

Use of implantable cardioverter defibrillators in Canadian and US survivors of out-of-hospital cardiac arrest

David H. Birnie MB ChB MD, Christie Sambell BSc, Helen Johansen PhD, Kathryn Williams MS, Robert Lemery MD, Martin S. Green MD, Michael H. Gollob MD, Douglas S. Lee MD PhD, Anthony S.L. Tang MD

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ABSTRACT

Background: Cardiac arrest due to ventricular arrhythmia in the absence of a reversible cause or contraindication has been a class I indication for insertion of an implantable cardioverter defibrillator since 1998. We compared and contrasted the use of implantable cardioverter defibrillator therapy in Canada and the United States among adults who survived a cardiac arrest.

Method: Data on hospital separations from April 1, 1994 through March 31, 2003 were obtained from the Health Person-Oriented Information Database maintained by Statistics Canada and from the US National Hospital Discharge Survey on all patients with a primary diagnosis of cardiac arrest, ventricular fibrillation or ventricular flutter for the same 9-year period. We excluded all records of patients with a secondary diagnosis of acute myocardial infarction.

Results: In Canada, 3793 patients survived to discharge after a cardiac arrest; 628 (16.6%) of these were implanted with a cardioverter defibrillator before discharge. The implant rate rose steadily from 5.4% in 1994/95 to 26.7% in 2002/03. In the United States, 23 688 (30.2%) of 78 538 such survivors received an implantable cardioverter defibrillator before discharge. Logistic regression analysis indicated that sex, age, fiscal year, the hospital's teaching status, hospital size and patient history of heart failure were positive predictors of implantable cardioverter defibrillator implantation. Age, renal failure, liver failure and cancer were negative predictors of receiving an implantable cardioverter defibrillator.

Interpretation: The rate of use of implantable cardioverter defibrillator therapy for cardiac arrest survivors in Canada is increasing, but still is lower than the rate in the United States.

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Sudden cardiac death is the second-leading cause of death in the United States, with over 400 000 deaths annually^{1,2} (comparable data for Canada are unavailable). Most such sudden deaths are from ventricular fibrillation secondary to coronary artery disease;³ primary ventricular arrhythmias, bradycardia, asystole and pulseless electrical activity are the other broad mechanisms. Studies⁴⁻⁶ published prior to the major trials⁷⁻⁹ of implantable cardioverter

defibrillators showed that survivors of sudden cardiac arrest are at high risk of another episode within a few years; over half of the deaths that result are due to recurrences.

There have been 3 large randomized studies that compared cardioverter defibrillator implantation with the best known medical therapy, in patients surviving sudden cardiac death.⁷⁻⁹ The largest of these was the Antiarrhythmics Versus Implantable Defibrillators (AVID) trial, reported in 1997,⁷ which at 1 year found a relative reduction in deaths of 39%; the other studies^{8,9} showed similar results. A meta-analysis¹⁰ of all 3 studies indicated that implantable cardioverter defibrillators reduced the relative risk of recurrent sudden cardiac death by 50% (95% confidence interval [CI] 0.37%–0.67%) and death from any cause by 28% (95% CI 0.60%–0.87%). Since 1998, the guidelines of the American College of Cardiology and the American Heart Association have recommended that a “cardiac arrest due to ventricular fibrillation or ventricular tachycardia not due to a transient or reversible cause is a class I indication for an implantable cardioverter defibrillator.”¹¹ The Canadian guidelines, first published in 2000, are similar.¹² Previous data from Ontario have revealed a low rate of cardioverter defibrillator implantation (12.8%) after an out-of-hospital cardiac arrest.¹³ The aims of our study were 3-fold: to examine temporal trends of cardioverter defibrillator implantation in Canada during periods before and after publication of the related trials and guidelines; to compare implant rates in Canada with those in the United States; and to examine in detail the factors influencing implantation in Canada.

Methods

Study population

We obtained data on all Canadian and US patients with a primary diagnosis of cardiac arrest, ventricular fibrillation or ventricular flutter and not also having a diagnosis of myocardial infarction who survived to be discharged from hospital for the period April 1, 1994 through March 31, 2003. Data

From the University of Ottawa Heart Institute (Birnie, Williams, Lemery, Green, Gollob, Tang); the Health Statistics Division (Sambell, Johansen), Statistics Canada, Ottawa; and the Institute for Clinical Evaluative Sciences (Lee), Toronto, Ont.

from patients with a primary diagnosis of ventricular tachycardia were not included for analysis because the data sources do not contain detail sufficient to adequately assess each patient's suitability for cardioverter defibrillator implantation.

Medical data were coded according to the *International Classification of Diseases (ICD)*.¹⁴⁻¹⁶ All diagnostic and procedure codes examined in this article were unchanged over the 9-year study period; they are listed, respectively, in Appendix 1 and Appendix 2 (available at www.cmaj.ca/cgi/content/full/177/1/41/DC1).

Canadian data source

Data on hospital separations for the study period were obtained from the Health Person-Oriented Information database maintained by Statistics Canada. This database tracks patients from admission until in-hospital death or final discharge (including transfers between acute-care hospitals). For each patient, a primary diagnosis and up to 16 secondary diagnoses were abstracted. Medical data were coded according to the ICD's 9th revision (ICD-9)¹⁴ or the 10th revision enhanced for Canada (ICD-10-CA).¹⁵ Health Person-Oriented Information data are derived from the Discharge Abstracts Data set maintained by the Canadian Institute for Health Information. In 2002/03, the discrepancy rates¹⁷ between initial abstraction and subsequent audit for demographic data was 0.2%; for intervention codes, less than 1.0%; and for major clinical category, 4.2%. Since the database does not track interprovincial transfers, data were not extracted for provinces and territories that lacked implanting capacity for the device during any part of the study period. Thus, data from Yukon, Nunavut, the Northwest Territories, Newfoundland, New Brunswick and Prince Edward Island were excluded.

The database tracks patients between hospitals until in-hospital death or final discharge; data on patients' disposition at discharge were unavailable for some years within the

study period. We examined overall survival and the implantation rates of cardioverter defibrillators among survivors. Unlike other provinces, British Columbia records preadmission deaths as admissions to hospital; BC was therefore excluded from the initial analysis of survival until hospital discharge. Data from surviving BC patients were then included in all subsequent analyses.

US data source

The National Hospital Discharge Survey has been conducted continuously by the National Center for Health Statistics since 1965.¹⁸ This survey continues to be the principal source for national data on the characteristics of patients discharged from nonfederal short-stay hospitals in the United States. Its 3-stage probability design involves sampling within geographic areas, then hospitals within these areas and, finally, the discharges at individual hospitals. Available data relating to the personal characteristics of a patient include birth date (converted to age), sex, race, ethnicity, marital status, US Postal Service zip code and expected sources of payment of patients' medical expenses, as well as administrative items such as admission and discharge dates, type and source of admission, and status at discharge. Medical information about each patient (up to 7 diagnoses and up to 4 procedures) is coded according to ICD-9-CM (clinical modification).¹⁶

Because of the complex multistage design of the National Hospital Discharge Survey, the data must be weighted to produce national estimates; the estimation procedure produces national estimates that are unbiased.¹⁹ Estimates of the sampling variability that occurs by chance are provided by approximate relative standard errors. Details of the calculation of the estimates are provided elsewhere.¹⁸

The US National Center for Health Statistics produces a multiyear file of the survey's discharge and weight data, relative standard error tables and census population estimates.

Table 1: Baseline demographics of 3793 Canadian patients admitted with cardiac arrest and surviving to hospital discharge, by sex

Characteristic	Number of patients (%)*			Risk difference, men v. women, % (95% CI)	p
	Men n = 2482	Women n = 1311	All n = 3793		
Age, mean (SD), yr	64.3 (15.5)	65.8 (17.6)	64.9 (16.2)		0.007
Liver failure	22 (0.9)	9 (0.6)	31 (0.8)	0.3 (-0.3 to 0.9)	0.30
Renal failure	193 (7.8)	99 (7.6)	292 (7.7)	0.2 (-1.6 to 2.0)	0.80
Heart failure	703 (28.3)	356 (27.2)	1059 (27.9)	1.1 (-1.9 to 4.1)	0.49
Acute myocardial infarction	117 (4.7)	42 (3.2)	159 (4.2)	1.5 (0.2 to 2.8)	0.027
Neurologic disability	335 (13.5)	145 (11.1)	480 (12.6)	2.4 (0.2 to 4.6)	0.041
Neoplasm	67 (2.7)	32 (2.4)	99 (2.6)	0.3 (-0.7 to 1.3)	0.64
Admitting hospital					
Teaching hospital	774 (31.2)	334 (25.5)	1108 (29.2)	5.7 (2.7 to 8.7)	< 0.001
With ≥ 100 beds	2231 (89.9)	1130 (86.1)	3361 (88.6)	3.8 (1.6 to 6.0)	< 0.001
Urban residence	2018 (81.3)	1018 (77.7)	3036 (80.0)	3.6 (0.9 to 6.3)	0.010

Note: CI = confidence interval, SD = standard deviation.

*Unless otherwise indicated.

An ongoing quality-control program recodes 5%–10% of the data independently, with discrepancies resolved by the chief survey coder. In 2002, for example, overall error rates for medical coding and other data entry were less than 0.1%.¹⁸ Moreover, the quality of the National Hospital Discharge Survey has been shown to be very good in independent validation studies^{20,21} and its data have been used in multiple publications.^{22–24} In its files for public use, however, information on the sampling variability of the survey's complex multistage design is insufficient to permit logistic regression modelling.

Statistical analysis and ethics approval

The Z-test was used to test simple relationships between continuous measures and receipt of a cardioverter defibrillator implant, and the population proportions test for categorical measures (presented as percentages). Logistic regression was used to create a multivariable model with odds ratios and confidence intervals by sex, admitting hospital size (≥ 100 v. < 100 beds), teaching status of the admitting hospital (teaching or nonteaching), patient residence (rural or nonrural, decided via patients' postal codes) and comorbidities (Appendix 2, available at www.cmaj.ca/cgi/content/full/177/1/41/DC1). Stepwise selection methods were used to identify the statistically significant independent predictors of cardioverter defibrillator implantation. All 2-way interactions in the main effects model were considered and included in the model by means of stepwise selection. The Hosmer and Lemeshow goodness-of-fit test was used to evaluate the model. All tests used $p \leq 0.05$ to indicate statistical significance.

The study was approved by the ethics board of the University of Ottawa Heart Institute.

Results

Canadian outcomes

In the year 2000, the total estimated population of the 7 provinces included in our analysis was 29 260 050; that of the excluded provinces and territories was 1 530 784. There were 9699 hospital admissions with a primary diagnosis of cardiac arrest, ventricular fibrillation or ventricular flutter in the 6 provinces (i.e., excluding BC as well). Hence, the prevalence in 2000 of patients who experienced an out-of-hospital cardiac arrest and survived to hospital admission was 3.8 per 100 000 population. Of these 9699 patients, 1537 (15.8%) had a secondary diagnosis of myocardial infarction and were excluded from further analysis. There was no significant change in the annual percentage of patients excluded because of a secondary diagnosis of myocardial infarction; for example, 14.6% of patients were excluded in 1993/94, compared with 15.8% in 2002/03.

Of the 8162 eligible patients, 3256 (39.9%) survived to be discharged from hospital, a survival rate that varied little over the study period. Corresponding data from British Columbia (i.e., on 537 patients who survived until discharge) were then added, making a total of 3793 patients who survived until discharge. Of these survivors, 628 (16.6%) received an implantable cardioverter defibrillator before hospital discharge. Patients' demographics at baseline are shown, stratified by sex,

in Table 1; device implantation rates, stratified by year and age group, are shown in Appendix 3 (available at www.cmaj.ca/cgi/content/full/177/1/41/DC2). Implantation rates were relatively similar across age groups less than 70 years (20%–29%), but declined to 12.0% in the 70–79 year age group and even less (2.7%) in patients aged over 80 years. Figure 1, which graphs the annual rates in Canada and the United States, reveals that cardioverter defibrillator implant rates have progressively increased in both countries, and that the US rate, recently, was at least twice that in Canada. Univariate predictors of device implantation in Canada are shown in Figure 2, along with details of logistic regression analysis to show the independent predictors of receiving an implantable cardioverter defibrillator. Independent predictors were age, sex, teaching status and size of the admitting hospital, year and comorbidity. Figure 3 shows Canadian implant rates by year, stratified by sex.

When we repeated the entire analysis after excluding an additional 414 patients with concomitant diagnoses of another potentially reversible cause of cardiac arrest (acute myocardial ischemia, hypokalemia, hyperkalemia or drug reaction), the results were similar to those presented (data not shown).

US outcomes

Data were drawn from the entire US population, estimated at 274 634 000 from census data gathered in 2000.²⁵ Between April 1994 and March 2003, an estimated 182 058 patients without myocardial infarction were admitted with cardiac arrest; 78 538 (43.1%) survived until discharge. Among 75 538 survivors discharged home, 23 688 (30.2%) received an implantable cardioverter defibrillator during their stay. Figure 1 compares the temporal pattern of device implantation with that of Canada.

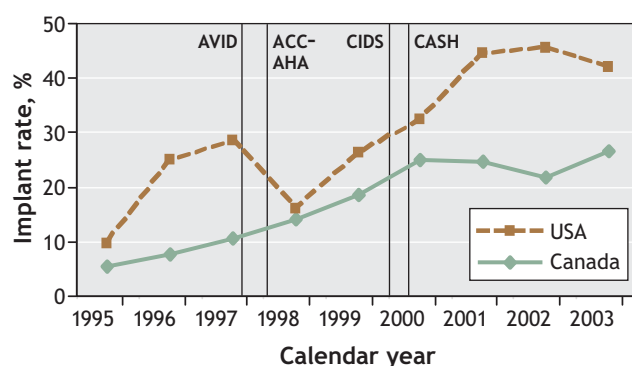


Figure 1: Cardioverter defibrillator implant rates in survivors of out-of-hospital cardiac arrest in the United States and Canada. Data points centre on fiscal years, which end on March 31. Vertical lines indicate the publication of major secondary-prevention trials and guidelines, as follows. AVID = Antiarrhythmics Versus Implantable Defibrillators trial,⁷ published November 1997: *N Engl J Med* 1997;337:1576. ACC-AHA = American College of Cardiology–American Heart Association guidelines,¹¹ April 1998: *J Am Coll Cardiol* 1998;31:1175. CIDS = Canadian Implantable Defibrillator Study,⁸ March 2000: *Circulation* 2000;101:1297. CASH = Cardiac Arrest Hamburg Study,⁹ August 2000: *Circulation* 2000;102:748.

Interpretation

The main findings of the study are that implantation rates for implantable cardioverter defibrillators after out-of-hospital cardiac arrests in Canada are increasing (26.7% in 2002/03) but are still behind those in the United States (42.0% in the same fiscal year). However, we also found a significant sex disparity in implantation rates (male patients were twice as likely as female patients to receive an implantable cardioverter defibrillator) and evidence of issues with care access, knowledge translation and guideline penetration: patients initially admitted to a teaching hospital were almost 3 times as likely to receive an implantable cardioverter defibrillator as those admitted to a nonteaching hospital (Figure 2).

The appropriate rate of cardioverter defibrillator implantation after surviving a cardiac arrest is unclear. Some patients will have had a cardiac arrest unrelated to ventricular arrhythmia. About 5% of patients will have major neurologic impairment after their arrest;²⁶ some patients will have clinically important comorbidity or terminal illness; and in some patients, the ventricular arrhythmia causing the arrest will be clearly related to a reversible cause. (For example, patients with acute myocardial infarction causing their cardiac arrest do not require an implanted cardioverter defibrillator. Therefore, we excluded such patients in our study.) Perhaps the best available contemporary data are from a study²⁶ involving 200 patients in a single US county who experienced an out-of-hospital cardiac

arrest between 1990 and 2001. Of these, 84 patients survived until hospital discharge, of whom 35 (42%) received an implantable cardioverter defibrillator. Even this implant rate may be an underestimate, because many of the patients in this study had their arrest before publication of the large trials of implantable cardioverter defibrillators.⁷⁻⁹ Our data showed that US implantation rates of cardioverter defibrillators are consistently higher than in Canada (lately, more than double our rate: Figure 1); data for revascularization procedures have shown a similar trend.^{27,28} Although it is possible that the gap between the countries in part reflects overuse of implantable cardioverter defibrillators in the United States, an analysis²⁹ of the US Medicare database suggested that they were actually underutilized.

Differences in cardiac care according to sex have been described for 20 years; most of the previous data related to the management of coronary artery disease.³⁰⁻³² We show clear evidence of a sex differential in access to implantable cardioverter defibrillator therapy for the secondary prevention of sudden cardiac death. Two previous studies^{13,26} were underpowered to detect a sex difference. A third²² did find evidence of a sex gap in the United States but suggested that the gap had closed by 2000. A number of explanations for our findings are possible: perhaps there are some additional confounding factors that make male survivors of sudden cardiac death different from female survivors; perhaps women decline cardioverter defibrillator implantation more often than

Variable	Odds ratio (95% confidence interval)	
	Unadjusted	Adjusted
Neoplasm	0.082 (0.02-0.335)	0.066 (0.009-0.48)
Renal failure	0.639 (0.461-0.886)	0.5 (0.34-0.74)
Liver failure	0.736 (0.286-1.894)	0.21 (0.05-0.91)
Age	0.77 (0.736-0.805)	0.76 (0.72-0.8)
Fiscal year	1.234 (1.192-1.277)	1.25 (1.2-1.3)
Heart failure	1.641 (1.386-1.943)	1.75 (1.43-2.14)
Male sex	1.998 (1.659-2.406)	1.99 (1.61-2.47)
Teaching hospital	3.165 (2.685-3.732)	3.15 (1.89-5.26)
≥ 100 beds	5.468 (3.429-8.717)	2.91 (2.4-3.52)

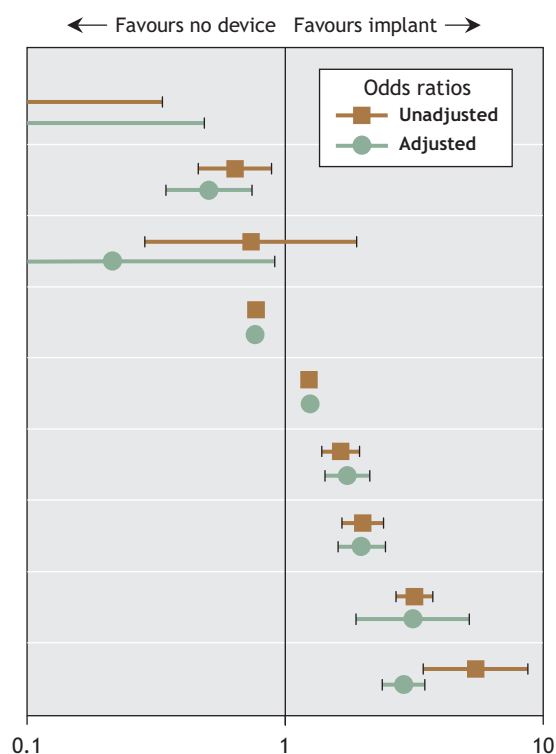


Figure 2: Odds ratios, both unadjusted and adjusted for all variables in the model, for predictors of cardioverter defibrillator implantation in Canadian survivors of out-of-hospital cardiac arrest. All other variables considered for the model, including presence of acute myocardial ischemia, were not predictive for use of this therapy.

men do; and perhaps a sex bias exists in referrals. However, it is clear that male and female patients with implants have similar rates of appropriate therapy from the device.^{33,34}

We also found evidence of a major gap in the use of these devices depending on the status of the admitting hospital: patients initially admitted to a teaching hospital were 2.91 times likelier to receive an implantable cardioverter defibrillator as those admitted to a nonteaching hospital. There is probably more than 1 reason for this. Knowledge translation is likely to be a key factor.³⁵ Availability of electrophysiologists and implanting centres may be an issue, since countries with more electrophysiologists and cardioverter defibrillator implanting centres (such as the United States and Germany) have higher implantation rates than countries with lower levels of service (e.g., the United Kingdom, Canada and France).²⁹ Some physicians may also be concerned about the cost of the technology, although implantable cardioverter defibrillators have been shown to be moderately cost-effective for secondary prevention of death (US\$67 000 per life-year gained).³⁶

This study has several limitations. The validity of the data depends on the appropriate use of codes at the time of hospital discharge. In the United States, internal audits of the National Hospital Discharge Survey and previous studies^{20,21} have indicated that the validity of its data is acceptable. The discrepancy rate for the Canadian database is higher than that reported for the US discharge survey. No data exist on the discrepancy rates of the medical codes used in our study (we speculate that the discrepancy rates for the relatively unequivocal primary codes in our study would be less). Because clinical information from administrative databases may be incomplete, we may not have controlled for all confounders. Finally, it is not possible to check for consistency of coding between the Canadian and US databases. Since the coding processes are very similar, however, we do not anticipate that this would lead to a bias of any consequence to the results.

Despite the limitations noted, we believe that this is the most comprehensive population-based study of implantable cardioverter defibrillator utilization in survivors of out-of-

hospital cardiac arrest. We found that implant rates in Canada are increasing but are still substantially behind those in the United States. There was evidence of a significant sex disparity in cardioverter defibrillator implantation as well as a major issue in care access, knowledge translation and guideline penetration. Further investigation is required to identify reasons for these several gaps in care and to devise and implement strategies to address them.

This article has been peer reviewed.

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Contributors: David Birnie developed the concept, design and direction of the project and wrote the manuscript. David Birnie, Christie Sambell, Helen Johansen, Kathryn Williams and Douglas Lee coordinated the project. David Birnie and Kathryn Williams selected the International Classification of Diseases codes that were used. Extraction and all analyses of the Canadian data from the Health Person Oriented Information initiative were performed by Christie Sambell, supervised by Helen Johansen. All authors were involved in the critical revision of the manuscript and approved the final version for publication.

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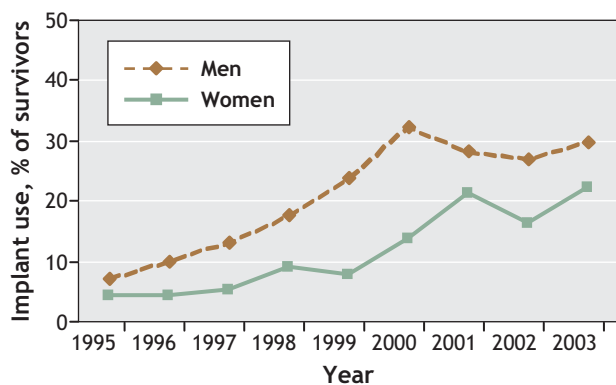


Figure 3: Cardioverter defibrillator implant rates in male and female survivors of out-of-hospital cardiac arrest in Canada by year, 1994–2003. (Data points centre on fiscal years, which end on March 31.)

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Correspondence to: Dr. David Birnie, Ottawa Heart Institute, 40 Ruskin Rd., Ottawa ON K1Y 4W7; fax 613 761-4407; dbirnie@ottawaheart.ca

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