31, 2001.

Baseline characteristics of patients with and without ICD were compared by $\chi^2$ test. Long-term survival was estimated by life-table method, and survival of subgroups compared by log-rank test. The impact of ICD implantation on survival was estimated by a Cox proportional hazards model, with adjustment for patient characteristics, including age, gender, race, ESRD etiology, prior ESRD duration, calendar year of hospitalization, concomitant AMI or coronary revascularization during hospitalization, and comorbid medical conditions, the last determined by using a previously developed comorbidity profiling methodology [13].

To further analyze the impact of ICD implantation on survival, and to account for the potential confounding effects of differing characteristics of patients receiving ICDs and those not receiving ICDs on outcome, a propensity model was used [14]. The propensity score for a patient is the estimated probability of ICD implantation, given the characteristics of the patient. All variables included in the Cox model were used in the propensity model. Other variables added to the propensity analysis were coronary angiography performed within 30 days of the index admission, and two-way interactions of variables used in the Cox model. The propensity score was incorporated into the Cox model through stratification by propensity score tertiles. The C statistic was calculated in the propensity model (with the study patients analyzed by lowest, middle, and highest propensity tertiles for ICD implantation) as a measure of strength of association of ICD implantation with survival.

## RESULTS

A total of 30,518 patients had an index event of cardiac arrest or ventricular fibrillation/flutter, among whom 288 patients had a prior ICD implant, and these patients were excluded (of these 288 patients with prior ICD implants, 131 survived at least 30 days and were discharged alive from hospital). Of the remaining 30,230 patients, only 7853 patients were identified to be alive at 30 days after the index event. In this group of 7853 patients, 529 received ICD implants and 69 (13% of 529) died before discharge; a total of 1742 patients without ICD implant (24% of 1742) died before discharge. There were 22,377 patients who were not eligible for inclusion (because they did not have at least 30-day survival after the index event). Of these 22,377 patients, 37 received ICD implants and 22 of these patients (59% of 37) died before discharge, while 22,340 patients did not receive ICD implants and 21,258 (95% of 22,340) patients died before discharge.

There were 6042 dialysis patients in the final study cohort. Only 460 patients (7.6%) received ICD therapy. The mean ± SD age for the entire cohort was 63.1 ± 14.0 years (ICD group, 63.1 ± 13.1 years; no-ICD group, 63.1 ± 14.2 years). The mean ± SD follow-up duration was 17.9 ± 15.5 months for the ICD group and 14.0 ± 14.9 months for the no-ICD group. During the study period, the following occurred (numbers from ICD and no-ICD groups, respectively): deaths 227 and 3858; renal transplants 8 and 101; and loss to follow-up 6 and 26.

Table 1 summarizes the patient characteristics. ICD therapy was used relatively more frequently in patients who were male, white, without diabetic ESRD, and with AMI. Coronary angiography was performed in 1512 patients (25%). About one third (36.3%) of patients receiving ICDs did not have concurrent coronary angiography. Diagnostic electrophysiologic studies were performed in only 10.2% of the entire study cohort. Of the patients receiving EP studies, 416 did and 202 did not receive ICDs. In the ICD group, 44 patients (9.6%) had no concurrent claims for diagnostic electrophysiologic studies.

Figure 1 displays estimated survival. The 1-, 2-, 3-, 4-, and 5-year survival in the ICD group was 71%, 53%, 36%, 25%, and 22%, respectively; in the no-ICD group, it was 49%, 33%, 23%, 16%, and 12% ($P < 0.0001$).

Table 2 provides the results of the Cox model. The most powerful predictors of death were older age, diabetic ESRD, and the comorbid conditions of congestive heart failure and peripheral vascular disease. ICD implantation was independently associated with a 42% reduction in death risk [relative risk 0.58 (95% CI 0.50, 0.66)]. Surgical (but not percutaneous) coronary revascularization during the same hospitalization was independently associated with a 44% reduction in death risk.

**Table 1.** Baseline patient characteristics

| Characteristic | All patients ($N = 6042$) | ICD ($N = 460$) | No ICD ($N = 5582$) | $P$ value[a] |
|---|---|---|---|---|
| Age *years* (%) | | | | 0.007 |
| <45 | 694 (11.5) | 41 (8.9) | 653 (11.7) | |
| 45 to 64 | 2118 (35.1) | 167 (36.3) | 1951 (35.0) | |
| 65 to 74 | 1896 (31.4) | 170 (37.0) | 1726 (30.9) | |
| ≥75 | 1334 (22.1) | 82 (17.8) | 1252 (22.4) | |
| Gender *number* (%) | | | | <0.0001 |
| Male | 2833 (46.9) | 262 (57.0) | 2571 (46.1) | |
| Female | 3209 (53.1) | 198 (43.0) | 3011 (53.9) | |
| Race *number* (%) | | | | 0.0961 |
| White | 3458 (57.2) | 285 (62.0) | 3173 (56.8) | |
| Black | 2218 (36.7) | 152 (33.0) | 2066 (37.0) | |
| Other | 366 (6.1) | 23 (5.0) | 343 (6.1) | |
| End-stage renal disease etiology number (%) | | | | <0.0001 |
| Diabetes | 2854 (47.2) | 164 (35.7) | 2690 (48.2) | |
| Hypertension | 1605 (26.6) | 127 (27.6) | 1478 (26.5) | |
| Other | 1583 (26.2) | 169 (36.7) | 1414 (25.3) | |
| Prior end-stage renal disease duration *years* (%) | | | | |
| <1 | 1268 (21.0) | 95 (20.7) | 1173 (21.0) | |
| 1 to <2 | 1243 (20.6) | 89 (19.3) | 1154 (20.7) | |
| 2 to <5 | 2159 (35.7) | 154 (33.5) | 2005 (35.9) | |
| ≥5 | 1372 (22.7) | 122 (26.5) | 1250 (22.4) | |
| Comorbidity *number* (%) | | | | |
| Acute myocardial infarction | 1361 (22.5) | 132 (28.7) | 1229 (22.0) | 0.001 |
| Atherosclerotic heart disease | 3163 (52.4) | 273 (59.3) | 2890 (51.8) | 0.0018 |
| Congestive heart failure | 3395 (56.2) | 278 (60.4) | 3117 (55.8) | 0.0563 |
| Cardiac (other) | 3207 (53.1) | 286 (62.2) | 2921 (52.3) | <0.0001 |
| Cancer | 591 (9.8) | 52 (11.3) | 539 (9.7) | 0.2527 |
| Chronic obstructive pulmonary disease | 1396 (23.1) | 95 (20.7) | 1301 (23.3) | 0.1941 |
| Cerebrovascular accident/transient ischemic attack | 1106 (18.3) | 70 (15.2) | 1036 (18.6) | 0.0748 |
| Gallbladder disease | 422 (7.0) | 30 (6.5) | 392 (7.0) | 0.6854 |
| Gastrointestinal bleeding | 1176 (19.5) | 101 (22.0) | 1075 (19.3) | 0.16 |
| Liver disease | 185 (3.1) | 11 (2.4) | 174 (3.1) | 0.3851 |
| Peripheral vascular disease | 2125 (35.2) | 141 (30.7) | 1984 (35.5) | 0.0347 |
| Concurrent events in hospital *number* (%) | | | | |
| Acute myocardial infarction | 1094 (18.1) | 103 (22.4) | 991 (17.8) | 0.013 |
| Coronary artery bypass surgery | 242 (4.0) | 20 (4.3) | 222 (4.0) | 0.6967 |
| Percutanous transluminal coronary angioplasty | 273 (4.5) | 34 (7.4) | 239 (4.3) | 0.002 |
| Coronary artery stent | 168 (2.8) | 20 (4.3) | 148 (2.7) | 0.0334 |
| Coronary angiogram | 1512 (25.0) | 293 (63.7) | 1219 (21.8) | <0.0001 |
| Electrophysiologic study | 618 (10.2) | 416 (90.4) | 202 (3.6) | <0.0001 |

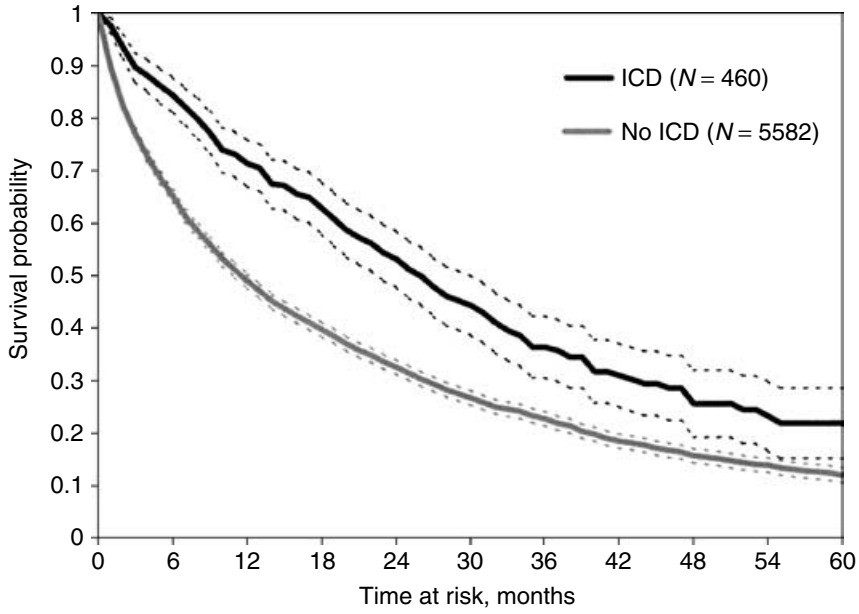
ICD is implantable cardioverter defibrillator.
[a]By $\chi^2$ test.

The relation of ICD implantation and survival was assessed in each tertile of propensity, (Table 3). In the lowest propensity tertile for ICD implantation, there were 23 ICD patients, and the relative risk of death associated with ICD was 0.45 (0.26, 0.81). In the middle third propensity group, there were 78 ICD patients, and the relative risk of death in the ICD group was 0.61 (0.45, 0.84). In the upper third propensity tertile, there were 359 ICD patients, and the relative risk of death in the ICD group was 0.65 (0.55, 0.76). The C statistic for the propensity model equaled 0.81. These data imply that the survival advantage attributable to ICD implants was unlikely to be explained by differences in baseline characteristics of patients selected for ICD implantation compared to those patients not receiving ICDs, as the survival advantage associated with ICD implantation was present in all three tertiles of propensity.

## DISCUSSION

This retrospective, observational study supports the use of ICDs for the "secondary" prevention of death in cardiac arrest survivors on dialysis. In this study the apparent protective effect of ICDs was manifest surprisingly early, as seen in the rapid divergence of the survival curves. Although the contribution of selection bias to survival cannot be excluded (or apportioned), we believe that these data imply that arrhythmic mechanisms play an important role in the subsequent mortality of cardiac arrest survivors on dialysis, and that ICDs may improve survival in these patients.

Our study population of dialysis patients was characterized by a high mortality rate, when viewed from the perspective of ICD trials in non-ESRD patients. In the Antiarrhythmics versus Implantable Defibrillators (AVID) trial [9] comparing two treatment strategies for




| Number at risk: | | | | |
|---|---|---|---|---|
| No ICD | 2239 | 1149 | 562 | 246 |
| ICD | 243 | 136 | 61 | 25 |

**Fig. 1. Estimated unadjusted survival of dialysis patients with and without an implantable cardioverter-defibrillator (ICD).** $P < 0.0001$ by log rank test for comparison of patients with ICD to those without ICD. Dashed lines indicate 95% CIs.

patients resuscitated from ventricular fibrillation, ventricular tachycardia with syncope, or sustained ventricular tachycardia (and ejection fraction of ≤40% and hemodynamic compromise from the arrhythmia), the overall mortality of patients was considerably lower than in our present study. In AVID the reported 1-, 2-, and 3-year unadjusted life-table survivals were respectively 89%, 82%, and 75% in the ICD arm and 82%, 75%, and 64% in the patients receiving antiarrhythmic drugs. This contrasts with the unadjusted life-table survival in the present study: the 1-, 2-, and 3-year survival were respectively 71%, 53%, and 36% for dialysis patients receiving ICDs and 49%, 33%, and 23% for dialysis patients not receiving ICDs. Although the overall mortality in our dialysis study population was much higher, the relative benefit from ICDs was similar, with a 42% reduction in overall death risk in our study and 38% in AVID.

Our data indicate that ICD therapy is apparently underused in dialysis patients. To exclude moribund patients (whom clinicians would be less likely to refer for ICD implantation), we restricted our analysis to postcardiac arrest 30-day survivors who had been discharged from the hospital. Nevertheless, only 8% of the study cohort received ICDs. Only 10% of the entire study cohort received diagnostic electrophysiologic studies. Clearly, the reason for not implanting an ICD was unrelated to a negative finding on a diagnostic electrophysiologic study. Our study also raises an issue regarding selection of dialysis patients for ICD therapy, as we observed an unbalanced distribution of ICD implantation related to gender and (and, to a lesser extent, race), with women and blacks less likely to receive ICD therapy.

A recent publication by Voight et al [15] analyzed the incidence of ICD therapy in survivors of cardiac arrest in the United States from 1996 through 2001. There were 113,262 patients admitted for cardiac arrest and 49,517 patients survived to discharge. In this group of 49,517 patients, 30.7% received an ICD before discharge (rising from 23.6% in 1996 to 46.3% in 2001). Race (black versus white) [odds ratio 0.19 (95%CI 0.13, 0.29)] and renal failure (severity unspecified) [odds ratio 0.25 (95%CI 0.14, 0.46)] were found to be independent negative predictors of ICD utilization in their study. Voight et al conclude that the rates of ICD therapy after cardiac arrest remain "very low." Viewed from the perspective of Voight et al that a 30.7% ICD utilization is "very low," our finding of a 7.6% ICD utilization reinforces our contention that ICD therapy is underutilized in dialysis patients.

There are several plausible explanations for the apparent underutilization of ICDs after cardiac arrest in dialysis patients. It is plausible that concerns regarding potential complications (e.g., infection and difficulties with vascular access) might dissuade clinicians from ICD implantation. Prior publications have reported that the likelihood of receiving therapies proven to reduce mortality in clinical trials on treatment of AMI (including aspirin, beta blockers, angiotensin converting enzyme inhibitors, and reperfusion therapy) is inversely related to severity of renal failure [16–20]. The underutilization of these therapies in patients with chronic kidney disease may be a

**Table 2.** Results of Cox proportional hazards model of all-cause mortality [a]

| | Hazards ratio (95% CI) | *P* value[a] |
|---|---|---|
| Implantable cardioverter defibrillator | 0.58 (0.50, 0.66) | <0.0001 |
| Age *years* | | |
| <45 | 0.81 (0.72, 0.91) | 0.0006 |
| 65 to 74 | 1.23 (1.14, 1.34) | <0.0001 |
| ≥75 | 1.55 (1.42, 1.69) | <0.0001 |
| Gender | | |
| Male | 1.06 (1.00, 1.13) | 0.0563 |
| Race | | |
| Black | 0.91 (0.85, 0.97) | 0.0052 |
| Other | 0.90 (0.78, 1.03) | 0.1307 |
| End-stage renal disease etiology | | |
| Diabetes | 1.29 (1.19, 1.41) | <0.0001 |
| Hypertension | 1.09 (0.99, 1.19) | 0.0653 |
| Prior end-stage renal disease duration *years* | | |
| 1 to <2 | 1.01 (0.91, 1.11) | 0.9097 |
| 2 to <5 | 1.04 (0.95, 1.13) | 0.395 |
| ≥5 | 1.04 (0.94, 1.15) | 0.4205 |
| Comorbidity | | |
| Acute myocardial infarction | 1.07 (0.99, 1.16) | 0.0943 |
| Atherosclerotic heart disease | 1.05 (0.97, 1.13) | 0.2202 |
| Congestive heart failure | 1.18 (1.10, 1.27) | <0.0001 |
| Cardiac (other) | 1.04 (0.97, 1.12) | 0.2217 |
| Cancer | 1.10 (1.00, 1.22) | 0.0617 |
| Chronic obstructive pulmonary disease | 1.09 (1.01, 1.18) | 0.0195 |
| Cerebrovascular accident/transient ischemic attack | 1.04 (0.96, 1.13) | 0.3454 |
| Gallbladder disease | 0.98 (0.87, 1.11) | 0.8027 |
| Gastrointestinal bleeding | 1.08 (1.00, 1.17) | 0.0431 |
| Liver disease | 1.12 (0.94, 1.34) | 0.1971 |
| Peripheral vascular disease | 1.26 (1.18, 1.35) | <0.0001 |
| Concurrent events in hospital | | |
| Acute myocardial infarction | 1.13 (1.04, 1.23) | 0.003 |
| Coronary artery bypass surgery | 0.56 (0.47, 0.67) | <0.0001 |
| Percutaneous transluminal coronary angioplasty | 0.85 (0.66, 1.09) | 0.2071 |
| Coronary artery stent | 0.91 (0.66, 1.25) | 0.5666 |
| Year of admission | | |
| 1997 | 0.94 (0.85, 1.03) | 0.1852 |
| 1998 | 0.91 (0.83, 1.00) | 0.0579 |
| 1999 | 0.86 (0.78, 0.96) | 0.0042 |
| 2000 | 0.83 (0.75, 0.93) | 0.0008 |
| 2001 | 0.94 (0.82, 1.08) | 0.3588 |

[a]The reference group had the following characteristics: no ICD; age 45 to 64 years; female gender; white race; other end-stage renal disease etiology; prior end-stage renal disease duration <1 year; no comorbid conditions; no concurrent events during hospital stay; prevalent dialysis patients in 1996.

reflection of both "therapeutic nihilism" and a paucity of clinical trial data in this special group of high risk patients [21]. Unfortunately, patients on dialysis are at high risk for cardiac death and thus potentially have the most to lose by not receiving life-saving therapies. This paradigm applies equally to aspirin and defibrillators; if aspirin is underprescribed, it should not be a surprise that ICDs are underutilized.

The 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices from the American College of Cardiology, American Heart Association, and North American Society for Pacing and Electrophysiology is recommended as a definitive background source document for clinicians [22]. Three of the "class I" ("conditions for which there is evidence and/or general agreement that a given procedure or treatment is beneficial, useful, and effective") recommendations for ICD therapy are pertinent to the present discussion: "cardiac arrest due to ventricular fibrillation or ventricular tachycardia not due to a transient or reversible cause, spontaneous [ventricular tachycardia] in association with structural heart disease, and spontaneous sustained [ventricular tachycardia] patients without structural heart disease not amenable to other treatments. Two "class III ("conditions for which there is evidence and/or general agreement that a procedure/treatment is not useful/effective and in some cases may be harmful) ICD therapy recommendations are applicable to our discussion: "ventricular tachycardia due to a transient or reversible disorder (e.g., AMI, electrolyte imbalance, drugs, or trauma when correction of the disorder is considered feasible and likely to substantially reduce the risk of recurrent arrhythmia" and "terminal illness with projected life expectancy less than 6 months."

In the present study we have focused on (presumably nonmoribund) cardiac arrest survivors; arguably most of these patients would have a class I indication for ICD placement. It is also noteworthy that most dialysis

**Table 3.** Characteristics of the study population by propensity tertiles

| | Tertile 1 | | | Tertile 2 | | | Tertile 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | No ICD | ICD ($N = 23$) | $P$ value[a] | No ICD | ICD ($N = 78$) | $P$ value[a] | No ICD | ICD ($N = 359$) | $P$ value[a] |
| Age *years* | | | | | | | | | |
| <45 | 14.2 | 17.4 | 0.731 | 11.9 | 7.7 | 0.506 | 8.4 | 8.6 | 0.845 |
| 45 to 64 | 35.2 | 39.1 | | 33.4 | 38.5 | | 36.4 | 35.7 | |
| 65 to 74 | 23.3 | 26.1 | | 33.5 | 29.5 | | 37.2 | 39.3 | |
| ≥75 | 27.3 | 17.4 | | 21.2 | 24.4 | | 18.0 | 16.4 | |
| Gender | | | | | | | | | |
| Male | 30.9 | 30.4 | 1.000 | 51.3 | 56.4 | 0.419 | 58.1 | 58.8 | 0.814 |
| Female | 69.1 | 69.6 | | 48.7 | 43.6 | | 41.9 | 41.2 | |
| Race | | | | | | | | | |
| White | 50.2 | 60.9 | 0.340 | 58.6 | 62.8 | 0.558 | 62.8 | 61.8 | 0.916 |
| Black | 41.7 | 39.1 | | 36.1 | 30.8 | | 32.4 | 33.1 | |
| Other | 8.1 | 0.0 | | 5.3 | 6.4 | | 4.8 | 5.0 | |
| End-stage renal disease etiology | | | | | | | | | |
| Diabetes | 64.7 | 65.2 | 0.055 | 41.3 | 30.8 | 0.108 | 36.3 | 34.8 | 0.746 |
| Hypertension | 23.3 | 8.7 | | 29.9 | 30.8 | | 26.3 | 28.1 | |
| Other | 12.0 | 26.1 | | 28.8 | 38.5 | | 37.4 | 37.0 | |
| Prior end-stage renal disease duration *years* | | | | | | | | | |
| <1 | 19.7 | 17.4 | 0.947 | 23.8 | 19.2 | 0.407 | 19.3 | 21.2 | 0.681 |
| 1 to <2 | 21.8 | 17.4 | | 20.5 | 16.7 | | 19.5 | 20.1 | |
| 2 to <5 | 40.5 | 47.8 | | 33.1 | 42.3 | | 33.7 | 30.6 | |
| ≥5 | 18.0 | 17.4 | | 22.6 | 21.8 | | 27.5 | 28.1 | |
| Comorbidity | | | | | | | | | |
| Acute myocardial infarction | 15.6 | 26.1 | 0.158 | 21.5 | 28.2 | 0.162 | 30.4 | 29.0 | 0.612 |
| Atherosclerotic heart disease | 43.3 | 69.6 | 0.018 | 52.6 | 61.5 | 0.133 | 60.9 | 58.2 | 0.372 |
| Congestive heart failure | 47.8 | 43.5 | 0.834 | 58.9 | 60.3 | 0.907 | 61.9 | 61.6 | 0.952 |
| Cardiac (other) | 39.8 | 60.9 | 0.053 | 56.5 | 59.0 | 0.727 | 62.5 | 63.0 | 0.904 |
| Cancer | 9.1 | 8.7 | 1.000 | 8.9 | 14.1 | 0.155 | 11.2 | 10.9 | 0.926 |
| Chronic obstructive pulmonary disease | 27.1 | 39.1 | 0.237 | 21.5 | 20.5 | 0.889 | 20.8 | 19.5 | 0.615 |
| Cerebrovascular attack/transient ischemic attack | 25.5 | 13.0 | 0.230 | 15.5 | 19.2 | 0.426 | 13.7 | 14.5 | 0.736 |
| Gallbladder disease | 9.0 | 0.0 | 0.257 | 5.0 | 6.4 | 0.593 | 7.0 | 7.0 | 1.000 |
| Gastrointestinal bleeding | 19.4 | 30.4 | 0.188 | 16.5 | 11.5 | 0.277 | 22.4 | 23.7 | 0.578 |
| Liver disease | 5.6 | 4.3 | 1.000 | 1.5 | 1.3 | 1.000 | 2.1 | 2.5 | 0.549 |
| Peripheral vascular disease | 40.3 | 56.5 | 0.136 | 35.8 | 37.2 | 0.810 | 29.5 | 27.6 | 0.482 |
| Concurrent events in hospital | | | | | | | | | |
| Acute myocardial infarction | 14.9 | 26.1 | 0.141 | 14.1 | 20.5 | 0.136 | 25.5 | 22.6 | 0.254 |
| Coronary artery bypass surgery | 1.6 | 0.0 | 1.000 | 3.5 | 0.0 | 0.110 | 7.4 | 5.6 | 0.257 |
| Percutaneous transluminal coronary angioplasty | 0.9 | 4.3 | 0.187 | 1.9 | 2.6 | 0.657 | 11.2 | 8.6 | 0.160 |
| Coronary artery stent | 0.4 | 4.3 | 0.098 | 1.1 | 2.6 | 0.223 | 7.2 | 4.7 | 0.104 |
| Coronary angiogram | 1.6 | 0.0 | 1.000 | 5.8 | 7.7 | 0.460 | 64.9 | 79.9 | <0.001 |

ICD is implantable cardioverter defibrillator.
[a]By Fisher's exact test.

patients probably do have some type of structural heart disease, as left ventricular hypertrophy has been reported in 75% of incident dialysis patients. One potential source of confusion is the issue of "electrolyte imbalance" and what is considered to be an easily treatable, potentially reversible condition whose correction is "likely to substantially reduce the risk of recurrent arrhythmia" (even King Solomon might have had difficulty applying this guideline to dialysis patients). Although the use of low potassium dialyzate was a risk factor for cardiac arrest during hemodialysis in one series, predialysis hyperkalemia was not implicated [23]. Significantly, most cardiac arrests occur outside of dialysis centers (about one cardiac arrest would be expected annually in a hemodialysis center with 100 chronic patients) [23, 24].

We believe that the key issue for clinicians caring for these patients relates to the issue of clinical success by therapeutic strategy. For whatever reason, 92% of our study cohort did not receive ICDs. Based on their subsequent outcome, it would be difficult to argue that this group did well with a "conservative strategy." In the context of current ICD practice guidelines and the observational data presented in the present study, an increased awareness by clinicians of the potential utility of ICDs in dialysis patients would be desirable.

There are important limitations to this study. The data were derived from Medicare claims; important clinical data such as left ventricular ejection fraction, exercise capacity, serum potassium levels**,** and severity of coronary artery disease were unavailable. Data regarding utilization of pharmacologic agents (e.g., beta blockers) were unavailable. In this retrospective study, the contribution of selection bias for ICD use cannot be excluded.

Our study focused on the select 20% of dialysis patients surviving 30 days after cardiac arrest and discharged alive after hospitalization; these patients would be potential candidates for "secondary" prevention of sudden cardiac death. For most of the remaining 80% of the dialysis cohort hospitalized for cardiac arrest and not included in our study, the clinical paradigm of "secondary" prevention would not be applicable, either due to mortality or postarrest clinical status. Our study ignored the larger question of primary prevention of sudden cardiac death, which is the single greatest contributor to all-cause mortality in dialysis patients. Our data support studies on the prevention of sudden cardiac death in dialysis patients, including a prospective randomized trial of ICD therapy for the primary prevention of sudden cardiac death in dialysis patients.

## ACKNOWLEDGMENTS

This study was supported by an unrestricted research grant from Medtronic Inc., Minneapolis, Minnesota. We thank Charena Lankford and James Kaufmann for assistance with the manuscript.

*Correspondence to Charles A. Herzog, M.D., Chronic Disease Research Group, Minneapolis Medical Research Foundation, 914 South 8th Street, Suite D-206, Minneapolis, MN 55404.*
*E-mail: cherzog@nephrology.org*

## REFERENCES

1. U.S. Renal Data System: *USRDS 2003 Annual Data Report*, Bethesda, MD, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 2003
2. Herzog CA, Ma JZ, Collins AJ: Poor long-term survival after acute myocardial infarction among patients on long-term dialysis. *N Engl J Med* 339:799–805, 1998
3. U.S. Renal Data System: *USRDS 2004 Annual Data Report*, Bethesda, MD, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 2004
4. U.S. Renal Data System: *USRDS 2002 Annual Data Report*, Bethesda, MD, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 2002
5. Amann K, Rychlik I, Miltenberger-Milteny G, Ritz E: Left ventricular hypertrophy in renal failure. *Kidney Int* 68:S78–S85, 1998
6. Amann K, Ritz E: Cardiac disease in chronic uremia: pathophysiology. *Adv Renal Replace Ther* 4:212–224, 1997
7. Ritz E, Amann K, Tornig J, *et al*: Some cardiac abnormalities in renal failure. *Adv Nephrol Necker Hosp* 27:85–103, 1997
8. Amann K, Buzello M, Simonaviciene A, *et al*: Capillary/myocyte mismatch in the heart in renal failure–a role for erythropoietin? *Nephrol Dial Transplant* 15:964–969, 2000
9. The Antiarrhythmics versus Implantable Defibrillators (AVID) Investigators: A comparison of antiarrhythmic-drug therapy with implantable defibrillators in patients resuscitated from near-fatal ventricular arrhythmias. *N Engl J Med* 337:1576–1583, 1997
10. Kuck KH, Cappato R, Siebels J, Ruppel R: Randomized comparison of antiarrhythmic drug therapy with implantable defibrillators in patients resuscitated from cardiac arrest: The Cardiac Arrest Study Hamburg (CASH). *Circulation* 102:748–754, 2000
11. Connolly SJ, Gent M, Roberts RS, *et al*: Canadian implantable defibrillator study (CIDS): A randomized trial of the implantable cardioverter defibrillator against amiodarone. *Circulation* 101:1297–1302, 2000
12. Connolly SJ, Hallstrom AP, Cappato R, *et al*: Meta-analysis of the implantable cardioverter defibrillator secondary prevention trials. AVID, CASH and CIDS studies, Antiarrhythmics vs Implantable Defibrillator Study, Cardiac Arrest Study Hamburg, Canadian Implantable Defibrillator Study. *Eur Heart J* 21:2071–2078, 2000
13. Collins AJ, Ma J, Constantini E, Everson S: Dialysis unit and patient characteristics associated with reuse practices and mortality: 1989–1993. *J Am Soc Nephrol* 9:2108–2117, 1998
14. Rosenbaum PR, Rubin DB: The central role of the propensity score in observational studies for causal effects. *Biometrika* 70:41–55, 1983
15. Voigt A, Ezzeddine R, Barrington W, *et al*: Utilization of implantable cardioverter-defibrillators in survivors of cardiac arrest in the United States from 1996 to 2001. *J Am Coll Cardiol* 44:855–858, 2004
16. Berger AK, Duval S, Krumholz HM: Aspirin, beta-blocker, and angiotensin-converting enzyme inhibitor therapy in patients with end-stage renal disease and an acute myocardial infarction. *J Am Coll Cardiol* 42:201–208, 2003
17. Wright RS, Reeder GS, Herzog CA, *et al*: Acute myocardial infarction and renal dysfunction: a high-risk combination. *Ann Intern Med* 137:563–570, 2002
18. Shlipak MG, Heidenreich PA, Noguchi H, *et al*: Association of renal insufficiency with treatment and outcomes after myocardial infarction in elderly patients. *Ann Intern Med* 137:555–562, 2002
19. Beattie JN, Soman SS, Sandberg KR, *et al*: Determinants of mortality after myocardial infarction in patients with advanced renal dysfunction. *Am J Kidney Dis* 37:1191–1200, 2001

20. McCullough PA, Sandberg KR, Borzak S, *et al*: Benefits of aspirin and beta-blockade after myocardial infarction in patients with chronic kidney disease. *Am Heart J* 144:226–232, 2002
21. Herzog CA: Cardiovascular disease and dialysis patients: Is therapeutic nihilism justified? *Semin Dial* 12:285–287, 1999
22. Gregoratos G, Abrams J, Epstein AE, *et al*: ACC/AHA/NASPE 2002 guideline update for implantation of cardiac pacemakers and antiarrhythmia devices: Summary article. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (ACC/AHA/NASPE Committee to Update the 1998 Pacemaker Guidelines). *J Cardiovasc Electrophysiol* 13:1183–1199, 2002
23. Karnik JA, Young BS, Lew NL, *et al*: Cardiac arrest and sudden death in dialysis units. *Kidney Int* 60:350–357, 2001
24. Becker L, Eisenberg M, Fahrenbruch C, Cobb L: Cardiac arrest in medical and dental practices: Implications for automated external defibrillators. *Arch Intern Med* 161:1509–1512, 2001