PROGNOSIS OF CARDIAC ARREST IN PATIENTS RECEIVING HOME CARE

PROGNOSIS OF CARDIAC ARREST IN PATIENTS RECEIVING HOME CARE IN ONTARIO, CANADA

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Lay Abstract

The proportion of older adults receiving home care is growing. The home care population is frail and medically complex, with a greater risk for cardiac arrest. This thesis aims to evaluate the prognosis and prognostic factors influencing survival and other health outcomes, to develop a statistical model that can predict 30-day survival post-cardiac arrest. Findings from my research demonstrate that patients receiving home care have worse survival outcomes post-cardiac arrest compared to well-being older adults living in the community. In my research, frailty was associated with survival and declines in post-cardiac arrest functional independence and cognitive performance among patients receiving home care. Our statistical model performed better than valid frailty measures and had respectable accuracy for group-level prognostication. The home care population is ideally positioned for proactive and shared decision-making about end-of-life care preferences, bearing in mind their receipt of detailed and routine health assessments.

Abstract

Background: The home care population is a cohort of medically complex older adults at risk for cardiac arrest and poor post-cardiac arrest health outcomes.

Research Question: What is the prognosis of cardiac arrest among patients receiving home care, and what pre-arrest features and geriatric syndromes (e.g., frailty) are prognostic of survival and post-cardiac arrest health?

Methods: Following a systematic review and meta-analysis that evaluated the prognostic association between frailty and post-cardiac arrest outcomes, a population-based retrospective cohort was created of adults (≥18 years) who received cardiac arrest care at a hospital in Ontario, Canada, between 2006 and 2018. Patients receiving home care and nursing home residents were identified using the Home Care Dataset and the Continuing Care Reporting System. Arrests were analyzed overall and within distinct sub-groups of in-hospital (IHCA) and out-of-hospital cardiac arrests (OHCA). The primary outcome for this thesis was 30-day survival post-cardiac arrest. Frailty was measured using the Clinical Frailty Scale and a valid frailty index. The odds of survival from cardiac arrest were estimated using multivariable logistic regression. Prognostic models were internally validated using bootstrap resampling (n= 2000).

Results: We found high certainty evidence for an association between the Clinical Frailty Scale and death prior to hospital discharge after IHCA (OR = 2.93; 95% CI = 2.43 – 3.53) after adjusting for age as a minimum confounder. Our retrospective cohort contained 86,836 unique adult cardiac arrests, of which 39,610 were OHCA and 47,226 were IHCA. Patients receiving home care represented 10.7% of the cohort and were less likely to survive to hospital discharge (RD = -6.4; 95%CI = -7.4– -5.2) and one-year

(RD = -12.8; 95%CI = -14.6 – -10.9) post-cardiac arrest compared to community-dwelling individuals receiving no support in the community. Frail patients receiving home care had worse odds of 30-day survival when measured with the CFS (OR=0.78; 95%CI = 0.61-0.98) and a frailty index (OR=0.89; 95%CI = 0.85-0.95), after adjusting for age, sex, and arrest setting. My prognostic model out-performed the two valid frailty measures and demonstrated *fair* discriminative accuracy (AUROC = 0.66; 95%CI=0.65-0.65) and good calibration (Slope = 0.95) for group-level prognostication when internally validated among patients receiving home care.

Conclusion: Patients receiving home care have a worse absolute risk of death when compared to community-dwelling individuals receiving no community-based support services. Frailty is associated with survival and post-cardiac arrest declines in cognition and function when evaluated in patients receiving home care. The prognostic model developed within my thesis outperformed the ability of frailty to predict 30-day survival and is suitable for group-level prognostication.

Dedication

I dedicate this thesis to Nonna and Nonno, Mario and Graziella Celsi. Their struggles with our current health system are the motivating factor for my research in geriatrics and end-of-life care.

Acknowledgements

First, I would like to acknowledge and show gratitude to my Ph.D. supervisor, Dr. Andrew Costa. His mentorship and persistent encouragement throughout the years facilitated my growth as a clinical researcher and, more importantly, as a person. One lesson I will always remember and take forward with me: *high tides rise all ships.*

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Finally, I would like to acknowledge my thesis committee, Dr. Kerstin de Wit, Dr. Andrew Worster, Dr. Lauren Griffith, and Dr. Farid Foroutan. Your constructive feedback and critical discussions helped ensure my work was rigorous and impactful. I am grateful for your mentorship and believe it will impact me for the rest of my academic career.

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List of Abbreviations

ADL	Activities of Daily Living
aOR	Adjusted Odds Ratio
AUROC	Area Under the Receiver Operating Characteristic Curve
CAHP	Cardiac Arrest Hospital Prognosis
CI	Confidence Interval
CFS	Clinical Frailty Scale
CHESS	Changes in Health, End-Stage Disease and Signs and Symptoms
COSCA	Core Outcome Set for Cardiac Arrest
COPD	Chronic Obstructive Pulmonary Disease
CPR	Cardiopulmonary Resuscitation
DAD	Discharge Abstract Database
DNR	Do-Not-Resuscitate
ED	Emergency Department
EPV	Events Per Variable
FI	Frailty Index
GO-FAR	Good Outcome Following Attempted Resuscitation
GRADE	Grading of Recommendations, Assessment, Development and Evaluations
HFHS	Hospital Frailty Risk Score
HIREB	Hamilton Integrated Research Ethics Board
HR-QoL	Health-Related Quality of Life
ICD	International Classification of Disease

ICHOM	International Consortium for Health Outcome Measurement
IHCA	In-Hospital Cardiac Arrest
N	Sample Size
NACRS	National Ambulatory Care Reporting System
OHCA	Out-of-Hospital Cardiac Arrest
OR	Odds Ratio
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROGRESS	Prognosis Research Strategy Group
QUIPS	Quality in Prognosis Studies
RAI-HC	Resident Assessment Instrument – Home Care
RD	Risk Difference
ROSC	Return of Spontaneous Circulation
SD	Standard Deviation

Declaration of Academic Achievement

This thesis is made up of an introductory chapter (Chapter 1), a systematic review (Chapter 2), three original retrospective cohort studies (Chapters 3-5) and a discussion chapter (Chapter 6). I (Fabrice Mowbray) was responsible for the conceptualization, writing, analysis, interpretation, and revisions of all studies and chapters within this thesis. I consulted with my Ph.D. supervisor (Dr. Andrew Costa) and thesis committee members (Dr. Kerstin de Wit, Dr. Andrew Worster, Dr. Lauren Griffith, and Dr. Farid Foroutan) when clinical, contextual, or methodological guidance was warranted.

For the systematic review in Chapter 2, I recruited the assistance of graduate students (Donna Manlongat, Rebecca Correia, and Ryan Strum) to support abstract screening, full-text review, and risk of bias assessment, as multiple authors are required to conduct these tasks independently and in duplicate for methodological rigour. A medical librarian (Rachel Couban) conducted the search and extracted all articles for analysis within Covidence ©. Original data were cut and extracted by an ICES analyst in accordance with ICES standard procedures for student investigators. Prior to the submission of manuscripts to an academic journal, I collaborated with a panel of clinical and contextual experts to review and contribute to the final drafts, including Dr. Aaron Jones, Dr. Luke Turcotte, Donna Manlongat, Rebecca Correia, Ryan Strum, Dr. Paul Hebert, Dr. George Heckman, Dr. Connie Schumacher, Dr. Dennis Ko, Dr. Eric Mercier, Dr. Shannon Fernando, Dr. Daniel McIsac, Matthew Douma, Dr. John Muscedere, and Dr. Jerry Nolan.

CHAPTER ONE

Introduction

Home Care

The hospitalization of older adults can be detrimental to their overall health and functional independence (1–4). Poor health outcomes and adverse health events (e.g., delirium, nosocomial infections, falls) are more prevalent among older adults admitted for in-patient care (5–7). Healthcare experts and policymakers have advocated for efforts to facilitate home-based care of non-emergent conditions for older adults and complex patients (8).

Home care is a term that encompasses a wide array of personal and clinical support services, such as personal support, nursing care, physical or occupational therapy, and mental health care, among others (9). Providing home care services has been shown to improve overall health and independence in older adults, and models of home care can delay or prevent admission to long-term care facilities in medically complex patients (8,10). Home care has also proven to be a more cost-effective service to provide health care than care provided in acute and long-term care beds (11).

In Canada, home care is a publicly funded health service that relies on profit and non-profit agencies to provide these services. Traditionally, home care is classified as ‘short-stay’ for those enrolled in services for less than 60 days and ‘long-stay’ for individuals enrolled for 60 days or longer. Roughly 1-in-20 Canadians rely on home care services to support independence or medical management within their private dwelling. Short-stay clients characteristically require temporary support for post-operative or post-acute home care. In contrast, long-stay clients require ongoing support with daily living tasks and chronic disease management. Many patients receiving home care report unmet health and support needs with publicly available services, and one in four report supplementing publicly funded services with private care (12). Family caregivers are commonly relied upon as a source of support for patients receiving home care, providing 80% of their care and 20 hours of support per week on average (13). The high care load likely explains why family caregivers are twice as likely to report caregiver distress in the emergency department (ED) compared to those caring for community-dwelling individuals not enrolled in home care (14). Moving forward, when referencing patients receiving home care within this thesis, it should be implied that I am referring to patients receiving publicly funded long-stay services.

InterRAI is an international non-for-profit coalition of clinicians, researchers, and policymakers who develop and validate standardized assessment tools to follow patients throughout the patient health care journey and across multiple health sectors, including primary care, home care, long-term care, acute care, and mental health care, among others (15,16). In Ontario and many jurisdictions, mandates exist to ensure publicly-funded home care clients receive routine and comprehensive health assessments using the interRAI home care (RAI-HC) instrument upon service enrollment (within six weeks) and yearly thereafter or sooner if warranted (e.g., increase in medical acuity, return from the hospital, etc.) (9). The RAI-HC is also utilized in the provinces of Alberta, British Columbia, Manitoba, Newfoundland, Nova Scotia, Saskatchewan, and the Yukon Territories. The RAI-HC contains over 250 assessment items and evaluates a multitude of health domains, including function, cognition, communication, psychosocial well-being, disease profiles, symptomology, medication and clinical intervention, and health service needs (17). The content and construct validity of the RAI-HC and its encompassing assessment items have been validated on an international scale (18–20).

Population ageing, coupled with a limited supply of long-term care beds, has increased the prevalence of frailty and health instability among patients receiving home care (21). In Canada, it is estimated that 20% of individuals residing in long-term care institutions could be managed in the home care setting, given their similar support needs and clinical profiles (8). The prevalence of frailty, multimorbidity, and cardiopulmonary diseases, are high in the home care population (22), a likely explanation for their worse health outcomes and intensive health service needs (14,23). The medical complexity seen in the home care population results in the receipt of fragmented health care spread across multiple health sectors and clinical specialists, further compromising health outcomes (24). The cardiovascular profiles of patients receiving home care are commonly high-risk, given the high prevalence of congestive heart failure, coronary artery disease, and hypertension in this population (22,25). These diagnoses and complex clinical presentations increase the risk of cardiac arrest among patients receiving home care services.

Cardiac Arrest

Cardiac arrest is a sudden loss of systemic blood circulation and tissue oxygenation due to inadequate or absent cardiac output (26). Prompt initiation of cardiopulmonary resuscitation is needed to return systemic circulation and prevent sudden cardiac death in the event of a cardiac arrest (27). Cardiopulmonary resuscitation for Basic Life Support traditionally involves compressions to the sternum, and ventilatory support (via mouth-to-mouth, facemask, or bag-valve-mask) or defibrillation, where appropriate (28). Cardiac arrests are traditionally dichotomized and classified as in-hospital cardiac arrest (IHCA) or out-of-hospital cardiac arrest (OHCA), depending on the arrest setting. Cardiac arrests are commonly evaluated within these sub-groups considering the epidemiology, patient features, arrest etiology, and health outcomes, are significantly different between those arresting in-hospital versus out-of-hospital (29,30).

The incidence of IHCA is between one and six patients for every 1000 hospital admission (31,32). Outside of the hospital setting, the global incidence rate for OHCA is 55 arrests per 100,000 person-years (33). While the incidence is relatively low compared to other cardiovascular events (e.g., myocardial or cerebral infarction), the event of cardiac arrest is often debilitating or lethal. Fewer than one-in-seven will survive to one-year post-cardiac arrest, with 13% surviving an in-hospital arrest and 7% surviving an out-of-hospital arrest (34,35). Irrespective of the arrest setting, most survivors report worse functional independence, cognitive impairment, mental illness, or quality of life post-cardiac arrest (36–39).

Public perceptions and estimates of survival from cardiac arrest are overly optimistic and often misinformed by televised programing (40,41), underscoring the need for pragmatic discussion and advance care planning to promote value-congruent end-of-life care. Advance care planning is a shared decision-making process to identify and discuss patient prognosis, knowledge, attitudes, values, and preferences about end-of-life care to create patient-driven goals of care and resuscitation directives (42,43). Advance care planning should ideally be conducted in the primary care setting, where health care providers have long-term relationships with their patients (44). Advance care planning is too often postponed until hospitalization or critical illness (45), resulting in uninformed or surrogate decision-making and end-of-life care that is not congruent with patient preferences (i.e., overtreatment) (46).

Most patients consider their end-of-life preference and medical directives (47,48), though only one-in-ten will discuss advance care directives with their primary care provider (47–49). Many patients are unaware that they can record their end-of-life preferences, and when knowledgeable, they prefer to have end-of-life discussions initiated by their health care provider (48,49). Advance care planning is commonly overlooked or not prioritized by health care providers who are overburdened by large medically-complex patient rosters (50). The lack of advance care planning is concerning as pro-active and shared decision-making can greatly influence patient knowledge, values, preferences, and satisfaction (51–53). Ideally, end-of-life discussions should take place with all patients, though time constraints and high patient rosters often require clinicians to limit and focus these discussions toward those in greatest need. The greater propensity for cardiac arrest and the poor likelihood of survival underscores the importance of having these discussions with patients receiving home care.

Frailty

Frailty is a multidimensional syndrome characterized by a heightened vulnerability to poor health outcomes and a diminished physiologic reserve, inhibiting homeostatic recovery from stressors (54,55). Frailty has proven to be a robust predictor of patient-important health outcomes like survival and quality of life (56,57). Healthcare experts have emphasized the value of measuring frailty alongside routine clinical assessments across all healthcare sectors (58–61). Clinicians and resuscitation scientists have recently acknowledged and validated the informational value of considering frailty during advance care planning in the general public (62,63). However, little is known about how frailty influences post-cardiac outcomes within the home care population, where rates of frailty are more prevalent and less heterogeneous.

Prognosticating Cardiac Arrest Outcomes

Goals of care and patient values are assessed and re-evaluated by regulated health professionals using the RAI-HC, highlighting an opportune time to evaluate patient knowledge, attitude, and preferences about end-of-life care. The comprehensive and recurrent nature of the RAI-HC assessments at a population level is ideal for evaluating the prognostic effect of geriatric syndromes and high-risk features on survival outcomes (64,65). Health data within the RAI-HC are commonly used to evaluate the epidemiology, overall prognosis, and prognostic factors to support the derivation of prognostic models (15,16). These data are needed to inform and support clinical and shared decision-making about the patient's goals of care and the futility of clinical interventions (66).

Survival after cardiac arrest is strongly associated with frailty (57,58), suggesting that a comprehensive and multidimensional frailty measure could act as a prognostic model (62). Frailty is also associated with patient-important outcomes like death location (i.e., hospital) and admission to long-term care after cardiac arrest (62), demonstrating the importance of its consideration for advance care planning. Efforts have been made within interRAI to develop and validate several frailty measures for use within the RAI-HC (54,67–70). Prognostic scales have been developed and utilized within the RAI-HC instrument for decades to identify and evaluate health instability (64) and geriatric assessment urgency (71), acting as case examples for future prognostic efforts. The incidence and outcomes of cardiac arrest are not routinely collected within the RAI-HC. However, the data are reported to the Canadian Institute of Health Information and housed alongside population-based ambulatory and acute care health data sets, highlighting the feasibility of data linkage and the assessment of geriatric syndromes (i.e., frailty) within the domain of resuscitation research.

Data Sources

The data leveraged in this thesis were housed within ICES (formerly known as the Institute of Clinical and Evaluative Sciences), a not-for-profit organization with 75+ provincial data sets for health system planning and evaluation in Ontario, Canada. This research received a waiver of ethics review by the Hamilton Integrated Research Ethics Board, as informed consent is not required to leverage this data in accordance with Section 45 of Ontario's Personal Health Information Protection Act (72). Home care assessments were extracted from the Home Care Dataset (HCD) and linked to ambulatory and acute care health records in the National Ambulatory Care Reporting System (NACRS) and Discharge Abstract Database (DAD), respectively.

Cardiac arrests were identified within these data sets using a validated series of Canadian Classification of Health Interventions codes to identify those who received cardiopulmonary resuscitation and the International Statistical Classification of Disease and Related Health Problems 10th edition codes to identify incidents of cardiac arrest codes (73–75). The time, etiology, and location of death were extracted from the provincial Vital Statistics and Death database. Bearing that nursing home residents are at greater risk for poor arrest outcomes and share similar clinical profiles, we extracted data on arrests in this population for a comparison group, extracting data from the Continuing Care Reporting System (CCRS). The availability and linkage of these population-based datasets create a unique opportunity to evaluate cardiac arrest prognosis and prognostic factors, like frailty. Figure 1 displays a flow diagram of study eligibility and distributions between IHCA and OHCA.

Thesis Objectives and Overview

The primary objective of this thesis is to identify pre-arrest prognostic factors that influence the likelihood of survival post-cardiac arrest among home care in Ontario, Canada, between January 2006 and March 2018, inclusive. This sandwich thesis comprises one systematic review and three retrospective cohort studies, including an overall prognosis study, a prognostic factor study, and a prognostic model study. The reporting of prognosis studies followed the Strengthening the reporting of observational studies in epidemiology (STROBE) guidelines (76) and the Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis (TRIPOD) statement (77). Study methods were guided by recommendations from the Prognosis Research Strategy (PROGRESS) group (78–80).

Chapter two contains a published systematic review and meta-analysis titled *Prognostic association of frailty with post-arrest outcomes following cardiac arrest: A systematic review and meta-analysis* (62). This study synthesized and statistically pooled data on the association between frailty and survival for patients who experienced cardiac arrest. The meta-analysis pooled three studies and concluded that individuals who experience IHCA with frailty had approximately three times the odds of dying before hospital discharge compared to those without frailty. This review identified the Clinical Frailty Scale (54,62) as the most commonly used frailty measure in resuscitation research, informing its use and value for future chapters evaluating frailty. This study also sets the stage for the following chapters by demonstrating that frail populations (i.e., home care) are likely to have worse odds of survival and, thus, are likely to benefit from advance care planning. This review was published in *Resuscitation and* received a written commendation from the editors (81) (https://www.resuscitationjournal.com).

Chapter three contains an overall prognosis study titled *Prognosis of Cardiac Arrest in Home Care Clients and Nursing Home Residents: A Population-Based Retrospective Cohort Study*. This study is novel in that it is the first to date to examine the prognosis of cardiac arrest in the home care population and across differing pre-arrest community support needs (i.e., long-term care and no support needs). This study found that patients receiving home care and nursing home residents had worse prognoses of immediate and long-term survival post-cardiac arrest than community-dwelling individuals receiving no publicly funded support services. These two populations shared similar prognoses, suggesting an overlap in medical complexity and frailty among these cohorts. This chapter was published in *Resuscitation Plus* (https://www.sciencedirect.com/journal/resuscitation-plus). The findings from this study highlight the need for future chapters evaluating prognostic factors and geriatric syndromes (i.e., frailty) among patients receiving home care.

Chapter four contains a prognostic factor study titled *Prognostic association between frailty and post-arrest health outcomes in patients receiving home care: A population-based cohort study*. This study evaluates the association between frailty and post-arrest health outcomes in patients receiving home care who received cardiac arrest care at a hospital in Ontario, Canada. This prognostic factor study retrospectively calculated two valid frailty measures: the Clinical Frailty Scale and a 43-item frailty index developed by Armstrong and colleagues (67).

This study found that frailty was associated with 30-day and one-year survival post-cardiac arrest, irrespective of the frailty measure used, and after adjusting for age, sex, and arrest setting. Frailty was only associated with post-arrest declines in functional independence and cognitive performance when using the more detailed frailty index. This study emphasized the value of frailty as an informative prognostic factor to inform advance care planning and resuscitation directives. However, the discriminative accuracy of all frailty models was poor despite using robust and comprehensive measures. Poor accuracy suggests factors above and beyond frailty will likely improve the predictive accuracy of models forecasting survival post-cardiac arrest, validating the need for a prognostic model in the home care population. This paper is currently under review in *Resuscitation* (https://www.resuscitationjournal.com).

Chapter five contains a prognostic model study titled *Derivation and Internal Validation of a Prognostic Model Predicting 30-Day Survival Post-Cardiac Arrest: A Population-Based Analysis of Patients Receiving Home Care.* This study developed and internally validated a prognostic model to predict 30-day survival post-cardiac arrest among patients receiving home care. Model accuracy was suitable for group-level predictions and was similar between those who arrested in-hospital and out-of-hospital. Model accuracy was similar when evaluated solely in those 75 years and older as a sensitivity analysis. The model developed and validated can accurately predict the 30-

survival post-cardiac arrest and is suitable for incorporation within the RAI-HC. This manuscript is currently being written up for publication.

Chapter six summarizes the findings and implications of the four studies in this sandwich thesis. This chapter revisits the themes of home care, frailty, and their relation to post-arrest health outcomes. A detailed review of the thesis strengths and limitations can also be found in this chapter. Finally, this chapter concludes by discussing future goals and research needed in the domain of geriatric resuscitation.

Related Works

When conducting our systematic review, we found no other reviews evaluating frailty and survival from cardiac arrest. However, an updated review was published the following year based on our prior work (82). Cardiac arrest outcomes have been well studied in the general public and nursing home residents, though scant work exists evaluating frailty and cardiac arrest outcomes in the home care population. One study in Ontario, Canada, developed a prognostic model to predict the risk of overall mortality using the RAI-HC and achieved good accuracy (65). However, the etiology and risk profiles of those who die post-cardiac arrest are vastly different from those who die from all causes. Prognostic models exist predicting survival after cardiac arrest (83,84). However, these instruments are not specific to the home care population and often leverage data not available for consideration during pre-arrest advance care planning (e.g., duration of resuscitation, laboratory values).

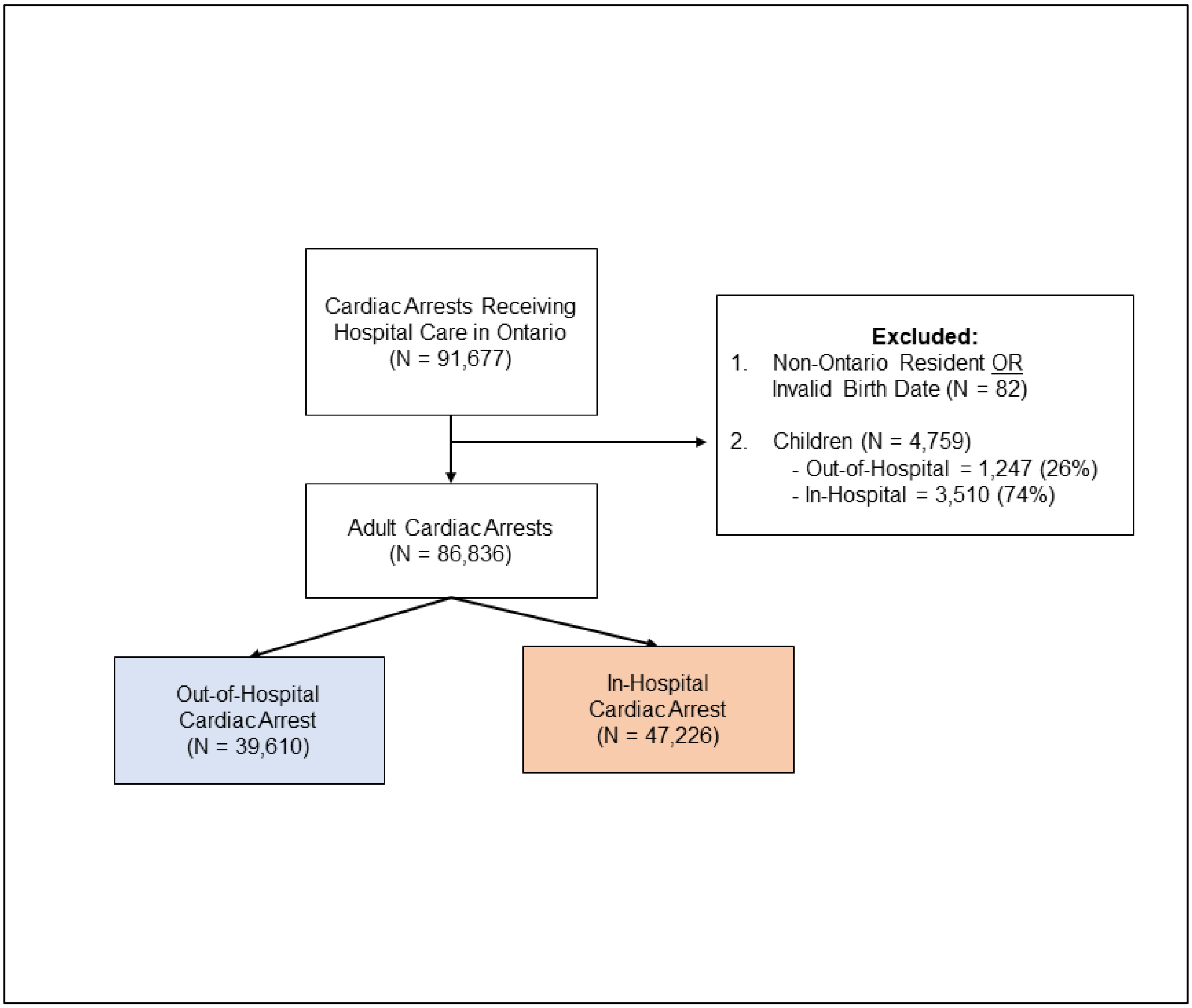
Conclusion

This thesis provides novel data on the prognosis and prognostic factors of cardiac arrest in a population-based cohort of patients receiving home care services in

Ontario, Canada. The chapters of this thesis build upon each other as prognosis research should (78–80) and includes an overall prognosis study, a prognostic factor study, and finally, a prognostic model study.

Tables and Figures

Figure 1. Flow Diagram of 86,836 Cardiac Arrests in Ontario, Canada, Between 2016 and 2018



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CHAPTER TWO

Prognostic Association of Frailty with Post-Arrest Outcomes Following Cardiac Arrest: A Systematic Review and Meta-Analysis

Summary

This second chapter synthesized and evaluated the literature to date (i.e., 2020) reporting an association between frailty and post-cardiac arrest health outcomes in the adult population (≥18 years). Specifically, the outcomes of survival to hospital discharge, return of spontaneous circulation, and discharge home from the hospital were evaluated. The Risk of Bias was assessed using the Quality in Prognosis Studies (QUIPS) instrument, and the certainty of the evidence was evaluated using the GRADE guidelines. Findings from this study set the stage for the chapters to come by demonstrating an association between frailty and survival post-cardiac arrest. I (Fabrice Mowbray) was primarily responsible for developing the original search, text review, data extraction, and writing this manuscript.

Citation:

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ABSTRACT

Objective: To synthesize the current evidence examining the association between frailty and a series of post-arrest outcomes following the provision of cardiopulmonary resuscitation (CPR).

Data Sources: We searched MEDLINE, PubMed (exclusive of MEDLINE), EMBASE, CINAHL, and Web of Science from inception to August 2020 for observational studies that examined an association between frailty and post-arrest health outcomes, including in-hospital and post-discharge mortality. We conducted citation tracking for all eligible studies.

Study Selection: Our search yielded 20,480 citations after removing duplicate records. We screened the title, abstract and full-texts independently and in duplicate.

Data Extraction: The prognosis research strategy group (PROGRESS) and the critical appraisal and data extraction for systematic reviews of prediction modelling studies (CHARMS) guidelines were followed. Study and outcome-specific risk of bias were assessed using the QUIPS (Quality in Prognosis Studies) instrument. We rated the certainty of evidence using the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) recommendations for prognostic factor research.

Data Synthesis: Four studies were included in this review, and three were eligible for statistical pooling. Our sample comprised 1,134 persons who experienced in-hospital cardiac arrest (IHCA). The mean age of the sample was 71 years. The study results were pooled according to the specific frailty instrument. Three studies used the Clinical Frailty Scale (CFS) and adjusted age (our minimum confounder); the presence of frailty was associated with an approximate three-fold increase in the odds of dying in-hospital after IHCA (aOR = 2.93; 95% CI = 2.43 – 3.53, high certainty). Frailty was also associated with decreased incidence of ROSC (return of spontaneous circulation) and discharge home following IHCA. One study with a high risk of bias used the Hospital Frailty Risk Score and reported a 43% decrease in the odds of discharge home for patients with frailty following IHCA.

Conclusion: High certainty evidence was found for an association between frailty and in-hospital mortality following IHCA. Frailty is a robust prognostic factor that contributes valuable information and can inform shared-decision making and policies surrounding advance care directives.

Registration: PROSPERO Registration # CRD42020212922

Introduction

Frailty is a multidimensional syndrome characterized by a heightened vulnerability to adverse health events and diminished physiologic reserve, inhibiting homeostatic recovery from stressors.[1,2] Frailty is a robust predictor of patient-important health outcomes and health service use across all ages.[3–5] Geriatric syndromes, like frailty, are commonly overlooked by health care providers and disease-centric models of care.[6,7] Emphasis has been placed on measuring frailty alongside routine clinical assessments in acute care, home care and long-term care to support clinical decision-making and health system planning.[8–10]

Clinicians and resuscitation scientists have recently examined the utility of frailty to inform shared-decision making surrounding the provision of cardiopulmonary resuscitation (CPR) and other resuscitative measures following cardiac arrest. Approximately one-in-ten will survive a cardiac arrest in the hospital setting, with worse odds for arrests that occur in the community.[11,12] Many survivors report physical disabilities, cognitive impairment, mental illness, or decreased quality of life post-arrest,[13–15] highlighting the importance of pragmatic discussions regarding advance care directives.

Public perceptions and media portrayals of survival following CPR are known to be optimistic.[16–18] Prior work demonstrates that pre-emptive discussions regarding resuscitative measures and patient prognosis improves knowledge and can influence end-of-life care decisions.[19,20] Advanced knowledge of patient prognosis following cardiac arrest is necessary to determine if resuscitation efforts are futile and ensure value-congruent care. Frailty provides a concise measure to gauge patient resilience and may support decision-making around the provision of CPR and end-of-life care.

Our objective was to synthesize the available evidence on the association between frailty and patient-important outcomes following the provision of CPR when accounting for age.

Methods

The reporting of this review is in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines; a completed checklist can be found in *Appendix A*.[21] We conducted this systematic review and meta-analysis per recommendations from Riley and colleagues and the PROGRESS (Prognosis Research Strategy Group) group.[22–25] The critical appraisal and data extraction for systematic reviews of prediction modelling studies (CHARMS) checklist was used to frame the research question.[25,26] This study was registered with the PROSPERO systematic review registry (Registration # CRD42020212922).

Research Question

In adults who require CPR for cardiac arrest (either in-hospital or out-of-hospital), is frailty associated with:

- Mortality (in-hospital, and at one-, three- and twelve-months post-arrest)
- Return of spontaneous circulation (ROSC)
- Functional status at discharge and one-month post-discharge
- Health-related quality of life (HR-QoL) at 90-days and one-year post-arrest
- Discharge to home from the index hospitalization

Outcomes were selected based on recommendations from the Core Outcome Set for Cardiac Arrest (COSCA) initiative and the International Consortium for Health Outcome Measurement (ICHOM) – Older Person Working Group.[27,28]

Data Sources and Search Strategy

We searched the following electronic databases from inception until August 2020: (i) MEDLINE E-pub Ahead of Print, In-Process and Other Non-Index citations, (ii) PubMed exclusive of MEDLINE citations, (iii) EMBASE, (iv) CINAHL, and (v) Web of Science. We consulted an academic-affiliated librarian (RC) for the systematic literature search. We developed a conservative search strategy to identify any prognostic factors reported in patients who required CPR for cardiac arrest, mindful that factor-specific search strategies may overlook eligible articles.

We included search terms informed by Haynes's balanced (for sensitivity and specificity) search strategies for prognosis, clinical prediction, and etiology/risk studies. Our search was also informed by terms used in previous systematic reviews of prognostic factors.[29–32] Text and MeSH terms for CPR and cardiac arrest were utilized along with a combination of prognosis terms.[25] A detailed search strategy can be found in *Appendix B.* Citation tracking was conducted on all eligible studies to highlight articles potentially missed by our search strategy. Our search was restricted to adults and non-animal studies. We excluded conference proceedings and abstracts because limited methodological description hinders the risk of bias assessment. We elected not to limit our search to older adults, given that frailty also occurs in younger persons.[33]

Study Selection and Screening

We included observational study designs (prospective and retrospective) that enrolled adults (≥ 90% of the sample aged 18 and older) who received CPR and reported an association between frailty and the aforementioned outcomes. Studies were required to provide an explicit and multidimensional definition of frailty, or describe the frailty instrument used. Studies were excluded from our review if they were purposed to examine the efficacy of a specific clinical treatment (e.g., mechanical chest compression), focused on the prognostic effect of a particular clinical therapy (e.g., targeted temperature management, extracorporeal membrane oxygenation, etc.), defined frailty using a single-dimensional measure (e.g., laboratory finding, radiographic imaging, etc.), the timing of outcome measurement was not specified, or outcomes were measured only beyond one-year post-arrest without time-to-event analysis. We also excluded case studies and case series, given their lack of a comparison group. Studies were not excluded based on language, sample size or time of publication. We excluded randomized clinical trials (exclusive of post-hoc analyses), for many of the reasons listed above, mindful of the fact that patients recruited for these studies are commonly unrepresentative of the general patient population.[34]

Titles and abstracts were imported into Covidence software (Melbourne, Australia), where citations were screened and duplicates removed. Title and abstract screening were conducted independently and in duplicate by four reviewers, including two registered nurses (FM, DM), a paramedic (RS) and a health services researcher (RHC), all with graduate-level training in health research methodology. Two reviewers (FM, DM) conducted full-text screening independently and in duplicate.

A standardized and piloted inclusion form was created and was used during these tasks; this form is shown in *Appendix C*. Cases of disagreement over titles and abstracts were included for full-text review. Any disagreement between reviewers regarding study inclusion following full-text review was resolved through discussion; no third-party adjudication was necessary.

Data Extraction

Two reviewers (FM, RHC) extracted data independently and in duplicate. Data were extracted on: authors, year of publication, study design, single versus multisite, data registries, recruitment time-frame, country of study, inclusion and exclusion criteria, site of arrest (in-hospital versus out-of-hospital), total sample size, the proportion of frail individuals, the proportion of adults ≥ 65 and those ≥ 75 years of age, definition and timing of outcomes, number of events, baseline demographics (e.g., age, sex, frailty, multimorbidity), the prognostic factors entered into the multivariable model, unit of change for continuous predictors, classification for categorical predictors, the unadjusted and adjusted point estimates of risk and lower and upper confidence intervals (CI).

Data Synthesis and Analysis

We synthesized data using **R** and the '*meta*' package.[35] A random-effects model was used for all statistical pooling,[36] given that models of care, patient populations, and outcomes are likely to vary between institutions and regions. Study results were pooled according to the specific frailty instrument used. For the primary analysis, we present the pooled odds ratios (OR) for all studies that statistically adjusted for age, mindful of its influence on post-arrest outcomes.[37,38] A sensitivity analysis was conducted to examine the influence of frailty instrument cut-off values on adjusted parameter estimates. We conducted a secondary set of meta-analyses using crude estimates to determine if frailty is robust to confounding bias. More specifically, if crude and adjusted estimates are similar, frailty may drive health outcomes to a greater extent than other factors. We assessed for statistical heterogeneity by visualization of forest plots, and evaluation of the I^2 statistics ($\leq 40\%$) and the chi-square test for homogeneity ($p \geq .05$). We were able to obtain all missing data on effect estimates from corresponding authors.

Risk of Bias

We evaluated the risk of individual study bias independently and in duplicate using the Quality in Prognostic Studies (QUIPS) instrument.[39] We determined the risk of bias by evaluating six distinct domains: study participation, study attrition, prognostic factors, outcome measurement, study confounding, and statistical analysis and reporting. Individual domains were rated as low or high risk of bias, with two or more high-risk domains resulting in a classification of 'high' risk of bias. Paired reviewers independently assessed each study and outcome. To identify overfit models, we also assessed the event-per-variable (EPV) for all multivariable models to ensure the ratio was >10. If not, this item was rated as high risk of bias under the domain *Statistical Analysis and Reporting.*

Certainty of Estimates

Two investigators (FM, FF) independently evaluated the overall confidence in estimates by using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach. [40,41] Certainty was rated as either high, moderate, low or very low, with observational studies considered high confidence until proven otherwise.[40] An individual assessment of confidence was given for each association measured using a specific frailty instrument. Adjusted effect sizes were converted to absolute risks using methods proposed by Foroutan and colleagues.[42] We chose 10 % absolute risk difference (RD) as our clinical importance threshold to determine if there is prognostic value in measuring frailty across post-arrest outcomes.

Results

The literature search yielded 20,480 citations after removing duplicate records; four studies were included in the review and three were eligible for statistical pooling (Figure 1). Agreement between reviewers was weak for title and abstract screening (kappa = 0.4) but excellent for full-text screening (kappa = 0.97). Table 1 displays the individual study characteristics, including 1,134 persons who experienced IHCA between 2008 and 2018. No studies examining frailty and relevant outcomes following out-of-hospital cardiac arrest (OHCA) were eligible for study inclusion. All studies were retrospective in nature and included patients from Canada, the United Kingdom and Australia. Most participants were male (n = 694; 61.2%). The mean age of participants was 71, and 26% of individuals were classified as frail using the Clinical Frailty Scale (CFS) or the Hospital Frailty Risk Score (HFRS). All four studies examined in-hospital mortality as an outcome, and two studies each examined ROSC [43,44] and discharge to home after IHCA.[43,45]

Risk of Bias Assessment

Most studies (75%) that examined the association between frailty and in-hospital mortality used the CFS to operationalize frailty. These three studies were determined to have a low risk of bias.[43,44,46]. One study by Smith and colleagues measured frailty using the Hospital Frailty Risk Score (HFRS) and was determined to be at high risk of bias in the domains of *prognostic factor measurement* and *statistical analysis and reporting*.[45] This study was rated down for using the HFRS, a frailty measure based solely on documented International Classification of Disease (ICD) codes and for using stepwise regression driven by univariable statistical significance (e.g., $p < 0.2$).

Two studies examined the association between frailty and ROSC, although one was determined to be at high risk of bias under the domains of *study confounding* and *statistical analysis and reporting*, providing only unadjusted estimates for this outcome.[44] Two studies examined discharge to home after an IHCA; however, one was rated high risk of bias providing unadjusted estimates.[45]

In-Hospital Mortality

Adjusted Associations Between Frailty and In-hospital Mortality. All three studies using the CFS also adjusted for age, our minimum confounder. Our pooled relative estimate determined that the presence of frailty is associated with an approximate three-fold increase in the odds of dying in hospital after an IHCA (adjusted OR [aOR] = 2.93; 95% CI = 2.43 – 3.53; I^2 = 0%). The absolute risk of in-hospital mortality was 13% higher for individuals with frailty (RD = 0.13; 95% CI = 0.11 – 0.14). There is high certainty evidence that frailty, when measured using the CFS, is associated with in-hospital mortality.

Smith and colleagues reported no significant association between the HFRS and in-hospital mortality (OR = 1.55; 95% CI = 0.8 – 3.02), although this study was determined to be at high risk of bias.[45] There is very low certainty in this reported estimate because of serious concerns with risk of bias and imprecision.

Sensitivity Analysis. Two studies used a CFS value of five or greater to determine the presence of frailty [43,46] and one study by Wharton and colleagues used a value of six or greater.[44] The pooled adjusted relative effect in the studies that used a CFS cut-off value of five determined that individuals with frailty have approximately three times the odds of dying during hospitalization after IHCA (aOR = 2.9; 95% CI = 2.42 – 3.5). The absolute risk of in-hospital mortality was 13 % higher for individuals with frailty when excluding the study by Wharton and colleagues (RD = 0.13; 95% CI = 0.12 – 0.14).

Unadjusted Associations Between Frailty and In-hospital Mortality. In studies that operationalized frailty using the CFS, the pooled relative effect estimate was an 11-fold increase in the relative odds of death during hospitalization after an IHCA (OR = 11; 95% CI = 5.05 – 23.92; I^2 = 0%). The absolute risk of in-hospital mortality was 19% higher for individuals with frailty (RD = 0.19; 95% CI = 0.16 – 0.2). Using the Hospital Frailty Risk Score (HFRS), Smith and colleagues found individuals with frailty had an approximate 3-fold increase in the odds of dying during hospitalization after IHCA (OR = 2.79; 95% = 1.52 – 5.15). We calculated the pooled absolute effect and determined the absolute risk of in-hospital mortality was 13% higher in individuals with frailty following IHCA (RD = 0.13; 95% = 0.11 – 0.33).

Return of Spontaneous Circulation

Two studies examined the association between frailty and ROSC using the CFS.[43,44] Fernando and colleagues used a CFS cut-off of five or greater and conducted the only study to provide adjusted results.[43] After adjusting for age, shockable rhythm and multimorbidity, among other factors, frail individuals had a 37% reduction in the odds of achieving ROSC after IHCA (aOR = 0.63; 95% CI = 0.41 – 0.93). We determined the absolute adjusted risk of ROSC for this study to be 12% lower in patients with frailty after IHCA (RD = -0.12; 95% CI = -0.22 – -0.02). We have very low certainty in this estimate, rating down for serious risk of bias and imprecision.

The pooled unadjusted relative effect was calculated and determined that individuals with frailty are 49% less likely to achieve ROSC after an IHCA (OR = 0.51; 95%CI = 0.32 – 0.79). The absolute unadjusted effect determined that following an IHCA, the absolute risk of ROSC was 17% lower in individuals with frailty (RD = -0.17; 95% CI = -0.31 – -0.06).

Discharge Home

Using the CFS, Fernando and colleagues determined that people with frailty had a 49% reduction in the odds of being discharged home after an IHCA, after adjusting for age, shockable cardiac rhythm and multimorbidity (aOR = 0.51; 95% CI = 0.43 – 0.63).[43] We calculated the absolute risk of being discharged home to be 14% lower for individuals with frailty after IHCA (RD = -0.14; 95%CI = -0.10 – -0.17). Our crude analysis of the raw data found no statistical significance. There is very low certainty in the association between frailty, when measured with the CFS, and being discharged home after an IHCA, rating down for very serious risk of bias and imprecision.

The only other study to examine the probability of discharge to home was Smith and colleagues, [45] and they determined that individuals with frailty had an 87% reduction in the odds of being discharged home after an IHCA (OR = 0.13; 95% CI = 0.04 – 0.41). Adjusted analyses found that patients with frailty had a 76% reduction in the odds of being discharged home after in-hospital mortality (OR = 0.24; 95% CI = 0.07

– 0.82). There is very low certainty in the association between frailty, measured with the HFRS, and being discharged home after an IHCA, rating down for very serious risk of bias and imprecision.

Discussion

We conducted a systematic review and meta-analysis to evaluate the association between frailty and post-arrest outcomes in individuals who require CPR for cardiac arrest. Our pooled estimates for frailty, when measured with the CFS, found that individuals with frailty have approximately three times the odds of dying during hospitalization after an IHCA. This translates to a 13% increase in absolute risk of death for individuals with frailty, surpassing our clinical importance threshold of a 10% absolute risk difference. Two cut-off values in the CFS (five and six) were used to determine the presence of frailty. Our sensitivity analysis demonstrated that excluding the one study that used a CFS cut-off of six had little influence on the pooled estimate (Δ OR = 0.03). It has already been established that the CFS is prognostic of mortality in in-patient, emergency department, surgical, intensive care, home care and long-term care settings.[47–50] Hospitalized patients with frailty (CFS ≥ 5) who require rapid response services are at also greater risk for mortality and hospital dependence.[51]

One study operationalized frailty using the HFRS and determined that frailty was not associated with in-hospital mortality. However, this study was rated as a high risk of bias based on their use of the HFRS to operationalize frailty and the use of backwards stepwise regression for predictor selection. We rated use of the HFRS as being at high risk of bias, considering the measure is based on documented diagnoses, which can vary greatly based on diagnostician and funding practices.[52] Most frailty screeners, like the CFS, determine the presence of frailty through evaluation of functional capacity rather than diagnoses like the HFRS. Functional capacity is known to be a robust predictor of patient outcomes and recovery,[53–55] and the value of assessing functional status has been well established in complex older patients with heart failure, stroke and cancers.[56–58] Like other geriatric syndromes, functional concerns are commonly overlooked and underdocumented,[7,59] highlighting a potential lack of construct validity for the HFRS, which relies solely on documented diagnoses. Next, stepwise methods, especially when based on univariable findings or significance, increase the risk of unreliable predictor selection and biased model estimates.[60] These limitations may explain why the findings of this study diverge significantly from the body of literature demonstrating an association between the HFRS and mortality in hospitalized patients.[61–63]

Implications for Practice, Policy, and Research

We identified high-certainty evidence that frailty, when measured with the CFS, is associated with greater odds of in-hospital mortality after an IHCA. There may also be a relationship between frailty and discharge to home following an IHCA. These are two key patient-important outcomes, highlighting the prognostic value of frailty for informing shared-decision making about end-of-life treatment plans. More specifically, frailty screening can be used to identify high-risk individuals who are less likely to respond to CPR following a cardiac arrest. Measuring frailty in the ED has proven to be a feasible and accurate method to stratify patient risk when examined with measures like the CFS or the ED frailty index. [48,64] Advanced knowledge of patient frailty in the ED can support proactive and shared-decision making about patient values and goals of care.

Clinical prediction models and decision rules are commonly used to support advance decision-making regarding the futility of CPR and termination-of-resuscitation. Frailty should be considered as an informative predictor or effect modifier in these models to improve model accuracy and precision. Including a practical and valid measure of frailty, like the CFS, as a Utstein variable is likely to improve the measurement and reporting of frailty in future resuscitation studies.

The lack of frailty measurement in current prediction models is likely the broader consequence of geriatric syndromes being overlooked in the clinical setting.[7] This suggests that additional education regarding the prognostic value of frailty and other geriatric syndromes may be needed to promote practice and policy change. While our findings are specific to cardiac arrests that occur in-hospital, we would expect that mortality rates after OHCA are worse, suggesting mortality rates may be higher for frail individuals succumbing to cardiac arrest in the community.

Strengths and Limitations

Our study included a comprehensive search, and the majority of studies were determined to be at low risk of bias. We obtained all missing data on effect estimates from corresponding authors. Our methods followed the recommendations of PROGRESS. However, this study was not without its limitations. The primary pooled analysis examining the association between frailty and in-hospital mortality is driven largely by a single study, weighted at 95%. All studies included in this review were retrospective in nature and are therefore subject to biases associated with such designs. Additionally, studies examining the association between frailty and in-hospital mortality with the CFS used different cut-off values (five and six) to define frailty.

However, our sensitivity analysis determined that this difference in cut-off value had little influence on the final pooled estimates.

We were also unable to include any data examining the association between frailty and post-arrest outcomes in OHCA due to invalid frailty measurement. More specifically, Sulzgruber and colleagues examined the influence of frailty on patient outcomes in OHCA.[65] However, they used a vague and unidimensional definition of frailty, driven solely by the need for assistance with activities of daily living.

Our review protocol initially listed shockable cardiac rhythm, along with age, in our minimum confounder set. We elected to remove it given a lack of clarity about whether shockable cardiac rhythm has a prognostic or mediating effect on the relationship between frailty and post-arrest outcomes. Future studies are needed to delineate this effect, given the consequences of inappropriately adjusting for mediators. Its worth noting that the majority of studies (75%) in our review statistically adjusted for shockable cardiac rhythm.

Agreement between reviewers for title and abstract screening was weak (kappa = 0.4). However, our decision to include all discrepancies in the full-text review mitigates the risk of overlooking eligible studies at this stage. Finally, we were unable to examine several planned sub-group analyses given the limitations of the data.

Conclusion

This study identified that frailty, when measured with the CFS, is an essential prognostic factor to consider when discussing goals of care with patients or conducting resuscitation research. When measured with the CFS, individuals with frailty had approximately three times the odds of dying in-hospital after an IHCA. Low-certainty evidence suggests that individuals with frailty are less likely to be discharged home after an IHCA. Future research is needed to examine the prognostic value of frailty in OHCA and determine if frailty is associated with other patient-important outcomes, including post-arrest functional capacity and health-related quality of life.

Tables and Figures

Table 1. Study Characteristics

Author, Year	Country	Sites	Population	Sample Size	Frail	Frailty Measure	Frailty Definition	Adjusted for Age	Outcomes Examined
Ibitoye, 2020	UK	Single	Hospitalized patients (> 60 years) who received CPR between May 2017 and December 2018.	90	40	CFS	≥ 5	Yes	In-hospital Mortality *
Fernando, 2020	Canada	Multi	Hospitalized adults (≥ 18 years) who experienced IHCA between 2013 and 2016.	477	124	CFS	≥ 5	Yes	In-hospital Mortality * ROSC * Discharged home *
Wharton, 2019	UK	Single	Hospitalized patients (> 16 years) who experienced IHCA in 2017.	179	56	CFS	≥ 6	Yes	In-hospital Mortality * ROSC
Smith, 2019	Australia	Single	Hospitalized patients who experienced IHCA between 2008 and 2017.	388	72	HFRS	≥ 5	Yes	In-hospital Mortality * Discharged home*

CFS = Clinical Frailty Scale; HFRS = Hospital Frailty Risk Score; IHCA = in-hospital cardiac arrest; ROSC = return of spontaneous circulation

* Both crude and statistically adjusted results were reported (or obtained) for the outcome

Table 2. Summary of Findings (Clinical Frailty Scale)

Outcomes	**Relative Effect (95% CI)**	**Anticipated Absolute Effects**		**№ of Participants (Studies) [a]**		**Certainty of the Evidence (GRADE)**	**Comments**
		Risk without Frailty	**Risk with Frailty**				
In-hospital Mortality	**aOR 2.93** (2.43 – 3.53)	**732 per 1,000**	**862 per 1,000 (851 – 871)**	**746 (3)**		⊕⊕⊕⊕ **High**	Frailty is associated with in-hospital mortality.
ROSC	**aOR = 0.63** (0.41 – 0.93)	**484 per 1,000**	**366 per 1,000 (288 – 437)**	**656 (2)[b]**	**477 (1)[c]**	⊕⊕◯◯ **Low [d]**	Frailty may be associated with ROSC. Our confidence in the estimate is limited.
Discharge-to-home	**aOR 0.51** (0.43 – 0.63)	**385 per 1000**	**282 per 1,000**	**117 (1)**		⊕◯◯◯ **Very Low [e]**	Frailty may or may not be associated with discharge to home. We have very little confidence in this estimate.

CI = confidence interval; aOR = adjusted odds ratio; ROSC = return of spontaneous circulation
a. Single column denotes that the same sample size was used for both crude and adjusted findings
b. Crude estimates
c. Multivariable estimates
d. Rated down (-2) for serious imprecision and risk of bias
e. Rated down (-2) for very serious imprecision and (-2) for very serious risk of bias.

Figure 1. PRISMA Flowchart Summarizing the Literature Search and Study Selection

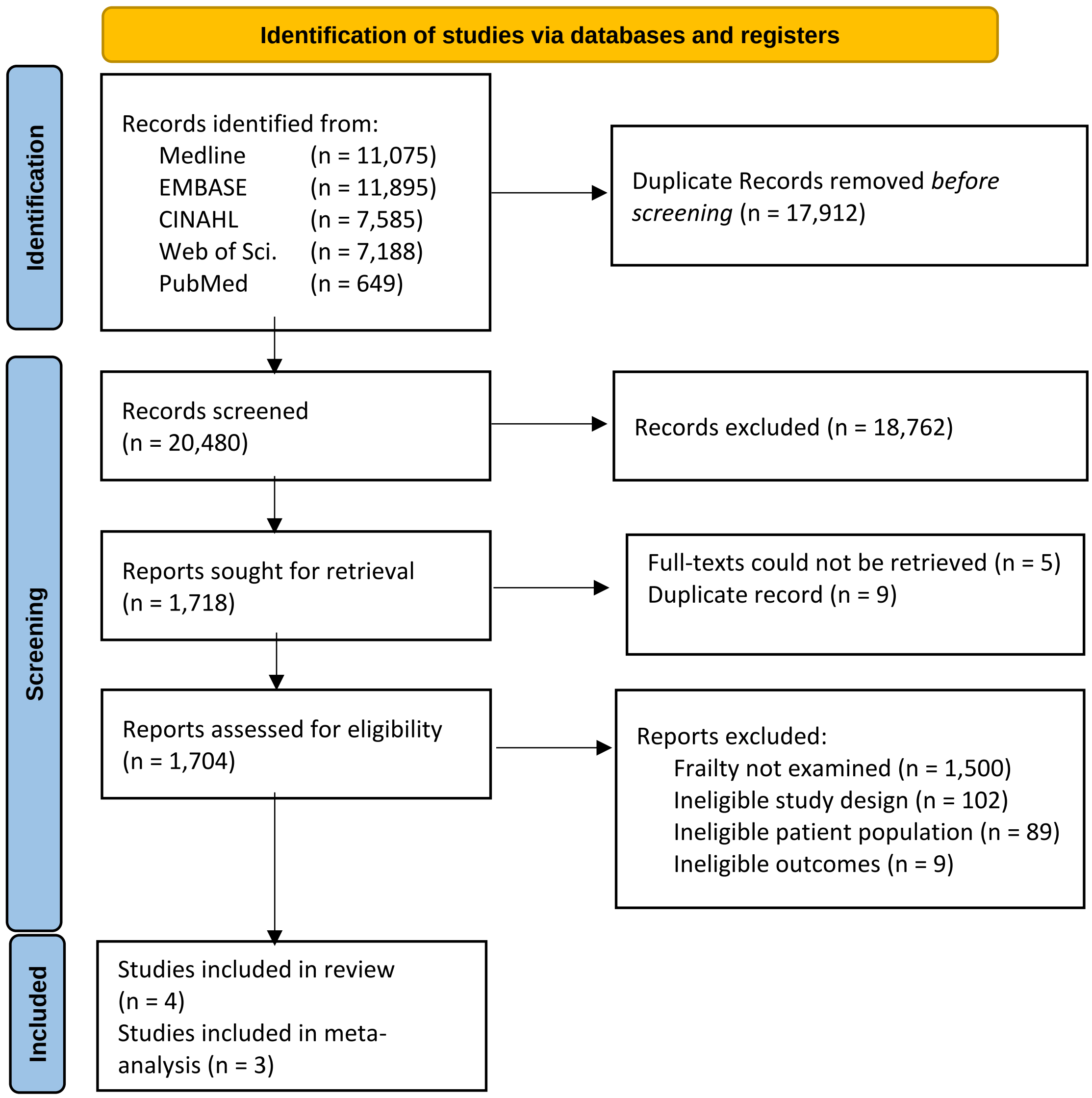
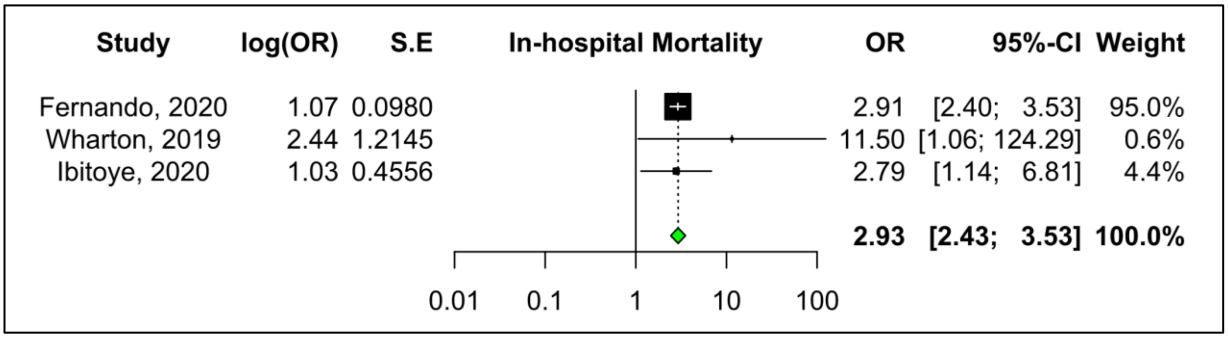


Figure 2. Forest Plot of Associations Between the Clinical Frailty Scale and In-Hospital Mortality



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CHAPTER THREE

Prognosis of Cardiac Arrest in Patients Receiving Home Care and Nursing Home Residents: A Population-Based Retrospective Cohort Study

Summary

This chapter contains the first of three studies investigating the prognosis and prognostic factors associated with survival post-cardiac arrest. This study is an overall prognosis study, evaluating the prognosis of survival to 30-days and one-year post-cardiac arrest among two frail populations in Ontario, Canada – home care and long-term care (i.e., nursing home residents). Community-dwelling individuals not enrolled in home care or living in a nursing home were used as the reference group. This study is novel in its analysis of cardiac arrest outcomes in the home care population, and it sets the stage for future chapters by showcasing home care as a high-risk population.

Patients receiving home care and nursing home residents had worse prognoses of survival to 30 days and one-year post-arrest. Patients receiving home care and nursing home residents were found to have a similar risk reduction compared to those receiving no support services in the community, suggesting an overlap of medical complexity and frailty among these two populations. The risk reductions in the populations were robust to the confounding of age, suggesting risk in these groups is driven by their prevalence of geriatric syndromes. I (Fabrice Mowbray) was primarily responsible for the study ideation, analysis, and drafting of the original manuscript.

Citation:

Mowbray, F.I., Jones, A., Foroutan, F., Strum R.P., Turcotte, L., De Wit, K., Worster, A., Griffith, L.E., Heckman, G., Hebert, P., Ko, D., Schumacher, C., Gayowski, A., Costa, A.P. Prognosis of cardiac arrest in patients receiving home care and nursing home residents: A population-based retrospective cohort study. *Resuscitation Plus.* 2022;12;100328.

ABSTRACT

Aim: To evaluate the prognosis of 30-day survival post-cardiac arrest among patients receiving home care and nursing home residents.

Methods: We conducted a population-level retrospective cohort study of community-dwelling adults (≥18 years) who received cardiac arrest care at a hospital in Ontario, Canada, between 2006 to 2018. We linked population-based health datasets using the Home Care Dataset to identify patients receiving home care and the Continuing Care Reporting System to identify nursing home residents. We included both out-of-hospital and in-hospital cardiac arrests. We determined unadjusted and adjusted associations using logistic regression after adjusting for age and sex. We converted relative measures to absolute risks.

Results: Our cohort contained 86,836 individuals. Most arrests (55.5%) occurred out-of-hospital, with 9,316 patients enrolled in home care and 2,394 residing in a nursing home. When compared to those receiving no support services, the likelihood of survival to 30-days was lower for those receiving home care (RD= -6.5; 95%CI= -7.5 – -5.0), with similar results found within sub-groups of out-of-hospital (RD= -6.7; 95%CI= -7.6 – -5.7) and in-hospital arrests (RD= -8.7; 95%CI= -10.6 – -7.3). The likelihood of 30-day survival was lower for nursing home residents (RD= -7.2; 95%CI= -9.3 - -5.3), with similar results found within sub-groups of out-of-hospital (RD= -8.6; 95%CI= -10.6 – -5.7) and in-hospital arrests (RD= -5.0; 95%CI= -7.8 – -2.1).

Conclusion: Patients receiving home care and nursing home residents had worse overall prognoses of survival post-cardiac arrest compared to those receiving no pre-

arrest support, highlighting two medically-complex groups likely to benefit from advance care planning.

Introduction

Despite recent advancements in cardiac arrest management, the one-year survival rate is 13% for arrests that occur in-hospital and 8% for out-of-hospital (1,2). The minority who survive commonly report post-arrest physical disabilities, cognitive impairment, mental illness, and decreased quality of life (3–5). Post-arrest outcomes are worse among older adults and those with frailty (6,7).

Patients receiving home care and nursing home residents are two older, medically-complex populations with high rates of frailty and emergency service use (8–10). Approximately 30% of older adults in Canada receive publicly funded home care or reside in a nursing home (11,12). Home care is a term that encompasses a wide array of personal and clinical support services, such as personal support, nursing care, physical or occupational therapy, and mental health care (13). When medical complexity or service needs extend beyond what is available in the home care setting, individuals and families often turn to nursing homes, which provide 24-hour support and residence. In Canada, it is estimated that 20% of individuals residing in long-term care institutions could be managed in the home care setting, given their similar support needs and clinical profiles (14).

The high rates of cardiorespiratory illness and advanced disease in these populations increase their risk for cardiac arrest (15), suggesting proactive decision-making about end-of-life is of great importance upon service enrollment. Research comparing post-cardiac arrest survival between nursing home residents and community-dwelling older adults has been inconsistent (16–20). Little is known about the rates of survival post-cardiac arrest in patients receiving home care, an expanding population with unmet care needs in the community (21). Fundamental prognosis studies are essential to assess the relative burden of disease and target individuals most likely to benefit from advance care planning (22).

Our objective for this study was to evaluate the likelihood of survival to 30 days post-cardiac arrest among patients receiving home care and nursing home residents compared to community-dwelling individuals not enrolled in community support services. We hypothesized that home care and nursing home populations would have worse prognoses of 30-day survival post-cardiac arrest. Our secondary objective was to evaluate survival to one-year and in-home death. We provide absolute risk estimates for both in-hospital and out-of-hospital cardiac arrest.

Methods

Study Design and Data Sources

We conducted a population-based retrospective cohort study linking multiple de-identified administrative health datasets housed within ICES, formerly known as the Institute of Clinical and Evaluative Sciences. We extracted data on all patients who received cardiac arrest care from any hospital in Ontario between January 1, 2006, and December 31, 2018. We classified patients as in-hospital cardiac arrest if the arrest occurred following a hospital admission or out-of-hospital cardiac arrest if the arrest or management occurred in the pre-hospital or ED setting. While the ED is physically located within the hospital system, most cardiac arrests managed in the ED occur in the pre-hospital setting and are commonly classified as out-of-hospital arrests (23,24).

The Home Care Dataset and Continuing Care Reporting System were used to identify patients receiving long-stay home care services (>60 days) and nursing home residents. We extracted patient demographics (e.g., age and sex) from the Registered Person Data Base. We collected data on relevant diagnoses, visit characteristics, clinical interventions, and emergency department disposition for out-of-hospital arrests from the National Ambulatory Care Reporting System dataset. For in-hospital arrests, we collected this data from the Discharge Abstract Database. We used the Assistive Devices Program dataset to identify individuals who were approved for supportive functional (e.g., wheelchair, cane, scooter) or sensory (e.g., hearing aids, communication devices) health devices. We used the Ontario Myocardial Infarction Dataset to identify individuals who received pre-arrest hospital care in Ontario for myocardial infarction. We used the Vital Statistics and Death database to identify the completion of an autopsy and the etiology, location, and timing of death. The databases used in our study are routinely checked for quality and validated for use with conducted population-level health research in Ontario and Canada (25,26)

A waiver of ethics review was approved by the Hamilton Integrated Research Ethics Board, as informed consent is not required to leverage this data in accordance with Section 45 of Ontario's Personal Health Information Protection Act (27). We reported our findings in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (28).

Cohort and Exposures

We extracted data on all patients aged 18 and older who received hospital care (ED or inpatient) at any hospital in Ontario for cardiac arrest. We used a follow-up window of one-year post-cardiac arrest. For individuals who had an in-hospital cardiac arrest, we included only those arrested within 72 hours of ED registration. We elected to use the ED registration time as the reference point for time-based measures, as it signals the first interaction with the hospital system. Given our interest in pre-arrest support needs, a 72-hour time frame was chosen to mitigate the risk of unknown confounders and health decline that arises throughout the hospital stay (29). Prior work has demonstrated that in-hospital arrests are most likely to occur within two days of hospital admission (30). Thus, we allowed a 24-hour buffer period for patients admitted and boarded in the ED while awaiting transfer to an inpatient unit.

We used a validated series of Canadian Classification of Health Interventions codes to identify those who received cardiopulmonary resuscitation (IHZ30JN, IHZ3OJY) and International Statistical Classification of Disease and Related Health Problems (ICD-10) codes to identify incidents of cardiac arrest (I46.1, I46.2, I46.8, I49.0, I49.01, I49.02, R96.0, R96.1, R98, R99) (23,31,32). In the rare case where two arrests occurred within the study period, we used the first event only, given the worse odds of survival following rearrest (33,34), to mitigate the risk of correlated observations. We excluded patients who were not residents of Ontario and those without a valid Ontario Health Insurance Plan number or birthdate. We excluded patients who received a surgical intervention prior to their arrest within the 72-hour observation window to best capture arrests exacerbated by medical conditions rather than surgical or traumatic causes, which are less common, and require different clinical interventions (30).

We measured age as a categorical variable due to data privacy limitations within ICES, with years of age collapsed to 18-49, 50-64, 65-74, 75-84, and 85+ years. Triage acuity was assessed following ED registration using the Canadian Triage Acuity Scale, a five-item ordinal scale used in hospitals across Canada with a score of one indicating the highest medical acuity (35). We used ICD-10 codes to determine pre-arrest morbidity status.

Outcomes

Our primary outcome for this study was survival to 30 days post-cardiac arrest. We elected to use this time frame, knowing it closely approximates survival to hospital discharge and based on recommendations from the Utstein guidelines (36,37). We also examined survival to one year and the likelihood of in-home death.

In-home death was defined as any death that did not occur within a health institution (e.g., hospital, rehabilitation center, nursing home, etc.). Both survival and location of death are known to be patient-important outcomes and key priorities for cardiac arrest research per the Core Outcome Set for Cardiac Arrest (COSCA) initiative and the International Consortium for Health Outcome Measurement (ICHOM) – Older Person Working Group (38,39).

Analysis

For descriptive statistics, we report measures of frequency and central tendency. Odds ratios and 95% confidence intervals (CIs) were calculated using logistic regression and converted to absolute risks as recommended by the Prognosis Research Strategy (PROGRESS) group and the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) prognosis working group (22,40). For multivariable models, we adjusted for age and sex, mindful that these are two prognostic factors that influence health trajectories, post-cardiac arrest outcomes and bystander response for out-of-hospital arrests (41,42). We did not include nursing home residents in the analysis of death location, as we could not delineate the specific type of institution where an individual died (e.g., nursing home versus hospital) using our data. We evaluated prognoses in the overall cohort and within sub-groups of out-of-hospital and in-hospital cardiac arrest. Missing data was scant (< 0.1%) and deleted within each analysis, given the descriptive nature of this study. Data were managed and analyzed in **R** version 3.6.0.

Results

Our cohort contained 86,836 individuals who experienced cardiac arrest either out-of-hospital or in-hospital. Most arrests occurred in-hospital (n = 47,226; 55.5%), and of the 39,610 (45.65) who arrested out-of-hospital, 7,207 (18.1%) were dead upon hospital arrival despite pre-hospital cardiopulmonary resuscitation. Most in the cohort were not enrolled in pre-arrest support services (85.9%), were male (60.3%), transferred by ambulance (83.3%), and presented to the hospital during daytime hours (60.2%). Figure 1 displays a flow diagram of patient inclusion and survival. Pre-arrest frequencies, proportions, and relative risk estimates across pre-arrest support status, age strata, and arrest setting can be found in Supplemental Tables 1–3.

Pre-Arrest Characteristics Associated with Enrollment in Support Services

Table 1 displays the pre-arrest patient features, stratified between those receiving home care, residing in a nursing home, and those not enrolled in support services. Figure 2 displays a forest plot of patient characteristics associated with the absolute risk of needing home care or nursing home residence. A positive association was found between age and enrollment in home care or nursing home residence, with those 85 years and older in greatest need compared to those 50 and under (RD = 38.7; 95% CI = 37.9 – 39.4) when compared to those aged 18 to 49 years. Those receiving home care or residing in a nursing home had higher rates of congestive heart failure (50.8% vs 29.3%), chronic obstructive pulmonary disease (COPD) (49.7% vs 35.5%), and dementia (37.5% vs 8.3%), compared to those without these services. Respiratory-related illnesses like COPD exacerbations (RD = 8.1; 95% CI = 6.4 – 10.2) and pneumonia (RD = 8.8; 95% CI = 6.9 – 10.9) were more likely to be the cause of death in these cohorts, compared to those with no pre-arrest support services.

Pre-Arrest Features Between Arrest Settings

Table 2 compares pre-arrest patient features between out-of-hospital and in-hospital cardiac arrest. We found the oldest cohort (85+) had the greatest chances of out-of-hospital arrest compared to those under 50 years (RD = -17.7; 95%CI = -18.9 – -16.8). However, those with high-risk diagnoses like congestive heart failure (RD = 5.6; 95%CI = 4.9 – 6.3), COPD (RD = 11.2; 95%CI = 10.6 – 11.7), and dementia (RD = 7.2; 95%CI = 6.3 – 8.1) were more likely to arrest in-hospital. Those who arrested in-hospital were also more likely to be female (RD = 8.9; 95%CI = 8.4 – 9.5) and to arrest during the daytime between 0700 to 1900 hours (RD = 21.3; 95%CI = 21.3 – 22.5).

Post-Cardiac Arrest Survival

Adjusted odds ratios and confidence intervals can be found in Supplemental Tables 4-6 for the overall, out-of-hospital, and in-hospital cohorts.

30-Day Survival. Overall, 31,180 (36.0%) survived to 30 days post-cardiac arrest. Most patients died after one-week post-cardiac arrest (61.9%). After adjusting for age and sex, patients receiving home care (RD = -6.5; 95%CI = -7.5 – -5.0) and nursing home residents (RD = -7.2; 95%CI = -9.3 - -5.3) had worse prognoses of survival to 30-days compared to those receiving no support services. Patients receiving home care services had a worse prognosis of 30-day survival in out-of-hospital settings (RD = -6.7; 95%CI = -7.6 – -5.7) and in-hospital settings (RD = -8.7; 95%CI = -10.6 – -7.3). Nursing home residents had similar results in the out-of-hospital (RD = -8.6; 95%CI = -10.6 – -5.7) and in-hospital settings (RD = -5.0; 95%CI = -7.8 – -2.1). Figure 3 displays the probability of survival to one month between home care clients, nursing home residents, and those receiving neither service. Figure 4 displays a forest plot of absolute risk differences between pre-arrest support needs and survival (30-day and one-year) post-cardiac arrest after adjusting for age and sex.

One-Year Survival. Approximately three in ten (31.6%) survived to one-year post-cardiac arrest. After adjusting for age and sex, those receiving home care (RD = -9.6; 95%CI = -10.5 – -8.5) and those residing in a nursing home (RD = -11.8; 95%CI = -13.6 – -9.7) has worse prognoses of one-year survival post-cardiac arrest compared to those receiving no pre-arrest supports. Patients receiving home care had a worse prognosis of one-year survival in both the out-of-hospital (RD = -7.7; 95%CI = -8.6 – -6.9) and in-hospital setting (RD = -13.2; 95%CI = -14.8 – -11.5), compared to those receiving no pre-arrest support. Similarly, nursing home residents had a worse absolute risk of survival in the out-of-hospital (RD = -8.7; 95%CI = -9.9 – -7.4) and in-hospital settings (RD = -12.8; 95%CI = -16.1 – -10.2).

In-Home Death

After excluding nursing home residents, only 4,586 (7.8%) of deaths occurred in the home setting. Patients receiving home care services were less likely to die at home within a year of cardiac arrest in the out-of-hospital cohort only (RD = -1.3; 95%CI = -2.2 – -0.05). Age had a negative and graduated relationship with home death, whereby the likelihood of home death decreased more with each increase in age strata. Pre-hospital death was similar between those who died in-home (13.9%) and those who did not (12.1%).

Discussion

We determined that patients who require home care or nursing home residence are less likely to survive to 30 days post-cardiac arrest than those not receiving pre-arrest support services. The absolute risk differences were similar between patients receiving home care and nursing home residents and between out-of-hospital and in-hospital cardiac arrests. We demonstrated that younger people have better survival outcomes and are more likely to die at home, and patients receiving home care were more likely to die in their homes if arrests occurred out-of-hospital.

Comparison to Prior Studies

Little is known about the prognosis of cardiac arrest in the home care population. However, our study parallels the prior work showing that nursing home residents have worse survival outcomes than community-dwelling older adults (13,15,16). Our study provides a novel population-based comparison of survival across the three cohorts in Ontario, Canada: home care clients, nursing home residents, and community-dwelling residents receiving no pre-arrest support services. Our study confirms that age is a pre-arrest prognostic factor inversely associated with survival outcomes for out-of-hospital and in-hospital arrests (7,43).

Clinical and Policy Implications

Home care clients and nursing home residents were less likely to survive to 30 days and one-year post-cardiac arrest. Patients receiving home care clients were more likely to die at home if they arrested in the out-of-hospital setting. These two patient-important outcomes should be discussed during advance care planning in home care and nursing home populations (39). These populations are at greater risk for cardiac arrest, given their advanced age and greater prevalence of late-stage chronic disease. Foreknowledge about pre-arrest support status is readily available in most clinical settings; this prognostic factor should be considered during shared decision-making about preferences for end-of-life care and directives.

We demonstrated that identifying enrollment in pre-arrest support services was associated with 30-day and one-year survival with similar absolute risks between home care and nursing home populations (< 3% difference). The similar prognoses of these populations could signal a significant overlap in the rates of frailty and medical complexity found among them. The longstanding lack of long-term care beds has a downstream effect on the home care population, resulting in greater health decline at home and upon admission to long-term care. Nursing home residents were older, though home care clients were more likely to arrest with a high-risk chronic condition such as congestive heart failure and chronic obstructive pulmonary disease. Arrests could theoretically have occurred in the least frail nursing home residents and the frailest home care clients. Another possibility is nursing home residents are more likely to experience a witnessed arrest and receive cardiopulmonary resuscitation, given their access to 24-hour nursing and support care (17,18).

Overly optimistic public perceptions and media portrayals highlight a disconnect in public health communication and the importance of clinician-driven pragmatic discussions about end-of-life care (44,45). End-of-life care planning is commonly postponed until critical illness (46), resulting in uninformed or surrogate decision-making and end-of-life care that is not congruent with patient preferences (i.e., overtreatment) (47). Proactive and shared-decision making about advance care directives have the potential to realign patient knowledge, values, and preferences with realistic expectations (48,49). Home care clients and nursing home residents are ideally set up for informed and shared decision-making about end-of-life wishes upon service enrollment, given the provision of detailed and routine assessments within these populations. These pragmatic discussions become more important as home care clients and nursing home residents age. Older patients are less likely to die at home and are more likely to die in a hospital, which could contrast with their care preferences or directives (39,50).

Strengths and Limitations

Our study is novel in providing a population-level evaluation of survival post-cardiac arrest and the probability of in-home death according to pre-arrest support needs (e.g., home care and long-term care), age group and sex. Population-level data is ideal for evaluating the prognosis of those who experience cardiac arrest, as it can best capture the low incidence rates of cardiac arrests to inform policymaking at a regional or national level (51).

For in-hospital arrests, we could not provide a true measure of overall prognosis, as data were not originally extracted on all in-hospital arrests that occurred, but rather those that occurred within a 72-hour window, for previously mentioned reasons. This limitation could explain our high survival rates for in-hospital arrests, as patients are at greater risk for medical decompensation the longer the hospital length of stay (52).

Another plausible reason for our high survival rate is that patients enrolled in home care or nursing home residence are more likely to have a do-not-resuscitate directive and are likely healthier than residents with these advanced orders (53). For out-of-hospital arrests, we likely missed a small proportion of those who received resuscitation in the community but were not transferred to a hospital.

Using ICD-10 codes in administrative records to identify co-morbidities is a limitation when trying to understand diagnoses in this population, given the inherent degree of coding errors and accuracy of information transcription (54). We could not delineate if institutional death occurred in a nursing home or hospital, so we were forced to exclude nursing home residents from this analysis. Due to cell size limitations, we could not examine age as a continuous variable. We were thus forced to categorize the variable, though we used as many cut-offs as possible to promote the precision of statistical estimates. Finally, we lacked data on multimorbidity and frailty, two unique prognostic factors that would have added richness to this analysis (55).

Conclusion

We found that home care clients and nursing home residents had worse prognoses of 30-day and one-year survival post-cardiac arrest. We also demonstrated that older adults were less likely to die at home post-cardiac arrest. Our findings emphasize the need for proactive discussions about end-of-life care during admission and follow-up assessment in the home care and nursing home populations.

Conflicts of Interest

The authors have conflicts or competing interests to declare.

Acknowledgements

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Tables and Figures

Figure 1. Flow Diagram of Patient Inclusion and Survival

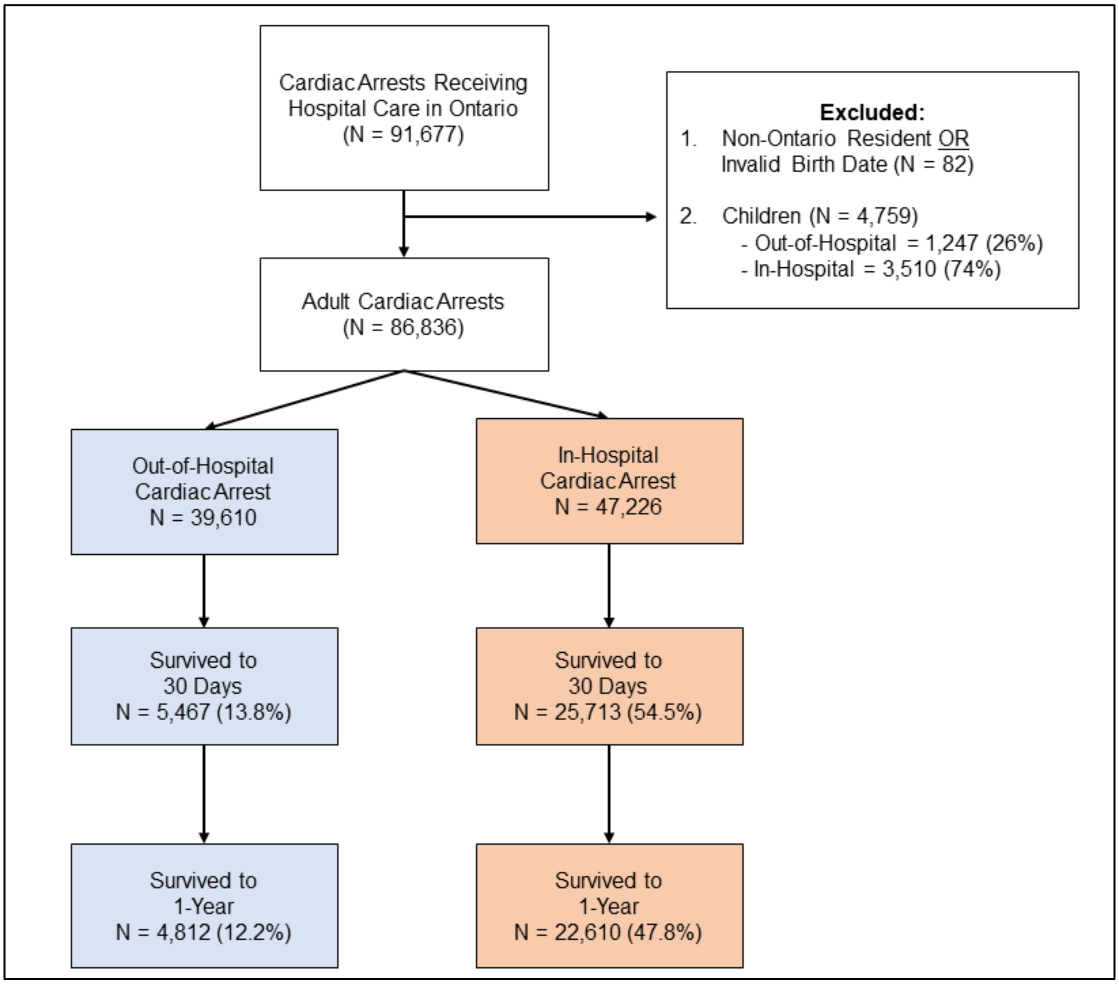
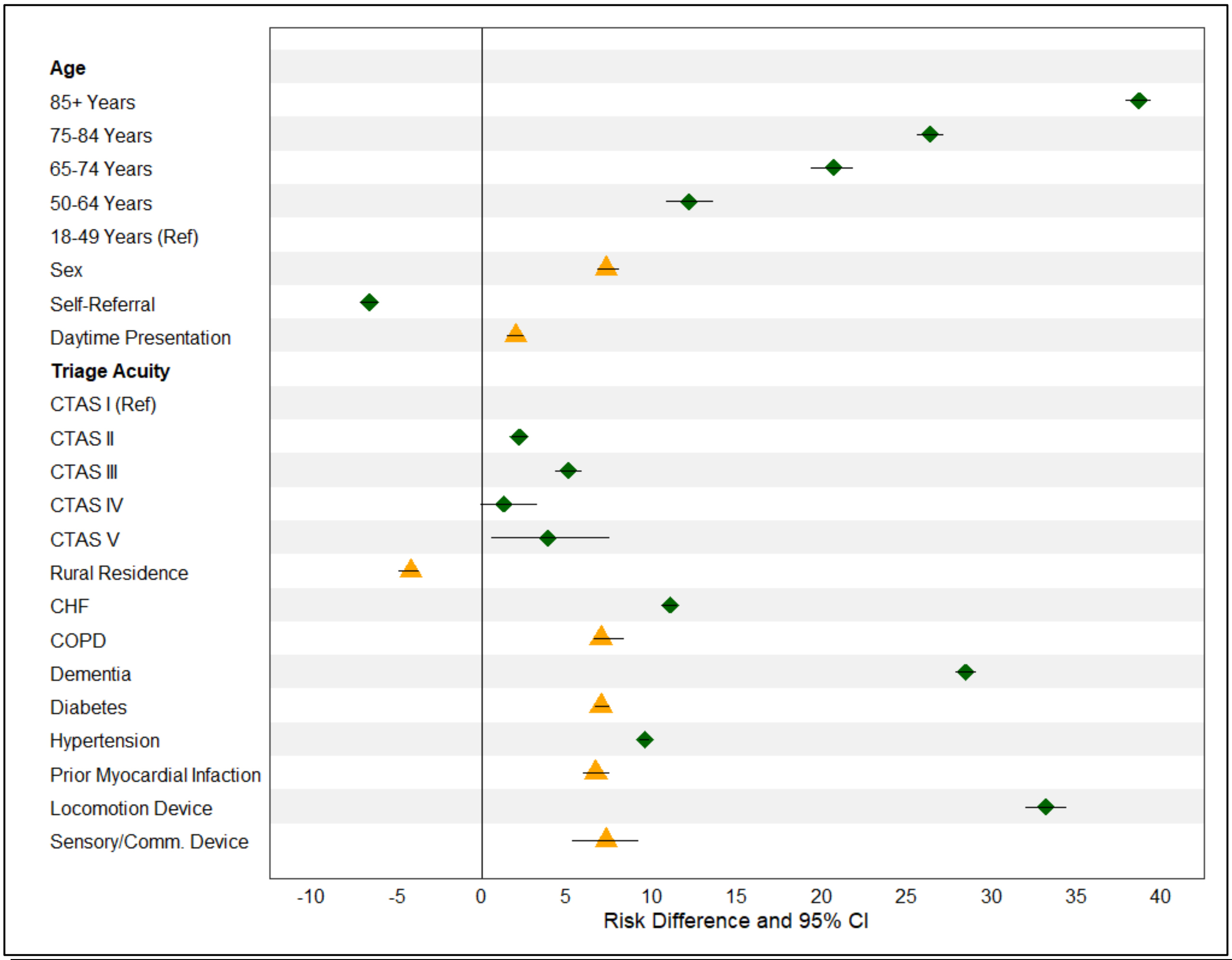


Figure 2. Patient Features Associated with Enrollment in Pre-Arrest Support Services Among 86,836 Individuals who Experienced Cardiac Arrest in Ontario, Canada



CI = Confidence Interval; CHF = Congestive Heart Failure; COPD = Chronic Obstructive Pulmonary Disease; CTAS = Canadian Triage Acuity Scale; Ref = Reference Group

Figure 3. Probability of Survival to 30-days Post-Cardiac Arrest Between Support Needs for 86,836 Individuals who Experienced Cardiac Arrest in Ontario, Canada

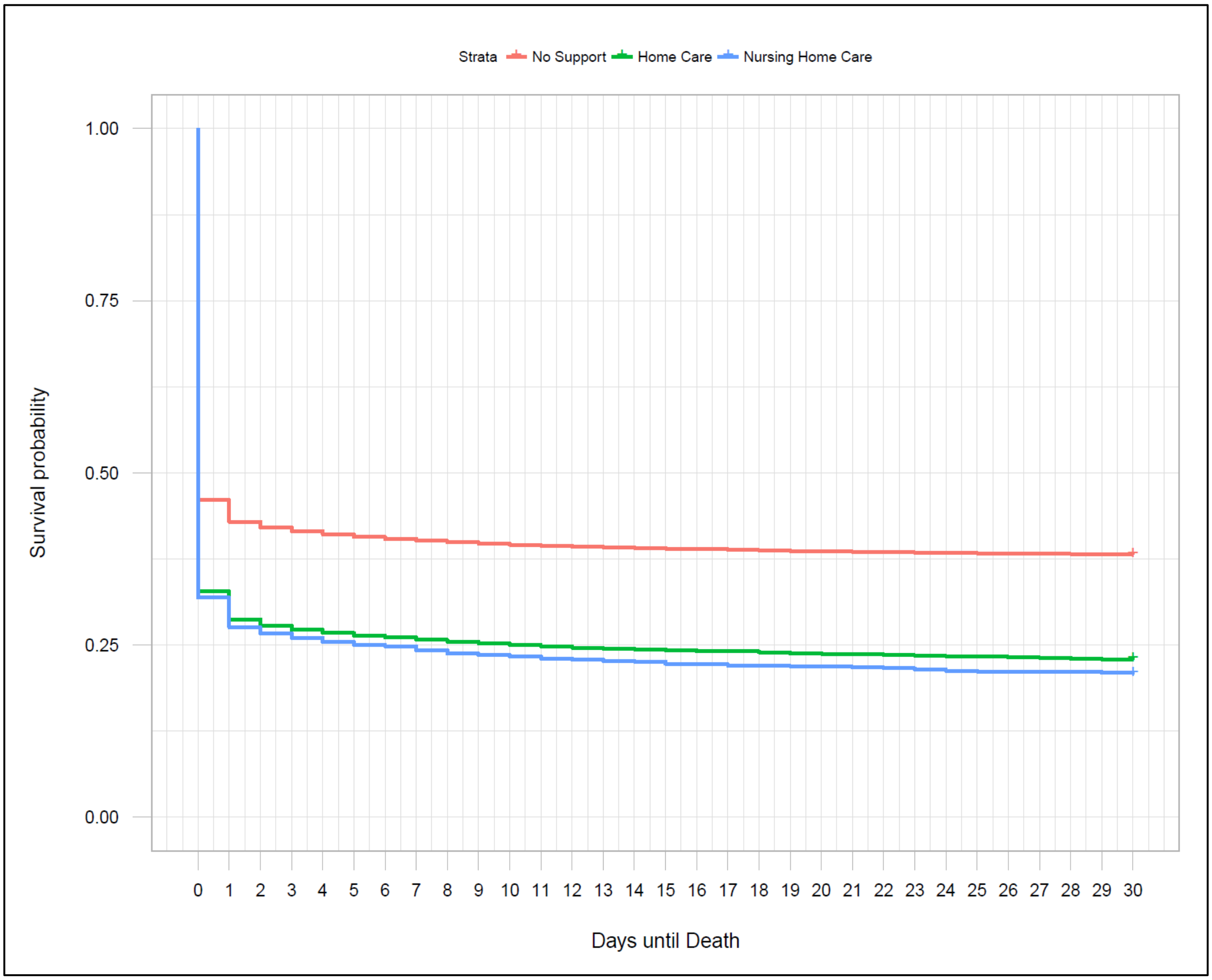


Figure 4. Forest Plot of Adjusted Risk Differences of 30-Day and One-Year Survival Between Pre-Arrest Support Services Compared to No Pre-Arrest Support Needs (N = 86,836)

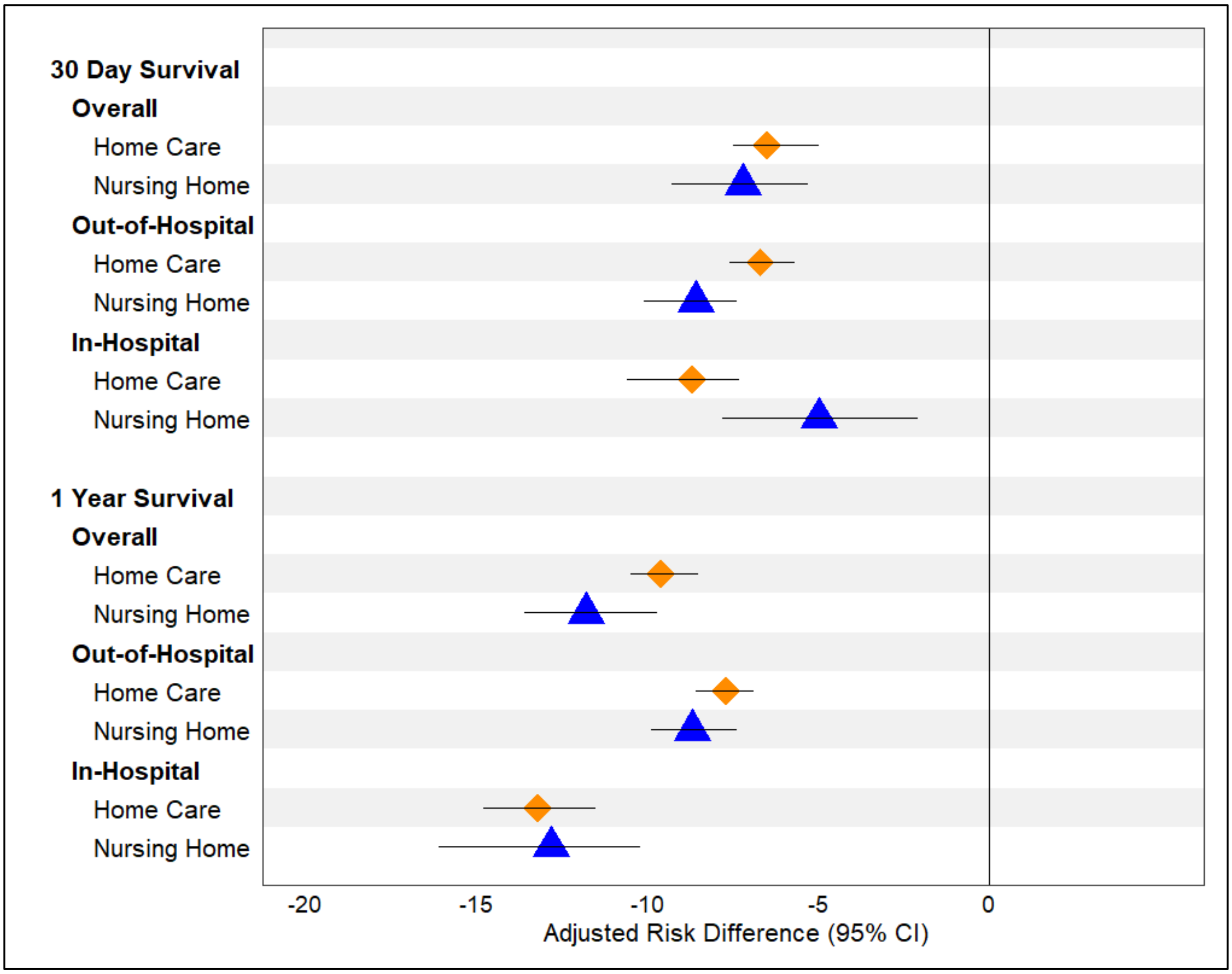


Table 1. Patient Features Compared Between Pre-Arrest Support Status in 86,836 Adults Who Experienced Cardiac Arrest

Variable	No Support N (%) 74,586 (85.9)	Home Care N (%) 9,316 (10.7)	Nursing Home N (%) 2,934 (3.4)	All Cardiac Arrests N (%)
Age (Years)				
85+	7,466 (10)	2,831 (30.4)	1,160 (39.5)	11,457 (13.2)
75 – 84	15,301 (20.5)	3,021 (32.4)	1,033 (35.2)	19,355 (22.3)
65 – 74	15,697 (21.0)	1,769 (18.9)	439 (15.0)	17,905 (20.6)
50 – 64	20,039 (26.9)	1,257 (13.4)	264 (9.0)	21,506 (24.8)
18 – 49	16,083 (21.6)	438 (4.7)	38 (1.3)	16,559 (19.1)
Sex (Female)	27,983 (37.5)	4,822 (51.7)	1,640 (55.9)	34,466 (39.7)
In-Hospital Arrest	40,526 (54.3)	5,240 (56.2)	1,460 (49.7)	47,226 (55.4)
Mode of Arrival (Walk-In)	13,254 (17.8)	1,146 (12.3)	113 (3.9)	14,513 (16.7)
Daytime Presentation *	44,474 (59.6)	5,995 (64.3)	1,796 (61.2)	52,265 (60.2)
Triage Acuity (CTAS)				
I	44,429 (59.6)	5,061 (54.3)	1,505 (51.2)	50,995 (58.9)
II	19,868 (26.6)	2,564 (27.5)	960 (33.7)	23,392 (27.0)
III	8,616 (11.6)	1,468 (15.8)	405 (13.8)	10,489 (12.1)
IV	1,057 (1.4)	143 (1.5)	30 (1.0)	1,230 (1.4)
V (Least Urgent)	422 (0.6)	59 (0.6)	25 (0.9)	506 (0.6)
Rural Residence	10,569 (14.2)	997 (10.7)	245 (8.4)	11,811 (13.6)
Diagnoses				
Congestive Heart Failure	21,902 (29.4)	4,840 (52.0)	1,379 (47)	28,121 (32.4)
COPD	26,468 (35.5)	4,716 (50.7)	1,366 (46.6)	32,550 (37.5)
Dementia	6,195 (8.3)	2,579 (27.7)	2,020 (68.8)	10,794 (12.4)
Diabetes	26,178 (35.1)	4,607 (49.5)	1,433 (48.8)	32,218 (37.1)
Hypertension	48,688 (65.3)	7,813 (84.0)	2,506 (85.4)	59,007 (67.9)
Prior Myocardial Infarction	7,566 (10.0)	1,556 (16.2)	385 (12.9)	10,866 (10.7)
Approved for Health Device				
Locomotion	2,270 (3.0)	1,546 (16.6)	537 (18.3)	44,353 (5.0)
Sensory & Communication	1,381 (1.8)	299 (3.2)	73 (2.4)	1,753 (2.0)
Autopsy Completed	1,423 (3.0)	81 (1.1)	17 (0.7)	1,521 (2.6)
Underlying Cause of Death				
Atherosclerotic Heart Disease	6,552 (13.4)	870 (11.3)	233 (9.2)	7,655 (13)
Acute Myocardial Infarction	6,410 (13.2)	763 (9.9)	209 (8.3)	7,382 (12.5)
COPD Exacerbation	1,138 (2.3)	335 (4.4)	79 (3.1)	1,552 (2.6)
Pneumonia	1,137 (2.3)	290 (3.7)	141 (5.6)	1,568 (2.7)
Diabetes	1,128 (2.3)	232 (3.0)	68 (2.7)	1,428 (2.4)

CI = Confidence Interval; COPD = Chronic Obstructive Pulmonary Disease; CTAS = Canadian Triage Acuity Scale

Table 2: Comparison of Pre-Arrest Features Between 39,610 (45.5%) Out-of-Hospital Arrests and 47,226 (55.5%) In-Hospital Arrests in Ontario, Canada

Variable	Out-of-Hospital	In-Hospital
Age (Years)		
85+	6,131 (15.5)	5,326 (11.3)
75 – 84	9,078 (22.9)	10,277 (21.8)
65 – 74	8,331 (21.0)	9,574 (20.3)
50 – 64	10,020 (25.3)	11,540 (24.4)
18 – 49	6,050 (15.3)	10,509 (22.3)
Sex (Female)	13,662 (34.5)	20,804 (44.1)
Mode of Arrival (Walk-In)	3,618 (9.1)	10,895 (23.1)
Daytime Presentation *	23,581 (59.5)	28,684 (60.7)
Triage Acuity (CTAS)		
I	32,936 (83.4)	18,059 (38.3)
II	4,355 (11)	19,037 (40.4)
III	1,640 (4.1)	8,849 (18.7)
IV	186 (0.4)	1,044 (2.2)
V (Least Urgent)	357 (0.9)	149 (0.3)
Rural Residence	5,899 (14.9)	5,912 (12.5)
Diagnoses		
Congestive Heart Failure	11,703 (29.5)	16,418 (34.8)
COPD	12,297 (31)	20,253 (42.9)
Dementia	4,225 (10.7)	6,569 (13.9)
Diabetes	14,105 (35.6)	18,113 (38.4)
Hypertension	26,825 (67.7)	32,182 (68.1)
Prior Myocardial Infarction	6,011 (15.2)	3,496 (7.4)
Pre-Arrest Support Services		
Homecare	4,076 (10.3)	5,240 (11.1)
Nursing Home	1,474 (3.7)	1,460 (3.1)
None	34,060 (86.0)	40,526 (85.8)
Approved for Health Device		
Locomotion	1,890 (4.8)	2,463 (5.2)
Sensory & Communication	806 (2.0)	947 (2.0)
Autopsy Completed	997 (2.9)	524 (2.1)
Underlying Cause of Death		
Atherosclerotic Heart Disease	6,434 (18.4)	1,312 (5.4)
Myocardial Infarction	5,698 (16.5)	1,684 (6.9)
COPD Exacerbation	566 (1.6)	989 (4.1)
Pneumonia	401 (1.2)	1,167 (4.8)
Diabetes	1126 (3.3)	302 (1.3)
COPD = Chronic Obstructive Pulmonary Disease; CTAS = Canadian Triage Acuity Scale		

Supplemental Table 1: Pre-Arrest Features Compared Between 12,250 Individuals who Required Pre-Arrest Support Services and Those Who Did Not

Variable	No Support N (%) 74,586 (85.9)	Home Care N (%) 9,316 (10.7)	Nursing Home N (%) 2,934 (3.4)	Outcome: Formal Support (N = 12, 250)	
				Odds Ratio (95% CI)	**Risk Difference %** (95% CI)
Age (Years)					
85+	7,466 (10)	2,831 (30.4)	1,160 (39.5)	18.10 (16.37-20.0)	38.7 (37.9 – 39.4)
75 – 84	15,301 (20.5)	3,021 (32.5)	1,033 (35.2)	8.95 (8.13-9.88)	26.4 (25.6 – 27.2)
65 – 74	15,697 (21)	1,759 (18.9)	439 (15.0)	4.75 (4.30-5.26)	20.7 (19.5 – 21.9)
50 – 64	20,039 (26.9)	1,257 (13.5)	264 (9.0)	2.56 (2.31-2.85)	12.2 (10.9 – 13.6)
18 – 49	16,083 (21.6)	438 (4.7)	38 (1.3)	–	–
Sex (Female)	27,983 (37.5)	4,822 (51.7)	1,640 (55.9)	1.85 (1.78-1.93)	7.3 (6.8 – 7.8)
Mode of Arrival (Walk-In)	13,254 (17.8)	1,146 (12.3)	113 (3.9)	0.53 (0.49-0.56)	-6.6 (-7.2 – -6.1)
Daytime Presentation *	44,474 (59.6)	5,995 (64.3)	1,796 (61.2)	1.18 (1.13-1.23)	2.0 (1.5 – 2.5)
Triage Acuity (CTAS)					
I	44,429 (59.6)	5,061 (54.3)	1,505 (51.2)	–	
II	19,868 (26.6)	2,564 (27.5)	960 (33.7)	1.2 (1.15-1.25)	2.2 (1.8 – 2.7)
III	8,616 (11.6)	1,468 (15.8)	405 (13.8)	1.47 (1.39-1.55)	5.1 (4.3 – 5.9)
IV	1,057 (1.4)	143 (1.5)	30 (1.0)	1.11 (0.93-1.29)	1.3 (-0.8 – 3.3)
V (Least Urgent)	422 (0.6)	59 (0.6)	25 (0.9)	1.34 (1.05-1.69)	3.9 (0.6 – 7.5)
Rural Residence	10,569 (14.2)	997 (10.7)	245 (8.4)	0.68 (0.64-0.72)	-4.2 (-4.9 – -3.7)
Diagnoses					
Congestive Heart Failure	21,902 (29.4)	4,840 (51.9)	1,379 (47)	2.48 (2.38-2.57)	11.1 (10.6 – 11.5)
COPD	26,468 (35.5)	4,716 (50.6)	1,366 (46.5)	1.79 (1.72-1.86)	7.0 (6.6 – 7.5)
Dementia	6,195 (8.3)	2,579 (27.6)	2,020 (68.9)	6.64 (6.34-6.94)	28.5 (27.9 – 29.1)
Diabetes	26,178 (35.1)	4,607 (49.5)	1,433 (48.8)	1.79 (1.73-1.87)	7.0 (6.7 – 7.5)
Hypertension	48,688 (65.3)	7,813 (83.8)	2,506 (85.4)	2.84 (2.70-3.0)	9.6 (9.3 – 9.9)
Prior Myocardial Infarction	7,566 (10.1)	1,556 (16.7)	385 (13.1)	1.64 (1.56-1.73)	6.7 (6.0 – 7.5)
Approved for Health Device					
Locomotion	2,270 (3.0)	1,546 (16.6)	537 (18.3)	6.52 (6.12-6.95)	33.2 (31.9 – 34.4)
Sensory & Communication	1,381 (1.8)	299 (3.2)	73 (2.4)	1.66 (1.47-1.86)	7.2 (5.3 – 9.2)

Autopsy Completed	1,423 (3.0)	81 (1.1)	17 (0.7)	0.32 (0.26-0.40)	-9.1 (-10.0 – -7.9)
Underlying Cause of Death					
Atherosclerotic Heart Disease	6,552 (13.4)	870 (11.3)	233 (9.2)	0.77 (0.72-0.83)	-2.8 (-3.5 – -2.1)
Acute Myocardial Infarction	6,410 (13.2)	763 (9.9)	209 (8.3)	0.69 (0.64-0.74)	- 4.1 (-4.8 – -3.3)
COPD Exacerbation	1,138 (2.3)	335 (4.4)	79 (3.1)	1.75 (1.57-1.97)	8.1 (6.4 – 10.2)
Pneumonia	1,137 (2.3)	290 (3.7)	141 (5.6)	1.83 (1.63-2.05)	8.8 (6.9 – 10.9)
Diabetes	1,128 (2.3)	232 (3.0)	68 (2.7)	1.27 (1.11-1.44)	3.2 (1.3 – 5.0)
CI = Confidence Interval; COPD = Chronic Obstructive Pulmonary Disease; CTAS = Canadian Triage Acuity Scale					

Supplemental Table 2: Pre-Arrest Characteristics Compared Between 48,717 Older Adults and Younger Counterparts

Variable	**Adult** 18 – 64 **N (%)** 38,119 (43.9)	**Older Adults** 65 – 84 **N (%)** 37,260 (42.9)	**Oldest Adults** 85+ Years **N (%)** 11,457 (13.2)	**Odds Ratio** (95% CI)	**Risk Difference** (95% CI)
Sex (Female)	13,470 (35.3)	14,967 (40.1)	6,008 (52.4)	X	X
Mode of Arrival (Walk-In)	7,128 (18.7)	6,209 (16.7)	1,176 (10.3)	0.78 (0.75-0.81)	-3.6 (-4.1 – -3.0)
Daytime Presentation *	21,617 (56.7)	23,320 (62.6)	7,328 (64)	1.29 (1.26-1.33)	5.5 (5.0 – 6.1)
Triage Acuity (CTAS)					
I	22,988 (60.5)	21,325 (57.4)	6,682 (58.4)	–	–
II	10,333 (27.1)	10,113 (27.2)	2,946 (25.8)	1.04 (1.01-1.07)	0.7 (0.2 – 1.3)
III	3,974 (10.5)	4,945 (13.3)	1,570 (13.8)	1.35 (1.29-1.41)	3.4 (2.8 – 3.8)
IV	538 (1.4)	530 (1.4)	162 (1.4)	1.06 (0.94-1.18)	0 (0 – 2.0)
V (Least Urgent)	184 (0.4)	252 (0.7)	70 (0.6)	1.43 (1.19-1.72)	0.2 (0.1 – 0.3)
Rural Residence	5,350 (14.1)	5,434 (14.1)	1,026 (9.0)	0.93 (0.9-0.97)	- 1.8 (-2.7 – -0.8)
Diagnoses					
Congestive Heart Failure	6,317 (16.5)	16,146 (43.3)	5,658 (49.4)	4.07 (3.95-4.21)	21.2 (21.0 – 21.6)
COPD	10,498 (27.5)	17,406 (46.7)	4,651 (40.6)	2.18 (2.11-2.24)	14.9 (14.4 – 15.3)
Dementia	1,181 (3.1)	5,944 (16.0)	3,669 (32)	7.68 (7.22-8.18)	14.2 (14.0 – 14.4)
Diabetes	10,693 (28.1)	17,361 (46.5)	4,164 (36.3)	2.03 (1.97-2.08)	13.7 (13.3 – 14.1)
Hypertension	17,769 (46.6)	30,987 (83.2)	10,251 (89.4)	6.31 (6.11-6.51)	20.8 (20.7 – 21.0)
Prior Myocardial Infarction	2,225 (5.7)	5,491 (14.3)	1,791 (15.2)	2.79 (2.65-2.92)	8.2 (7.9 – 8.4)
Pre-Arrest Support Services					
Homecare	1,695 (4.4)	4,790 (12.9)	2,831 (24.7)	4.22 (4.0-4.46)	40.8 (39.9 – 41.4)
Nursing Home	302 (0.8)	1,472 (4.0)	1,160 (10.1)	8.18 (7.27-9.25)	45.0 (44.7 – 45.2)
None	36,122 (94.8)	30,988 (83.1)	7,466 (65.1)	–	–
Approved for Health Device					
Locomotion	1,075 (2.8)	2,227 (6.0)	1,051 (9.1)	2.48 (2.31-2.61)	3.8 (3.5 – 3.9)
Sensory & Communication	281 (0.7)	874 (2.3)	589 (5.2)	4.20 (3.69-4.77)	2.2 (2.1 – 2.3)
Autopsy Completed	980 (5.0)	489 (1.8)	52 (0.5)	0.28 (0.25-0.31)	-3.1 (-3.4 – -2.9)
Underlying Cause of Death					
Atherosclerotic Heart Disease	2,372 (11.8)	3,947 (13.9)	1,336 (13.1)	1.17 (1.12-1.24)	1.8 (1.3 – 2.3)
Acute Myocardial Infarction	2,071 (10.3)	3,947 (13.9)	1,364 (13.4)	1.38 (1.31-1.45)	3.4 (2.8 – 3.9)
COPD Exacerbation	293 (1.5)	1,041 (3.6)	218 (2.1)	2.27 (2.0-2.58)	1.8 (1.6 – 2.1)
Pneumonia	340 (1.7)	758 (2.7)	470 (4.6)	1.90 (1.69-2.14)	1.6 (1.3 – 1.8)
Diabetes	404 (2.0)	829 (2.9)	195 (1.9)	1.32 (1.18-1.49)	0.7 (0.5 – 0.09)

Supplemental Table 3: Risk of In-hospital Cardiac Arrest in 86,836 Individuals who Received Hospital Care for Cardiac Arrest

Variable	OHCA N=39,610 (45.6%)	IHCA N=47,226 (55.4%)	All Cardiac Arrests N (%)	Outcome: In-Hospital Cardiac Arrest	
				Odds Ratio (95% CI)	Risk Difference (%) (95% CI)
Age (Years)					
85+	6,131 (15.5)	5,326 (11.3)	11,457 (13.2)	0.5 (0.48-0.52)	-17.7 (-18.9 – -16.8)
75 – 84	9,078 (22.9)	10,277 (21.8)	19,355 (22.3)	0.65 (0.63-0.68)	-11.2 (-12.1 – -10.0)
65 – 74	8,331 (21.0)	9,574 (20.3)	17,905 (20.6)	0.66 (0.63-0.69)	-11.2 (-12.0 – -9.6)
50 – 64	10,020 (25.3)	11,540 (24.4)	21,506 (24.8)	0.66 (0.64-0.69)	-10.9 (-11.7 – -9.7)
18 – 49	6,050 (15.3)	10,509 (22.3)	16,559 (19.1)	–	–
Sex (Female)	13,662 (34.5)	20,804 (44.1)	34,466 (39.7)	1.49 (1.45-1.53)	8.9 (8.4 – 9.5)
Mode of Arrival (Walk In)	3,618 (9.1)	10,895 (23.1)	14,513 (16.7)	2.98 (2.86-3.1)	21.9 (21.3 – 22.5)
Daytime Presentation *	23,581 (59.5)	28,684 (60.7)	52,265 (60.2)	1.05 (1.02-1.08)	1.2 (0.05 – 1.8)
Triage Acuity (CTAS)					
I	32,936 (83.4)	18,059 (38.3)	50,995 (58.9)	–	–
II	4,355 (11)	19,037 (40.4)	23,392 (27.0)	7.97 (7.67-8.27)	30.4 (30.1 – 30.6)
III	1,640 (4.1)	8,849 (18.7)	10,496 (12.1)	9.84 (9.31-10.41)	34.5 (34.1 – 34.8)
IV	186 (0.4)	1,044 (2.2)	1,230 (1.4)	10.2 (8.77-12.0)	37.2 (36.1 – 38.2)
V (Least Urgent)	357 (0.9)	149 (0.3)	506 (0.6)	0.76 (0.62-0.92)	-6.8 (-11.9 – -2.1)
Rural Residence	5,899 (14.9)	5,912 (12.5)	11,811 (13.6)	0.82 (0.79-0.85)	-5.0 (-6.0 – -4.1)
Diagnoses					
Congestive Heart Failure	11,703 (29.5)	16,418 (34.8)	28,121 (32.4)	1.27 (1.23-1.31)	5.6 (4.9 – 6.3)
COPD	12,297 (31)	20,253 (42.9)	32,550 (37.5)	1.67 (1.62-1.71)	11.2 (10.6 – 11.7)
Dementia	4,225 (10.7)	6,569 (13.9)	10,794 (12.4)	1.35 (1.3-1.41)	7.2 (6.3 – 8.1)
Diabetes	14,105 (35.6)	18,113 (38.4)	32,218 (37.1)	1.12 (1.09-1.16)	2.7 (2.1 – 3.5)
Hypertension	26,825 (67.7)	32,182 (68.1)	59,007 (67.9)	1.02 (0.99 – 1.05)	0.5 (-0.3 – 1.2)
Prior Myocardial Infarction	6,011 (15.2)	3,496 (7.4)	10,866 (10.7)	0.45 (0.43-0.47)	-20.3 (-21.4 – -19.3)
Pre-Arrest Support Services					
Homecare	4,076 (10.3)	5,240 (11.1)	9,316 (10.7)	1.08 (1.04 – 1.13)	1.9 (1.0 – 3.0)
Nursing Home	1,474 (3.7)	1,460 (3.1)	2,934 (3.4)	0.83 (0.77 – 0.90)	-4.7 (-6.5 - -2.6)
None	34,060 (86.0)	40,526 (85.8)	74,586 (85.9)	–	–
Approved for Health Device					
Locomotion	1,890 (4.8)	2,463 (5.2)	44,353 (5.0)	1.10 (1.03 – 1.17)	2.3 (0.7 – 3.8)
Sensory & Communication	806 (2.0)	947 (2.0)	1,753 (2.0)	0.99 (0.89 – 1.08)	-0.2 (-2.9 – 1.5)
Autopsy Completed	997 (2.9)	524 (2.1)	1,521 (2.6)	0.64 (0.57 – 0.71)	-11.2 (-14.1 – -8.6)

Underlying Cause of Death					
Atherosclerotic Heart Disease	6,434 (18.4)	1,312 (5.4)	7,655 (13)	0.25 (0.24-0.27)	-34.1 (-35.1 – -32.5)
Myocardial Infarction	5,698 (16.5)	1,684 (6.9)	7,382 (12.5)	0.38 (0.36 – 0.40)	-24.6 (-25.8 – -24.6)
COPD Exacerbation	566 (1.6)	989 (4.1)	1,552 (2.6)	2.53 (2.28-2.81)	20.3 (18.3 – 22.2)
Pneumonia	401 (1.2)	1,167 (4.8)	1,568 (2.7)	4.2 (3.82-4.8)	25.2 (24.0 – 26.4)
Diabetes	1126 (3.3)	302 (1.3)	1,428 (2.4)	0.37 (0.33-0.42)	-24.1 (-26.5 – -21.3)

Supplemental Table 4: Adjusted Relative Risk of Survival and Death Location in 86,636 Individuals

	30-Day Survival N=31,180 (35.9%)	**1-Year Survival** N=27,422 (31.6%)	**Home Death** N = 4,584 (5.4%)
Support Status			
Homecare	0.75 (0.71-0.80)	0.62 (0.59-0.66)	0.96 (0.87-1.05)
Nursing Home	0.72 (0.65-0.79)	0.54 (0.48-0.61)	**NA**
No Support	–	–	–
Age			
85+	0.11 (0.10-0.12)	0.09 (0.08-0.10)	0.57 (0.51-0.64)
75 – 84	0.21 (0.20-0.22)	0.18 (0.17-0.19)	0.65 (0.58-0.71)
65 – 74	0.33 (0.31-0.34)	0.28 (0.27-0.30)	0.66 (0.59-0.72)
50 – 64	0.50 (0.48-0.52)	0.47 (0.45-0.48)	0.82 (0.74-0.90)
18 – 49	–	–	–
Sex (Male)	0.73 (0.71-0.75)	0.72 (0.70-0.75)	1.01 (0.95-1.08)

Data presented as odds ratio (95% confidence intervals)
Note: Nursing home residents (N=2,934) were excluded from analysis of death location

Supplemental Table 5: Adjusted Relative Risk of Survival and Death Location in 39,610 Out-of-Hospital Cardiac Arrests

	30-Day Survival N=5,467 (13.8%)	**1-Year Survival** N=4,813 (12.1%)	**Home Death** N = 2634 (6.9%)
Support Status			
Homecare	0.50 (0.44-0.57)	0.37 (0.31-0.43)	0.81 (0.70-0.93)
Nursing Home	0.35 (0.26-0.44)	0.27 (0.19-0.37)	**NA**
No Support	–	–	–
Age			
85+	0.35 (0.31-0.40)	0.28 (0.24-0.32)	0.65 (0.56-0.76)
75 – 84	0.59 (0.53-0.65)	0.51 (0.46-0.56)	0.83 (0.73-0.94)
65 – 74	0.75 (0.53-0.65)	0.70 (0.63-0.77)	0.76 (0.67-0.87)
50 – 64	0.95 (0.87-1.03)	0.91 (0.84-0.99)	0.86 (0.76-0.97)
18 – 49	–	–	–
Sex (Male)	0.91 (0.86-0.96)	0.89 (0.84-0.96)	0.97 (0.89-1.07)

Data presented as odds ratio (95% confidence intervals)
Note: Nursing home residents (N=2,934) were excluded from the analysis of death location

Supplemental Table 6: Adjusted Relative Risk of Survival and Death Location in 47,225 In-Hospital Cardiac Arrests

	30-Day Survival N=25,713 (55.5%)	**1-Year Survival** N=23,812 (50.4%)	**Home Death** N = 4,584 (9.7%)
Support Status			
Homecare	0.71 (0.66-0.75)	0.59 (0.55-0.63)	1.10 (0.96-1.25)
Nursing Home	0.82 (0.73-0.92)	0.59 (0.51-0.66)	**NA**
No Support	–	–	–
Age			
85+	0.07 (0.06-0.07)	0.06 (0.06-0.07)	0.44 (0.37-0.52)
75 – 84	0.11 (0.10-0.12)	0.10 (0.09-0.11)	0.43 (0.36-0.50)
65 – 74	0.19 (0.18-0.20)	0.17 (0.16-0.18)	0.49 (0.41-0.57)
50 – 64	0.35 (0.32-0.37)	0.33 (0.31-0.35)	0.71 (0.61-0.84)
18 – 49	–	–	–
Sex (Male)	0.87 (0.84-0.90)	0.86 (0.83-0.90)	1.05 (0.96-1.16)

Data presented as odds ratio (95% confidence intervals)
Note: Nursing home residents (N=2,934) were excluded from analysis of death location

Supplemental Table 7: STROBE Reporting Checklist

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	1
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	2
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	2-3
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	3/4
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	2
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4/5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5/6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1

		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1/2 Figure 1/2
		(b) Indicate number of participants with missing data for each variable of interest	Supplemental Table
		(c) Summarise follow-up time (eg, average and total amount)	3
Outcome data	15*	Report numbers of outcome events or summary measures over time	7-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Figure 2 Supplemental Tables 1-3
		(*b*) Report category boundaries when continuous variables were categorized	4
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7-9
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7-9
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11/12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10/11
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

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CHAPTER FOUR

Prognostic Association Between Frailty and Post-Arrest Health Outcomes in Patients Receiving Home Care: A Population-Level Cohort Study

Summary

This chapter contains a prognostic factor study evaluating the association between frailty and post-cardiac arrest health outcomes. A sub-group of patients receiving home care from the prior study cohort was utilized, excluding those without home care assessments in the six months pre-arrest. Frailty was measured using two valid instruments – the Clinical Frailty Scale and a frailty index. Frailty was operationalized both as binary and full forms of the measures. This study builds on the previous chapter by evaluating how distinct geriatric syndromes within the home care population are prognostic of survival. This study is novel in evaluating post-cardiac arrest declines in functional independence and cognitive performance.

Frailty was associated with survival using both frailty measures in both binary and full forms and remained significant after adjusting for age, sex, and arrest setting. Associations remained significant within distinct sub-groups of OHCA and IHCA. Frailty was associated with a decline in functional independence and cognitive performance only when using the more detailed frailty indices, suggesting geriatric syndromes unique to these two measures are prognostic of outcomes beyond survival. I (Fabrice Mowbray) was primarily responsible for the study ideation, analysis, and drafting of the original manuscript.

Citation:

Mowbray, F.I., Turcotte, L., Strum R.P., De Wit, K., Worster, A., Griffith, L.E., Mercier E, Heckman, G., Hebert, P., Schumacher C, Gayowski, A., Costa, A.P. (2022). Prognostic association between frailty and post-arrest health outcomes in patients receiving home care: A population-based cohort study. *Resuscitation.* [*in*-review]

ABSTRACT

Aim: To evaluate the association between frailty and post-arrest survival, functional decline, and cognitive decline, among patients receiving home care.

Methods: We conducted a population-based retrospective cohort study of patients receiving home care in Ontario, Canada, linking administrative health data sets to interRAI home care assessments. Frailty was measured using the Clinical Frailty Scale (CFS) and a valid frailty index. We used multivariable logistic regression to measure the association between frailty and post-arrest outcomes after adjusting for age, sex, and arrest setting. Functional independence and cognitive performance were measured using the interRAI ADL Long-Form and Cognitive Performance Scale, respectively.

Results: Our cohort consisted of 7,901 patients receiving home care; most patients arrested out-of-hospital (55.4%) and were 75 years or older (66.3%). The 30-day survival rate was 14.8%, and most patients who survived to discharge had declines in post-arrest functional independence (65.8%) and cognitive performance (46.5%). A one-point increase in the CFS decreased the odds of 30-day survival by 8% (aOR=0.92; 95%CI = 0.87-0.97). A 0.1 unit increase in the frailty index reduced survival odds by 9% (aOR = 0.91; 95%CI = 0.86-0.96). The frailty index was associated with declines in functional independence (OR = 1.16; 95%CI = 1.02-1.31) and cognitive performance (OR = 1.24; 95%CI = 1.09-1.42), while the CFS was not.

Conclusion: Frailty is associated with cardiac arrest survival and post-arrest cognitive and functional decline in patients receiving home care. Post-cardiac arrest cognitive and functional status are best predicted using more comprehensive frailty indices.

Introduction

Frailty is a multidimensional syndrome characterized by a heightened vulnerability to adverse health events and diminished homeostatic recovery from stressors (1,2). Frailty has proven to be a robust predictor of patient-important health outcomes like survival and quality of life (3,4). Thus, an emphasis has been placed on measuring frailty using routine clinical assessments (5–8). Clinicians and resuscitation scientists have recently acknowledged and validated the prognostic value of frailty for advance care planning (9,10).

The home care population is medically complex, with a high prevalence of frailty and a greater risk for cardiac arrest, given their advanced age and high rates of cardiopulmonary disease (11,12). In Canada, individuals receiving publicly-funded home care services in many provinces are assessed using the interRAI Resident Assessment Instrument Home Care (RAI-HC) (13). Several frailty measures can be derived from the interRAI assessments (14–17), which could be used for proactive and informed decision-making regarding end-of-life preferences, including those related to cardiopulmonary resuscitation. While cardiac arrest prognosis was previously studied in nursing home residents (18–21), little is known about related outcomes in community-dwelling individuals receiving home care services.

Our primary objective was to examine the association between frailty and survival following cardiac arrest in patients receiving home care using two validated frailty measures. Our secondary objective was to examine the association between frailty and post-arrest changes in functional independence and cognitive performance. Our tertiary objective was to evaluate the association between distinct geriatric syndromes commonly used to define valid measures of frailty and post-cardiac arrest survival.

Methods

Study Design

We conducted a population-based retrospective cohort study linking multiple de-identified and validated administrative health datasets housed within ICES, a not-for-profit organization with 75+ provincial data sets in Ontario, Canada. We were granted a waiver of ethics review from the Hamilton Integrated Research Ethics Board (HiREB), as informed consent is not required to leverage this data in accordance with Section 45 of Ontario's Personal Health Information Protection Act. We reported our findings in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (22).

Data Sources

We identified patients receiving publicly-funded long-stay home care (>60 days) using the Home Care Reporting Dataset, a population-based dataset. RAI-HC assessments were extracted from the Home Care Dataset. The RAI-HC contains over 250 assessment items and evaluates various health domains, including function, cognition, communication, psychosocial well-being, disease profiles, symptomology, medication and clinical intervention, and health service needs, among other factors (23). The content and construct validity of the RAI-HC and its encompassing assessment items have been validated on an international scale (24–26). This dataset did not have data from less detailed interRAI contact assessments.

We obtained follow-up data on post-arrest function and cognition from the most recent post-discharge interRAI assessment occurring within one-year post-cardiac arrest. Post-arrest interRAI assessments that occurred within one-year post-arrest were extracted from publicly funded home care, long-term care, or post-acute care settings. Where multiple post-arrest assessments were available, we used the assessment most proximal to the arrest date, irrespective of the assessment setting.

We classified cardiac arrests that occurred pre-hospital or within the emergency department (ED) as out-of-hospital and were identified using the National Ambulatory Care Reporting System (NACRS). Cardiac arrests identified within the NACRS dataset are commonly classified as out-of-hospital (27,28), as most cardiac arrests managed in the ED occur in the pre-hospital setting. We extracted data on patient age and sex from the Registered Persons Database and used the Vital Statistics and Death database to determine the etiology and date of death. The databases used in this study are routinely checked for quality and have been validated for clinical and health services research in Ontario and Canada (26,29).

Study Population

We included all long-stay home care clients who received cardiac arrest care from a hospital in Ontario, Canada, between January 1st, 2006 and March 31st, 2018. Specifically, we included patients 18 and older who were transported to the hospital for cardiac arrest care and those hospitalized who arrested within 72 hours of ED registration. The ED registration time was utilized as the reference point for time-based measures, as it signals the first interaction with the hospital system. We selected a 72-hour time frame to mitigate the risk of health decline found with lengthy hospital admissions (30,31). Prior work has demonstrated that in-hospital arrests are most likely to occur within two days of hospital admission (32). We excluded those without a valid Identification Key Number and birth or death date. We also excluded patients without a RAI-HC assessment in the six-month (180-days) pre-arrest to ensure assessment data accurately depicts patient features.

We used a validated set of Canadian Classification of Health Interventions codes were used to identify those who received cardiopulmonary resuscitation (IHZ30JN, IHZ3OJY) and International Classification of Disease codes to identify the incidence of cardiac arrest (I46.1, I46.2, I46.8, I49.0, 149.01, I49.02, R960, R96.1, R98, R99) (27,28,33). We used the first event in cases where two arrests occurred within the study period. We excluded patients who underwent surgery pre-arrest during their index hospital visit best capture arrests caused by exacerbated medical illness rather than surgical or traumatic etiologies, which are less common and require different clinical interventions (32).

Patient Characteristics and Exposures

We measured age as a categorical variable due to data privacy limitations within ICES, with years of age collapsed to 18-49, 50-64, 65-74, 75-84, and 85+ years. We assumed patients enrolled in hospice services or palliative care goals were binned together and assumed to have indicated a preference not to undergo cardiopulmonary resuscitation. We assessed triage acuity following ED registration using the Canadian Triage Acuity Scale, a five-item ordinal scale used across Canada with scores of one indicating the highest medical acuity (34).

We measured cognitive performance was measured using a validated measure, the Cognitive Performance Scale (35–37), with scores ranging from zero (intact) to six (very severe impairment) based on performance with decision-making, verbal expression, and short-term memory. The Cognitive Performance Scale has been validated against gold standards for cognitive assessment like the Mini-Mental State Exam, the Montreal Cognitive Assessment (36,38), and the clinical assessment of regulated health care providers (37). Impaired comprehension was defined as any person unable to understand a conversation or direction *sometimes*, *usually*, or *always.* For descriptive statistics, we measured functional independence using the Activities of Daily Living (ADL) Hierarchy Scale, a validated scale ranging from zero (independent) to six (total dependence) based on dependency on eating, personal hygiene, toilet use, and locomotion (39).

We measured health instability using the Changes in Health, End-Stage Disease and Signs and Symptoms (CHESS) (40,41). The CHESS is predictive of overall mortality and ranges from zero (no health instability) to five (very high instability) based on: changes in decision-making capacity or independence with ADLs, palliative care referral, edema, weight loss, malnutrition, or dyspnea (40). We defined caregiver distress as the expression of stress, anger, or depression from a non-professional caregiver. We defined polypharmacy as taking five or more medications simultaneously (42). Pre-arrest ED use or hospitalization (with an overnight stay) were extracted from the RAI-HC for all events that occurred within 90 days prior to the assessment.

Frailty. Frailty was measured using the Clinical Frailty Scale (CFS) and a valid frailty index that was derived for use within the RAI-HC. The CFS is a 9-item ordinal scale that ranges from one (very fit) to nine (terminally ill), is commonly used to predict survival post-cardiac arrest, and has been validated for retrospective calculation (43,44). The frailty index was calculated as a health deficit accumulation model using 43 items (see supplemental file) from the RAI-HC and is predictive of mortality and admission to long-term care (45,15,46). We elected to use this frailty index over a more comprehensive 83-item frailty index calculated from the RAI-HC to decrease the likelihood of overfitting statistical models (46). We operationalized frailty measures in their full forms to leverage the benefits of their granularity and adhere to best practices in frailty measurement (47). We also provide estimates of the association between frailty measures and

Outcomes

The primary outcome for our study was 30-day survival, using the date of arrest as the reference point. Our secondary outcomes for this study include one-year survival and declines in functional independence or cognitive performance compared to pre-arrest function. We defined a decline in physical independence as an increase in ADL Long-Form Scale in the RAI-HC from the pre-arrest score. The ADL Long-Form is the most sensitive of all interRAI scales when assessing functional independence over time, with scores ranging between 0-28 based on independence in tasks of eating, bathing, toilet use, personal hygiene, dressing, locomotion, and bed mobility (39,48,49). We defined a decline in cognitive performance as an increase in the Cognitive Performance Scale from pre-arrest assessment. Those with a maximum score pre-arrest ADL Long-Form and Cognitive Performance Scale were excluded from outcomes beyond survival to avoid possible ceiling effects (see figure 1). Outcomes for this study are patient-important and recommended for evaluation by the Core Outcome Set for Cardiac Arrest (COSCA) initiative and the International Consortium for Health Outcome Measurement – Older Person Working Group (50,51).

Analysis

We reported descriptive statistics using measures of frequency and central tendency. We calculated odds ratios and 95% confidence intervals using multivariable logistic regression. We provide both unadjusted and adjusted associations between frailty and post-arrest outcomes. Adjusted models controlled for age, sex, and arrest setting (in-hospital versus out-of-hospital). These factors can influence survival and the likelihood of bystander response to cardiac arrest (52–54). Associations between post-arrest outcomes and the CFS were evaluated and reported using a one-point increase as the unit of measurement and a 0.1 unit increase for the frailty index. We conducted a sub-group analysis of associations within distinct cohorts of in-hospital and out-of-hospital arrests. Finally, we also evaluated the associations between pre-arrest features and 30-day survival. Missing data were scant (< 1%) for pre-arrest assessment data and were deleted within each analysis. Data were managed and analyzed in **R** version 3.1.

Results

Our cohort contained 7,901 home care clients who received hospital care for cardiac arrest, representing 85% of the overall cohort and those who received a RAI-HC assessment within six months pre-arrest. Most arrests occurred out-of-hospital (55.5%), and one-fifth (26.0%) survived to hospital discharge or transfer. Less than 2% of the cohort had documented palliative goals of care or were actively receiving palliative care services. The median time between arrest and pre-arrest assessment was 66 days (IQR = 88), and 70 days (IQR = 94) for post-arrest assessment. Pre-arrest frailty and health instability were similar between those with (46%) and without (47%) assessment data post-discharge (see supplemental file). *Figure 1* displays the patient flow diagram and proportion of health outcomes in the cohort.

One-half of patients had mild-to-severe cognitive impairment (49.9%), and 28% had a diagnosis of dementia. The need for assistance with ADLs was documented for roughly one-half of the cohort (46.7%). One-fifth (23.1%) of patients received a CHESS score of three or greater, indicating pre-arrest health instability. The median CFS score was six, and the median frailty index score was 0.3 (range = 0-0.64). Those who arrested out-of-hospital were more likely to be older (85 years; 36.7% versus 27.8%) and diagnosed with dementia (21.9% vs 16.4%). *Table 1* describes the pre-arrest features for the overall cohort and compares in-hospital and out-of-hospital arrests.

Survival

A total of 1,165 (14.8%) survived to 30 days post-arrest, and 744 (9.8%) were alive at one-year. Figure 2 displays a forest plot of the associations between frailty scores and survival, functional decline, and cognitive decline, after adjusting for age, triage acuity, and arrest setting. A one-point increase in the CFS resulted in a 9% reduction in 30-day survival (OR = 0.91; 0.86-0.96) and a 12% reduction in one-year survival (OR=0.88; 95%CI = 0.83-0.94). Similarly, a 0.1-unit increase in the frailty index reduced the odds of 30-day survival by 8% (OR=0.92; 95%CI = 0.87-0.97) and 1-year survival by 13% (OR = 0.87; 95%CI = 0.82-0.83). Adjusted and unadjusted associations, along with AUROC values, are displayed across the range CFS and Armstrong Index in the supplemental file.

Post-Arrest Decline in Functional Independence and Cognitive Performance

Of those who survived and received a RAI-HC assessment post-discharge, most survivors experienced a functional decline (65.8%), and roughly half (46.5%) had cognitive decline. These outcomes were significantly associated with frailty when measured using the frailty index, with a 0.1-unit increase increasing the odds of functional decline by 16% (OR = 1.16; 95%CI = 1.02-1.31) and the odds of cognitive decline by 24% (OR = 1.24; 95%CI = 1.09-1.42). The CFS was not associated with these outcomes.

Pre-Arrest Features Associated with 30-Day Survival

Older age was associated with a lower likelihood of survival, with those 85 years and older having 78% lower odds of surviving to 30-days post-cardiac arrest (OR = 0.22; 95%CI 0.16-0.29) compared to those between 18-49 years. Females were more likely to survive to 30-days post-arrest (OR = 1.14; 95%CI = 1.02-1.30). Those with severe or very severe cognitive impairment (CPS 5-6) had 47% lower odds of survival to 30 days compared to those with intact or borderline intact performance (CPS 0-1; OR = 0.53; 95%CI = 0.47-0.71). Those who required assistance with ADL also had lower odds of 30-day survival (OR = 0.76; 95%CI = 0.67-0.86). Chronic obstructive pulmonary disease appears to have a crude protective effect (OR = 1.60; 95%CI = 1.41-1.83). However, most with chronic obstructive pulmonary disease did not have cardiac comorbidities like congestive heart failure (33%) or coronary artery disease (38%) and were more likely to arrest in hospital than out-of-hospital (31% vs 26%). Figure 3 displays a forest plot of pre-arrest features and their crude associations with 30-day survival.

Discussion

In this study, we documented that frailty, regardless of how it was measured, was independently associated with a significant decrease in 30-day and one-year survival. Specifically, each 1-point increase in the CFS was associated with an 8% decline in post-cardiac arrest survival among home care clients. Similar decreases in survival were noted with each 0.1 increase in the frailty index. Fewer than 15% survived to 30 days, and the majority assessed post-discharge had functional or cognitive decline post-arrest (77.4%) and greater health instability (53.7%).

Comparison to Prior Relevant Studies

We validate prior studies demonstrating a relationship between frailty and survival following cardiac arrest. However, almost all studies focus solely on in-hospital cardiac arrest, a single frailty measure, and are at greater risk for statistical fragility given the relatively small sample sizes (55–60). However, an association between frailty and out-of-hospital arrests has been reported (61). A recent study by Jonsson and colleagues (60) found no difference between admission and discharge cognition for those arresting in-hospital. However, this study differed from ours in that they only included those who survived to 30 days post-cardiac arrest (i.e., healthier) and utilized the Cerebral Performance Category scale to operationalize cognition.

Almost all prior resuscitation studies used the CFS to operationalize frailty, with a cut-off of five or greater used in all studies except one, which used a cut-off of six (56). We evaluated all cut-offs of the CFS, and using a higher cut-off of six or seven significantly improved the discriminative accuracy of our model (see supplemental file). To our knowledge, no studies exist evaluating the association between a frailty index and post-cardiac arrest outcomes.

Implications

The odds of survival after cardiac arrest were low in patients receiving pre-arrest home care services, irrespective of arrest setting, with less than 10% surviving to one year. Poor survival and a high prevalence of frailty in patients receiving home care underscores the importance of pragmatic discussions and shared decision-making about end-of-life preferences upon service enrollment and during follow-up assessments. Our study showcases the importance of reassessing home care clients and their care goals upon return from the hospital, considering most patients discharged from the hospital had declines in functional independence or cognitive performance and greater health stability compared to pre-arrest assessment. Re-assessment of support needs (e.g., personal support, hours of care) and referrals (e.g., memory clinic, geriatrician) may be needed, given the risk for worse functional independence and cognitive performance post-arrest. Caregivers should be included in the discussions of advance care planning and care needs and evaluated for signs of distress, as their responsibilities and overall care load are like to increase post-arrest. In the out-of-hospital setting, frailty can complement intra-arrest factors commonly reported (e.g., bystander response, initial cardiac rhythm, etc.) to inform discussions between paramedics and physicians about termination-of-resuscitation in home care clients.

Both frailty measures were associated with post-arrest survival after statistical adjustment, suggesting that the evaluation of frailty for advance care planning is informative and frailty offers prognostic value above and beyond key prognostic factors of age, sex, and arrest setting. We found that frailty is associated with declines in functional independence and cognitive performance, two outcomes reported to be important by patients, geriatricians, and resuscitation scientists (50,51,62). However, the association was only found when using the frailty index, suggesting more detailed assessments or assessment items unique to the more comprehensive frailty index (e.g., symptomology, nutrition, mood, etc.) are more sensitive to prognosticating health declines post-arrest (supplemental file).

Strengths and Limitations

Our study is novel in providing a population-based evaluation of frailty on a broad range of post-cardiac arrest outcomes among patients receiving home care services (10). However, for in-hospital arrests, we could not provide data on all arrests, as data were only available for in-hospital arrests that occurred within a 72-hour window. However, this allowed us to assess a cohort less likely to be influenced by health declines associated with the length of hospital stays in older adults (31,63,64). Post-arrest interRAI assessments were only available for roughly half of those who survived hospital discharge. However, pre-arrest frailty and health instability measures were similar between those with and without post-cardiac arrest RAI-HC assessments. Finally, data on intra-arrest prognostic factors, like bystander response and initial cardiac rhythm, would have added contextual knowledge to this study.

Conclusion

Frailty is associated with survival and post-arrest declines in cognition and function. Frail patients were less likely to survive at 30 days and one year using two valid frailty measures after adjusting for age, sex, and arrest setting (in-hospital versus out-of-hospital). Most patients assessed post-hospital discharge experienced a decline in functional independence or cognitive performance from pre-arrest assessment, and the frailty index was associated with these declines. Advance care planning efforts and prognostic models will likely benefit from considering pre-arrest frailty.

Tables and Figures

Figure 1. Flow Diagram of Cohort and Post-Arrest Outcomes

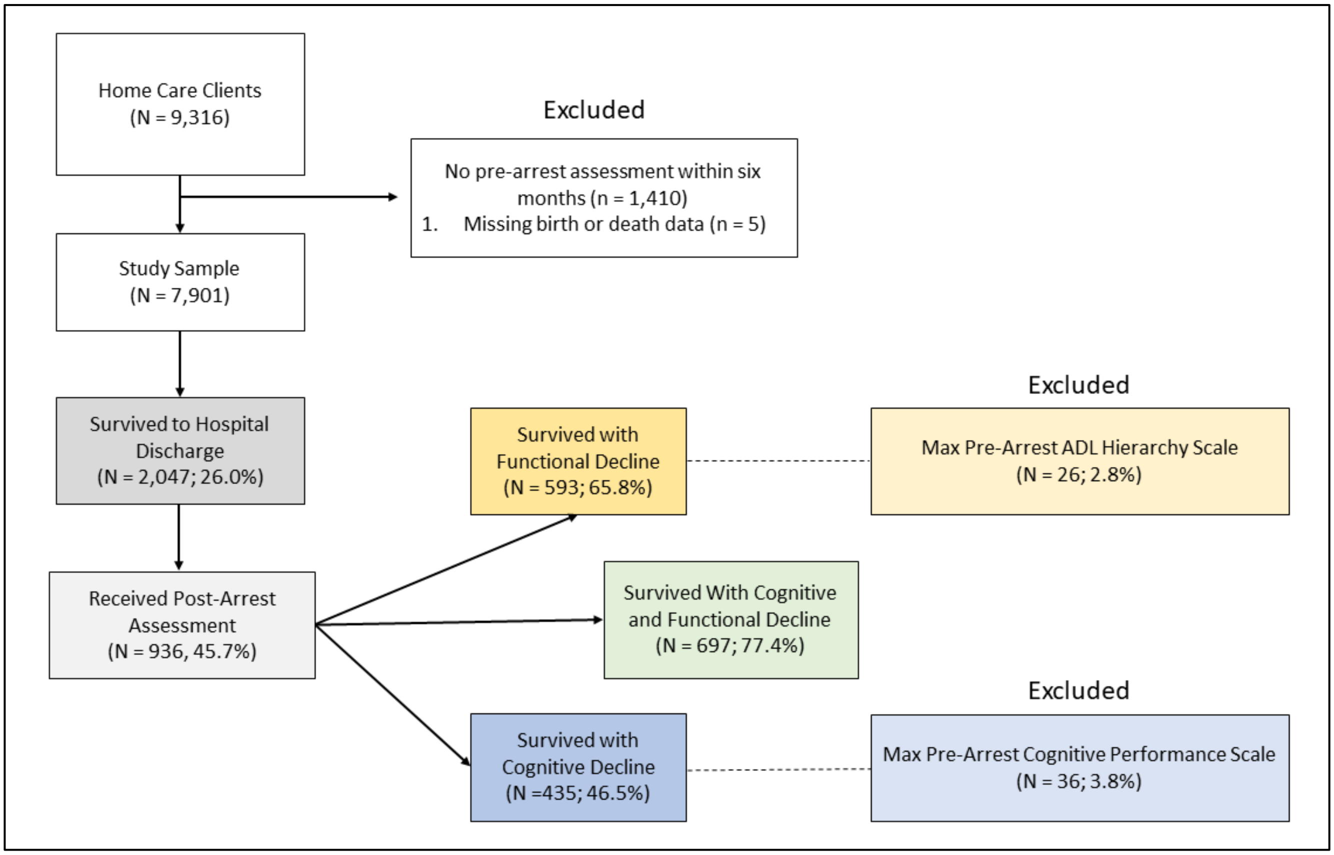
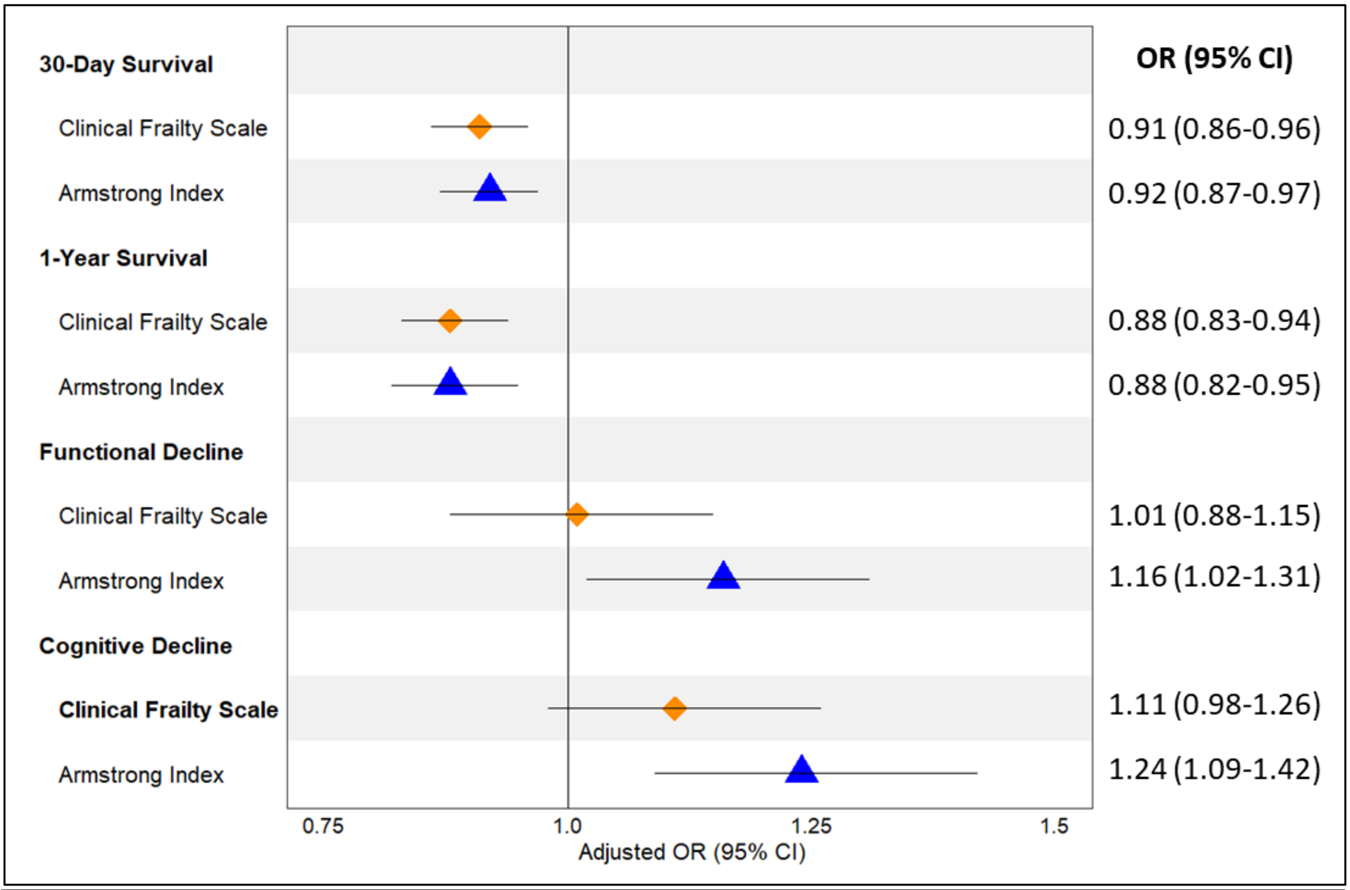


Table 1. Pre-Arrest Features in 7,901 Home Care Clients living in Ontario, Canada, Between 2006–2018

Variable	N (%)	Out-of-Hospital N = 4380 (55.5%)	In-Hospital N=3,521 (44.5%)
Age			
85+	2,588 (32.8)	1,609 (36.7)	979 (27.8)
75 – 84	2,645 (33.5)	1,440 (32.9)	1,205 (34.2)
65 – 74	1,439 (18.2)	716 (16.4)	723 (20.5)
50 – 64	952 (12.1)	485 (11.1)	467 (13.3)
18 – 49	277 (3.5)	130 (3.0)	147 (4.2)
Sex (Female)	5,123 (64.8)	2,217 (50.6)	1,852 (52.6)
Palliative or Hospice Recipient	149 (1.9)	96 (2.2)	53 (1.5)
Triage Acuity			
1 (Most Urgent)	4,486 (56.7)	3,512 (80.5)	974 (27.7)
2	1,932 (24.5)	554 (12.7)	1,378 (39.2)
3	1,269 (16.1)	237 (5.4)	1,032 (29.3)
4	133 (1.7)	14 (0.3)	119 (3.4)
5	60 (0.8)	45 (1.0)	15 (0.4)
Cognitive Performance Scale			
0 – 1 (Intact/Borderline Intact)	3,958 (50.1)	2,073 (47.3)	1,885 (53.5)
2 – 4 (Mild/Moderate Impairment)	3,440 (43.5)	1,983 (45.3)	1,457 (41.4)
5 – 6 (Severe/Very Severe Impairment)	503 (6.4)	324 (7.4)	179 (5.1)
Impaired Comprehension §	1,186 (15.0)	755 (17.2)	431 (12.2)
ADL Hierarchy			
0 – 1 (Independent/Supervision Required)	4,211 (53.3)	2,237 (51.1)	1,974 (56.1)
2 – 4 (Mild/Moderate Impairment)	2,955 (37.4)	1,701 (38.8)	1,254 (35.6)
5 – 6 (Severe/Very Severe Impairment)	735 (9.3)	442 (10.1)	293 (8.3)
Daily or Moderate-to-Excruciating Pain	4,398 (55.6)	2,421 (55.3)	1,977 (56.2)
Diagnoses			
Congestive Heart Failure	1,979 (25.0)	1,148 (26.2)	831 (23.6)
Chronic Obstructive Pulmonary Disease	2,206 (28.0)	1,121 (26.0)	1,085 (30.8)
Dementia	1,538 (19.5)	959 (21.9)	579 (16.4)
Diabetes	2,897 (36.7)	1,650 (37.7)	1,247 (35.4)
Coronary Artery Disease	2,573 (32.6)	1,483 (33.9)	1,090 (31.0)
Cancer (Excluding Skin Cancer)	1,207 (15.2)	669 (15.3)	538 (15.3)
Chronic Kidney Disease	1,085 (13.8)	672 (15.3)	413 (11.7)
Health Services Use in Prior 90 Days			
Emergency Department	1,920 (24.3)	1,019 (23.3)	901 (25.6)
Hospital Admission (Overnight Stay)	3,523 (43.1)	1,936 (44.2)	1,587 (45.1)
Polypharmacy (5+ medications)	6,506 (82.3)	3,600 (82.2)	2,938 (83.4)
CHESS Score (3+)	2,218 (28.1)	1,279 (29.2)	939 (26.7)
Frailty			
Clinical Frailty Scale (5+)	7,446 (94.2)	4,153 (94.8)	3,293 (93.5)
Frailty Index (> 0.3)	3,727 (47.4)	2,198 (50.3)	1,529 (43.7)

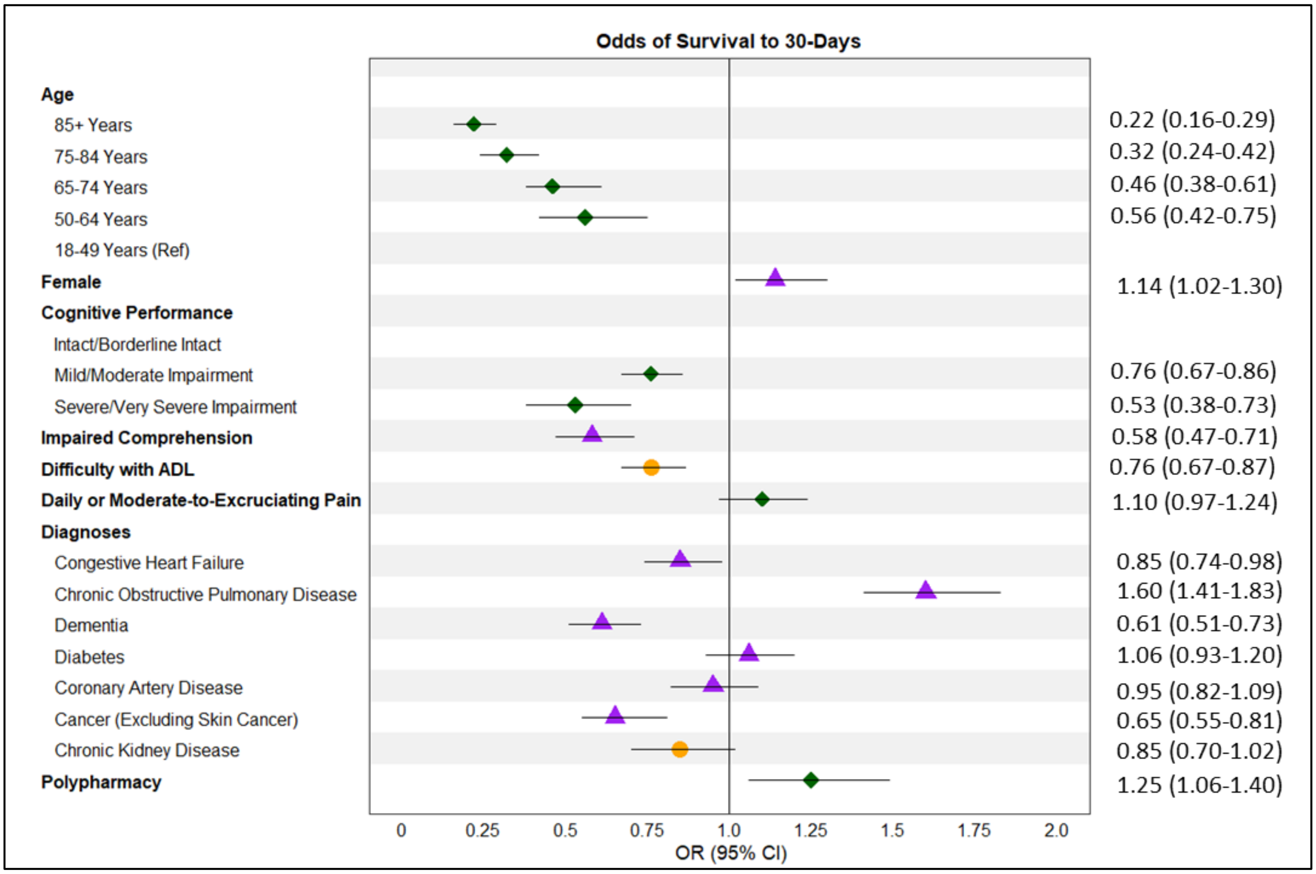
ADL = Activities of Daily Living
§ Understands people often, sometimes, or rarely

Figure 2. Association Between Frailty Scales and Survival to 30-Days after Cardiac Arrest



Statistics reported as odds per 1 point increase in Clinical Frailty Scale and 0.1 unit increase in Armstrong Index

Figure 3. Association Between Pre-Arrest Features and 30-Day Survival in 7,091 Home Care Clients



Supplemental Data

Table 1. Unadjusted and Adjusted Odds Ratios Between Frailty Measures and Post-Arrest Outcomes 7,901 Home Care Clients

Frailty	30-Day Survival N=1,165 (14.8%)	1-Year Survival N=744 (9.8%)	Decline in Function N=593 (65.8%)	Decline in Cognition N = 435 (46.5%)
Clinical Frailty Scale (Per 1-point unit increase)	0.87 (0.83-0.92)	0.85 (0.80-0.90)	1.05 (0.93-1.19)	1.14 (1.0-1.28)
Adjusted Model	0.91 (0.86-0.96)	0.88 (0.83-0.94)	1.01 (0.88-1.15)	1.11 (0.98-1.26)
Clinical Frailty Scale (5 ≤)	0.64 (0.50-0.81)	0.56 (0.43-0.73)	1.94 (1.14-3.33)	1.87 (1.08-3.32)
Adjusted Model	0.78 (0.61-0.98)	0.79 (0.52-0.91)	1.66 (0.95-2.90)	1.58 (0.90-2.86)
Armstrong Index (Per 0.1-unit increase)	0.86 (0.81-0.90)	0.82 (0.77-0.88)	1.18 (1.04-1.34)	1.25 (1.10-1.42)
Adjusted Model	0.92 (0.87-0.97)	0.87 (0.82-0.93)	1.16 (1.02-1.31)	1.24 (1.09-1.42)
Armstrong Index (0.3 ≤)	0.75 (0.66-0.85)	0.70 (0.59-0.82)	1.32 (1.02-1.80)	1.56 (1.18-2.05)
Adjusted Model	0.79 (0.70-0.90)	0.73 (0.62-0.85)	1.31 (1.01-1.72)	1.63 (1.23-2.17)

Note: Statistics reported as odds ratios (95% confidence intervals)
Outcomes other than survival were only measured in those who survived to hospital discharge
Adjusted models controlled for age and sex

Table 2. Discriminative Accuracy of Frailty Measures Using Multiple Thresholds to Predicting 30-Days Survival

Frailty Measure	N (%)	OR (95% CI)	AUROC (95% CI)
Clinical Frailty Scale			
9 Terminally Ill	91 (1.2)	0.55 (0.25-1.07)	0.50 (0.50-0.50)
>8 Living with Very Severe Frailty	164 (1.7)	0.37 (0.18-0.66)	0.51 (0.50-0.51)
>7 Living with Severe Frailty	2,865 (36.2)	0.70 (0.60-0.79)	0.54 (0.53-0.56)
>6 Living with Moderate Frailty	6,591 (83.4)	0.71 (0.61-0.83)	0.53 (0.51-0.54)
>5 Living with Mild Frailty	7,446 (94.2)	0.64 (0.50-0.81)	0.51 (0.50-0.52)
>4 Living with Very Mild Frailty	7,598 (96.1)	0.72 (0.54-0.97)	0.50 (0.50-0.51)
>3 Managing Well	7,659 (96.9)	0.79 (0.57-1.13)	0.50 (0.50-0.51)
>2 Fit	7,815 (98.9)	1.18 (0.65-2.35)	0.50 (0.50-0.50)
>1 Very Fit (Reference)	–	–	–
Armstrong Index			
>0.5	482 (6.1)	0.59 (0.42-0.80)	0.51 (0.51-0.52)
>0.4	1,674 (21.1)	0.64 (0.54-0.76)	0.53 (0.52-0.55)
>0.3	3,727 (47.1)	0.75 (0.66-0.85)	0.53 (0.52-0.55)
>0.2	6,091 (77.1)	0.75 (0.65-0.86)	0.53 (0.51-0.54)
>0.1 (Reference)	–	–	–

AUROC = Area Under the Receiver Operating Characteristic Curve; CI = Confidence Interval: OR = Odds Ratio

Table 3. Associations Between Pre-Arrest Features and 30-Day Survival Between Out-of-Hospital and In-hospital Arrests

Variable	**Out-of-Hospital** OR (95%CI)	**In-Hospital** OR (95% CI)
Age		
85+	0.29 (0.16-0.56)	0.22 (0.15-0.32)
75 – 84	0.49 (0.25-0.88)	0.27 (0.19-0.39)
65 – 74	0.50 (0.27-0.98)	0.41 (0.28-0.58)
50 – 64	0.74 (0.40-1.46)	0.50 (0.34-0.72)
18 – 49	–	–
Sex (Female)	0.81 (0.62-1.07)	1.23 (1.06-1.43)
Do-Not-Resuscitate Order/Palliative	0.38 (0.06-1.22)	0.72 (0.35-1.35)
Cognitive Performance Scale		
0–1 (Intact/Borderline Intact)		
2–4 (Mild/Moderate Impairment)	0.71 (0.54-0.94)	0.85 (0.73-0.98)
5–6 (Severe/Very Severe Impairment)	0.58 (0.31-1.03)	0.64 (0.43-0.92)
Impaired Comprehension §	0.58 (0.37-0.87)	0.72 (0.56-0.92)
Impairment with Activities of Daily Living ¶	0.71 (0.54-0.93)	0.85 (0.73-0.99)
Daily or Moderate-to-Excruciating Pain	0.99 (0.75-1.30)	1.12 (0.96-1.31)
Diagnoses		
Congestive Heart Failure	0.91 (0.67-1.24)	0.90 (0.75-1.08)
Chronic Obstructive Pulmonary Disease	0.88 (0.63-1.19)	1.72 (1.47-2.02)
Dementia	0.78 (0.54-1.08)	0.69 (0.55-0.86)
Diabetes	1.25 (0.95-1.63)	1.08 (0.92-1.25)
Coronary Artery Disease	1.30 (0.99-1.71)	0.92 (0.78-1.09)
Cancer (Excluding Skin Cancer)	0.83 (0.55-1.22)	0.58 (0.45-0.72)
Chronic Kidney Disease	1.27 (0.88-1.77)	0.85 (0.69-1.08)
Health Services Use in Prior 90 Days		
Emergency Department	1.11 (0.81-1.50)	1.08 (0.91-1.28)
Hospital Admission (Overnight Stay)	1.05 (0.80-1.37)	1.30 (1.12-1.51)
Polypharmacy (5+ medications)	0.93 (0.66-1.31)	1.35 (1.09-1.67)

§ Understands people often, sometimes, or rarely
¶ Defined as an ADL Hierarchy Score of 1 or greater

Table 4. Comparison of Pre-Arrest Frailty Status Between Home Care Clients with (N = 936) and without (N = 1,111) post-arrest assessments in home care or long-term care within one year of arrest

Variable	No Missing	Missing
Frailty Index Mean (Standard Deviation)	0.29 (0.12)	0.29 (0.11)
Clinical Frailty Scale (Percentage ≥ 5)	92.7%	93.0%
CHESS (Percentage ≥ 3)	24.9%	22.0%

Table 5. Health Domains Evaluated within the Clinical Frailty Scale and Frailty Index

Clinical Frailty Scale	Armstrong Index
Activities of Daily Living (5)	Activities of Daily Living (6)
Instrumental Activities of Daily Living (6)	Instrumental Activities of Daily Living (8)
Diagnoses (28)	Diagnoses (16)
Self-Reported Health (1)	Self-Reported Health (1)
Smoking/Drinking (3)	Health Stability (1)
Stamina (2)	Weight / Weight Loss (2)
Prognosis of Less than Six Months (1)	Mood (6 items)
	Vision (1)
	Bladder Incontinence (1)
	Balance (1)

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CHAPTER FIVE

Derivation and Internal Validation of a Prognostic Model to Predict 30-Day Survival Post Cardiac Arrest: A Population-Based Analysis of Patients Receiving Home Care

Summary

This chapter describes the creation and internal validation of a prognostic model to predict 30-day survival post-cardiac arrest in the home care population. The findings from prior studies were used to justify the need for a model in the home care population and to inform the predictor and outcome selection of this study. The methodology of this study was guided by recommendations from the Prognosis Research Strategy (PROGRESS) group. Reporting of study findings adheres to the Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis (TRIPOD) statement.

The prognostic model in this study is well-suited to support group-level predictions of 30-day survival post-cardiac arrest in patients receiving home care services. Our model had similar discriminative accuracy among both in-hospital and out-of-hospital arrests. Our model had good calibration in the IHCA population, though significantly underpredicted survival in the OHCA population. Compared to a comprehensive frailty index and the Clinical Frailty Scale, our model performed better when predicting 30-day survival post-cardiac arrest. I (Fabrice Mowbray) was primarily responsible for the study ideation, analysis, and drafting of the original manuscript.

ABSTRACT

Aim: We set out to develop and internally validate a prognostic model to predict 30-day survival post-cardiac arrest in patients receiving home care and to compare model performance between in-hospital and out-of-hospital arrests.

Methods: We conducted a population-based retrospective cohort study of patients receiving home care in Ontario, Canada, linking administrative health data sets to interRAI home care assessments. We utilized multivariable logistic regression to predict 30-day survival and bootstrap resampling (n=2000) to internally validate our model. We evaluated discriminative accuracy using the Area Under the Receiver Operating Characteristic Curve and R^2. We evaluated calibration using the Brier Score, Calibration Slopes, and visual inspection of calibration plots. We evaluated sub-group performance across arrest settings (in-hospital vs out-of-hospital) and conducted a sensitivity analysis excluding those under 75 years of age.

Results: Our cohort contained 7,091 individuals, and most cardiac arrests occurred in the hospital setting (55%). The 30-day survival rate was 14.8%. Our prognostic model had fair discriminative accuracy and calibration when predicting 30-day survival (AUROC = 0.66 [95%CI=0.65-0.65]; Calibration Slope = 0.95). We found similar discriminative performance when we employed our model in sub-groups of in-hospital and out-of-hospital arrests and when excluding those under 75 years of age.

Conclusion: Our prognostic model can inform advance care planning among patients receiving home care and can be readily embedded within provincially mandated interRAI home care assessments. Our model outperformed two valid and multidimensional frailty measures in predicting post-cardiac arrest survival.

Introduction

Home care services are rapidly expanding to support the multifaceted needs of an aging population that favours and benefits from home-based care (1,2). Older adults are at greater risk for hospital-acquired functional decline, cognitive impairment, and poor health outcomes during their in-patient stay (2–4). Patients receiving home care are medically-complex with higher rates of multimorbidity, geriatric syndromes, and health service use, than community-dwelling individuals not enrolled in home care (5,6). Advanced age and high rates of cardiopulmonary disease in the home care population increase their risk of cardiac arrest and sudden cardiac death. Less than 15% will survive to one year after a cardiac arrest (7,8), with prognoses likely worse for patients receiving home care services given their high prevalence of frailty (9,10). A high incidence and poor prognosis in the home care population underscore the need for pragmatic discussions and advance care planning.

Publicly-funded home care clients in Canada receive standardized and detailed health assessments by regulated health care professionals upon service enrollment and annually at minimum, using the nationally mandated interRAI home care (RAI-HC) assessment (11,12). The RAI-HC contains over 250 assessment items, evaluating multiple health domains, including functional, cognitive, and psychosocial health, diagnoses, health instability, and health service use, among other factors (13). The systematic collection of population-level data ideally positions patients enrolled in home care and their clinicians to develop proactive and data-driven end-of-life care plans in a collaborative manner (14,15).

Clinical prediction models are commonly developed to support real-time decision-making about individualized prognosis based on unique patient or health system features (16,17). Prognostic models have been developed using pre-arrest health data to predict survival from cardiac arrest (18,19). However, the prognostic value of geriatric syndromes is commonly overlooked by clinicians and cardiac arrest prediction models to date (18–21). Little is known about prognostic factors or the performance of a prognostic model in predicting survival post-cardiac arrest among patients receiving home care services.

Our primary objective was to develop and internally validate a prognostic model to predict 30-day survival post-cardiac arrest among patients receiving home care. Our secondary objective was to evaluate model performance in discrete sub-groups of out-of-hospital (OHCA) and in-hospital arrests (IHCA). A tertiary objective of our study was to compare the discriminative accuracy of our model against two valid and multidimensional measures of frailty, the Clinical Frailty Scale and a frailty index.

Methods

Study Design

We conducted a population-based retrospective cohort study linking multiple de-identified and validated administrative health datasets housed within ICES, a not-for-profit organization in Ontario, Canada, that collates population-level health datasets (75+) to support health system planning. Our methods were in accordance with recommendations from the Prognosis Research Strategy (PROGRESS) group (16). When reporting our results, we adhered to the Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis (TRIPOD) statement (22). We received a waiver of ethics review from the Hamilton Integrated Research Ethics Board (HiREB), as informed consent is not required to leverage this data in accordance with Section 45 of Ontario's Personal Health Information Protection Act.

Data Sources

We used the Home Care Dataset (HCD) to identify and extract data on patients receiving long-stay (> 60 days) home care services prior to their cardiac arrest. The HCD is a population-based dataset housing information on home care enrollment and service use. We extracted data on pre-arrest patient features, geriatric syndromes, diagnoses, and health service use, from the interRAI home care dataset, which houses all Resident Assessment Instrument – Home Care (RAI-HC) assessments for publicly funded home care clients. The RAI-HC is a mandated primary home care assessment instrument in Ontario and many Canadian provinces. In Ontario, patients are typically first evaluated with a brief contact assessment and receive a comprehensive evaluation with the RAI-HC yearly thereafter unless warranted (e.g., increase in medical acuity, return from the hospital, etc.) (12). The content and construct validity of the RAI-HC and the encompassing assessment items have been validated on an international scale (23–25). We extracted data on patient age and sex from the Registered Persons Database.

Cardiac arrests that occurred pre-hospital or within the emergency department were identified using the National Ambulatory Care Reporting System (NACRS) dataset and were classified as OHCA. NACRS is a national database collated by the Canadian Institute of Health Information and designed to capture population-level information on ambulatory and community-based health services. Cardiac arrests that occurred in-hospital (i.e., post-admission) were identified using the Discharge Abstract Database and were classified as IHCA. Though physically located within the hospital, the emergency department manages only 10% of cardiac arrests within the hospital premises (26). Emergency patients are typically healthier than those who arrest within an in-patient unit (27–29). These figures are likely why cardiac arrest studies in Ontario typically classify arrests within the emergency department as out-of-hospital (30,31). The Vital Statistics and Death database was used to determine the etiology and date of death. The databases used in this study are routinely checked for quality and have been validated for clinical and health services research in Ontario and Canada (25,32).

Cohort

We included patients aged 18 and older receiving long-stay home care services prior to a cardiac arrest in Ontario between January 1st, 2006, and March 31st, 2018. To be included in our sample, patients had to be transferred to a hospital for definitive cardiac arrest care from the pre-hospital setting or arrest within 72 hours of hospital presentation post-hospitalization. We selected this time frame to ensure that prognosis of cardiac arrest was influenced primarily by pre-arrest features rather than in-hospital care or hospital-associated health decline (33,34) and to capture most arrests, which are known to occur within 48 hours of hospital admission (35).

We excluded patients without a RAI-HC assessment in the six months (180 days) prior to cardiac arrest to ensure that assessment data accurately depicts pre-arrest features. We also excluded patients that received surgery during hospitalization prior to IHCA to best capture arrests exacerbated by medical conditions rather than surgical or traumatic causes, which are less common, and require different clinical interventions

(35). Those without a valid Identification Key Number and birth date or death date were also excluded.

We used a validated series of Canadian Classification of Health Interventions codes to identify those who received cardiopulmonary resuscitation (IHZ30JN, IHZ3OJY) and International Classification of Disease codes (10th ed.) to identify the incidence of cardiac arrest (I46.1, I46.2, I46.8, I49.0, 149.01, I49.02, R960, R96.1, R98, R99) (30,36,37). In the rare case where two arrests occurred within the study period, only the first event was used, given the worse odds of survival following re-arrest (38–40), and to mitigate the risk of correlated observations.

Pre-Cardiac Arrest Predictors

We selected predictors a priori using the clinical expertise of a multidisciplinary team (nursing, medicine [emergency, critical care, geriatrics], paramedicine) and prior relevant literature concerning pre-arrest predictors of survival post-cardiac arrest and overall in patients receiving home care (18,41,42). We also evaluated the prognostic value of assessment items included within current RAI-HC measures purposed to identify health instability, assessment urgency, and frailty (45–47). We avoided mathematically driven predictor selection methods (e.g., stepwise, subset), which have been shown to increase the risk of overfitting statistical models (48,49).

We measured age as a categorical variable due to data privacy limitations within ICES, with years of age collapsed to 18-49, 50-64, 65-74, 75-84, and 85+. We refrained from further collapsing these categories to capture as much variance as possible. We measured biological sex (male, female) as a dichotomous variable and included it in our model to account for the sex-related differences in aging and out-of-hospital bystander response (50,51). We extracted data on high-risk diagnoses that influence health stability and frailty, including congestive heart failure, chronic obstructive pulmonary disease, renal failure, dementia, and cancers, not including skin malignancies (52,53).

We evaluated functional independence using the interRAI ADL (Activities of Daily Living) Long-Form, a valid 28-item measure that scores patients between 0 and 28 based on independence with tasks of eating, bathing, toilet use, personal hygiene, dressing, locomotion, and bed mobility (54–56). We elected to use the ADL Long-Form as it is the most comprehensive and sensitive to ADL changes of all interRAI functional scales (55,56). We evaluated cognitive performance using the interRAI Cognitive Performance Scale, a valid score ranging from zero to six, based on impairments with decision-making, verbal expression, and short-term memory (57–59). The Cognitive Performance Scale has been validated against gold standards for cognitive assessment like the Mini-Mental State Exam, the Montreal Cognitive Assessment (58,60), and the clinical assessment of regulated health care providers (59). We collapsed the Cognitive Performance Scale into three categories capturing those with no or borderline cognitive impairment (0 to 1), mild to moderate cognitive impairment (2 to 4), and severe to very severe impairment (5 to 6). We measured health instability using the CHESS – Changes in Health, End-Stage Disease and Signs and Symptoms (45,46). The CHESS is predictive of overall mortality and ranges from zero (no health instability) to five (very high instability), based on seven binary markers, including: changes in decision-making capacity or independence with ADLs in the 90 days prior, presence of edema or dyspnea, unintended weight loss (>5% in 30 days or >10% in 180 days), decrease in food and fluid intake, and referral for palliative care (45). We elected to include the

CHESS rather than the individual components making up the scale to decrease the number of parameters entered within the prognostic model.

We defined polypharmacy as an individual taking nine or more medications simultaneously rather than the traditional definition of five or more medications (61). We selected a higher cut-off to account for the high prevalence of polypharmacy found in the home care population (62). We defined frequent pre-hospitalization as any patient with two or more hospitalizations that included an overnight stay in the 90 days before their RAI-HC assessment. We evaluated multiple rather than single pre-arrest hospitalization to better identify signals of medical complexity and unmet acute health needs, given the high baseline risk for hospitalization among patients receiving home care. We defined social isolation as any person who spends long-periods (e.g., morning, evening) or all their time alone and those reporting loneliness, mindful of the long-standing relationships between social isolation and health outcomes and knowing that these patients are less likely to receive by-stander response (63). Self-reported health was assessed at time of RAI-HC assessment with patients being asked "In general how would you rate your overall health?" The RAI-HC compares those with a self-rating of *poor*, to those with a self-rating of *excellent, good,* or *fair*.

Frailty

We measured frailty using the Clinical Frailty Scale (CFS) and a valid frailty index using the RAI-HC. The CFS is a nine-item ordinal scale that ranges from one (very fit) to nine (terminally ill), is commonly used to predict survival post-cardiac arrest, and has been validated for retrospective calculation (64,65). The frailty index was calculated as a health deficit accumulation model using 43 items (see supplemental file) from the RAI-

HC and is predictive of mortality and admission to long-term care (66–68). We elected to use this frailty index over a more comprehensive 83-item index calculated from the RAI-HC to decrease the likelihood of an overfit statistical model (68). We operationalized frailty measures in their full forms to leverage the benefits of their granularity and to adhere to best practices in frailty measurement (69).

Outcome

We evaluated 30-day survival post-cardiac arrest as the outcome of this study. We elected to use 30 days given its common use in resuscitation research and the fact that it closely approximates the prognosis of survival to hospital discharge (70). We selected the former of the two per Utstein recommendations (70,71).

Analysis

We screened predictors of multicollinearity and imbalanced distributions prior to analysis. Specifically, we excluded variables with a variance inflation factor of 10 or greater and variables with a ratio greater than 20:1 between the first and second most common values (72). We reported descriptive statistics using measures of frequency and central tendency. We utilized multivariable logistic regression to prognosticate 30-day survival. We used bootstrap resampling (n=2000) to internally validate our model and to evaluate statistical differences between model performance. We evaluated model performance in all patients and within distinct sub-groups of in-hospital and out-of-hospital arrests. We report the Area Under the Receiver Operating Characteristic Curve (AUROC) and R^2 value as measures of discriminative accuracy. We assessed model calibration by evaluating calibration slopes, brier scores, and inspection of calibration plots (see supplemental file). We excluded only five cases due to missing death data. We managed and analyzed data using **R** version 3.1 and the *RMS* package to develop and validate prognostic models. The *pROC package* was used to evaluate and compare.

Results

Our cohort contained 7,901 patients receiving home care who received cardiac arrest hospital care in Ontario, Canada; this represents 85% of all patients receiving home care, excluding those without a RAI-HC assessment within six months before cardiac arrest. Most arrests occurred out-of-hospital (55.5%). The mean time between pre-arrest assessment and arrest was 66 days (SD = 51.5). Those 75 years and older had the greatest incidence of cardiac arrest (66.3%), and most arrests occurred in women (64.8%). Roughly half of the sample had cognitive impairment (49.9%) or required assistance with ADLs (46.7%), and 28.1% had at least moderate health instability, defined as a CHESS score of three or greater.

Approximately one-quarter had congestive heart failure (25.0%) or chronic obstructive pulmonary disease (28.0%), and 15.2% had a diagnosis of cancer. Most patients took nine or more medications daily (60.9%). Many patients required hospitalization within 90 days before pre-arrest RAI-HC assessment (44.6%), and 20.7% required multiple pre-arrest hospital admissions. Most patients reported *poor* self-reported health (69.3%). Few patients (3.3%) had palliative goals of care or a life expectancy of six months or less at the pre-arrest RAI-HC assessment. Table 1 provides the frequencies and proportions of pre-arrest features overall and between sub-groups of in-hospital and out-of-hospital arrests. *Figure 1* displays the patient flow diagram and proportion of health outcomes in the cohort.

Survival and Model Performance

A total of 1,165 (14.8%) survived to 30 days post-cardiac arrest, and 744 (9.8%) were alive at one-year. Our model included a total of 15 statistical parameters and 13 variables, including age, sex, ADL Long-Form, CHESS, Cognitive Performance Scale, congestive heart failure, chronic obstructive pulmonary disease, renal failure, dementia, cancer, polypharmacy, multiple prior hospitalizations, poor self-reported health (binary), and social isolation. This predictor combination resulted in an event-per-variable ratio of >70:1 for the overall cohort, 58:1 for the in-hospital cohort, and 19:1 for the out-of-hospital cohort. Our model had an AUROC of 0.66 (95%CI = 0.64-0.68), an R^2 value of 0.07 (95%CI = 0.05-0.09), and demonstrated good calibration (Brier Score = 0.12; Calibration Slope = 0.94), with predictive accuracy degrading at the tail ends of the optimism estimates.

Sub-group and Sensitivity Analyses

Our model had similar discriminative accuracy when employed among IHCA and OHCA. Among in-hospital arrests, our model fit had *fair* accuracy with an AUROC of 0.66 (95%CI = 0.65-0.67), an R^2 value of 0.07 (95%CI = 0.06-0.08), and good calibration overall (Brier Score = 0.16; Calibration Slope = 0.93). In the out-of-hospital cohort, our model had an AUROC = 0.63 (95%CI = 0.61-0.65) and worse calibration when compared to in-hospital arrests (Brier Score = 0.05; Calibration Slope = 0.78). When excluding patients under the age of 75 (33.8%), our model had similar predictive accuracy with an AUROC of 0.63 (95%CI = 0.62-0.64), though worse calibration when compared to the overall cohort (Brier Score 0.5; Calibration Slope = 0.88).

Frailty

The frailty index (AUROC = 0.55; 95%CI = 0.53-0.57) and the Clinical Frailty Scale (AUROC = 0.56; 95%CI = 0.54-0.58) were poor classifiers of 30-day survival post-cardiac arrest, and our model performed significantly better than both frailty measures ($p < .05$).

Discussion

We developed and internally validated a prognostic model to predict 30-day survival post-cardiac arrest in patients receiving home care services. Our model is well suited to support group-level decision-making about advance care directives and end-of-life care post-cardiac arrest among patients receiving home care. Discriminative accuracy was similar when evaluated in a sub-group of in-hospital arrests, though our model had worse calibration in the out-of-hospital population. Overall our model underestimated the probability of survival in all populations.

Comparison to Relevant Prognostic Models

Prognostication of survival post-cardiac arrest has been extensively studied for IHCA and OHCA. Our sample size and event rate were significantly larger than the vast majority of prior clinical prediction models (median N = 591), and our cohort differed by having a greater proportion of older adults and females (21), two common features of the home care population (73). When compared to the best-performing prediction models for OHCA (e.g., OHCA Score, Cardiac Arrest Hospital Prognosis [CAHP] Score) and IHCA (e.g., Good Outcome Following Attempted Resuscitation [GO-FAR]), our model performed worse. The differing performance is likely due to our lack of arrest-specific (e.g., cardiac rhythm, witnessed arrest, bystander cardiopulmonary resuscitation) and hospital-specific predictors (e.g., laboratory values, medication use) utilized by these models (74–76). The inclusion of these predictors is likely to improve prognostic efforts, though their consideration limits the opportunity for pre-arrest advance care planning in the community.

No models identified were specific to the home care population. However, efforts have been made to predict overall mortality in patients receiving home care services using items of the RAI-HC. The CHESS Scale predicts 90-day mortality in palliative (47) and neurologically-impaired patients receiving home care (46). Knowing that the CHESS has proven to be a robust predictor of health instability and overall mortality, we included this scale within our prognostic model.

Hsu and colleagues recently developed an algorithm to predict time-to-death within six months in the home care population, with the RESPECT algorithm demonstrating good accuracy and calibration with items of the RAI-HC (42). Our model had worse discriminative accuracy when compared to the RESPECT score (AUROC = 0.65 versus 0.75). However, we believe this is likely due to different populations of interest between the models. The RESPECT score predicts overall survival, rather than post-cardiac arrest survival and includes significantly more individuals (~ 140,000) and statistical parameters (n > 65). The RESPECT score also leveraged patient age in its full continuous form, improving the statistical power and precision of this important prognostic factor. Finally, the distribution of death dates and patient features are also less heterogenous in the cardiac arrest population compared to the general home care population, likely inhibiting the prognostic value of our model, despite a similar predictor set.

Implications

We developed and internally validated a prognostic model that can predict 30-day survival post-cardiac arrest using population-based data routinely collected as standard practice in the Ontario home care population. Our model is well-suited for group-level predictions given its derivation within the complex-adaptive system of the Ontario health care system. Our model can be readily employed upon home care service enrollment and re-calculated during follow-up assessments where jurisdictions use interRAI home care assessments.

Our model discriminated survival slightly worse in the out-of-hospital setting; this difference was not statistically significant, suggesting predictions can be used to support advance care planning between arrest settings. The difference in discriminative ability is likely due to the lack of data on important arrest-specific factors (e.g., arrest response) known to influence health outcomes and the greater variance among the OHCA population (19). However, foreknowledge of these factors is not available to patients during advance care planning. Our model also underestimated survival to a greater extent in the OHCA population, with worse calibration in this population, considering there is a greater proportion of immediate deaths post-resuscitation. Our model performed best among the middle 80% of risk probabilities.

Our model did not perform like a diagnostic screener where the risk of false positives can have detrimental effects on the prognoses, clinical interventions, and the perspectives of those misclassified. False positive misclassification would likely have little influence on the intended population, knowing that advance care planning efforts are recommended for frail populations, like patients receiving home care services.

Further, this model is designed to support decision-making rather than provide a definitive recommendation. Resources other than time are not likely to be wasted by the uptake of our prognostic model, considering that it was built for immediate integration within the RAI-HC. Our model performs better when compared to an already implemented population-level clinical prediction model like the DIVERT Scale, which is purposed to predict ED use among patients receiving home care services.

Strengths and Limitations

Our study is novel in its derivation and validation of a prognostic model to predict survival post-cardiac arrest in the home care population. Our prognostic model was developed using a population-based cohort and a larger sample size than most cardiac arrest prognostic models. The relatively large sample size and event rate are another strength of our study, mindful that most cardiac arrest clinical prediction models have proven to be overfit (21). However, our study is not without its limitations.

For in-hospital arrests, data were only available for arrests that occurred within a 72-hour window. However, this allowed us to assess a cohort less likely to be influenced by health declines associated with the length of hospital stays in older adults (1,2). For out-of-hospital arrests, we could not delineate individuals who arrested pre-hospital versus in the ED, though most arrests managed in the ED occur in the pre-hospital setting. Our model is likely overfit for out-of-hospital predictions, given the low event rate of 30-day survival (N = 227). However, this appears to be a problem in most studies evaluating out-of-hospital arrests, given the low incidence and likelihood of survival.

Conclusion

We developed a prognostic model well-suited to predict 30-day survival post-cardiac arrest in patients receiving home care services. Our model discriminated post-cardiac arrest survival similarly among IHCA and OHCA. When compared to a comprehensive frailty index and the Clinical Frailty Scale, our model performed better in predicting 30-day survival. Future prognostic efforts are needed to predict the absolute mortality risk and to evaluate survival without significant post-arrest declines in functional independence and cognitive performance.

Tables and Figures

Figure 1. Flow Diagram of Study Inclusion and Post-Cardiac Arrest Survival Rates in 7,901 Home Care Clients in Ontario, Canada

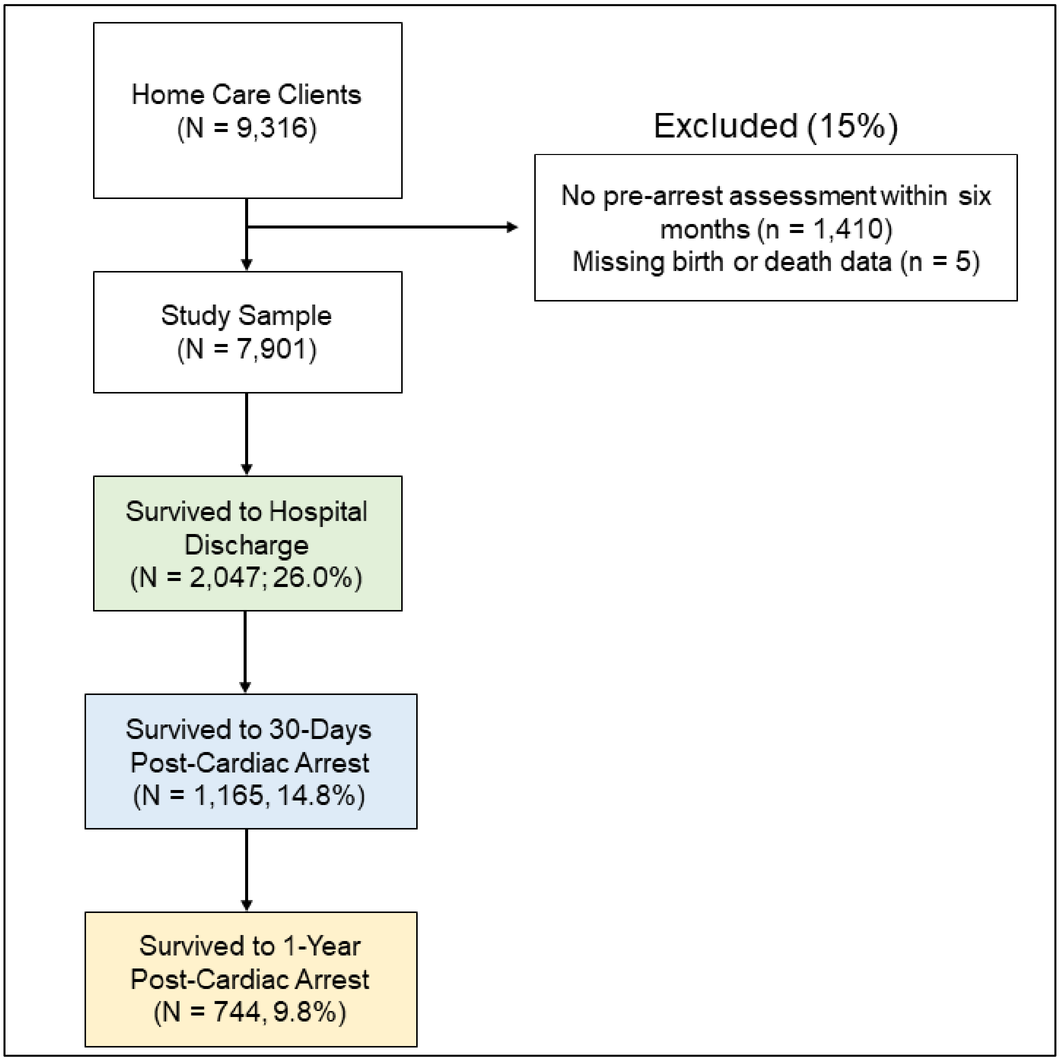


Table 1. Pre-Cardiac Arrest Features among 7,901 Home Care Clients living in Ontario, Canada between 2006–2018

Variable	All Arrests N (%)	Out-of-Hospital 4,380 (55.4%)	In-Hospital 3,521 (44.6%)
Age			
85+	2,588 (32.8)	1,609 (36.7)	979 (27.8)
75 – 84	2,645 (33.5)	1,440 (32.9)	1,205 (34.2)
65 – 74	1,439 (18.2)	716 (16.4)	723 (20.5)
50 – 64	952 (12.1)	485 (11.1)	467 (13.3)
18 – 49	277 (3.5)	130 (3.0)	147 (4.2)
Sex (Female)	5,123 (64.8)	2,217 (50.6)	1,852 (52.6)
Cognitive Performance Scale			
0 – Intact	2,611 (33.0)	1,346 (30.7)	1,265 (35.9)
1 – Borderline Intact	1,347 (17.1)	727 (16.6)	620 (17.6)
2 – Mild Impairment	2,388 (29.6)	1,336 (30.5)	1,002 (28.5)
3 – Moderate Impairment	964 (12.2)	561 (12.8)	4,003 (11.5)
4 – Moderate/Severe Impairment	138 (1.8)	86 (2.0)	52 (1.5)
5 – Severe Impairment	352 (4.5)	233 (5.3)	119 (3.4)
6 – Very Severe Impairment	151 (1.9)	91 (2.1)	60 (1.7)
ADL Long Form Score *	5 (10)	5 (11)	4 (10)
CHESS			
0 – No Health Instability	1,316 (16.7)	688 (15.7)	628 (17.8)
1 – Minimal Health Instability	2,109 (27.0)	1,138 (26.0)	971 (27.6)
2 – Low Health Instability	2,258 (28.6)	1,275 (29.1)	983 (27.9)
3 – Moderate Health Instability	1,689 (21.3)	956 (21.8)	733 (20.8)
4 – High health Instability	500 (6.3)	301 (6.9)	199 (5.7)
5 – Very High Instability	29 (0.4)	22 (0.5)	7 (0.2)
Diagnostic Profile			
Congestive Heart Failure	1,979 (25.0)	1,148 (26.2)	831 (23.6)
Chronic Obstructive Pulmonary Disease	2,206 (28.0)	1,121 (26.0)	1,085 (30.8)
Dementia	1,538 (19.5)	959 (21.9)	579 (16.4)
Diabetes	2,897 (36.7)	1,650 (37.7)	1,247 (35.4)
Coronary Artery Disease	2,573 (32.6)	1,483 (33.9)	1,090 (31.0)
Cancer (Excluding Skin Cancer)	1,207 (15.2)	669 (15.3)	538 (15.3)
Chronic Kidney Disease	1,085 (13.8)	672 (15.3)	413 (11.7)
Psychiatric Diagnosis	1,327 (16.8)	695 (15.8)	632 (18.0)
Polypharmacy (≥ 9 Medications)	4,810 (60.9)	2,666 (60.9)	2,144 (60.9)
Pre-Arrest Hospitalizations			
Single	2,683 (34.0)	1,483 (33.9)	1,200 (34.1)
Multiple (≥ 2)	840 (10.6)	452 (10.3)	387 (11.0)
Prior Falls			
Single	1,423 (18.0)	806 (18.4)	617 (17.5)
Multiple (≥ 2)	1,634 (20.7)	908 (20.7)	726 (20.6)
Poor Self-Reported Health	2,425 (69.3)	1,302 (29.7)	1,124 (31.9)
Social Isolation	3,041 (38.5)	1,541 (35.2)	1,500 (42.6)

ADL=Activities of Daily Living; CHESS=Changes in Health, End-Stage Disease and Signs and Symptoms
* Reported as median [inter-quartile range]

Table 2. Prognostic Model predicting 30-Day Survival Post-Cardiac Arrest in 7,901 Patients Receiving Home Care Services

Variable	**All Arrests** OR (95% CI)
Intercept	2.26 (1.65-3.05)
Age	
85+	4.74 (3.58 –6.41)
75 – 84	3.30 (2.50 –4.42)
65 – 74	2.37 (1.78 – 3.19)
50 – 64	2.05 (1.51 – 2.78)
18 – 49	–
Sex (Female)	0.88 (0.77-1.01)
ADL Long Form Score *	1.02 (1.01-1.03)
Health Instability (CHESS ≥ 3)	1.29 (1.11-1.50)
Diagnostic	
Congestive Heart Failure	1.19 (1.02-1.39)
Chronic Obstructive Pulmonary Disease	0.68 (0.60-0.79)
Cancer (Excluding Skin Cancer)	1.69 (1.38-2.07)
Renal Failure	1.32 (1.09-1.62)
Polypharmacy (≥ 9 Medications)	0.82 (0.72-0.95)
Pre-Arrest Hospitalization	0.81 (0.71-0.92)
Social Isolation	0.75 (0.66-0.87)
AUROC (95% CI)	0.66 (0.64-0.66)
Calibration Slope	0.94 (0.92-0.96)
Brier Score	0.12

ADL = Activities of Daily Living
AUROC = Area Under the Receiver Operating Characteristic Curve
CHESS = Changes in Health, End-Stage Disease and Signs and Symptoms
* Reported as median [inter-quartile range]

Supplemental Data

Figure 1. Receiver Operating Characteristic Curve for Predicting 30-Day Survival in 7,901 Patients Receiving Home Care in Ontario, Canada (AUROC = 0.66)

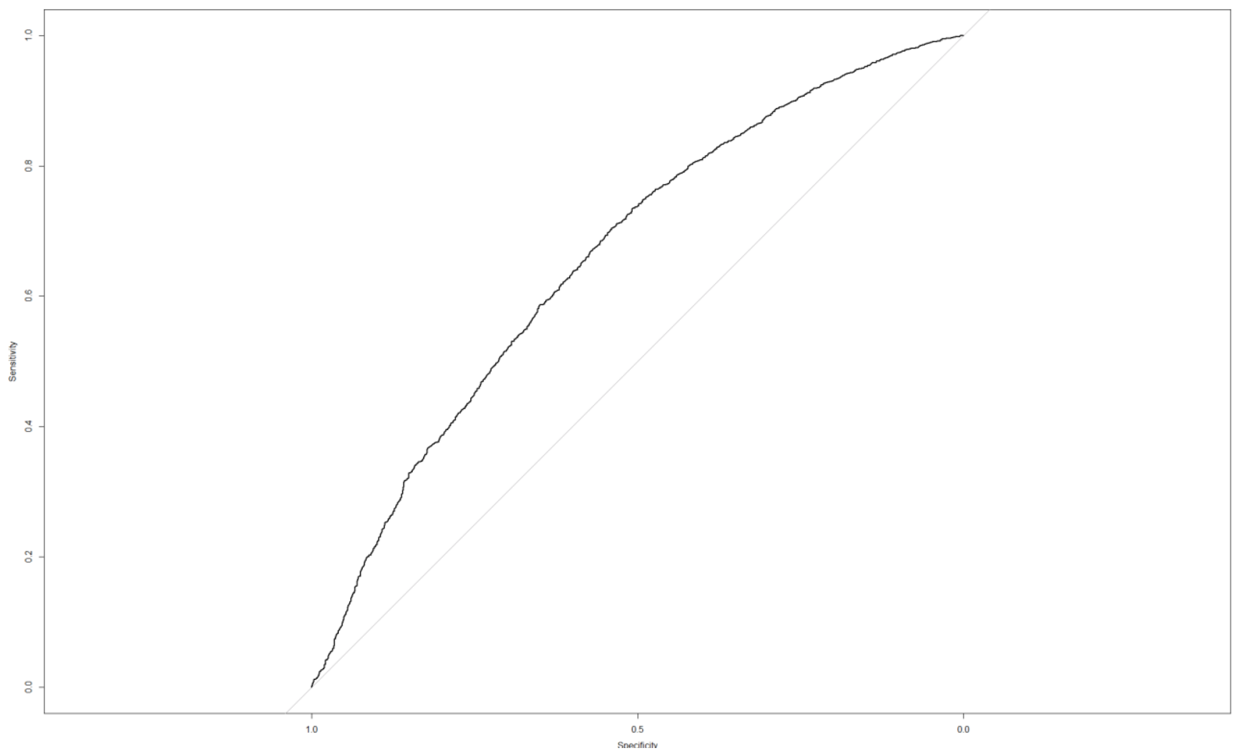


Figure 2. Calibration Curve of Prognostic Model in 7,091 Patients Receiving Home Care Services who had a Cardiac Arrest in Ontario, Canada (Brier Score = 0.12)

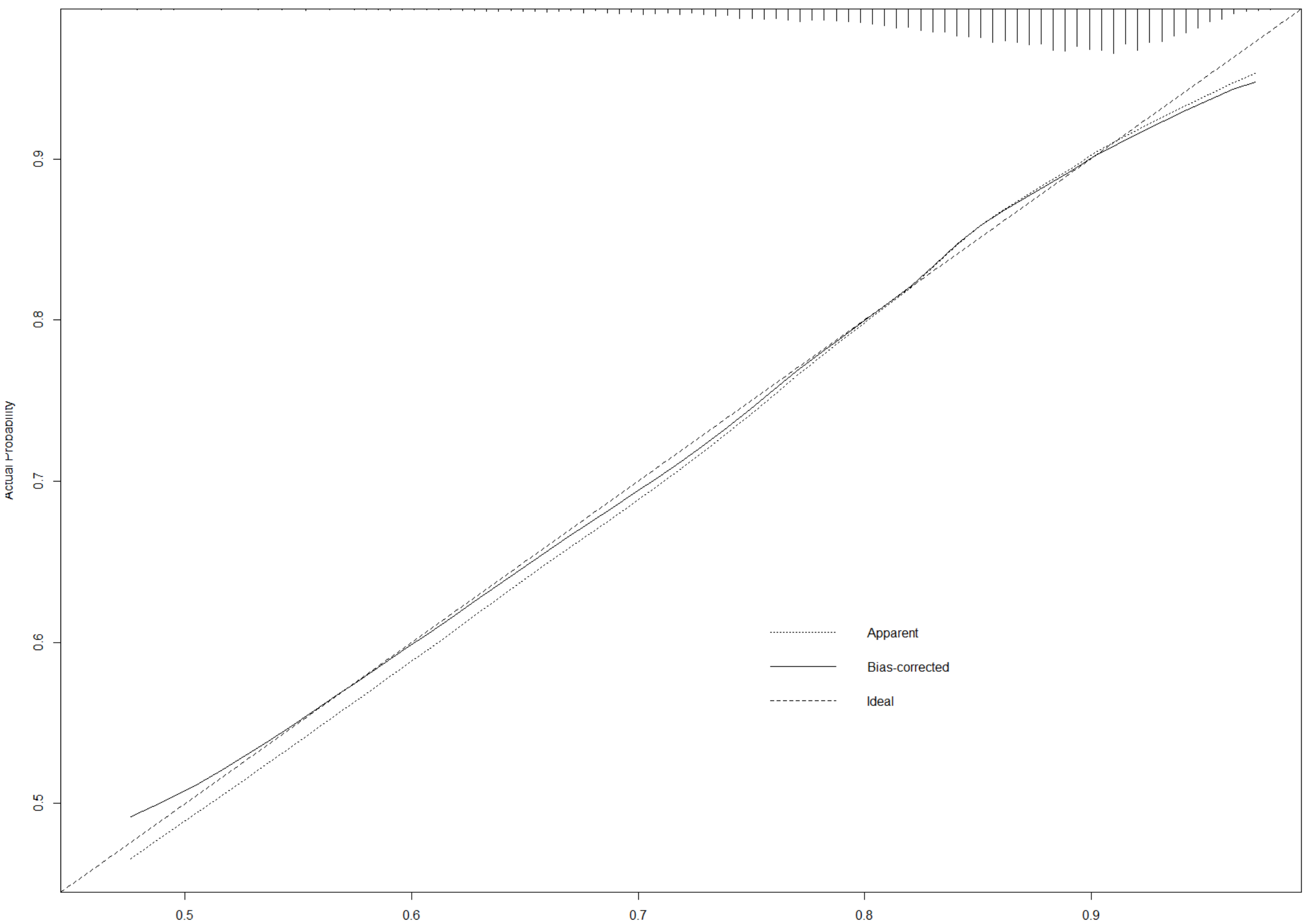


Figure 3. Calibration Curve of Prognostic Model in 3,521 Patients Receiving Home Care Services Who Arrested *In-Hospital* in Ontario, Canada (Brier Score = 0.18)

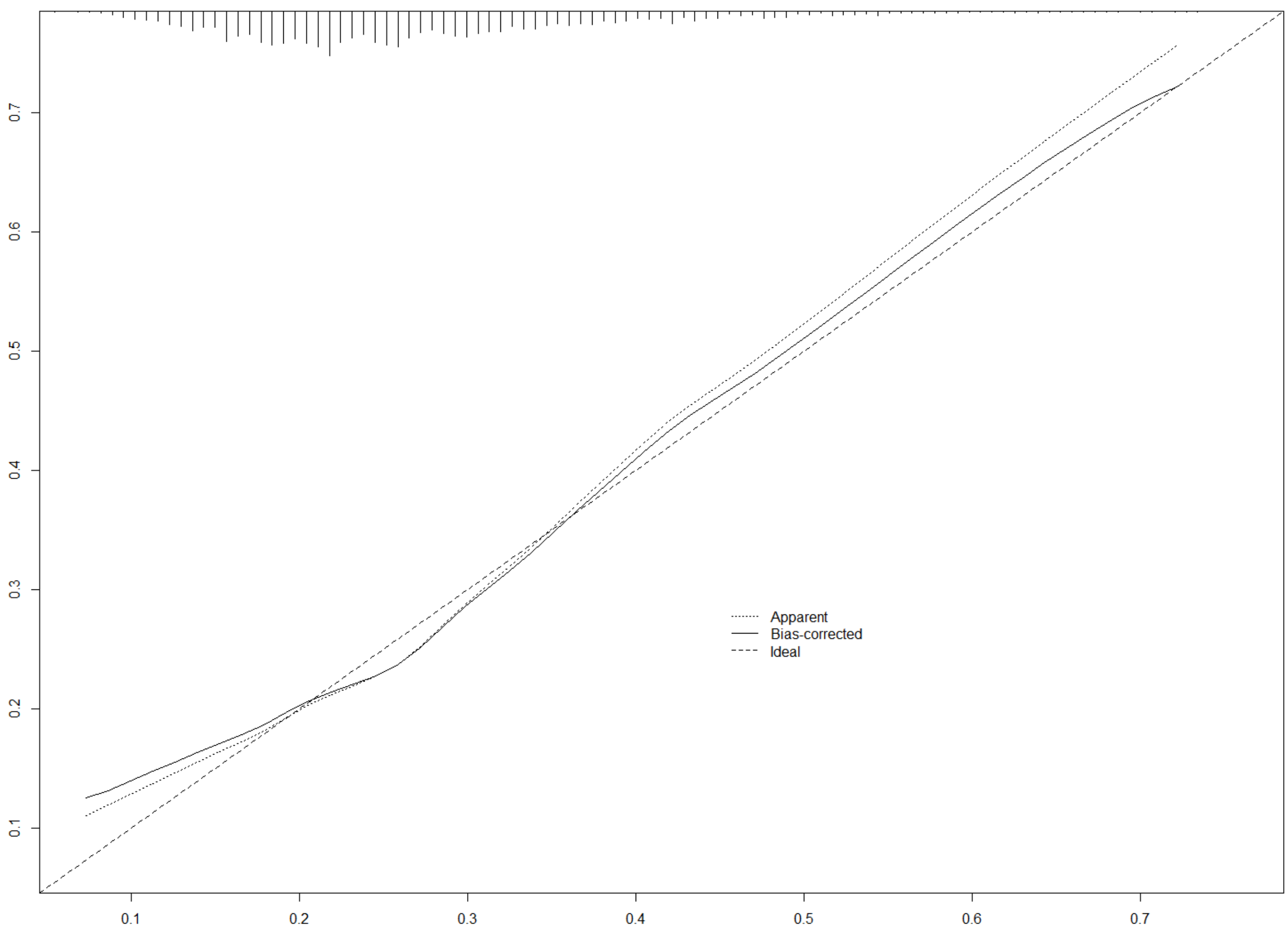


Figure 4. Calibration Curve of Prognostic Model in 4,380 Patients Receiving Home Care Services Who Arrested *Out-of-Hospital* in Ontario, Canada

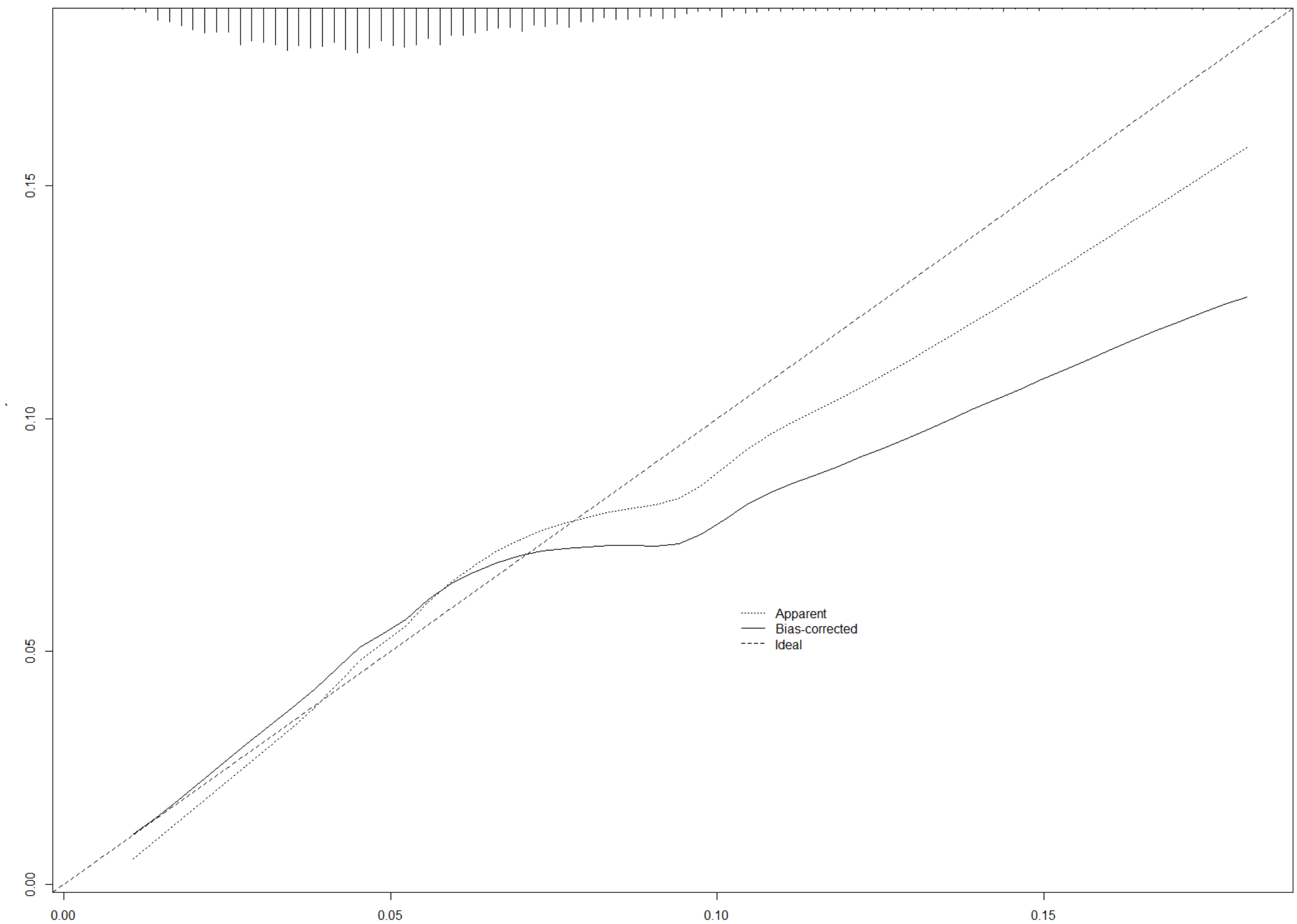
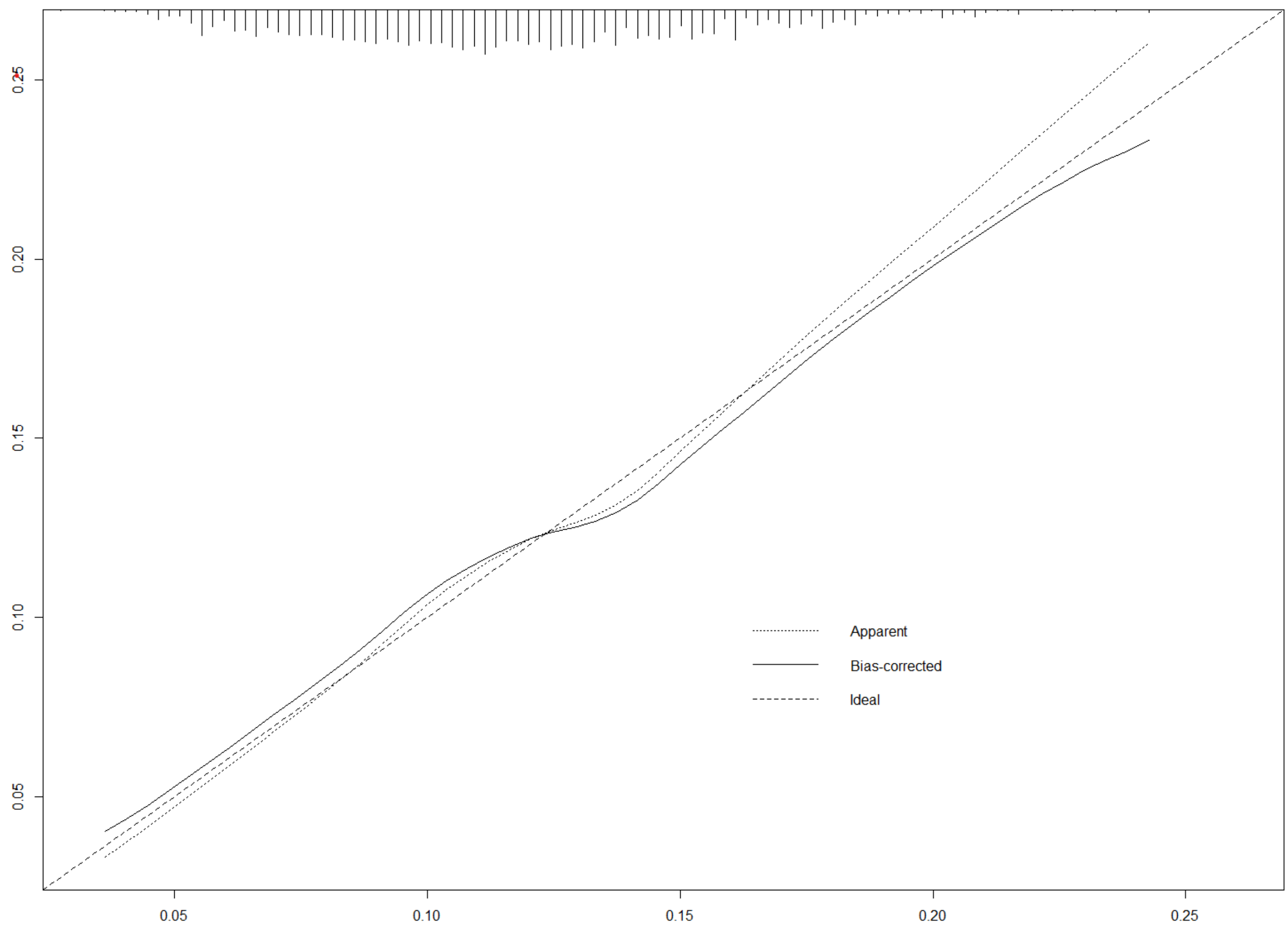


Figure 5. Calibration Curve of the Prognostic Model in 5,233 *Very Old* Patients (≥ 75 Years) Receiving Home Care Services in Ontario, Canada



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CHAPTER SIX

Discussion

Introduction

The prognosis of cardiac arrest and the prognostic factors influencing post-cardiac arrest outcomes have been well studied (1,2). However, little is known about post-cardiac outcomes in patients receiving home care services. Patients receiving home care are at greater risk for cardiac arrest and sudden cardiac death, given their high rates of frailty and geriatric syndromes (3,4). My thesis provides a novel investigation into the prognosis of cardiac arrest in patients receiving home care services. I also evaluated a panel of prognostic factors to inform the derivation and internal validation of a prognostic model to support advance care planning by providing predictions of 30-day survival post-cardiac arrest.

The first study of this thesis is a systematic review and meta-analysis that synthesized studies investigating the association between valid frailty measures and post-cardiac arrest outcomes. This study found high-certainty evidence of a negative association between the Clinical Frailty Scale and survival to hospital discharge after IHCA. This study set the foundation for the following chapters by showcasing the need for advance care planning in populations with high rates of frailty, like patients receiving home care.

The second study of my thesis found that those receiving home care and nursing home care had worse overall prognoses when compared to those not receiving these services. Survival outcomes among these two populations were similar, highlighting an overlap of frailty and medical complexity between patients receiving home care and nursing home residents. This study is the first to provide a population-based evaluation of cardiac arrest prognosis in those receiving home care.

My third study builds upon prior findings by further delineating what pre-arrest features and geriatric syndromes are associated with post-cardiac arrest outcomes in patients receiving home care. This study found that frailty is negatively associated with 30-day survival post-cardiac arrest. When using a more comprehensive frailty index, frailty was associated with post-cardiac arrest declines in functional independence and cognitive performance. This study is the first to evaluate the association between frailty and cardiac arrest outcomes in the home care population.

For the fourth study, I developed and internally validated a prognostic model to predict 30-day survival post-cardiac arrest using pre-arrest assessment items from the RAI-HC. My model is well-suited for population-level prediction of cardiac arrest prognosis in patients receiving home care services and demonstrates similar discriminative performance between sub-groups of IHCA and OHCA. The model also performed well after removing those under 75 years of age (33%) as a sensitivity analysis.

Comparison with Relevant Literature

Chapter 2. My systematic review examining the prognostic association between pre-arrest frailty and cardiac arrest outcomes was the first of its kind (5). My study demonstrated a positive association between the CFS and survival to hospital discharge post-cardiac arrest. An updated review was published the following year (2021) (6), pooling two additional studies and reporting an increased effect size (OR = 2.97 → OR = 3.56). High certainty evidence demonstrates a relationship between frailty and survival after cardiac arrest, validating the importance of considering frailty and the distinct features that define the syndrome (e.g., functional and cognitive impairment). However, almost all prior studies focus on in-hospital arrests and operationalize frailty using the CFS (5–7). Little is known about the prognostic value of frailty in the out-of-hospital setting. My research in the following chapters contributes novel information on the influence of frailty and OHCA health outcomes. I also provide the first estimates from a valid frailty index developed by Armstrong and colleagues (8).

Chapter 3. Many studies exist examining the prognosis of cardiac arrest and the prognostic factors that influence cardiac arrest outcomes. Distinct sub-group analyses have been conducted in nursing home residents (9–11), though there is limited data on post-cardiac arrest outcomes in the home care population. My overall prognosis study of cardiac arrest in patients receiving home care validates prior works reporting worse prognosis of cardiac arrest in nursing home residents. It also contributes new population-based estimates of risk in patients receiving home care.

Studies evaluating cardiac arrest outcomes in nursing home residents have characteristically reported relative associations rather than absolute risk. Relative measures do not account for baseline risk status (12,13), a primary reason the PROGRESS group recommends reporting absolute risk for prognosis studies. To support interpretation and data synthesis efforts moving forward, I report the absolute risk and provide relative estimates in the supplemental files.

Chapter 4. An association between frailty and survival after cardiac arrest has been previously reported, and the findings from this chapter validate this association in a new population of patients receiving home care. In this study, I evaluate the association between frailty and 30-day survival post-cardiac arrest by evaluating the CFS in its full form (i.e., per 1-point increase) and a frailty index. Most resuscitation studies evaluate an association using the CFS and binary cut-off of five or greater (5). However, the categorization of frailty measures has been discouraged due to losses in statistical power, the creation of arbitrary thresholds, and poor external validity (14,15). A higher CFS cut-off of six or seven in the home care population will likely improve prognostic efforts when dichotomizing the scale. My study found that most (95%) patients were classified as frail using the standard CFS cut-off of five.

Survival has been the primary outcome of interest in resuscitation studies (16). However, associations have also been reported between the CFS and discharge to long-term care, worse mental health, and overall health post-cardiac arrest (17,18). A recent study by Jonsson and colleagues (18) found no association between cognitive performance post-cardiac arrest and the CFS. However, it is worth noting that this study included a healthier population, excluding those with a CFS score above seven and only those who survived to 30 days post-cardiac arrest. They also evaluated cognitive performance with the Cerebral Performance Category, a differing but common measure used in resuscitation research. I found no association between the CFS and cognitive performance declines. However, I demonstrated that a more detailed frailty index was significantly associated with declines in cognitive performance and functional independence post-cardiac arrest.

Chapter 5. Many prognostic models and decision rules exist to support decision-making surrounding the prognosis of cardiac arrest and the futility of resuscitation efforts (19). Prognostic models to date have commonly excluded high-risk populations like terminally ill patients and nursing home residents, despite the common receipt of CPR in these populations. Though algorithms exist to predict overall mortality, little is known about cardiac arrest outcomes in the home care population.

The Changes in Health, End-Stage Disease, Signs and Symptoms (CHESS) Score, has proven to be prognostic of 90-day mortality in palliative patients receiving home care (23) and individuals with neurological conditions (24). The CHESS has proven to be a robust predictor of health instability and overall mortality, so I included this scale within my prognostic model. Efforts have also been made to predict time-to-death within six months in the home care population, with the RESPECT algorithm demonstrating good accuracy and calibration with items of the RAI-HC (25). My model had acceptable but worse discriminative accuracy when compared to the RESPECT algorithm (AUROC = 0.66 vs 0.75). However, the prediction of overall mortality allows for the inclusion of more home care clients (N = ~ 140,000) and a larger event rate. Additionally, the prediction of overall mortality allows for greater variability in pre-arrest features, likely to be constrained within a cohort of those experiencing cardiac arrest.

Prognostication of survival post-cardiac arrest has been extensively studied in in-hospital and out-of-hospital settings. My sample size and event rate were significantly larger than most prior clinical prediction models (median N = 591). It also differed by having a relatively older cohort and a higher proportion of females (19), two common features of the home care population (3). When compared to the most reliable prediction models for out-of-hospital (e.g., OHCA Score, Cardiac Arrest Hospital Prognosis [CAHP] Score) and in-hospital arrests (e.g., Good Outcome Following Attempted Resuscitation [GO-FAR]), my model performed significantly worse (20–22).

However, this is likely because these prior models include arrest-specific (e.g., cardiac rhythm, duration of resuscitation) or hospital-specific predictors (e.g., laboratory values, medication use), limiting their use for advance care planning in the community. Most currently available cardiac arrest clinical prediction models have proven to be overfit, as evidenced by significant drops in prognostic accuracy with external validation (19).

Implications of Thesis Findings

The findings from this thesis showcase the worse likelihood of survival post-cardiac arrest in patients receiving home care compared to community-dwelling individuals not receiving this service. The absolute risk of survival post-cardiac arrest was lower among patients receiving home care, irrespective of arrest setting, with the vast majority dying prior to hospital discharge. Poor prognosis and increased risk of cardiac arrest underscore the need for proactive end-of-life discussions in the home care population. Pragmatic advance care planning in the home care population is needed to ensure value-congruent care and to support a dignified and patient-centred death. Frail populations are known to have worse health outcomes post-cardiac arrest. My thesis demonstrated that frailty predicts survival, functional independence, and cognitive performance post-cardiac arrest among patients receiving home care. These findings highlight the importance of reassessing the needs and goals of care upon return from the hospital, considering most patients discharged from the hospital had declines in function and cognition post-cardiac arrest.

The discriminative accuracy of frailty measures alone was found to be weak in my thesis, though many pre-arrest geriatric syndromes known to drive these measures (e.g., functional independence) are both informative and prognostic of post-arrest outcomes. My prognostic model performed statistically better than valid and multidimensional frailty measures like the CFS and a frailty index in predicting survival to 30 days post-cardiac arrest. My model was developed using pre-arrest RAI-HC assessment items to embed this algorithm within the interRAI health assessment systems mandated in home care, long-term care, and post-acute care, following appropriate external validation.

Patients receiving home care are known to be medically complex and receive fragmented care across multiple clinical specialists. This highlights a case scenario where end-of-life discussions can easily be overlooked or miscommunicated. Goals of care are commonly evaluated within the RAI-HC, though a lack of prognostic evidence often limits discussions in home care. My thesis highlights the need for end-of-life discussion in this population and provides information on pre-arrest features and geriatric syndromes to inform these discussions.

Next Steps for the Program of Research

Future work is needed to externally validate my model within other high-risk populations like nursing home residents and post-acute care patients. Predicting time-to-death may help promote the precision of estimates and statistical power of my model. Future efforts will also aim to evaluate if my model is prognostic of more patient-important outcomes like declines in function and cognition.

Conclusion

Patients receiving home care have a worse likelihood of survival post-cardiac arrest when compared to community-dwelling adults not receiving the service. Frailty is an important prognostic factor associated with survival and post-cardiac arrest declines in function and cognition but performs poorly as a multidimensional prognostic model when used in isolation. I developed a prognostic model that can predict survival to 30 days post-cardiac arrest well-suited to predicting survival post-cardiac arrest.

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