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Original Article

ICD Implantation Rates in Cardiac Arrest Survivors in Canada

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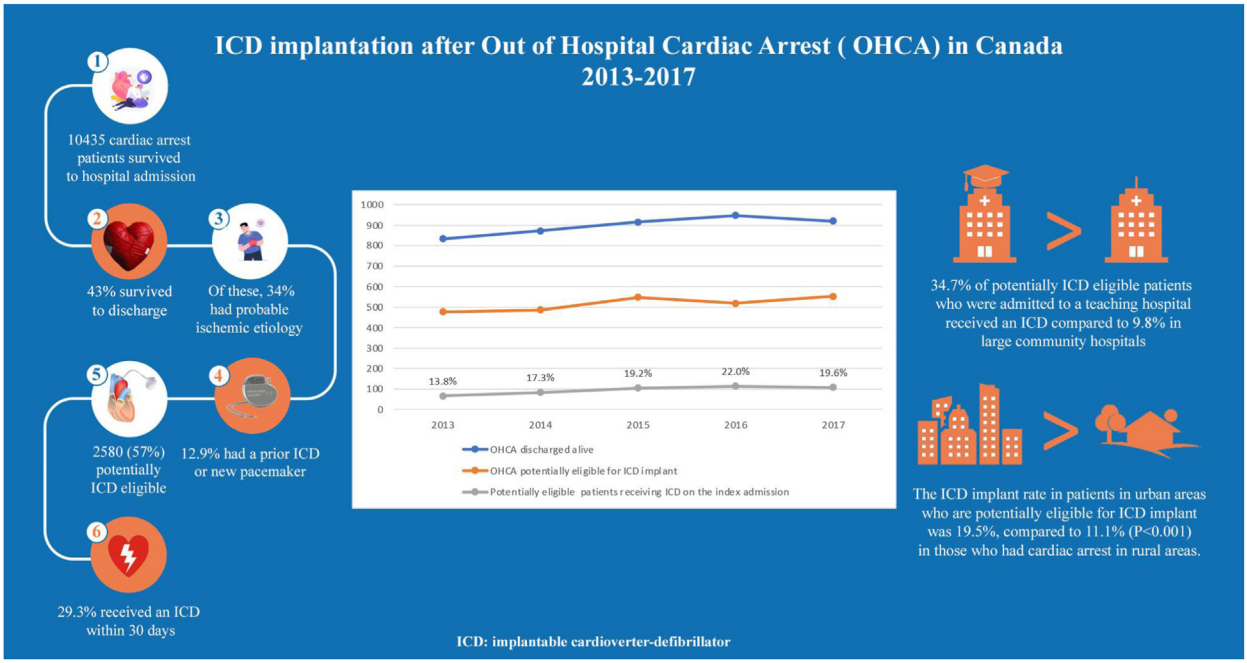

ABSTRACT

Background: Patients resuscitated from out-of-hospital cardiac arrest (OHCA) are at high risk of recurrence, posing a substantial burden on healthcare systems. Despite the established benefit of implantable cardioverter defibrillator (ICD) therapy in many such patients, and recommendations by guidelines, few studies have described the proportion of OHCA patients who receive guideline-concordant care.

Methods: The Canadian Institute for Health Information Discharge Abstract Database dataset was used to identify OHCA patients admitted to hospitals across Canada, excluding Quebec. We analyzed all patients without a probable ischemic or bradycardia etiology of cardiac arrest, who survived to discharge, to estimate the ICD

RÉSUMÉ

Contexte : Les patients ayant survécu à un arrêt cardiaque extra-hospitalier (ACEH) présentent un risque élevé de récidive, ce qui impose un lourd fardeau aux systèmes de soins de santé. Malgré l'avantage établi de la mise en place d'un défibrillateur cardioverteur implantable (DCI) chez un grand nombre de ces patients, et les recommandations des lignes directrices, peu d'études décrivent la proportion de patients victimes d'un ACEH ayant reçu des soins conformes aux lignes directrices.

Méthodologie : Nous avons recensé les admissions à l'hôpital de patients ayant subi un ACEH au Canada, à l'exception du Québec à partir de l'ensemble de données de la Base de données sur les congés

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implantation rates in patients who were *potentially eligible* to have an ICD.

Results: Between 2013 and 2017, a total of 10,435 OHCA patients who were admitted to the hospital were captured in the database; 4486 (43%) survived to hospital discharge, and 2580 survivors (57.5%) were *potentially eligible* to receive an ICD. Among these *potentially eligible* patients, 757 (29.3%) received an ICD during their index admission or within 30 days after discharge from the hospital. The ICD implantation rate during index admission increased from 13.8% in 2013 to 19.6% in 2017 (*P*-value for time trend < 0.05). The rate of ICD implantations in *potentially eligible* patients was higher in urban than in rural settings (19.5% vs 11.1%) and in teaching vs community hospitals (34.7% vs 9.8%).

Conclusions: Although ICD implantation rates show an increasing trend among patients with OHCA who are likely eligible for secondary prevention, significant underutilization of ICDs persists in these patients.

des patients de l'Institut canadien d'information sur la santé. Nous avons inclus dans notre analyse tous les patients pour lesquels la cause de l'arrêt cardiaque n'était probablement pas ischémique ou bradycardique et qui avaient survécu jusqu'à leur congé de l'hôpital, afin d'estimer les taux d'implantation d'un DCI chez les patients *potentiellement admissibles* à cette intervention.

Résultats : Entre 2013 et 2017, un total de 10 435 patients ayant subi un ACEH ont été hospitalisés selon la base de données; 4 486 (43 %) avaient survécu jusqu'à leur congé de l'hôpital, et 2 580 survivants (57,5 %) étaient *potentiellement admissibles* à l'implantation d'un DCI. Parmi les patients *potentiellement admissibles*, 757 (29,3 %) avaient reçu un DCI au moment de leur admission initiale ou dans les 30 jours suivant leur congé de l'hôpital. Le taux d'implantation de DCI lors de l'admission initiale est passé de 13,8 % en 2013 à 19,6 % en 2017 (valeur *p* pour la tendance au fil du temps $< 0,05$). Le taux d'implantation d'un DCI chez les patients *potentiellement admissibles* était plus élevé en milieu urbain qu'en milieu rural (19,5 % contre 11,1 %) et dans les hôpitaux d'enseignement/universitaires par comparaison avec les hôpitaux communautaires (34,7 % contre 9,8 %).

Conclusions : Bien que les taux d'implantation de DCI affichent une tendance à la hausse chez les patients ayant subi un ACEH qui sont probablement admissibles à des interventions de prévention secondaire, les DCI demeurent largement sous-utilisés chez ces patients.

Out-of-hospital cardiac arrest (OHCA) is one of the leading causes of mortality globally, posing a substantial clinical and economic burden on healthcare systems. In the US, the annual rate of OHCA is 56 per 100,000 population.[1-4] Among patients with OHCA, about 30% are admitted to the hospital, and about 7%-13% survive to hospital discharge.[5,6] The majority of these survivors have good functional capacity; however, they are at high risk of recurrent cardiac arrest if their arrest was not due to a reversible cause.[6,7]

Multiple randomized trials have documented the benefits of an implantable cardioverter defibrillator (ICD) in the "secondary prevention" of death in these patients.[8-12] Current Canadian and international guidelines strongly recommend ICD implantation after a cardiac arrest without a reversible cause in survivors with good neurologic function.[13-15]

Despite the established benefit of ICD therapy and guideline recommendations, few studies have described the proportion of OHCA patients who receive guideline-concordant care. Previous studies have shown that ICD implantation rates in eligible patients, in Ontario, Canada, were lower than expected.[8,9]

To the best of our knowledge, no recent assessment has been made of Canada-wide implantation rates, and the rates in urban vs rural centres with less access to subspecialty care. This study aims to characterize ICD implantation rates after OHCA in admitted patients who are *potentially eligible* for ICD implantation, using Canada-wide administrative data.

Methods

Data sources

The Discharge Abstract Database (DAD) dataset, maintained by the Canadian Institute for Health Information, was used to identify patients who were transported alive and discharged from hospitals following OHCA, and to identify comorbidities and in-hospital interventions. Data in the DAD are collected directly from acute-care facilities or from their respective regional authority or department of health. The DAD contains demographic data, and most of the administrative and clinical data, on all patients from acute inpatient facilities in all provinces and territories except Quebec.

Study sample

Adults aged 18-85 years, who sustained OHCA in Canada, excluding Quebec, between January 1, 2013 and December 31, 2017, and were transported to the hospital were identified using the International Classification of Disease, tenth revision (ICD-10) codes associated with cardiac arrest, and the Canadian Classification of Health Interventions codes for cardiopulmonary resuscitation (Supplemental Tables S1-S3). Patients were excluded if the arrest was due to trauma, if they had incomplete records, or if they had invalid health card numbers. Only the first event was considered for those with multiple arrests within the study period.

Interventions that occurred at a different Canadian healthcare institution than the initial hospital where the patient was admitted were included as part of the index admission. The interventions include angiography,

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percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG), ICD implantation, and pacemaker implantation. For example, an index admission would consist of a patient who was transported following OHCA to hospital A, then transferred to hospital B for a procedure, and subsequently discharged from hospital A, B, or C.

We categorized patients as having a "probable ischemic etiology" (PIE) for OHCA if they were coded for ST-segment elevation myocardial infarction (STEMI) or if they underwent coronary revascularization, either PCI or CABG, during the index hospitalization. We considered that the etiology of OHCA in patients who did not have a PIE for OHCA and received a pacemaker during their index admission was probably bradycardia. Patients who did not have a PIE as the etiology for their OHCA, did not have an ICD at the time of OHCA, and did not receive a pacemaker during the index admission were considered to be *probably eligible* for ICD implantation.

ICD -10 codes for all cardiac procedures and cardiac diagnoses and/or conditions are listed in Supplemental Tables S4-S6. The primary outcome was coding for ICD implantation during the index hospitalization; as a sensitivity analysis, we also assessed the rates of coding for ICDs implanted within 30 days of hospital admission among all who survived to discharge. Hospitals were designated as urban or rural, and as teaching or non-teaching, per Canadian Institute for Health Information definitions (Supplemental Table S7).

Statistical analysis

Categorical variables are presented as frequencies and percentages. Continuous variables are summarized using means and standard deviations, or medians and interquartile ranges, depending on the distributional characteristics of the data. To assess the association between patient characteristics and the likelihood of receiving an ICD, we performed χ^2 tests or Fisher's exact tests, as appropriate. To assess the sensitivity analysis of ICD implantation within 30 days of hospital admission among all survivors to discharge, we calculated the implantation rates and compared them using χ^2 tests or Fisher's exact tests. Changes in ICD implant numbers and rates over time were analyzed using logistic regression. All statistical analyses were performed using the statistical software package R (version 4.1.2; R Foundation, Vienna, Austria). Statistical significance was set at a *P*-value of less than 0.05.

Results

Baseline characteristics among all OHCA survivors

Between 2013 and 2017, a total of 10,435 OHCAs were captured in the Canada-wide DAD registry; 4486 of these patients (43%) survived to hospital discharge (Fig. 1). The baseline characteristics of the study cohort, based on their having probable ischemic etiology, are described in Table 1.

In-hospital mortality over the study period was 57%, with minimal year-to-year variation. Among those who survived to discharge from the hospital, 1648 (37.6%) had an admission for a cardiovascular condition over the 5 years before the event; 601 (13.4%) had a coronary angiogram, 234 (5.2%) had PCI, and 91 (2.0%) had CABG during the 5 years before the index OHCA. Among patients who survived to discharge, 99 (2.2%) had an (previously implanted) ICD at the time of cardiac arrest.

Utilization of cardiac procedures in patients with OHCA who survived to discharge

During the index hospitalization, 1977 patients (44.0%) had a coronary angiogram; 115 (2.6%) underwent CABG, 868 (19.3%) had PCI, and 402 (9.0%) had a pacemaker implanted. Within these patients, of those who were admitted with STEMI, 70.7% (890 of 1259) underwent coronary angiogram, with the percentage ranging between 44.6% and 83.6% across provinces and territories. Among those not coded as having STEMI, 33.7% (1087 of 3227) underwent angiography, with a range of 22.8% to 48.3% across provinces and territories.

The Canada-wide level of utilization of coronary revascularization procedures was 57.3% (721 of 1259) for patients admitted with STEMI, compared to 8.1% (262 of 3227) for those whose OHCA was not in the setting of STEMI. Coronary interventions (PCI or CABG) were performed more frequently in patients aged less than 65 years (59% vs 43%).

The rates of cardiac procedure utilization, including coronary interventions, CABG, and ICD and/or pacemaker implantation, among survivors of OHCA who were discharged alive, based on their having PIE vs not having PIE, are described in Figure 2.

ICD implantation rates

Overall, 4486 patients survived to discharge. Among this group, the ICD implantation rate was 14.5%. Among 1521 patients with a PIE of OHCA (they either had STEMI or underwent coronary revascularization), 97 (6.4%) received a pacemaker, and 7 already had an ICD. Among the remaining 1417 patients, 176 (12.4%) received an ICD. Among the remaining 2965 patients who did not receive coding for STEMI or undergo revascularization, 92 patients (3.1%) already had ICDs, and 293 patients received a pacemaker.

The remaining 2580 patients were *potentially eligible* for ICD implantation. Among this group, 477 patients (18.5%) received an ICD during the index admission (Fig. 2). Among these 2580 patients, an additional 280 received an ICD within 30 days of index admission, increasing the total number of ICD implants in our target group to 757. Adding these patients, the total ICD implantation rate in patients who were *potentially eligible* for ICD implantation within 30 days was 29.3%.

An increase occurred from 2013 to 2017 in both the absolute number of patients receiving an ICD and the proportion of potentially eligible patients who received an ICD (*P* for time trend < 0.05). Figure 3 describes the annual ICD implantation rate in both groups of patients, with and without PIE of OHCA. The total numbers of OHCA survivors, those without probable ischemic cause, and those who received an ICD within this subgroup during our study period are illustrated in Figures 3 and 4.

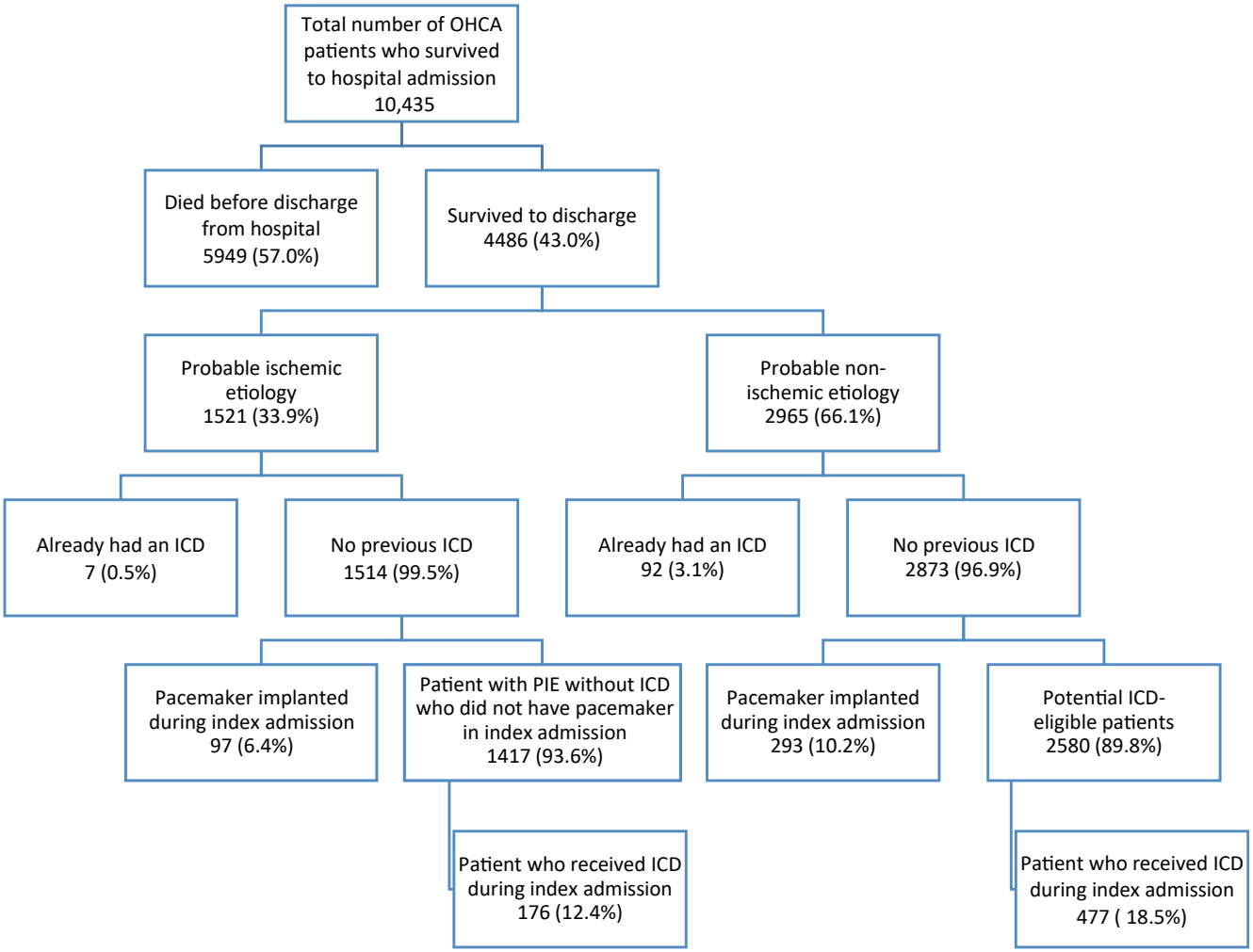

Figure 1. Categorization of all out-of-hospital cardiac arrests (OHCAs) resulting in hospital admission from the Canadian Institute for Health Information Discharge Abstract Database between January 1, 2013 and December 31, 2017. Probable ischemic etiology (PIE) is defined as arrest occurring with database coding for ST-segment elevation myocardial infarction or percutaneous coronary intervention or coronary artery bypass grafting performed during index hospitalization. ICD, implantable cardioverter defibrillator.

The percentage of ICD implants, in patients without PIE of OHCA who are likely eligible for an ICD, declined from 23.3% in patients younger than age 35 years to 13.1% in patients aged over 75 years (Table 2). Men were more likely to receive ICDs (21.8%), compared to women (13%; $P < 0.001$). Variation occurred between provinces in ICD implantation rates among patients likely eligible for an ICD (Table 3), ranging from 8.3% in New Brunswick to 31.4% in Saskatchewan.

The ICD implantation rate in patients in urban areas who are *potentially eligible* for ICD implantation was 19.5% (437 of 2239), compared to 11.1% (34 of 304; $P < 0.001$) in those who had a cardiac arrest in rural areas. In contrast, among patients with OHCA of presumed ischemic cause, ICD implantation rates were similar in urban (157 of 1258 [12.5%]) vs rural (12 of 140 [8.5%]) areas. Comparison of data from teaching hospitals vs community hospitals showed that 34.7% of *potentially ICD-eligible* patients (341 of 983) who were admitted to a teaching hospital received an ICD, compared to 9.8% (106 of 1080) in large community hospitals.

Discussion

Current guidelines recommend use of an ICD for patients after cardiac arrest due to ventricular arrhythmias in the absence of a reversible cause.[13-15] Our primary finding is that contemporary ICD implantation rates in survivors of OHCA in Canada are much lower than anticipated. Using a national dataset, among survivors of OHCA not due to a probably reversible ischemic cause, and thus patients *probably eligible* for ICD implantation, 18.5% received an ICD on the index admission. After 30 days, a total of 29.3% had received an ICD.

Our data also show that the underutilization of ICDs was consistent across Canada, with some interprovincial differences. A small, statistically significant increase over time

Table 1. Baseline characteristics of patients who survived to discharge, did not already have an ICD and did not receive a pacemaker

Characteristic	Probable ischemic etiology*	
	No	Yes
n	2580	1417
Demographics		
Age group, y		
18–25	88 (3.4)	3 (0.2)
26–35	161 (6.2)	8 (0.6)
36–45	209 (8.1)	75 (5.3)
46–55	434 (16.8)	289 (20.0)
56–65	607 (23.5)	435 (31.0)
66–75	655 (25.4)	416 (29.2)
76–85	426 (16.5)	191 (13.0)
Sex		
Male	1722 (66.7)	1160 (82.0)
Female	858 (33.3)	257 (18.0)
Index ED / hospital characteristics		
Patient location		
Urban	2239 (86.8)	1,258 (90.0)
Rural	304 (11.8)	140 (10.0)
Hospital type		
Teaching	983 (38.1)	809 (57.0)
Community		
Large	1080 (41.9)	422 (30.0)
Medium	462(17.9)	173 (12.0)
Small	55 (2.1)	13 (0.9)
Medical conditions within 5 y prior to index event		
Atrial fibrillation	121 (4.7)	55 (3.9)
Cancer	97 (3.8)	27 (1.9)
COPD	233 (9.0)	63 (4.4)
Coronary artery disease	501 (19.4)	1003 (71.0)
Diabetes	619 (24.0)	320 (23.0)
Dyslipidemia	73 (2.8)	51 (3.6)
Heart failure	357 (13.8)	238 (17.0)
Hypertension	777 (30.1)	625 (44.0)
Renal failure	449 (17.4)	189 (13.0)
Peripheral artery disease	1 (< 0.1)	3 (0.2)

Values are n (%).

COPD, chronic obstructive pulmonary disease; ED, emergency department; ICD, implantable cardioverter defibrillator.

* Probable ischemic etiology = all patients coded for ST-segment elevation myocardial infarction, or who underwent percutaneous coronary intervention or coronary artery bypass grafting during index admission.

occurred in the proportion of *probably eligible* patients who received an ICD during the study period, and considerable variation occurred in ICD implantation rates by age, sex, and hospital setting. In particular, implantation rates in younger patients, who almost certainly have a much higher lifetime risk of cardiac arrest recurrence than do older patients, were also relatively low.

In a prior study in Ontario,[9] the rate of ICD implantation in OHCA patients who did not have STEMI and were not revascularized was 32.8%, consistent with our Canada-wide data showing a 29.3% ICD implantation rate within 30 days of index hospital admission in patients without probable ischemic cause who did not have a pacemaker implanted. In that study, however, having access to initial cardiac rhythm and neurologic status made it possible to more accurately identify ICD-eligible patients. That study noted that 57% of the ICD-eligible patients (also including only patients with a presenting shockable rhythm from emergency medical services records, and with good neurologic function at hospital discharge) received an ICD implant, a percentage that is still below the expected guideline-concordant rate.[9]

This prior study, over a similar time frame as the current study, suggests that, at most, 20%-25% of cardiac arrest survivors included in our study may not be ideal ICD candidates, as they may not have had a shockable presenting rhythm (despite the fact that some patients have ventricular fibrillation as an initial rhythm, but not at the time of emergency medical services arrival), or they may have neurologic dysfunction (which may not mean an ICD is not indicated). The statistically significant increase in implantation rates over time is encouraging. Nevertheless, the overall implantation rate, even in 2017, was still below the expected rate. A database study by Birnie et al. in Canada and the US in 2007 showed that Canada had an ICD implantation rate of 26.7%, which confirms that the underutilization of ICDs did not significantly improve between the early 2000s and 2017.[8] Interestingly, these observations of potential underuse of ICDs for secondary prevention are not limited to Canada. Published studies in the US noted that the rate of ICD implantation, as secondary prevention in patients with OHCA who survived to hospital discharge, was between 22% and 24%.[16] Underutilization of guideline-directed ICD implantation may be a universal health issue.[17]

The ICD implantation rate was between 23.0% and 23.9% in patients age under 35 years. Considering that the incidence of ischemic causes, as one of the most common reversible causes of cardiac arrest, is lower in the younger population,[18] we expected the ICD implantation rate to be substantially higher in patients younger than age 35 years. Even if the overall "appropriate" implantation rate is underestimated in the DAD database, the DAD is unlikely to be systematically more inaccurate in the younger, compared to the older, population. Thus, this rate also indicates the probability of inappropriate underutilization of ICDs.

Underutilization of ICD implantation is evident across Canada. Considering the more than 70% use of coronary angiograms in patients with myocardial infarction in our dataset, neither lack of access to tertiary cardiology services or unavailability of procedural facilities explains the underutilization of ICD implants.

Unfortunately, a definitive understanding of the precise causes underpinning the low rates of ICD implantation remains elusive. To discern the precise causative factors, a comprehensive approach is warranted, encompassing the acquisition of individualized patient data, exhaustive examination of medical records, and structured interviews with both patients and their caregivers within the cohort of post–cardiac arrest patients.

Nonetheless, several explanations for this observation are plausible. These include the possibility of overdiagnosis of reversible pathophysiological mechanisms of cardiac arrest, the unavailability of easily accessible arrhythmia consultation services, and possibly inadequacy of education regarding indications for ICD within the framework of non-subspecialist medical practice. Additionally, a deficiency in the provision of comprehensive information to patients is possible, as it plays a pivotal role in facilitating informed decision-making when contemplating the potential implantation of ICDs. Disentangling patient-, caregiver-, and resource-related factors regarding the decision about whether to implant an ICD is not possible. Given

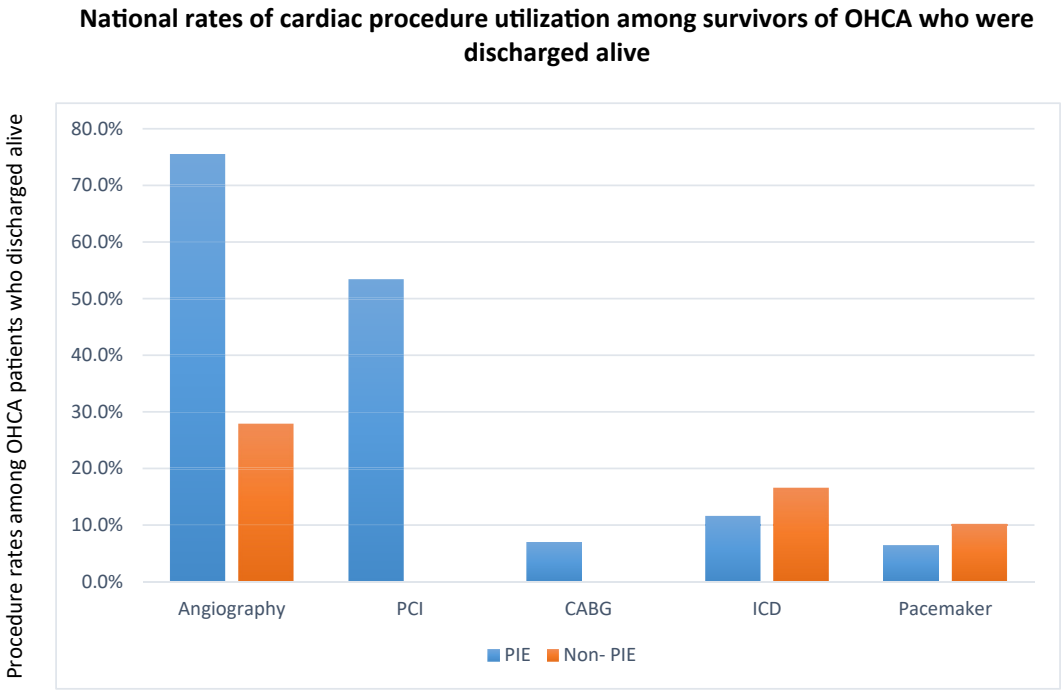

Figure 2. National rates of cardiac procedure utilization among survivors of out-of-hospital cardiac arrest (OHCA) who survived to hospital discharge, during index hospitalization, stratified by suspected etiology of arrest (ischemic vs non-ischemic). Probable ischemic etiology (PIE) is defined as arrest occurring with database coding for ST-segment elevation myocardial infarction or percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) performed during index hospitalization. ICD, implantable cardioverter defibrillator.

the high rate of angiography observed in this study, lack of access to tertiary-care facilities is unlikely to be an important contributor to the apparent low ICD implantation rate.

A substantial proportion of the patients were discharged from the hospital and readmitted for ICD implantation within 30 days of the index admission. This apparent delay

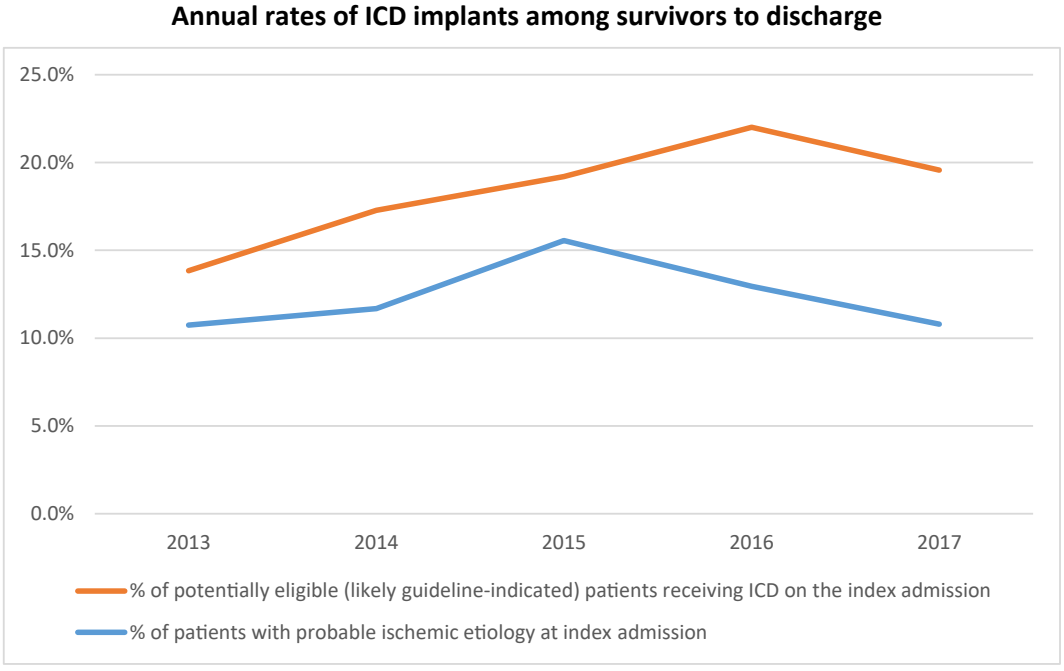

Figure 3. Trend in annual implantable cardioverter defibrillator (ICD) implantation rates during index hospital admission among patients who sustained out-of-hospital cardiac arrest and survived to discharge, 2013-2017.

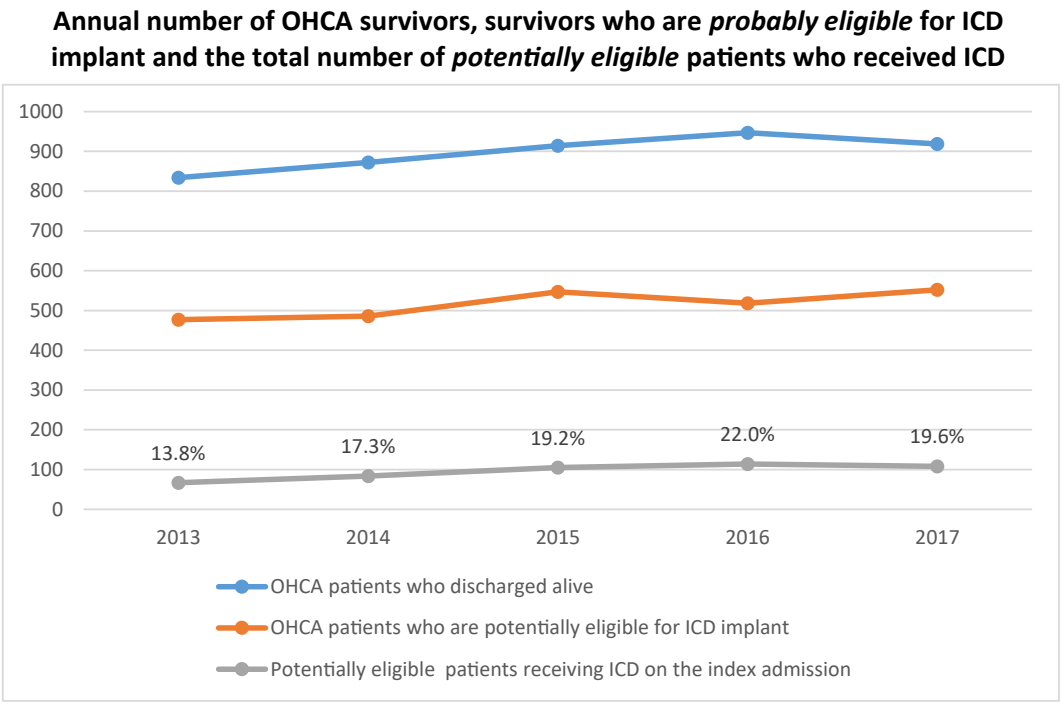

Figure 4. Annual number of out-of-hospital cardiac arrest (OHCA) survivors to discharge who were *probably eligible* for implantable cardioverter defibrillator (ICD) implantation, compared with the total number of *potentially eligible* patients who received an ICD, 2013-2017.

can be attributed to a constellation of factors, including the possibility that the primary healthcare institution lacked the capacity to implant an ICD. Other causes for this pattern may include the potential for improvement in neurologic status within the initial weeks after hospital discharge, making patients more appropriate for ICD implantation. Additionally, patients, their family members, and caregivers may have time to rethink ICD implantation. However, in prior studies, fewer than 5% of OHCA survivors to hospital discharge had poor neurologil function.[9]

The ICD implantation rate was lower within the older age group, among the female population, and among individuals admitted to medical centres situated in rural areas. These findings suggest that the selection of ICD candidates may be subject to a multifaceted array of influences. Disparities in healthcare infrastructure and resource allocation, differential treatment allocation based on gender, and age-related variances in therapeutic decision-making could collectively impact the clinical assessment of ICD candidacy, and potentially lead

Table 2. Implantation rates among survivors of out-of-hospital cardiac arrest to hospital discharge who were *potentially eligible* to receive an ICD

Characteristic	ICD	
	No	Yes
n	2103 (81.5)	477 (18.5)
Age, y		
Mean (± SD)	61.1 (15.69)	57.4 (15.83)
Median (IQR)	64 (52–73)	59 (48–69)
Age group, y		
18–25	67 (76.1)	21 (23.9)
26–35	124 (77.0)	37 (23.0)
36–45	169 (80.9)	40 (19.1)
46–55	341 (78.6)	93 (21.4)
56–65	488 (80.4)	119 (19.6)
66–75	544 (83.1)	111 (16.9)
76–85	370 (86.9)	56 (13.1)
Sex		
Male	1357 (79.2)	365 (21.8)
Female	746 (87.0)	112 (13.0)

Values are n (%), unless otherwise indicated.

ICD, implantable cardioverter defibrillator; IQR, interquartile range; SD, standard deviation.

Table 3. Implantable cardioverter defibrillator (ICD) implantation rates in patients who were likely to have indication for ICD implantation in different provinces

Provinces or territories	Non-PIE OHCA	ICD implants
British Columbia	615	117 (19.0)
Alberta	288	65 (22.6)
Saskatchewan	86	27 (31.4)
Manitoba	128	23 (18.0)
Ontario	1184	207 (17.5)
New Brunswick	84	7 (8.3)
Nova Scotia	106	20 (18.9)
Prince Edward Island	14	No data available
Newfoundland and Labrador	60	10 (16.7)
Territories (Northwest, Yukon, Nunavut)	15	No data available

Values are n or n (%).

OHCA, out-of hospital cardiac arrest; PIE, probable ischemic etiology.

to more underutilization in specific demographic subsets. The higher rate of ICD implantation in teaching hospitals may be attributed to the presence of superior medical infrastructure, regional referral patterns for resource-intensive cardiac procedures, a greater allocation of time for comprehensive patient and family consultations, and/or a prevailing adherence to guideline-oriented medical practices within academic healthcare institutions.

Limitations

We acknowledge that our data source, the DAD registry, has important limitations.[19] The DAD does not precisely outline the cause of cardiac arrest or its reversibility, which is ultimately critical for determining ICD eligibility—that is, whether an ICD is indicated or not. Recognizing that ascertainment of cardiac arrest etiology may remain elusive even for physicians with access to all clinical information, the administrative dataset does lack details such as echocardiographic findings, cardiology consultation notes, and electrocardiogram and/or rhythm strip data that would better refine our classification of "potentially eligible" for ICD implantation. Another limitation of our database is that approximately 30% of true cardiac arrests are not labeled as cardiac arrest in the DAD registry; they are coded as other diagnoses, including ischemic events, pulmonary emboli, drug intoxication, etc.[19] A reasonable assumption is that most of those "missing" OHCA patients who were coded as other diagnoses were less (or no more) likely to be indicated as appropriate to receive an ICD than the remaining 70% that are included in our study, and that the 70% who are indeed in the DAD are representative of all admitted cardiac arrest patients.[19]

A proportion of the OHCAs that were labelled as "not from a probable ischemic etiology" in our study may have been secondary to reversible non-arrhythmic causes, such as pulmonary emboli, medication overdose, or intoxication, in which ICD implantation is not warranted. Moreover, many survivors may not have adequate neurologic recovery, making them ineligible for an ICD implant due to poor prognosis or patient decline.

Accounting for patients with non-ischemic but reversible causes of cardiac arrest, those with comorbidities limiting the possible benefits of an ICD, and those who decline ICD implantation, the true guideline-concordant implantation rate is expected to be lower than 100%. Nevertheless, a likely possibility is that the proportion of patients who normally would be expected to be recommended per guidelines to undergo ICD implantation is substantially higher than the observed 29.3%. Such a difference in proportion is also likely to be particularly true for younger patients, in whom comorbidities are likely much less common.

Conclusion

We conclude that the use of secondary prevention ICD implantation after OHCA in patients who survived to discharge in our Canada-wide dataset was considerably below the expected levels. The reasons for this apparent underuse are likely multifactorial, and they may include patient, physician, and system factors. Further studies are warranted to determine the causes of non-guideline-compliant use of ICDs in secondary prevention and provide insight to target areas for improvement.

Ethics Statement

The study was approved by the St Michael's Hospital Research Ethics Board.

Patient Consent

The authors confirm that patient consent is not applicable to this article. This is a retrospective study using de-identified data; therefore, the IRB did not require consent from the patient.

Funding Sources

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Disclosures

The authors have no conflicts of interest to disclose.

References

1. Tan NS, Dorian P. Out-of-hospital cardiac arrest in the presence of ischemic heart disease: What is the long-term arrhythmic risk after revascularization? Can J Cardiol 2018;34:1079-82.
2. Ezekowitz JA, Armstrong PW, McAlister FA. Implantable cardioverter defibrillators in primary and secondary prevention: a systemic review of randomized, controlled trials. Ann Intern Med 2003;138:445-52.
3. Connolly SJ, Hallstrom AP, Cappato R, et al. Meta-analysis of the implantable cardioverter defibrillator secondary prevention trials. AVID, CASH and CIDS studies. Antiarrhythmic vs implantable defibrillator study. Cardiac arrest study Hamburg. Canadian implantable defibrillator study. Eur Heart J 2000;21:2071-8.
4. Parkash R, Tang A, Wells G, et al. Use of implantable cardioverter defibrillators after out-of-hospital cardiac arrest: a prospective follow-up study. CMAJ 2004;171:1053-6.
5. Sasson C, Rogers MAM, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes 2010;3:63-81.
6. Held EP, Reinier K, Chugh H, et al. Recurrent out-of-hospital sudden cardiac arrest: prevalence and clinical factors. Circ Arrhythm Electrophysiol 2022;15:e011018.
7. van der Lingen ACJ, Woudstra J, Becker MAJ, et al. Recurrent ventricular arrhythmias and mortality in cardiac arrest survivors with a reversible cause with and without an implantable cardioverter defibrillator: a systematic review. Resuscitation 2022;173:76-90.
8. Birnie DH, Sambell C, Johansen H, et al. Use of implantable cardioverter defibrillators in Canadian and US survivors of out-of-hospital cardiac arrest. CMAJ 2007;177:41-6.
9. Ho EC, Cheskes S, Angaran P. Implantable cardioverter defibrillator implantation rates after out of hospital cardiac arrest: Are the rates guideline-concordant? Can J Cardiol 2017;33:1266-73.
10. Millin MG, Comer AC, Nable JV, et al. Patients without ST elevation after return of spontaneous circulation may benefit from emergent

percutaneous intervention: a systematic review and meta-analysis. Resuscitation 2016;108:54-60.

11. Nikolaou NI, Welsford M, Beygui F, et al. Part 5: acute coronary syndromes. Resuscitation 2015;95:e121-46.

12. Lemkes JS, Janssens GN, van der Hoeven NW, et al. Coronary angiography after cardiac arrest without ST-segment elevation. N Engl J Med 2019;380:1397-407.

13. Bennett M, Parkash R, Nery P, et al. Canadian Cardiovascular Society/Canadian Heart Rhythm Society 2016 implantable cardioverter-defibrillator guidelines. Can J Cardiol 2017;33:174-88.

14. Zeppenfeld K, Tfelt-Hansen J, de Riva M, et al. 2022 ESC guidelines for the management of patients with ventricular arrhythmias and the prevention of sudden cardiac death. Eur Heart J 2022;43:3997-4126.

15. Al-Khatib SM, Stevenson WG, Ackerman MJ, et al. 2017 AHA/ACC/HRS guideline for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death: executive summary. Heart Rhythm 2018;15:e190-252.

16. Havmoeller R, Reinier K, Teodorescu C, et al. Low rate of secondary prevention ICDs in the general population: multiple-year multiple-source surveillance of sudden cardiac death in the Oregon sudden unexpected death study. J Cardiovasc Electrophysiol 2013;24:60-5.

17. Camm AJ, Nisam S. European utilization of the implantable defibrillator: Has 10 years changed the 'enigma'? Europace 2010;12:1063-9.

18. Allan KS, Morrison LJ, Pinter A, et al. "Presumed cardiac" arrest in children and young adults: a misnomer? Resuscitation 2017;117:73-9.

19. Wong MK, Morrison LJ, Qiu F, et al. Trends in short- and long-term survival among out-of-hospital cardiac arrest patients alive at hospital arrival. Circulation 2014;130:1883-90.

Supplementary Material

To access the supplementary material accompanying this article, visit *CJC Open* at https://www.cjcopen.ca/ and at https://doi.org/10.1016/j.cjco.2023.12.011.