Heart failure in young adults is associated with high mortality: a contemporary population-level analysis

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Summary for electronic table of contents

This is a contemporary retrospective cohort study describing the characteristics, health care utilization and outcome of young adults with heart failure (HF) using the link administrative databases in Alberta. A total of 34 548 patients with HF were identified between 2002 and 2014. We found that mortality in young adults with HF remains high with frequent hospitalization.

Abstract

Background. Data on young patients with heart failure (HF) are sparse. We examined the characteristics, healthcare utilization and survival of younger versus older patients with HF.

Methods. Analysis of linked administrative databases in Alberta, Canada. 34,548 patients with first hospitalization for HF as principal diagnosis were identified from 2002 to 2014. Patients were stratified into four age groups: 20-44, 45-54, 55-64, and ≥65 years.

Results. Of the 34548 patients, 496 (1.4%), 1319 (3.8%), 3359 (9.7%) and 29374 (85%) patients were aged 20-44, 45-54, 55-64 and ≥65 years, respectively. Incidence of HF hospitalization decreased over time among patients ≥65 years, and increased among men aged 20 – 64 years. In the year following the index HF hospitalization, younger compared to older patients were less likely to present to the emergency department (ED) (e.g. 67.2% of those aged 20-44 years vs. 74.8% of those aged ≥65 years) or be hospitalized: for any reason (48.5% vs. 61.2%), cardiovascular causes (28.6% vs. 34.4%), or HF (14.8% vs. 23.6%). Mortality rates were lower in younger patients aged 20-44 years, but still substantial: 3.9%, 12.4%, and 27.7% at 30 days, 1 year, and 5 years respectively.

Conclusions. Although young patients, especially those <45 years of age, accounted for a small proportion of the total population, adverse events were frequent, with half of the younger patients being readmitted, two thirds presenting to an ED, and over 10% dying within a year.

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Introduction

Heart failure (HF) is a major public health issue whose disease burden increases with advancing age.[1,2] Most studies utilizing Medicare or administrative claims data have examined patients 65 years or older and have often relied on hospitalization data alone.[3,4] Younger patients (<65 years) with HF are less well characterized, particularly with respect to the interplay between their attendance at outpatient clinics, emergency departments (EDs), and hospitals. Accordingly, we examined the characteristics, resource utilization, and outcomes in young versus older patients with HF in the province of Alberta, Canada.[5]

Methods

Databases

We linked the following five databases maintained by the Alberta Ministry of Health:[6,7] 1) the Discharge Abstract Database records information for all acute care hospitalizations (dates, principal diagnosis and up to 24 other diagnoses, procedures, length of stay and discharge status); 2) the Ambulatory Care Database records all visits to hospital-based physician offices or EDs and includes up to ten diagnosis fields; 3) the Practitioners Claims Database tracks all physicians' claims from outpatient services and records up to 3 diagnostic codes per encounter; 4) the Population Registry records basic demographic and geographic information for all 4.1 million citizens; and 5) the Alberta Vital Statistics records all deaths in the province. Each patient has a unique personal identifier allowing linkage of patient information across the databases, but the data are released to researchers in de-identified form.

Study population – incident and prevalent HF

We identified all patients over 20 years of age hospitalized with HF as a principal diagnosis (International Classification of Disease, version 10 (ICD-10) code I50) between 1st April 2002 and 31st March 2014 in Alberta, Canada. The specificity and sensitivity of HF coding within the Alberta Health databases is 98.7% and 77.3% respectively.[5,8] The first hospitalization with a principal diagnosis of HF during the study time period was considered the index hospitalization for each patient. Patients were

classified as either incident or prevalent HF patients at the time of their index hospitalization. Incident patients were those *without* a prior diagnosis of HF recorded in all available data sources, including hospitalizations (1994 onwards), hospital based outpatient clinic or ED visits (1997 onwards), and physician office claims (1994 onwards). Prevalent patients were those *with* a prior diagnosis of HF in any setting, and were further categorized as those with or without previous HF hospitalization. The HF incidence date for prevalent patients was the date of first diagnosis, regardless of setting. Concurrent hospitalizations or ED visits within 24 hours were considered the same episode of care.[9]

Variables and Outcomes

Comorbidities were identified using established ICD code case definitions previously validated in Alberta.[8] They were considered to be present if recorded in any diagnostic position prior to hospitalization or in outpatient clinic/ED record. If present only in physician office claims, a diagnosis had to be present in at least 5 claims to be considered a comorbidity. Annual median household income (MHI) in 2006 at the residential neighborhood level was obtained from census data from Statistics Canada. For prevalent patients, duration of disease was calculated as the number of days between the HF incidence date and the date of index HF hospitalization or first outpatient diagnosis.

Outcomes of interest included one-year resource utilization among patients discharged alive from the index hospitalization, including all ED attendances and re-hospitalizations, and specifically those related to cardiovascular disease or HF. We also examined unadjusted rates and comorbidity adjusted odds ratios of in-hospital, 30-day, 1-year and 5-year mortality.

Statistical analysis

We stratified patients based on their age at first HF hospitalization into 4 age categories: 20-44, 45-54, 55-64 and ≥65 years. Supplementary analyses by age and sex are provided in an online supplement. We described baseline characteristics by age categories among incident and prevalent HF patients. Results are presented as means and standard deviations or medians and interquartile range for continuous variables and proportions for categorical variables. The incidence rate of HF was calculated as the number of incident

cases divided by the number of persons within each observation year by age category. Estimated counts of Alberta population for each observation year were extracted from databases maintained by Conference Board of Canada (http://www.conferenceboard.ca/). Poisson regression models were used to assess the trend of HF incidence rate by age category. Logistic regression models were used to estimate the odds ratio of younger age compared with the referent age category ≥65 years. The model was adjusted for comorbidities, annual median household income in 2006, urban residence, type of hospital, and year of admission. All tests were two sided with a level of significance set at P <0.05. Analyses were performed using SAS version 9.4.

Results

Between 1st April 2002 and 31st March 2014, 34,548 patients experienced an index HF admission. Of these, 496 (1.4%), 1319 (3.8%) and 3359 (9.7%) patients were aged 20-44, 45-54 and 55-64 respectively. Those ≥65 years accounted for 85.0% of the population. Overall, 23427 (67.8%) had a prior diagnosis of HF and 11121 (32.2%) were incident presentations. The incidence of first HF hospitalization increased with increasing age (Table S1 in Supplementary Materials). Although low, incidence rates among younger men (age 20 – 64 years) increased over time (from 1 per 10,000 in 2002/03 to 1.4 per 10,000 in 2012/13), but were stable among younger women. In contrast, in patients ≥65 years, the incidence rates decreased over time among men and remained stable among women.

Baseline characteristics of incident and prevalent patients, by age category, are presented in Table 1. In both patient groups, except for rates of congenital heart disease and asthma, which were higher in the patients aged 20-44 and 45-54 years, rates of most comorbidities were higher in older patients. Younger patients had a shorter mean length of hospital stay compared to older patients, though median values were similar across age categories suggesting fewer very prolonged hospital admissions in younger patients. In the subset of patients with prevalent HF who had been managed entirely in the outpatient setting prior to the index HF hospitalization, we examined the median days from diagnosis to hospitalization. The median (interquartile range) increased with increasing age: 139, (12 – 1030) in patients aged 20-44 years; 226 (24 – 1405) ages 45–54; 405 (37 – 1528) ages 55–64; and 908 (140–2328) in those aged ≥65 years (p<0.0001)

Although the rates of subsequent ED presentations and re-hospitalizations within one year were lowest in younger patients, they were still substantial (Table 2). Approximately 70% of patients aged 20-44 years had a repeat ED visit compared with 75% of patients aged ≥65 years and rates of one-year re-hospitalization were approximately 50% and 60% in the two age groups, respectively. The in-hospital, 30 days, 1 and 5-year mortality rates were 3.9%, 12.4%, and 27.7% in the youngest patients and 11.5%, 35.3%, and 72.8% in the oldest age group, respectively (Figure 1). Differences in mortality between younger and older patients with HF remained even after adjustment for covariates (Table S2 in Supplementary Materials). All analyses stratified by *sex and age category* are presented in Tables S3 - S6 in Supplementary Materials.

Discussion

In this retrospective population-level cohort study, younger patients with HF had many important differences from their older counterparts. The incidence of HF hospitalization decreased over time among patients ≥65 years. Although low, incidence rates among younger men (age 20 – 64 years) increased over time but were stable among younger women. More than half of the younger patients had no prior history of HF in any setting, compared to just one quarter in those aged ≥65 years. For those with a prior diagnosis of HF in the outpatient setting, the time from diagnosis to first HF hospitalization was markedly shorter in younger compared to older patients. HF in the young was associated with a significant mortality and morbidity burden with approximately 50% of young patients being readmitted to hospital, ~70% presenting to the emergency department, and 12% dying within one year of index HF hospitalization.

As with previous studies, the incidence of first HF hospitalization in our study was lower in younger compared to older patients.[10-22] In developed countries the incidence and mortality of HF has generally been decreasing, leading to stable prevalence rates.[23-25] The elderly have experienced the greatest decline in incidence, reflecting improved control of risk factors such as hypertension and diabetes,[26,27] together with a declining incidence of myocardial infarction.[28,29] We observed a rise in incident HF among younger men (but not women) in Alberta. This is consistent with the findings from Sweden where the incidence of first HF hospitalization increased significantly from 1987-91 to 2002-2006 in those <54 years, relatively more so

in men compared to women.[10] The extent to which sex differences observed in our study and the Swedish registry are attributable to male predominance of drug abuse and excessive alcohol consumption require further study.

Previous studies of young patients with HF have largely been limited to hospitalizations,[10,12] with a few linked to ambulatory clinic visits.[17] To our knowledge, this is the only study to examine what appears to be a complex utilization pattern of ED services. After receiving an outpatient diagnosis of HF, we found young patients were admitted to hospital much sooner than older patients. Some plausible explanations for this finding is the different etiologies of HF in younger patients, including congenital heart disease and inherited cardiomyopathy. The population of adults with congenital heart disease is growing exponentially. This poses significant risk of adverse events including arrhythmia and heart failure and requires lifelong cardiology care. Transitions from pediatric to adult services are a recognized care gap, with up to half of patients not receiving appropriate follow-up.[30] Mutations such as cardiac troponin T or β-myosin heavy chain cause early onset ventricular dysfunction.[31-33] X-linked laminopathies and dystrophin defects may also contribute.[34,35] In other cohorts, ejection fraction is lowest in younger patients (EF was unavailable in our administrative dataset), potentially prompting physicians to admit them sooner.[36,37] Unlike older patients who may more readily attribute HF symptoms and functional limitation to age, younger patients with higher societal and family demands may be more likely to seek medical attention sooner.

After discharge from first HF hospitalization, younger patients had lower readmission rates to hospital than older patients. This may reflect atypical presentation in younger patients, who are less likely to have peripheral edema, pulmonary rales, and radiological evidence of pulmonary edema.[36] Physicians may be reassured by the absence of classical symptoms and signs and therefore discharge patients from the ED. Younger patients also have fewer comorbidities and less frailty, perhaps encouraging discharge and outpatient management. Nevertheless, young patients still had re-hospitalization rates by 1 year of approximately 50% for any cause and 15% for HF.

Mortality data in young patients with HF are scarce.[10,12,24] One-year case fatality after first hospitalization in the Swedish national registry was 11% to 12% in age groups from 18 to 54 years,[10] and 13% in the New South Wales study for those age 45-49 years.[12] We found five-year mortality rates of 28%,

32% and 42% among patients aged 20-44, 45-54, and 55-64 years, respectively. Our results provide a guide to counsel patients with respect to longer term prognosis.

Limitations

The linked administrative datasets in Alberta allow capture and follow-up of all interactions within the health care system. However, some limitations warrant consideration. The diagnosis of HF in hospital administrative registries relies on the accuracy of patient records and the responsible physicians. However, the accuracy of Alberta administrative data has been validated in patients with HF and for comorbidities. Data on ejection fraction, laboratory results, biomarkers, causes of HF are lacking. The number of younger patients is relatively small, increasing imprecision in results.

Conclusions

Compared to the elderly, younger patients with HF are more likely to present initially to secondary care, and be hospitalized sooner if diagnosed in primary care. Short and long-term mortality among young patients with HF remains high. After discharge, over half of the young patients with HF are readmitted and over two thirds present to an ED within a year. The high mortality and adverse outcomes rates are a major cause for concern, and warrant a better understanding.

Figure legends

Figure 1. Unadjusted 30 days, 1 and 5-year case fatality by age category among patients hospitalized with heart failure

References

1. McMurray JJ, Adamopoulos S, Anker SD, et al. ESC guidelines for the diagnosis and treatment of acute and chronic heart failure 2012: The Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2012 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association (HFA) of the ESC. Eur J Heart Fail 2012;14:803-69.

2. Yancy CW, Jessup M, Bozkurt B, et al. 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2013;62:e147-239.

3. Komajda M, Hanon O, Hochadel M, et al. Contemporary management of octogenarians hospitalized for heart failure in Europe: Euro Heart Failure Survey II. Eur Heart J 2009;30:478-86.

4. Forman DE, Cannon CP, Hernandez AF, Liang L, Yancy C, Fonarow GC. Influence of age on the management of heart failure: findings from Get With the Guidelines-Heart Failure (GWTG-HF). Am Heart J 2009;157:1010-7.

5. Kaul P, McAlister FA, Ezekowitz JA, Grover VK, Quan H. Ethnic differences in 1-year mortality among patients hospitalised with heart failure. Heart 2011;97:1048-53.

6. Ezekowitz JA, Bakal JA, Kaul P, Westerhout CM, Armstrong PW. Acute heart failure in the emergency department: short and long-term outcomes of elderly patients with heart failure. Eur J Heart Fail 2008;10:308-14.

7. Kaul P, Chang WC, Westerhout CM, Graham MM, Armstrong PW. Differences in admission rates and outcomes between men and women presenting to emergency departments with coronary syndromes. CMAJ 2007;177:1193-9.

8. Quan H, Parsons GA, Ghali WA. Validity of information on comorbidity derived from ICD-9-CCM administrative data. Med Care 2002;40:675-85.

9. Ezekowitz JA, Kaul P, Bakal JA, Quan H, McAlister FA. Trends in heart failure care: has the incident diagnosis of heart failure shifted from the hospital to the emergency department and outpatient clinics? Eur J Heart Fail 2011;13:142-7.

10. Barasa A, Schaufelberger M, Lappas G, Swedberg K, Dellborg M, Rosengren A. Heart failure in young adults: 20-year trends in hospitalization, aetiology, and case fatality in Sweden. Eur Heart J 2014;35:25-32.

11. Goyal A, Norton CR, Thomas TN, et al. Predictors of incident heart failure in a large insured population: a one million person-year follow-up study. Circ Heart Fail 2010;3:698-705.

12. Robertson J, McElduff P, Pearson SA, Henry DA, Inder KJ, Attia JR. The health services burden of heart failure: an analysis using linked population health data-sets. BMC Health Serv Res 2012;12:103.

13. Teng TH, Finn J, Hobbs M, Hung J. Heart failure: incidence, case fatality, and hospitalization rates in Western Australia between 1990 and 2005. Circ Heart Fail 2010;3:236-43.

14. Fox KF, Cowie MR, Wood DA, et al. Coronary artery disease as the cause of incident heart failure in the population. Eur Heart J 2001;22:228-36.

15. Loehr LR, Rosamond WD, Chang PP, Folsom AR, Chambless LE. Heart failure incidence and survival (from the Atherosclerosis Risk in Communities study). Am J Cardiol 2008;101:1016-22.

16. Blackledge HM, Tomlinson J, Squire IB. Prognosis for patients newly admitted to hospital with heart failure: survival trends in 12 220 index admissions in Leicestershire 1993-2001. Heart 2003;89:615-20.

17. Zarrinkoub R, Wettermark B, Wandell P, et al. The epidemiology of heart failure, based on data for 2.1 million inhabitants in Sweden. Eur J Heart Fail 2013;15:995-1002.

18. Yeung DF, Boom NK, Guo H, Lee DS, Schultz SE, Tu JV. Trends in the incidence and outcomes of heart failure in Ontario, Canada: 1997 to 2007. CMAJ 2012;184:E765-73.

19. Bibbins-Domingo K, Pletcher MJ, Lin F, et al. Racial differences in incident heart failure among young adults. N Engl J Med 2009;360:1179-90.

20. Goldberg RJ, Spencer FA, Farmer C, Meyer TE, Pezzella S. Incidence and hospital death rates associated with heart failure: a community-wide perspective. Am J Med 2005;118:728-34.

21. Cowie MR, Wood DA, Coats AJ, et al. Incidence and aetiology of heart failure; a population-based study. Eur Heart J 1999;20:421-8.

22. Tuppin P, Cuerq A, de Peretti C, et al. First hospitalization for heart failure in France in 2009: patient characteristics and 30-day follow-up. Arch Cardiovasc Dis 2013;106:570-85.

23. Gerber Y, Weston SA, Redfield MM, et al. A contemporary appraisal of the heart failure epidemic in Olmsted County, Minnesota, 2000 to 2010. JAMA Intern Med 2015;175:996-1004.

24. Jhund PS, Macintyre K, Simpson CR, et al. Long-term trends in first hospitalization for heart failure and subsequent survival between 1986 and 2003: a population study of 5.1 million people. Circulation 2009;119:515-23.

25. Roger VL. Epidemiology of heart failure. Circ Res 2013;113:646-59.

26. McAlister FA, Wilkins K, Joffres M, et al. Changes in the rates of awareness, treatment and control of hypertension in Canada over the past two decades. CMAJ 2011;183:1007-13.

27. Gregg EW, Li Y, Wang J, et al. Changes in diabetes-related complications in the United States, 1990-2010. N Engl J Med 2014;370:1514-23.

28. Yeh RW, Sidney S, Chandra M, Sorel M, Selby JV, Go AS. Population trends in the incidence and outcomes of acute myocardial infarction. N Engl J Med 2010;362:2155-65.

29. Roger VL, Weston SA, Gerber Y, et al. Trends in incidence, severity, and outcome of hospitalized myocardial infarction. Circulation 2010;121:863-9.

30. Reid GJ, Irvine MJ, McCrindle BW, et al. Prevalence and correlates of successful transfer from pediatric to adult health care among a cohort of young adults with complex congenital heart defects. Pediatrics 2004;113:e197-205.

31. Arbustini E, Diegoli M, Morbini P, et al. Prevalence and characteristics of dystrophin defects in adult male patients with dilated cardiomyopathy. J Am Coll Cardiol 2000;35:1760-8.

32. Stefanelli CB, Rosenthal A, Borisov AB, Ensing GJ, Russell MW. Novel troponin T mutation in familial dilated cardiomyopathy with gender-dependant severity. Mol Genet Metab 2004;83:188-96.

33. Kamisago M, Sharma SD, DePalma SR, et al. Mutations in sarcomere protein genes as a cause of dilated cardiomyopathy. N Engl J Med 2000;343:1688-96.

34. Cohen N, Muntoni F. Multiple pathogenetic mechanisms in X linked dilated cardiomyopathy. Heart 2004;90:835-41.

35. Rankin J, Ellard S. The laminopathies: a clinical review. Clin Genet 2006;70:261-74.

36. Wong CM, Hawkins NM, Jhund PS, et al. Clinical characteristics and outcomes of young and very young adults with heart failure: The CHARM programme (Candesartan in Heart Failure Assessment of Reduction in Mortality and Morbidity). J Am Coll Cardiol 2013;62:1845-54.

37. Wong CM, Hawkins NM, Petrie MC, et al. Heart failure in younger patients: the Meta-analysis Global Group in Chronic Heart Failure (MAGGIC). Eur Heart J 2014;35:2714-21.

Table 1. Baseline characteristics of hospitalized HF patients by age categories

	INCIDENT HF PATIENTS[1]				PREVALENT HF PATIENTS[2]			
Age	20-44	45-54	55-64	≥65	20-44	45-54	55-64	≥65
n	293	677	1467	8684	203	642	1892	20690
Male	59.3	50.2	43.2	28.5	40.7	49.8	56.8	71.5
Co-morbidities n (%)								
Prior MI	7 (2.4)	54 (8.0)	207 (14.1)	1470 (16.9)	29 (14.3)	204 (31.8)	732 (38.7)	8088 (39.1)
Prior Revasc.	6 (2.0)	47 (6.9)	178 (12.1)	935 (10.8)	12 (5.9)	143 (22.3)	533 (28.2)	4246 (20.5)
AF	49 (16.7)	157 (23.2)	398 (27.1)	3623 (41.7)	59 (29.1)	219 (34.1)	822 (43.4)	12494 (60.4)
Hypercholesterolemia	8 (2.7)	52 (7.7)	184 (12.5)	1099 (12.7)	13 (6.4)	123 (19.2)	417 (22.0)	3948 (19.1)
Hypertension	125 (42.7)	396 (58.5)	1033 (70.4)	7061 (81.3)	98 (48.3)	473 (73.7)	1602 (84.7)	18550 (89.7)
CVD	12 (4.1)	58 (8.6)	159 (10.8)	1936 (22.3)	19 (9.4)	72 (11.2)	381 (20.1)	6127 (29.6)
Diabetes mellitus	64 (21.8)	238 (35.2)	659 (44.9)	3145 (36.2)	55 (27.1)	317 (49.4)	1108 (58.6)	8765 (42.4)
Malignant disease	9 (3.1)	52 (7.7)	158 (10.8)	1586 (18.3)	9 (4.4)	31 (4.8)	185 (9.8)	4005 (19.4)
PAD	7 (2.4)	44 (6.5)	154 (10.5)	1432 (16.5)	21 (10.3)	92 (14.3)	434 (22.9)	5374 (26.0)
Renal failure	34 (11.6)	84 (12.4)	195 (13.3)	1652 (19.0)	45 (22.2)	156 (24.3)	521 (27.5)	6920 (33.4)
COPD	101 (34.5)	249 (36.8)	634 (43.2)	3640 (41.9)	91 (44.8)	350 (54.5)	1133 (59.9)	12383 (59.9)
Asthma	58 (19.8)	110 (16.2)	199 (13.6)	931 (10.7)	48 (23.6)	154 (24.0)	413 (21.8)	3490 (16.9)
CHD	33 (11.3)	30 (4.4)	22 (1.5)	111 (1.3)	50 (24.6)	57 (8.9)	106 (5.6)	537 (2.6)
Type of hospital								
Community small	48 (16.4)	146 (21.6)	345 (23.5)	2252 (25.9)	34 (16.7)	137 (21.3)	486 (25.7)	6011 (29.1)
Community medium	17 (5.8)	40 (5.9)	92 (6.3)	471 (5.4)	17 (8.4)	56 (8.7)	117 (6.2)	1102 (5.3)
Community large	58 (19.8)	111 (16.4)	250 (17.0)	1499 (17.3)	33 (16.3)	101 (15.7)	295 (15.6)	3611 (17.5)
Teaching	170 (58.0)	380 (56.1)	780 (53.2)	4462 (51.4)	119 (58.6)	348 (54.2)	994 (52.5)	9966 (48.2)
Concurrent ED	273 (93.2)	617 (91.1)	1338 (91.2)	7929 (91.3)	163 (80.3)	497 (77.4)	1586 (83.8)	18164 (87.8)
LOS, (Med, IQR)	8 (4, 13)	7 (5, 13)	8 (5, 13)	8 (5, 15)	7 (3, 11)	7 (4, 12)	7 (4, 13)	8 (5, 16)
MHI	59217 (52216, 72202)	58559 (52162, 67440)	58559 (52162, 67440)	58559 (52046, 67074)	58727 (52162, 69101)	58559 (52162, 68487)	58307 (52162, 67054)	57435 (52046, 65726)
Urban residence	236 (80.6)	527 (77.8)	1087 (74.1)	6813 (78.5)	158 (77.8)	472 (73.5)	1380 (72.9)	15769 (76.2)

MI=myocardial infarction; Revasc.: Revascularization; AF=atrial fibrillation; CVD= cerebrovascular disease; PAD=peripheral arterial disease; COPD=chronic obstructive pulmonary disease; CHD: Congenital Heart Disease; ED: Emergency Department; LOS: Length of stay; Med: Median; IQR=inter-quartile range; MHI: Median Household Income

1: Defined as patients **without** any prior diagnosis of HF in a physician's office, outpatient clinic, emergency department, or hospital

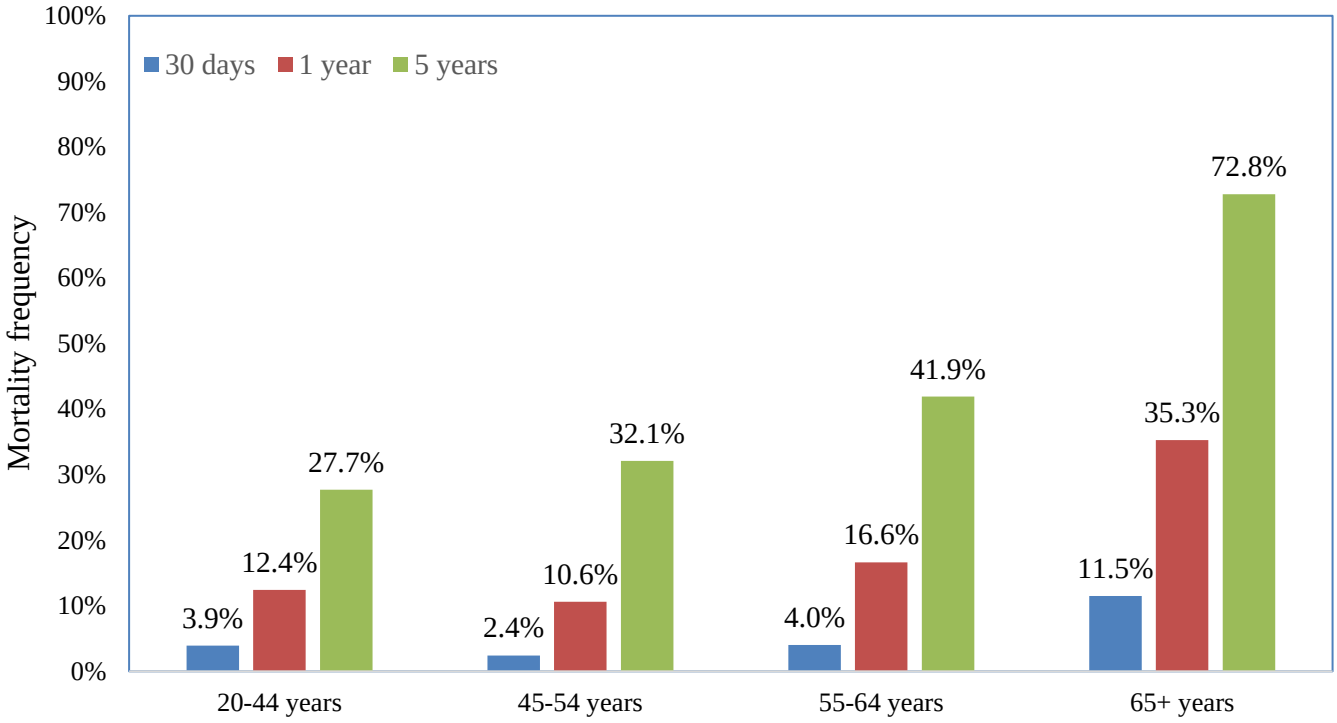
2: Defined as patients **with** a prior diagnosis of HF in a physician's office, outpatient clinic, emergency department, or hospital

Table 2. One-year non-fatal outcomes by age categories in patients discharged alive from HF hospitalization

Age	20-44	45-54	55-64	≥65
n discharged alive	433	1164	2913	23281
Any ED visit	291 (67.2)	763 (65.5)	2018 (69.3)	17415 (74.8)
% followed by hospitalization	105 (24.2)	287 (24.7)	816 (28.0)	8355 (35.9)
Median days to event (IQR)	46 (13, 131)	49 (10, 135)	47 (13, 135)	47 (14, 130)
HF ED visit	77 (17.8)	197 (16.9)	630 (21.6)	6126 (26.3)
% followed by hospitalization	48 (11.1)	117 (10.1)	411 (14.1)	4107 (17.6)
CV ED visit	133 (30.7)	366 (31.4)	1018 (34.9)	8797 (37.8)
% followed by hospitalization	69 (15.9)	191 (16.4)	577 (19.8)	5514 (23.7)
Any re-hospitalization	210 (48.5)	572 (49.1)	1571 (53.9)	14252 (61.2)
Median days to event	59 (18, 137)	70 (19, 167)	72 (22, 169)	67 (22, 166)
CV re-hospitalization	124 (28.6)	327 (28.1)	932 (32.0)	8019 (34.4)
Median days to event	61 (18, 145)	72 (19, 176)	87 (26, 194)	74 (24, 178)
HF re-hospitalization	64 (14.8)	171 (14.7)	526 (18.1)	5496 (23.6)
Median days to event	65 (18, 113)	61 (17, 171)	84 (24, 179)	71 (22, 175)

N (%) or median (IQR)
CV=cardiovascular; ED=emergency department; HF=heart failure; IQR=interquartile range.

Figure 1. Unadjusted 30 days, 1 and 5-year case fatality by age category among patients hospitalized with heart failure



Online Supplementary Materials

Table S1. Incidence (per 10000 population) of HF hospitalization by age category

Age	2002/ 03	2003/ 04	2004/ 05	2005/ 06	2006/ 07	2007/ 08	2008/ 09	2009/ 10	2010/ 11	2011/ 12	2012/ 13	2013/ 14	P value
Overall													
20-44	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.3	0.2	0.2	0.53
45-54	1.3	1.0	0.9	1.2	0.9	0.9	1.3	1.2	0.9	0.9	1.2	1.1	0.81
55-64	3.9	4.6	3.7	3.6	2.6	2.6	3	3.6	3.6	3.4	3.5	3.4	0.12
20-64	**0.9**	**1.0**	**0.8**	**0.9**	**0.8**	**0.7**	**0.9**	**0.1**	**0.9**	**1.0**	**1.0**	**1.0**	**0.13**
≥65	**22.2**	**22.7**	**21.6**	**20.9**	**17.2**	**17.1**	**16.7**	**17.3**	**18.1**	**19.4**	**19.5**	**20.1**	**<0.01**
Men													
20-44	0.2	0.1	0.2	0.2	0.3	0.2	0.1	0.1	0.2	0.3	0.3	0.3	0.09
45-54	1.2	1	0.9	1.5	1.2	1.3	1.8	1.6	0.9	1.1	1.7	1.3	0.16
55-64	4.6	6	4.5	4	3.1	3.3	4.1	4.6	4.3	4	4.7	4.3	0.57
20-64	**1.0**	**1.1**	**0.9**	**1.1**	**0.9**	**0.9**	**1.1**	**1.2**	**1.0**	**1.1**	**1.4**	**1.2**	**<0.01**
≥65	**22.2**	**23.1**	**24.9**	**22.3**	**17.4**	**17.3**	**19**	**17**	**16.9**	**19.1**	**18.8**	**20.7**	**<0.01**
Women													
20-44	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.26
45-54	1.3	0.9	0.9	0.8	0.7	0.5	0.7	0.9	0.9	0.7	0.6	0.9	0.14
55-64	3.1	3.3	2.9	3.2	2.2	1.9	1.9	2.6	2.8	2.7	2.2	2.4	0.06
20-64	**0.9**	**0.8**	**0.8**	**0.7**	**0.6**	**0.5**	**0.6**	**0.7**	**0.8**	**0.8**	**0.6**	**0.7**	**0.25**
≥65	**22.3**	**22.4**	**18.9**	**19.7**	**17**	**17**	**14.9**	**17.6**	**19**	**19.8**	**20.1**	**19.6**	**0.10**

Table S2. Unadjusted and adjusted outcomes stratified by age categories among patients hospitalized with HF

Age	20-44	45-54	55-64	≥65
In-hospital				
Population n	496	1319	3359	29374
Death (%)	3.4	2.4	3.7	12.3
OR (95% CI)	0.29 (0.18 , 0.47)	0.21 (0.15 , 0.30)	0.33 (0.27 , 0.40)	1
30 days				
Population n	487	1279	3265	28509
Death (%)	3.9	2.4	4.0	11.5
OR (95% CI)	0.34 (0.21 , 0.54)	0.22 (0.15 , 0.32)	0.37 (0.31 , 0.45)	1
Death/readmission n (%)	89/469 (19.0)	202/1241 (16.3)	583/3127 (18.6)	5355/24892 (21.5)
OR (95% CI)	0.99 (0.78 , 1.26)	0.80 (0.68 , 0.93)	0.91 (0.82 , 1.00)	1
1 year				
Population n	434	1169	2965	26034
Death (%)	12.4	10.6	16.6	35.3
OR (95% CI)	0.31 (0.23 , 0.41)	0.27 (0.22 , 0.32)	0.43 (0.39 , 0.48)	1
Death/readmission n (%)	214/417 (51.3)	576/1134 (50.8)	1620/2839 (57.1)	15279/22694 (67.3)
OR (95% CI)	0.72 (0.58 , 0.88)	0.64 (0.56 , 0.72)	0.74 (0.68 , 0.81)	1
5 years				
Population n	260	738	1776	16536
Death (%)	27.7	32.1	41.9	72.8
OR (95% CI)	0.21 (0.16 , 0.28)	0.24 (0.20 , 0.28)	0.32 (0.29 , 0.36)	1
Death/readmission n (%)	188/249 (75.5)	564/708 (79.7)	1494/1694 (88.2)	13574/14377 (94.4)
OR (95% CI)	0.35 (0.26 , 0.49)	0.34 (0.28 , 0.42)	0.54 (0.45 , 0.64)	1

CI=confidence interval; OR=odd ratio.

Variables include urban residence, prevalent episode, fiscal year of episode end date, presentation hospital (community small, community medium, community large, and teaching hospital), median household income, prior MI, prior revascularization, atrial fibrillation, cholesterol, hypertension, cerebo-vascular disease, diabetes mellitus, cancer, peripheral vascular disease, renal disease, COPD, asthma, and chronic heart disease.
Death/readmission post discharge is assessed only for patients that were discharged alive from the index hospitalization episode, within 30 days post discharge

Table S3. Baseline characteristics by sex and age categories of incident HF patients

Age	20-44		45-54		55-64		≥65	
	M	F	M	F	M	F	M	F
n	178	115	425	252	922	545	3998	4686
% (all incident and prevalent)	59.3	58.7	50.2	53.4	43.2	44.6	28.5	30.6
Co-morbidities (%)								
Prior MI	2.2	2.6	9.6	5.2	16.9	9.4	21.6	12.9
Prior revascularization	2.2	1.7	8.7	4.0	15.5	6.4	15.3	6.9
AF	20.8	10.4	28.0	15.1	31.1	20.4	42.4	41.1
Hypercholesterolemia	3.4	1.7	9.4	4.8	13.7	10.6	13.8	11.7
Hypertension	43.3	41.7	59.3	57.1	70.1	71.0	78.6	83.6
CVD	3.9	4.3	8.2	9.1	11.3	10.1	22.5	22.2
Diabetes mellitus	20.2	24.3	35.1	35.3	46.0	43.1	39.4	33.5
Malignant disease	1.1	6.1	3.5	14.7	10.0	12.1	22.8	14.4
PAD	2.2	2.6	7.5	4.8	11.3	9.2	19.5	13.9
Renal failure	11.2	12.2	14.4	9.1	13.9	12.3	21.2	17.2
COPD	30.9	40.0	31.8	45.2	38.9	50.5	45.1	39.2
Asthma	17.4	23.5	10.1	26.6	9.4	20.6	9.3	11.9
Congenital heart disease	12.9	8.7	4.5	4.4	1.3	1.8	1.3	1.3
Type of presentation hospital								
Community small	15.2	18.3	23.1	19.0	23.6	23.3	26.5	25.5
Community medium	5.1	7.0	5.6	6.3	6.3	6.2	6.4	4.6
Community large	23.0	14.8	16.7	15.9	16.9	17.2	17.4	17.1
Teaching	56.7	60.0	54.6	58.7	53.1	53.2	49.7	52.8
Concurrent ED	91.6	95.7	90.1	92.9	91.1	91.4	90.9	91.7
Length of stay								
Mean (SD)	10.6 (10.2)	10.7 (14.0)	12.4 (26.7)	10.1 (10.1)	13.3 (20.4)	13.4 (19.5)	14.7 (23.1)	16.2 (24.3)
Median (IQR)	8 (5, 13)	7 (4, 11)	7 (5, 13)	8 (5, 12)	8 (5, 14)	9 (5, 13)	8 (4, 15)	9 (5, 16)
Household income, Canadian dollars								
Median (IQR)	58928 (52216, 71759)	59383 (52162, 73945)	58307 (52046, 68487)	58599 (52249, 67440)	58559 (52162, 69101)	58559 (52216, 67054)	58559 (52162, 67054)	58559 (52001, 67074)

AF=atrial fibrillation; COPD=chronic obstructive pulmonary disease; CVD= cerebrovascular disease; IQR=inter-quartile range; MI=myocardial infarction; PAD=peripheral arterial disease

Table S4. Baseline characteristics by sex and age categories of patients with prevalent HF

Age	20-44		45-54		55-64		≥65	
	M	F	M	F	M	F	M	F
N	122	81	422	220	1214	678	10049	10641
% (all incident and prevalent)	40.7	41.3	49.8	46.6	56.8	55.4	71.5	69.4
Co-morbidities								
Prior MI	13.1	16.0	35.5	24.5	45.4	26.7	47.0	31.6
Prior revascularization	4.1	8.6	24.9	17.3	32.9	19.8	27.7	13.8
AF	27.9	30.9	35.5	31.4	47.4	36.4	61.3	59.5
Hypercholesterolemia	6.6	6.2	20.6	16.4	22.4	21.4	21.7	16.6
Hypertension	44.3	54.3	73.0	75.0	84.4	85.1	87.8	91.4
CVD	11.5	6.2	11.6	10.5	20.3	19.8	29.6	29.6
Diabetes mellitus	21.3	35.8	48.1	51.8	56.2	62.8	45.2	39.7
Malignant disease	2.5	7.4	4.5	5.5	9.6	10.2	23.2	15.7
PAD	9.8	11.1	13.7	15.5	23.6	21.8	29.5	22.6
Renal failure	18.9	27.2	23.2	26.4	26.7	29.1	37.0	30.1
COPD	43.4	46.9	50.0	63.2	57.6	64.0	63.1	56.7
Asthma	23.8	23.5	16.8	37.7	16.6	31.3	15.2	18.5
Congenital heart disease	21.3	29.6	5.5	15.5	4.8	7.1	2.8	2.4
Type of presentation hospital								
Community small	16.4	17.3	22.7	18.6	25.3	26.4	29.3	28.8
Community medium	10.7	4.9	9.0	8.2	5.9	6.6	5.5	5.2
Community large	14.8	18.5	15.4	16.4	14.6	17.4	17.3	17.6
Teaching	58.2	59.3	52.8	56.8	54.2	49.6	47.9	48.4
Concurrent ED	78.7	82.7	77.0	78.2	84.9	81.9	87.0	88.6
Length of stay								
Mean (SD)	11.1 (16.8)	11.1 (16.8)	10.2 (12.1)	12.6 (16.6)	12.5 (24.2)	13.9 (23.7)	14.6 (23.1)	16.4 (25.6)
Median (IQR)	7 (4, 11)	7 (3, 11)	6 (4, 11)	7 (5, 13)	7 (4, 13)	8 (4, 14)	8 (4, 15)	8 (5, 17)
Household income, Canadian dollars								
Median (IQR)	58559 (52046, 69101)	59383 (53684, 68271)	58307 (52162, 68487)	58579 (52216, 67964)	58559 (52162, 68487)	57256 (52046, 66577)	57871 (52162, 65726)	57435 (52001, 65282)

AF=atrial fibrillation; COPD=chronic obstructive pulmonary disease; CVD= cerebrovascular disease; IQR=inter-quartile range; MI=myocardial infarction; PAD=peripheral arterial disease

Table S5. One-year non-fatal outcomes by sex and age categories in patients discharged alive from HF hospitalization

Age	20-44		45-54		55-64		≥65	
	M	F	M	F	M	F	M	F
n discharged alive	259	174	748	416	1857	1056	11062	12219
Any ED visit	65.3	70.1	63.0	70.2	67.9	71.7	74.9	74.7
% followed by hospitalization	21.2	28.7	23.7	26.4	26.4	30.8	34.9	36.8
Median days to event (IQR)	59 (12, 148)	42 (14, 102)	51 (11, 148)	47 (10, 126)	48 (13, 135)	44 (13, 135)	46 (13, 134)	48 (14, 127)
HF ED visit	19.3	15.5	16.8	17.1	22.0	20.9	27.3	25.4
% followed by hospitalization	12.4	9.2	9.9	10.3	13.8	14.6	18.0	17.3
CV ED visit	32.4	28.2	31.7	31.0	35.9	33.2	38.5	37.1
% followed by hospitalization	16.6	14.9	16.6	16.1	19.7	20.0	24.0	23.4
Any re-hospitalization	49.0	47.7	47.9	51.4	52.8	56.0	61.6	60.9
Median days to event	66 (18, 174)	56 (19, 102)	67 (18, 173)	81 (19, 158)	75 (23, 168)	68 (20, 170)	67 (21, 164)	69 (23, 162)
CV re-hospitalization	30.1	26.4	30.9	23.1	32.8	30.5	35.2	33.8
Median days to event	64 (18, 153)	61 (17, 118)	67 (19, 176)	88 (20, 178)	90 (26, 196)	84 (27, 190)	77 (24, 180)	71 (23, 176)
HF re-hospitalization	15.1	14.4	16.3	11.8	17.7	18.8	23.9	23.3
Median days to event	47 (18, 103)	83 (42, 116)	61 (17, 171)	65 (21, 158)	88 (29, 180)	73 (22, 178)	73 (23, 177)	70 (22, 173)

N (%) or median (IQR)

CV=cardiovascular; ED=emergency department; HF=heart failure; IQR=interquartile range; SD=standard deviation.

Table S6. Unadjusted and adjusted outcomes stratified by sex and age categories among patients hospitalized with HF

Age	20-44		45-54		55-64		≥65	
	M	F	M	F	M	F	M	F
In-hospital								
Population n	300	196	847	472	2136	1223	14047	15327
Death (%)	2.7	4.6	2.1	3.0	3.2	4.7	12.3	12.2
OR (95% CI)	0.22	0.40	0.19	0.26	0.29	0.41	1	1
	(0.20,0.79)	(0.20,0.79)	(0.12,0.30)	(0.15,0.45)	(0.22,0.37)	(0.31,0.54)		
30 days								
Population n	296	191	819	460	2079	1186	13608	14901
Death (%)	3.4	4.7	1.8	3.5	3.4	5.1	11.6	11.4
OR (95% CI)	0.30	0.41	0.17	0.32	0.32	0.46	1	1
	(0.16,0.56)	(0.21,0.81)	(0.10,0.29)	(0.19,0.52)	(0.25,0.41)	(0.35,0.60)		
Death/readmission	53/286	36/183	129/800	73/441	369/2003	214/1124	2555/11874	2800/13018
n (%)	(18.5)	(19.7)	(16.1)	(16.6)	(18.4)	(19.0)	(21.5)	(21.5)
OR (95% CI)	0.98	1.06	0.82	0.81	0.93	0.92	1	1
	(0.72,1.34)	(0.72,1.54)	(0.67,1.00)	(0.63,1.06)	(0.82,1.06)	(0.79,1.08)		
1 year								
Population n	256	178	754	415	1875	1090	12398	13636
Death (%)	11.3	14.0	10.6	10.6	15.7	18.1	36.2	34.5
OR (95% CI)	0.28	0.36	0.27	0.27	0.41	0.48	1	1
	(0.19,0.41)	(0.23,0.56)	(0.21,0.34)	(0.19,0.37)	(0.36,0.46)	(0.40,0.56)		
Death/readmission	128/246	86/171	365/735	211/399	1018/1808	602/1031	7292/10778	7987/11916
n (%)	(52.0)	(50.3)	(49.7)	(52.9)	(56.3)	(58.4)	(67.7)	(67.0)
OR (95% CI)	0.75	0.68	0.63	0.67	0.75	0.76	1	1
	(0.58,0.98)	(0.50,0.94)	(0.54,0.74)	(0.54,0.82)	(0.67,0.83)	(0.66,0.87)		
5 years								
Population n	155	105	468	270	1114	662	7890	8646
Death (%)	25.2	31.4	33.5	29.6	41.3	42.9	73.9	71.8
OR (95% CI)	0.19	0.25	0.26	0.21	0.31	0.33	1	1
	(0.13,0.27)	(0.16,0.38)	(0.21,0.32)	(0.16,0.27)	(0.27,0.36)	(0.28,0.40)		

CI=confidence interval; OR=odd ratio.

Variables include prevalent episode, fiscal year of episode end date, presentation hospital (community small, community medium, community large, and teaching hospital), median household income, prior MI, prior revascularization, atrial fibrillation, cholesterol, hypertension, cerebo-vascular disease, diabetes mellitus, cancer, peripheral vascular disease, renal disease, COPD, asthma, and chronic heart disease.
Death/readmission post discharge is assessed only for patients that were discharged alive from the index hospitalization episode, within 30 days post discharge.