ORIGINAL RESEARCH

Trends From 1996 to 2007 in Incidence and Mortality Outcomes of Heart Failure After Acute Myocardial Infarction: A Population-Based Study of 20 812 Patients With First Acute Myocardial Infarction in Western Australia

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***Background*—**Advances in treatment for acute myocardial infarction (AMI) are likely to have had a beneficial impact on the incidence of and deaths attributable to heart failure (HF) complicating AMI, although limited data are available to support this contention.

***Methods and Results*—**Western Australian linked administrative health data were used to identify 20 812 consecutive patients, aged 40 to 84 years, without prior HF hospitalized with an index (first) AMI between 1996 and 2007. We assessed the temporal incidence of and adjusted odds ratio/hazard ratio for death associated with HF concurrent with AMI admission and within 1 year after discharge. Concurrent HF comprised 75% of incident HF cases. Between the periods 1996–1998 and 2005–2007, the prevalence of HF after AMI declined from 28.1% to 16.5%, with an adjusted odds ratio of 0.50 (95% CI, 0.44 to 0.55). The crude 28-day case-fatality rate for patients with concurrent HF declined marginally from 20.5% to 15.9% ($P<0.05$) compared with those without concurrent HF, in whom the case-fatality rate declined from 11.0% to 4.8% ($P<0.001$). Concurrent HF was associated with a multivariate-adjusted odds ratio of 2.2 for 28-day mortality and a hazard ratio of 2.2 for 1-year mortality in 28-day survivors. Occurrence of HF within 90 days of the index AMI was associated with an adjusted hazard ratio of 2.7 for 1-year mortality in 90-day survivors.

***Conclusions*—**Despite encouraging declines in the incidence of HF complicating AMI, it remains a common problem with high mortality. Increased attention to these high-risk patients is needed given the lack of improvement in their long-term prognosis. **(*J Am Heart Assoc.* 2013;2:e000172 doi: 10.1161/JAHA.113.000172)**

Key Words: acute myocardial infarction • epidemiology • heart failure • population-based study • prognosis

Ischemic heart disease (IHD) is a leading cause of heart failure (HF), which often develops as a complication of acute myocardial infarction (AMI).[1,2] The occurrence of HF after AMI is associated with a poor prognosis.[1,2] However, the treatment of AMI has improved dramatically in recent decades with the advent of early reperfusion strategies including percutaneous coronary intervention and evidence-based pharmacotherapies.[3–7] These advances in therapeutic interventions are likely to have had a beneficial impact on the incidence of and deaths attributable to HF complicating AMI, although limited data are available to support this assumption. Some studies have reported a reduced incidence of HF following AMI,[8–11] but other studies found an increasing incidence over time that paralleled the decrease in mortality after AMI.[12,13] Similarly, the in-hospital case-fatality rate of AMI has fallen dramatically over recent decades, whereas HF complicating AMI continues to be associated with high short- and long-term mortality.[10,13–16] Given the poor prognosis posed by new-onset HF after AMI, it is important to investigate the contemporary trends in incidence and mortality outcomes of this serious complication during the most

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recent era of early invasive intervention and evidence-based AMI management.

The objectives of the present study were (1) to investigate the sex-specific temporal trends in incidence of HF in 20 812 patients aged 40 to 84 years hospitalized with an index (first) AMI in Western Australia (WA) between 1996 and 2007, (2) to explore the clinical predictors of concurrent and late-onset HF after AMI, and (3) to determine if short-term (28-day) and 1-year mortality associated with HF after first AMI has changed over recent decades.

Methodology

Study Design and Population

Since the 1970s data for all hospitalizations in WA including principal and secondary (up to 20) discharge diagnoses have been maintained in the Hospital Morbidity Data (HMD) Collection, which is regularly audited for quality and accuracy.[17] The HMD is routinely linked to the Mortality Registry as part of the WA Data Linkage System using probabilistic matching, which has >99% accuracy.[17] Our study is a population-based cohort using linked health data comprising all WA residents aged 40 to 84 years who were admitted with a first AMI between 1996 and 2007 as a principal discharge diagnosis. First AMI was defined as occurring in a patient without a hospital admission for an AMI among the 21 discharge diagnoses in the previous 10 years. Patients with an HF history, which was defined on the basis of any HF hospitalization in the 10 years before the index AMI admission, were excluded.

AMI, as the principal diagnosis, was based on International Classification of Diseases (ICD) codes 410x (ICD-9-CM), and I21x (ICD-10-AM). Concurrent HF was defined as HF that was recorded during the index AMI admission and late-onset HF as occurrence within 1 year after discharge. Heart failure was identified in any of the 21 diagnosis fields by ICD codes 428x, 402.01, 402.11, 402.91, 404.1, 404.3, 425x, 518.4, 514, 391.8, and 398.91 (ICD-9-CM) and I50x, I11.0, I13.0, I13.2, I42x, J81, and I01.8 (ICD-10-AM).

Definitions of Comorbidities and Interventions

Comorbidities were identified from principal or secondary diagnosis fields within the 5 years before the incident admission or, if coded in a secondary diagnosis field, on the incident admission. Comorbid conditions were identified by the following ICD codes: ICD-9-CM 401-405 and ICD-10-AM I10-I15 for hypertension; ICD-9-CM 250 and ICD-10-AM E10-E14 for diabetes; 411-414x, I20x, and I22-I25 for other IHD (excluding AMI); 427.3 and I48 for atrial fibrillation; 585 and N18 for chronic renal failure; 430x-438x, 362.34, and 997.0 and I60-I69 and R47.0 cerebrovascular disease; and 440-444, 447, 448, and I70-I79 for peripheral vascular disease. A Charlson Comorbidity Index, as a weighted summary score, was also calculated for each person.[18] Coronary artery revascularization procedures, either percutaneous coronary intervention (PCI) or coronary artery bypass grafting, within 10 years before or concurrent with the index AMI admission were identified from the linked HMD.

Validity of the WA HMD Coding

The coding for HF as a principal discharge diagnosis in the WA HMD has been previously validated with a positive predictive value of 92.4% for "definite" HF and 98.8% for a combined "possible" and "definite" HF based on the Boston HF score.[19] The use of ICD-9-CM code 410 to define AMI has been validated in a local population.[20,21] The use of a 10-year look-back (clearance period) to exclude prior admissions for AMI or HF has been used previously to improve identification of incident cases.[22,23]

Data Analysis

Index hospitalizations for AMI were divided into 4 equal calendar periods—1996–1998, 1999–2001, 2002–2004, and 2005–2007—for comparison purposes. Patients were followed until death (all-cause) or 1 year after the first AMI hospitalization, with the last day of follow-up ending on December 31, 2007. All patients admitted from January 1, 1996, until before December 1, 2007, were included for 28-day survival analysis. For survival analysis to 1 year, only patients admitted with an index AMI between 1996 and 2006 were included. For trends in 1-year survival, we restricted our analysis to patients who survived ≥28 days from the date of index AMI admission.

Categorical variables are presented as proportions and continuous variables as means±standard deviations or medians and interquartile ranges. The Pearson chi-square test was used to test for differences in categorical variables and ANOVA, the *t* test, or the nonparametric Mann–Whitney test for continuous variables. Trends (in proportions) were assessed using the Cochran–Armitage trend test.

Age- and sex-adjusted logistic regression models were used to determine the odds ratios (ORs) of developing concurrent or late-onset HF associated with baseline risk characteristics and comorbidities. Multivariable logistic regression models were used to determine predictors of death within 28 days, with ORs and their 95% confidence intervals (CIs) reported. After ensuring that the assumption of proportional hazards was met, multivariable Cox proportional hazards regression models were used to determine hazard ratios (HRs) and 95% CIs for survival to 1 year in 28-day

survivors with HF modeled as a binary covariate (no HF, concurrent HF). To assess the impact of concurrent and late-onset HF together and to avoid an immortal time bias, we performed a landmark analysis in which we classified patients based on the occurrence of an intermediate event, namely, nonfatal HF hospitalization before a landmark point.[24] This analysis then evaluated patient outcomes from the landmark time through to the end of the follow-up period (1 year). We chose 90 days as our primary landmark point because the majority of incident HF cases (90.8%) occurred within 90 days of the initial AMI. Temporal trends in survival for calendar periods were determined using 1996–1998 as the base (comparator) period. Test for survival trend was performed with year modeled as a continuous variable in the regression analyses. Multivariable models were fully risk-adjusted for age and sex and for all potentially important covariates listed in Table 1 irrespective of nominal statistical significance. The risk adjustment model used has been previously reported.[25] Stratified analyses by HF diagnosis or sex were performed if a significant interaction was found between HF and calendar period or HF and sex. Statistical analyses were done with SAS version 9.1 and STATA version 10.

Ethics Approvals

Ethics approvals for this study were obtained from the Human Research Ethics Committees of the University of Western Australia and Department of Health, Western Australia.

Results

Descriptive data for the 20 812 patients (29.6% women) with a first AMI, stratified by the 4 calendar periods, from 1996–1998 to 2005–2007, are provided in Table 1. Although the mean age and sex mix of the patients did not change, there was an increasing frequency of several comorbidities over the study period including hypertension, diabetes, and IHD (excluding AMI). However, peripheral vascular disease and cerebrovascular disease were less prevalent. The frequency of coronary revascularization procedures, predominantly PCI, performed during the index AMI admission increased from 17.4% to 43.2% over the study period ($P<0.001$). However, patients with concurrent HF were less likely to undergo a revascularization procedure during the initial admission compared with their counterparts without concurrent HF (19.9% versus 33.3%, $P<0.001$).

The overall prevalence of any HF up to 1 year post-AMI decreased progressively over the observation period, from 28.1% to 16.5% ($P<0.001$), largely because of a decline in concurrent HF, which comprised 75% of incident HF cases (Table 1). By the last calendar period, the age- and sex-adjusted OR of developing any HF within 1 year after index AMI was 0.50 (95% CI, 0.44 to 0.55; $P<0.001$). Of those who developed new HF within 1 year after index AMI admission, 84.9%, 90.8%, and 95.0% had occurred by 30 days, 90 days, and 6 months, respectively.

Table 2 shows the baseline characteristics and clinical predictors of patients who developed concurrent or late-onset HF after a first AMI. Patients who developed HF were significantly older and more likely to be female compared with their counterparts without HF. After adjustment for age and sex, significant positive predictors of concurrent HF were hypertension, diabetes, atrial fibrillation, chronic renal failure, and peripheral vascular and cerebrovascular disease, whereas prior IHD was a negative predictor. Predictors of late-onset HF were identical to those of concurrent HF except for chronic renal failure.

The crude 28-day case-fatality rate in all AMI cases declined significantly over the observation period largely because of the patients without concurrent HF, in whom mortality declined from 8.4% to 3.2% ($P<0.001$; Table 1). Patients with concurrent HF had an overall 3-fold higher case-fatality rate relative to patients without concurrent HF, and their 28-day mortality declined marginally over the observation period, from 20.5% to 15.9% ($P=0.047$). The overall 1-year mortality in 28-day AMI survivors with versus without concurrent HF was 15.3% versus 3.6% ($P<0.001$), and the overall 1-year mortality in 90-day AMI survivors with compared with without incident HF was 10.9% versus 2.2% ($P<0.001$; Table 1). There was no significant change over the observation period in crude 1-year mortality in 28-day and 90-day AMI survivors with or without incident HF (Table 1). Men and women showed similar trends in the 28-day case-fatality rate and crude 1-year mortality (data not shown).

Table 3 shows adjusted ORs for death at 28 days, and Table 4 shows HRs for death between 28 days and 1 year and between 90 days and 1 year, after adjustment for age, sex, occurrence of HF, comorbidities, interventions, and calendar periods. Concurrent HF had a significant adverse impact on mortality, with an adjusted OR of 2.2 for 28-day mortality and an HR of 2.2 for 1-year mortality in 28-day survivors. In the landmark analysis, occurrence of HF within 90 days of index AMI was associated with an adjusted HR of 2.7 for 1-year mortality in 90-day survivors. The adjusted OR for death at 28 days declined progressively over the observation period, with a 60% lower risk of death for the whole cohort by the last calendar period (trend $P<0.001$). A significant concurrent HF–calendar period interaction was identified for 28-day mortality ($P<0.001$), with stratified analysis showing lesser reductions in adjusted OR of death at 28 days over successive calendar periods in patients with compared with those without concurrent HF (Table 3). A significant concurrent HF-sex interaction was also identified for 28-day mortality ($P<0.001$),

Table 1. Characteristics of Patients, Aged 40 to 84 Years, With a First Acute Myocardial Infarction According to Period of Hospitalization Between 1996 and 2007

Characteristics	Total	Period				*P* Value
		1996–1998	1999–2001	2002–2004	2005–2007	
Number of patients, n	20 812	4300	4714	5450	6348	
Female sex, n (%)	6162 (29.6)	1297 (30.2)	1377 (29.2)	1598 (29.3)	1890 (29.8)	0.73
Age, mean±SD, y	64.9±11.7	64.7±11.8	64.9±11.7	64.9±11.7	65.0±11.0	0.091
Comorbidities, n (%)						
Hypertension	9789 (47.0)	1893 (44.0)	2042 (43.3)	2420 (44.4)	3434 (54.1)	<0.001
Diabetes	4726 (22.7)	903 (21.0)	1012 (21.5)	1273 (23.4)	1538 (24.2)	<0.001
Other ischemic heart disease	11 493 (55.2)	2101 (48.8)	2370 (50.3)	3025 (55.5)	3997 (63.0)	<0.001
Atrial fibrillation	2585 (12.4)	494 (11.5)	565 (12.0)	707 (13.0)	819 (12.9)	0.07
Chronic renal failure	1093 (5.3)	228 (5.3)	223 (4.7)	296 (5.4)	346 (5.5)	0.33
Peripheral vascular disease	2302 (11.1)	657 (15.3)	570 (12.1)	549 (10.1)	526 (8.3)	<0.001
Cerebrovascular disease	2876 (13.2)	756 (17.6)	739 (15.7)	681 (12.5)	700 (11.0)	0.001
Interventions, n (%)						
Prior PCI or CABG	1179 (5.7)	204 (4.7)	272 (5.8)	313 (5.7)	390 (6.1)	<0.001
Within index admission	6551 (31.5)	750 (17.4)	1149 (24.4)	1912 (35.1)	2740 (43.2)	<0.001
PCI	5887 (28.3)	630 (14.7)	1015 (21.5)	1748 (32.1)	2494 (39.3)	<0.001
CABG	698 (3.4)	127 (3.0)	144 (3.1)	175 (3.2)	252 (4.0)	0.011
Heart failure, n (%)	4406 (21.2)	1210 (28.1)	1060 (22.5)	1086 (19.9)	1050 (16.5)	<0.001
Concurrent HF	3286 (15.8)	933 (21.7)	797 (16.9)	786 (14.4)	770 (12.1)	<0.001
Late onset	1120 (5.4)	277 (6.4)	263 (5.6)	300 (5.5)	280 (4.4)	<0.001
Deaths, n (%)						
28-Day deaths*	1515 (7.3)	472 (11.0)	414 (8.8)	333 (6.1)	296 (4.8)	<0.001
No concurrent HF	915 (5.3)	281 (8.4)	260 (6.6)	198 (4.3)	176 (3.2)	<0.001
Concurrent HF	600 (18.3)	191 (20.5)	154 (19.3)	135 (17.2)	120 (15.9)	0.047
1-Year deaths in 28-day survivors†						
No concurrent HF	519 (3.6)	113 (3.7)	133 (3.6)	166 (3.7)	107 (3.2)	0.54
Concurrent HF	376 (15.3)	122 (16.4)	95 (14.8)	96 (14.8)	63 (14.8)	0.77
1-Year deaths in 90-day survivors†						
No HF in 90 days	304 (2.2)	69 (2.4)	78 (2.2)	88 (2.1)	69 (2.1)	0.82
HF within 90 days	315 (10.9)	87 (10.3)	83 (10.8)	91 (11.6)	54 (10.9)	0.87

CABG indicates coronary artery bypass grafting; HF, heart failure; PCI, percutaneous coronary intervention; SD, standard deviation.
*Patients who were admitted before December 1, 2007.
†Patients with 1-year follow-up from date of index admission.

and stratified analysis showed that men with concurrent HF had a higher adjusted OR for 28-day mortality compared with women, with ORs of 2.75 (95% CI, 2.34 to 3.23) versus 1.58 (95% CI, 1.30 to 1.91), respectively (Table 3).

Table 4 shows that compared with the early survival gains, there was no further decline in adjusted HR for death between 28 days and 1 year (trend P=0.27) and a significant increase in adjusted HR for death between 90 days and 1 year in the last 2 calendar periods (trend P=0.02). Further stratified analyses by sex or occurrence of HF were not performed because the interaction terms were not significant. PCI performed during initial AMI admission was associated with an adjusted OR of 0.43 (95% CI, 0.35 to 0.52; P<0.001) for death at 28 days, an HR of 0.40 (95% CI, 0.31 to 0.51; P<0.001) for death between 28 days and 1 year, and an HR of 0.35 (95% CI, 0.27 to 0.44; P<0.001) for death between 90 days and 1 year. There was no significant interaction effect on mortality between concurrent HF and PCI during index

Table 2. Baseline Characteristics and Risk Predictors of Concurrent and Late-Onset Heart Failure in Patients With a First Acute Myocardial Infarction Between 1996 and 2007

Description	No HF	Concurrent HF	Late-Onset HF	Odds Ratio for Concurrent HF*	*P* Value	Odds Ratio for Late-Onset HF*	*P* Value
Cases, n (%)	14 440 (78.1)	3025 (16.4)	1024 (5.5)				
Age, y, median (IQR)	63 (54 to 73)	73 (65 to 79)	73 (64 to 79)	1.06 (1.06 to 1.07)†	<0.001	1.05 (1.04 to 1.05)†	<0.001
Female sex	4415 (26.9)	1307 (39.8)	440 (39.3)	1.24 (1.14 to 1.35)‡	<0.001	1.22 (1.07 to 1.41)‡	0.003
Comorbidities, n (%)							
Hypertension	6267 (43.4)	1632 (54.0)	581 (56.7)	1.17 (1.08 to 1.27)	<0.001	1.32 (1.16 to 1.50)	<0.001
Diabetes	2772 (19.2)	1045 (34.6)	342 (33.4)	2.05 (1.88 to 2.24)	<0.001	1.72 (1.50 to 1.97)	<0.001
Other IHD	7990 (55.3)	1509 (49.9)	486 (47.5)	0.88 (0.82 to 0.96)	0.003	0.81 (0.71 to 0.92)	0.001
Atrial fibrillation	1283 (8.9)	796 (26.3)	203 (19.8)	2.35 (2.13 to 2.60)	<0.001	1.33 (1.13 to 1.57)	0.001
Chronic renal failure	397 (2.8)	492 (16.3)	78 (7.6)	4.83 (4.21 to 5.55)	<0.001	1.18 (0.92 to 1.50)	0.18
Peripheral vascular disease	1387 (9.6)	560 (18.5)	190 (18.6)	1.57 (1.41 to 1.75)	<0.001	1.49 (1.26 to 1.76)	<0.001
Cerebrovascular disease	1672 (11.6)	719 (23.8)	265 (25.9)	1.56 (1.41 to 1.73)	<0.001	1.70 (1.46 to 1.97)	<0.001

HF indicates heart failure; IHD, ischemic heart disease; IQR, interquartile range.
*Age- and sex adjusted.
†Adjusted for sex.
‡Adjusted for age.

admission. Performance of coronary artery bypass grafting during initial admission had no effect on 28-day mortality but was associated with a lower adjusted HR of death at 1 year in 28-day survivors (HR, 0.37; 95% CI, 0.21 to 0.65; $P<0.001$) and at 1 year in 90-day survivors (HR, 0.33; 95% CI, 0.19 to 0.58; $P<0.001$).

Discussion

We investigated all patients without prior HF hospitalized with a first AMI in Western Australia between 1996 and 2007. Our findings indicate that the short-term case-fatality rate after first AMI and the incidence of HF declined substantially in both men and women over this period. Despite these encouraging trends, HF complicating AMI still occurs frequently and has a major adverse impact on short-term and long-term mortality.

The present study confirms that HF is more likely to complicate AMI in older persons, in women, and in people with added comorbidities including diabetes, hypertension, renal failure, and peripheral vascular disease.[2,11,26–28] By contrast, patients with prior IHD (excluding AMI) were less likely to develop HF, possibly because they were more likely to be on cardioprotective medications (eg, aspirin, β-blockers, ACEIs, statins) at onset of AMI. However, the observed temporal changes in comorbidities in our AMI cohort suggest that this factor alone is unlikely to explain the decline in incidence of HF.

In this population-based study, about 1 in 6 patients developed HF concurrent with their index AMI admission, and overall 1 in 5 had an HF discharge diagnosis within the first year after AMI. Previous estimates of the incidence of acute HF complicating AMI have varied between 10% and 48% depending on the type of study (population-based, registry, or clinical trial), inclusion of patients with prior AMI or prior HF as opposed to first events, duration of follow-up, and the period of the study.[2,4,8–13,29] However, more recent population-based studies from the United States[10] and Sweden[11] have reported a hospital incidence of HF after AMI in the same range as our present study. Concordant with previous studies,[8,11,13,15] most cases of HF occurred acutely in relation to the AMI or in the subsequent few months. However, it has been observed that with increasing post-AMI survival, the incidence of HF may actually rise over time.[8,11,13] For example, in a large cohort of elderly patients, HF developed in three-quarters in the 5 years after their first AMI, and this proportion increased over time as peri-AMI mortality rates declined.[13]

Importantly, the age- and sex-adjusted odds of developing HF within the first year after AMI declined by ≈50% over the study period. Other observational studies have also revealed a decline in the incidence of hospitalized patients with HF after AMI beginning in the early 1990s.[4,8–11] The declining incidence of HF has occurred coincidently with the broader application of evidence-based interventional and pharmacological treatments following AMI in recent decades.[3–6] In a

Table 3. Multivariable-Adjusted Odds of Death at 28 Days According to Calendar Periods and Stratified by Concurrent Heart Failure and Sex

Odds Ratio for Death Within 28 Days*										
	All Patients (n=20 668)		No HF (n=17 399)		Concurrent HF (n=3269)		Men (n=14 537)		Women (n=6131)	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Variable										
No concurrent HF	1.00						1.00		1.00	
Concurrent HF	2.17 (1.91 to 2.45)	<0.001					2.75 (2.34 to 3.23)	<0.001	1.58 (1.30 to 1.91)	<0.001
Calendar period										
1996–1998	1.00		1.00		1.00		1.00		1.00	
1999–2001	0.74 (0.63 to 0.86)	<0.001	0.69 (0.57 to 0.83)	<0.001	0.80 (0.62 to 1.02)	0.075	0.74 (0.60 to 0.90)	<0.001	0.72 (0.57 to 0.91)	0.006
2002–2004	0.49 (0.42 to 0.58)	<0.001	0.41 (0.34 to 0.51)	<0.001	0.65 (0.49 to 0.84)	0.001	0.53 (0.43 to 0.65)	<0.001	0.44 (0.34 to 0.56)	<0.001
2005–2007	0.40 (0.34 to 0.47)	<0.001	0.32 (0.26 to 0.39)	<0.001	0.59 (0.44 to 0.77)	<0.001	0.48 (0.39 to 0.59)	<0.001	0.29 (0.22 to 0.38)	<0.001

CABG indicates coronary artery bypass grafting; CI, confidence interval; HF, heart failure; IHD, ischemic heart disease; OR, odds ratio; PCI, percutaneous coronary intervention.
*Logistic regression model was adjusted for age, sex, concurrent HF, hypertension, diabetes, other IHD, atrial fibrillation, chronic renal failure, peripheral vascular disease, cerebrovascular disease, Charlson comorbidity index, history of PCI or CABG in last 10 years, and PCI within index admission.

previous study of nonfatal acute coronary syndrome cases in Western Australia,[21] we observed a high rate of aspirin discharge prescription between 1998 and 2003 (88%) and increased rates of prescription of clopidogrel (0% to 60%), statins (60% to 83%), β-blockers (61% to 77%), angiotensin-converting enzyme inhibitors/angiotensin receptor blockers (33% to 71%), and all 4 drug groups (10% to 50%) (unpublished data). A 2.5-fold increase in the rate of emergent revascularization procedures was also apparent over the period of the present study.

Over recent decades, the incidence and 28-day case-fatality rate of AMI have improved substantially in the WA population concordant with trends reported from other Western countries.[30–34] At the same time, new criteria for the diagnosis of AMI on the basis of the more sensitive troponin biomarkers have substantially increased the detection of smaller AMIs[21,22,30,35] and the incidence of non-ST-segment elevation MIs (NSTEMIs) relative to STEMIs.[31,33,34] This may in turn contribute to a reduced risk of subsequent HF and potentially to reduced severity of HF and better prognosis, although the latter is contentious.[36,37] The increase in diagnosis of less severe AMIs may well have contributed to the ≈50% reduction in the overall 28-day case-fatality rate and incidence of HF after AMI observed in the present study. However, the decline in 28-day case-fatality occurred largely in patients without HF, whereas patients with concurrent HF in the most recent calendar period remained at significantly higher risk of 28-day mortality than those without concurrent HF (15.9% versus 3.2%).

Our extended survival analysis confirmed that survivors of AMI complicated by HF, whether it was early or late onset, continued to have a high long-term mortality hazard, a point that has also been highlighted by other studies.[13–15,27,28] In fact, our landmark analysis suggested that although early survival gains have occurred in patients developing HF after AMI, this may be counterbalanced by an increased adjusted hazard for death between 90 days and 1 year. Thus, incident HF remains one of the most powerful predictors of late mortality after AMI. Actually, by the last calendar period, mortality was 3.2% at 28 days and 3.6% at 1 year in 28-day AMI survivors without HF, whereas mortality was 15.9% and 15.3%, respectively, for those with concurrent HF. It is therefore likely that most of the survival gains to be expected in the future will have to come from earlier and more aggressive application of guideline-recommended treatments in AMI patients at risk of HF as well as enhanced secondary prevention after HF occurrence.

Although we are unable to account for the propensity to undergo revascularization, it appears that an invasive strategy with PCI performed during initial AMI admission is associated with lower adjusted odds of death at 28 days and lower adjusted hazard of death between 28 days and 1 year

Table 4. Multivariable-Adjusted Hazard of Death Between 28 Days and 1 Year, and Between 90 Days and 1 Year According to Calendar Periods and Occurrence of Heart Failure

	Hazards Ratio for Death at 1 Year in 28-Day Survivors*		Hazards Ratio for Death at 1 Year in 90-Day Survivors†	
	All Patients (n=17 071)		All Patients (n=16 795)	
	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value
Variable				
No HF	1.00		1.00	
Concurrent HF	2.23 (1.93 to 2.58)	<0.001	—	
HF within 90 days	—		2.66 (2.24 to 3.15)	<0.001
Calendar period				
1996–1998	1.00		1.00	
1999–2001	1.07 (0.89 to 1.29)	0.47	1.20 (0.96 to 1.49)	0.12
2002–2004	1.16 (0.96 to 1.39)	0.12	1.30 (1.04 to 1.62)	0.02
2005–2007	1.10 (0.89 to 1.35)	0.38	1.34 (1.04 to 1.72)	0.02

CABG indicates coronary artery bypass grafting; CI, confidence interval; HF, heart failure; HR, hazard ratio; IHD, ischemic heart disease; PCI, percutaneous coronary intervention.
*Cox regression model was adjusted for age, sex, concurrent HF, diabetes, chronic renal failure, other IHD, atrial fibrillation, peripheral vascular disease, cerebrovascular disease, Charlson comorbidity index, history of PCI or CABG in the last 10 years, and PCI or CABG within index admission.
†Landmark analysis at 90 days with the Cox regression model adjusted for age, sex, HF within 90 days, diabetes, chronic renal failure, other IHD, atrial fibrillation, peripheral vascular disease, cerebrovascular disease, Charlson comorbidity index, history of PCI or CABG in the last 10 years, and PCI or CABG within index admission.

regardless of HF occurrence. This is in keeping with a meta-analysis of randomized clinical trials that showed that an invasive management strategy was superior to an initially conservative strategy among NSTEMI acute coronary syndrome cases, and that the benefit was greatest for patients at highest risk.[7] Yet, despite a favorable benefit-to-risk ratio, revascularization procedures were performed less frequently in our AMI subcohort with HF than in those without HF. Other observational studies have also shown that the occurrence of HF after AMI was a strong correlate of a conservative management strategy and underuse of revascularization procedures.[10,16,38–40] Furthermore, these same studies have also reported lower use of evidence-based pharmacotherapies including aspirin, heparin, β-blockers, statins, and fibrinolytics to the disadvantage of AMI cases complicated by HF.[10,16,26,29,38,40] Reasons for the disparities in treatment are unclear. However, patients at risk of HF after AMI are generally older and more often female and have a greater burden of comorbid conditions including diabetes and renal failure, which are generally predictive of a lower use of invasive interventions and evidence-based pharmacotherapies after AMI.[10,26,39,41] Therefore, reducing the apparent evidence-treatment gap in the pharmacological and invasive management of AMI patients complicated by HF is a high priority.

Study Strengths and Limitations

Our study is a large contemporary population-based study of patients admitted with a first AMI. The availability of a person-based record linkage means that we could determine those persons without prior HF who had a first AMI admission and enabled ascertainment of major comorbidities and invasive procedures that are essential for risk adjustment. An HMD principal diagnosis of AMI and HF has also been previously validated demonstrating good accuracy.[19,20,30] However, we have not performed a validation study of HF as a secondary diagnosis in the HMD. Nevertheless, there are several limitations. We did not assess for trends in the prevalence of STEMI and NSTEMI, as this may not be accurate using administrative coding. The diagnostic criteria for AMI, which incorporated the more sensitive troponin biomarkers, changed over the study period,[21,22,29] and we cannot determine whether the observed trend in the overall AMI case-fatality rate and HF incidence is related to a true trend in disease development or a reflection of smaller AMIs being included in the analysis in the latter period. However, even if smaller AMIs were included, that a concurrent or late-onset HF diagnosis was associated with persistently high crude mortality deserves close attention. We were unable to adjust for clinical severity of HF, but this does not diminish the importance of a recorded diagnosis of HF in the medical record, which we found to be associated with a 2- to 3-fold increased adjusted risk of 28-day and 1-year mortality. We could not assess for disparities in treatment between AMI patients (except for revascularization procedures) or changes in prescription of evidence-based pharmacotherapies over the period, except for that observed in a subset of nonfatal acute coronary syndrome cases between 1998 and 2003.[21] There was a potential immortal time bias when assessing the effect

of revascularization on 28-day mortality, but this was avoided in the 1-year landmark analysis. Because this is an observational study, care must be taken not to attribute a causal effect to the observed associations.

Conclusions

Despite encouraging declines in the incidence of HF complicating AMI over recent decades, it remains a common problem with high mortality. Concerted efforts at early detection of these high-risk patients, reducing disparities in guideline-recommended treatments and optimal secondary prevention, are needed given the lack of improvement in their long-term prognosis.

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Disclosures

None.

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