





ORIGINAL RESEARCH

# Age and Sex Differences and Temporal Trends in the Use of Invasive and Noninvasive Procedures in Patients Hospitalized With Acute Myocardial Infarction

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**BACKGROUND:** Few studies have examined age and sex differences in the receipt of cardiac diagnostic and interventional procedures in patients hospitalized with acute myocardial infarction and trends in these possible differences during recent years.

**METHODS AND RESULTS:** Data from patients hospitalized with a first acute myocardial infarction at the major medical centers in the Worcester, Massachusetts, metropolitan area were utilized for this study. Logistic regression analysis was used to examine age (<55, 55–64, 65–74, and ≥75 years) and sex differences in the receipt of echocardiography, exercise stress testing, coronary angiography, percutaneous coronary interventions, and coronary artery bypass graft surgery, and trends in the use of those procedures during patients' acute hospitalization, between 2005 and 2018, while adjusting for important confounding factors. The study population consisted of 1681 men and 1154 women with an initial acute myocardial infarction who were hospitalized on an approximate biennial basis between 2005 and 2018. A smaller proportion of women underwent cardiac catheterization, percutaneous coronary intervention, and coronary artery bypass graft surgery, while there were no sex differences in the receipt of echocardiography and exercise stress testing. Patients aged ≥75 years were less likely to undergo cardiac catheterization, percutaneous coronary intervention, and coronary artery bypass graft surgery, but were more likely to receive echocardiography compared with younger patients. Between 2005 and 2018, the use of echocardiography and coronary artery bypass graft surgery nonsignificantly increased among all age groups and both sexes, while the use of cardiac catheterization and percutaneous coronary intervention increased nonsignificantly faster in women and older patients.

**CONCLUSIONS:** We observed a continued lower receipt of invasive cardiac procedures in women and patients aged ≥75 years with acute myocardial infarction, but age and sex gaps associated with these procedures have narrowed during recent years.

**Key Words:** acute myocardial infarction ■ cardiac catheterization ■ coronary artery bypass graft surgery ■ echocardiography ■ exercise stress testing ■ percutaneous coronary intervention ■ trends over time

Cardiovascular disease remains the leading cause of death worldwide, claiming the lives of more than 17 million adults annually.<sup>1</sup> In 2019, more than 650 000 deaths in the United States were

attributed to heart disease.<sup>2</sup> Acute myocardial infarction (AMI) accounts for the majority of cardiac deaths and is more commonly diagnosed among men and older individuals.<sup>3–5</sup> Major advances in the diagnosis

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## CLINICAL PERSPECTIVE

### What Is New?

- Women and patients aged  $\geq 75$  years were less likely than men and younger patients to undergo invasive cardiac procedures (angiography, percutaneous coronary intervention, and coronary bypass graft surgery) during their hospitalization for a first acute myocardial infarction over a more than decade-long period under study (2005–2018).
- The use of noninvasive cardiac procedures, in particular exercise stress testing and echocardiography, was similar in both sexes and in the 4 age groups examined.

### What Are the Clinical Implications?

- The present study highlights the need for interventions to narrow/close age and sex disparities in the management of patients hospitalized for an acute myocardial infarction, including the implementation of disparity-focused clinical guidelines or the use of equity measurements in hospital reimbursement models.

## Nonstandard Abbreviations and Acronyms

<b>VIRGO</b>	Variations in Recovery: Role of Gender on Outcomes of Young AMI Patients
<b>WHAS</b>	Worcester Heart Attack Study

and clinical management of AMI have occurred over the past several decades with resultant improvements in both the in-hospital and long-term prognosis in men and women of all ages.<sup>6,7</sup>

Several prior studies have examined differences between men and women with regards to symptom presentation,<sup>8–12</sup> delays in seeking acute medical care,<sup>13–16</sup> and in-hospital and long-term survival,<sup>16–19</sup> while other investigations have examined sex differences in the diagnosis and management of AMI.<sup>20–26</sup> These studies suggest that men are more aggressively treated after an AMI than women, but more recent studies have shown increased use of diagnostic and therapeutic approaches for both sexes with narrowing of the gap in the receipt of diagnostic and interventional cardiac procedures.<sup>23,25</sup> A number of these studies, however, either lacked a community-based perspective<sup>26,27</sup> or failed to adjust for the influence of several sociodemographic and clinical factors that may have affected the receipt of these different diagnostic and treatment approaches in hospitalized patients.

The objectives of this community-based study were to examine age and sex differences, and changes over time therein, in the use of diagnostic and coronary revascularization procedures in the evaluation and management of patients hospitalized with a confirmed initial AMI at the major tertiary care medical centers in central Massachusetts on an approximate biennial basis between 2005 and 2018.

## METHODS

The data that support the findings of this study are available from the authors on reasonable request.

### Study Design and Case Ascertainment

Data for this investigation were derived from the WHAS (Worcester Heart Attack Study). Details of this study have been previously described.<sup>28–31</sup> In brief, this is a population-based investigation of AMI among residents of the Worcester metropolitan area who were hospitalized at all medical centers in central Massachusetts. The medical records of patients hospitalized with an independently confirmed AMI were individually reviewed and validated with the use of predefined diagnostic criteria, including diagnoses of ST-segment–elevation myocardial infarction (STEMI) and non–ST-segment–elevation myocardial infarction (NSTEMI). To be included in this study, at least 2 of the following 3 criteria were required to be met: (1) elevated serum cardiac enzyme levels; (2) positive clinical history; and (3) serial ECG findings consistent with the diagnosis of AMI. The institutional review board at the University of Massachusetts Medical School approved this study. Informed consent was waived because of the deidentified nature of data.

The study sample was limited to the most recent years under investigation (2005, 2007, 2009, 2011, 2015, and 2018) and to 3 major revascularization-capable hospitals in the greater Worcester metropolitan area. We further restricted the study population to patients hospitalized with an initial AMI to avoid including cardiac procedures for existing coronary artery disease.

### Data Collection

Patients' sociodemographic and clinical characteristics were abstracted from hospital medical records by trained physicians and nurses. Data were collected on patients' age, sex, race or ethnicity, medical history, clinical features of their index AMI, and the in-hospital development of heart failure, cardiogenic shock, atrial fibrillation, severe hemorrhage, and death.

The diagnostic procedures that we examined included echocardiography, exercise stress testing,

and cardiac catheterization, while the therapeutic procedures included the use of percutaneous coronary intervention (PCI) and coronary artery bypass graft (CABG) surgery.

## Statistical Analysis

The differences in the distribution of selected characteristics and use of diagnostic and therapeutic procedures between men and women of different age strata were compared using chi-square tests for discrete variables and ANOVA for continuous variables. We examined the potential statistical interaction between age and sex in the receipt of all invasive and noninvasive procedures in logistic regression models and did not find any statistically significant interactions. Therefore, results were reported for each age group and sex without further stratification.

Multivariable-adjusted logistic regression analyses were performed for purposes of examining temporal trends, age, and sex-specific differences in the receipt of diagnostic and therapeutic procedures during the patient's index hospitalization while controlling for several potentially confounding variables of prognostic importance. The variables controlled for in these analyses consisted of patient's medical history (eg, angina, diabetes, hypertension, stroke, or heart failure), development of an acute STEMI, acute clinical complications (eg, occurrence of heart failure, cardiogenic shock, atrial fibrillation, or severe hemorrhage during hospitalization), length of hospital stay, and hospital survival status. These potentially confounding variables were included based on their level of statistical significance ( $P < 0.05$ ) or because of their clinical relevance with regards to the receipt of the procedures under study. Linearity of trends, and log odds of cardiac procedure use, were assessed using Box-Tidwell tests.

We also stratified the present analyses according to the type of AMI patients may have experienced (eg, STEMI versus NSTEMI) during their index hospitalization since the administration of various cardiac procedures, especially invasive procedures, might be differentially indicated and utilized in these groups. The frequency of exercise stress testing and CABG surgery were small and did not produce reliable statistical estimates and therefore excluded from these stratified analyses.

We examined trends over time in the utilization of the examined procedures by graphing the percentage of procedure use during each period under study. Time was coded as a numerical variable, with the year 2005 set at time 0. Based on the observed distribution, and for ease of reporting and analysis, we assumed that changes in the receipt of cardiac procedures followed a linear pattern. Trends in the use of each procedure were examined in logistic regression analyses,

which allowed for the interpretation of incremental changes during the period under study and adjustment for changes in patient demographic and clinical characteristics over time. We examined the interaction between time and sex and age groups. We only found a statistically significant interaction between time and age groups in terms of changes over time in the use of echocardiography but not for the other diagnostic and interventional procedures we studied. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc).

## RESULTS

### Study Population Characteristics

The study population consisted of 2835 patients (1154 women and 1681 men) who were hospitalized at the 3 major central Massachusetts medical centers with an independently confirmed initial AMI. The median age of this study population was 66 years (interquartile range, 55–78 years), and the majority (89.8%) were of White race. Overall, women were  $\approx 6$  years older and were more likely to have several previously diagnosed comorbidities including diabetes, stroke, hypertension, or heart failure than men. In-hospital complications, including heart failure and death, were also more common in women than in men (Table 1). Older patients included a higher percentage of women and patients with an NSTEMI and were more likely to have developed several clinically important hospital complications than younger age groups (Table 1).

### Use of Cardiac Procedures According to Sex

Use of the noninvasive diagnostic procedures that we examined, namely echocardiography and exercise stress tests, was relatively similar between men and women during their index hospitalization (Table 1). However, men more frequently underwent an invasive diagnostic or therapeutic procedure, including cardiac catheterization, PCI, and CABG surgery than women (Table 1). Compared with men, women had a 34% to 47% lower odds of receiving these invasive procedures, even after adjusting for several potentially confounding factors (Table 2). The lower odds of undergoing a cardiac catheterization and a PCI in women were also similarly found in patients who were diagnosed with either a STEMI or an NSTEMI (Table 3).

### Use of Cardiac Procedures According to Age

A greater proportion of patients who were aged  $\geq 75$  years underwent echocardiography compared with patients aged  $< 55$  years, while the use of exercise stress tests

**Table 1. Characteristics of Patients Hospitalized With an Initial AMI According to Sex and Age: Worcester Heart Attack Study**

Characteristics	Sex		Age groups, y			
	Men (n=1681)	Women (n=1154)	<55 (n=617)	55–64 (n=611)	65–74 (n=565)	≥75 (n=1042)
Age	63.7 (13.3)	69.9 (14.1)	NA	NA	NA	NA
Women	NA	NA	179 (29.0)	170 (27.8)	223 (39.5)	582 (55.9)
SBP, mmHg	141.0 (39.0)	142.0 (36.0)	144.9 (26.5)	144.2 (29.4)	143.7 (30.0)	138.9 (29.2)
DBP, mmHg	82.0 (25.0)	76.0 (25.0)	88.5 (17.6)	85.1 (17.4)	78.6 (17.5)	72.7 (17.9)
Hemoglobin, g/dL	14.1 (2.0)	14.2 (48.1)	17.2 (65.6)	14.2 (1.9)	13.4 (2.0)	12.6 (1.9)
Creatinine, mg/dL	1.3 (1.1)	1.2 (0.9)	1.1 (0.9)	1.2 (1.2)	1.3 (1.2)	1.4 (0.8)
Length of stay, d	3.0 (3.0)	4.0 (4.0)	3.9 (6.2)	4.3 (4.5)	6.1 (67.2)	5.4 (41.8)
STEMI	693 (41.2)	380 (32.9)	312 (50.6)	279 (45.7)	202 (35.8)	280 (26.9)
Medical history, %						
Angina	95 (5.7)	73 (6.3)	25 (4.1)	21 (3.4)	32 (5.7)	90 (8.6)
Diabetes	489 (29.1)	387 (33.5)	131 (21.2)	164 (26.8)	219 (38.8)	362 (34.7)
Dyslipidemia	1058 (62.9)	701 (60.8)	367 (59.5)	374 (61.2)	383 (67.8)	635 (60.9)
Hypertension	1078 (64.1)	897 (77.7)	319 (51.7)	385 (63.0)	423 (74.9)	848 (81.4)
Stroke	89 (5.3)	108 (9.4)	12 (1.9)	23 (3.8)	41 (7.3)	121 (11.6)
Heart failure	183 (10.9)	188 (16.3)	23 (3.7)	44 (7.2)	71 (12.6)	233 (22.4)
Hospital complications, %						
Heart failure	413 (24.6)	383 (33.2)	91 (14.8)	94 (15.4)	158 (30.0)	453 (43.5)
Cardiogenic shock	107 (6.4)	70 (6.1)	18 (2.9)	25 (4.1)	50 (8.9)	84 (8.1)
Atrial fibrillation	291 (17.3)	210 (18.2)	22 (3.6)	60 (9.8)	100 (17.7)	319 (30.6)
Severe hemorrhage	303 (18.0)	231 (20.0)	77 (12.5)	91 (14.9)	115 (20.4)	251 (24.1)
Death	103 (6.1)	111 (9.6)	11 (1.8)	22 (3.6)	43 (7.6)	138 (13.2)
Noninvasive procedures, %						
Echocardiography	1166 (69.4)	832 (72.1)	402 (65.2)	421 (68.9)	397 (70.3)	778 (74.7)
Exercise treadmill test	61 (3.6)	49 (4.3)	22 (3.6)	14 (2.3)	24 (4.3)	50 (4.8)
Invasive procedures, %						
Cardiac catheterization	1439 (85.6)	789 (68.4)	596 (96.6)	568 (93.0)	487 (86.2)	577 (55.4)
PCI	1122 (66.8)	543 (47.1)	498 (80.7)	431 (70.5)	345 (61.1)	391 (37.5)
CABG	143 (8.5)	59 (5.1)	33 (5.4)	56 (9.2)	60 (10.6)	53 (5.1)

Results are presented as counts (percentages) for categorical variables and means (SDs) for numerical variables. AMI indicates acute myocardial infarction; CABG, coronary artery bypass surgery; DBP, diastolic blood pressure; NA, not applicable; PCI, percutaneous coronary intervention; SBP, systolic blood pressure; and STEMI, ST-segment–elevation myocardial infarction.

was relatively similar among all age strata examined. However, younger patients were more likely to have undergone cardiac catheterization and PCI, but were less likely to have undergone CABG surgery, compared with older patients, with the exception of CABG surgery in patients aged ≥75 years (Table 1). Adjustment for several factors of clinical importance did not change the observed association for cardiac catheterization and PCI; differences in the utilization of CABG surgery, however, in patients aged 55 to 64 years and 65 to 74 years were no longer statistically significant compared with those aged <55 years (Table 2). On the other hand, the use of CABG surgery was lower in patients aged ≥75 years when these factors were accounted for, compared with patients aged <55 years (Table 2). Similar findings were observed when these analyses were stratified according to AMI type (Table 3).

### Trends in the Use of Cardiac Procedures

The use of echocardiography increased during the period under study, for both men and women, from ≈60% in 2005 to >90% in 2018 (Table 4). Similar trends were observed in different age groups, with, however, a lower use of echocardiography in patients aged 65 to 74 years and ≥75 years (Table 2). The use of exercise stress tests varied in different age groups but was relatively stable in both men and women (Tables 2 and 5).

The use of cardiac catheterization and CABG surgery increased in both men and women during the period under study. The use of PCI increased slightly more in women (6.3%) than men (2.2%) between 2005 and 2018 (Table 5). When different age groups were examined, the use of cardiac catheterization and CABG increased in patients aged ≥55 years, with the most prominent increase occurring in patients aged

**Table 2. Multivariable-Adjusted ORs and 95% CIs for Receiving Cardiac Procedures During Hospitalization for an Initial AMI According to Sex and Age: Worcester Heart Attack Study**

	Trends	Sex groups		Age groups, y			
		Men (n=1681)	Women (n=1154)	<55 (n=617)	55–64 (n=611)	65–74 (n=565)	≥75 (n=1042)
Unadjusted models							
Noninvasive procedures							
Echocardiography	1.32 (1.26–1.39)*	Reference	1.14 (0.97–1.35)	Reference	1.19 (0.93–1.50)	1.26 (0.99–1.62)	1.58 (1.27–1.96)*
Exercise treadmill test	0.91 (0.81–1.02)	Reference	1.18 (0.80–1.73)	Reference	0.63 (0.32–1.25)	1.20 (0.67–2.17)	1.36 (0.82–2.27)
Invasive procedures							
Cardiac catheterization	1.14 (1.08–1.21)*	Reference	0.36 (0.30–0.44)*	Reference	0.47 (0.27–0.79)*	0.22 (0.13–0.36)*	0.04 (0.03–0.07)*
PCI	1.03 (0.98–1.07)	Reference	0.44 (0.38–0.52)*	Reference	0.57 (0.44–0.75)*	0.38 (0.29–0.49)*	0.14 (0.11–0.18)*
CABG	1.15 (1.06–1.26)*	Reference	0.58 (0.42–0.79)*	Reference	1.79 (1.14–2.79)*	2.10 (1.35–3.27)*	0.95 (0.61–1.48)
Adjusted models†							
Noninvasive procedures							
Echocardiography	1.41 (1.33–1.49)*	Reference	1.14 (0.95–1.36)	Reference	1.08 (0.84–1.39)	1.09 (0.83–1.42)	1.34 (1.04–1.73)*
Exercise treadmill test	1.34 (1.04–1.73)*	Reference	0.97 (0.65–1.45)	Reference	0.66 (0.33–1.30)	1.27 (0.69–2.31)	1.49 (0.86–2.59)
Invasive procedures							
Cardiac catheterization	1.06 (0.99–1.13)	Reference	0.53 (0.43–0.66)*	Reference	0.48 (0.28–0.83)*	0.31 (0.19–0.52)*	0.07 (0.05–0.12)*
PCI	0.95 (0.90–1.01)	Reference	0.56 (0.47–0.67)*	Reference	0.60 (0.45–0.80)*	0.53 (0.40–0.71)*	0.27 (0.20–0.35)*
CABG	1.17 (1.07–1.29)*	Reference	0.66 (0.47–0.91)*	Reference	1.51 (0.95–2.37)	1.47 (0.92–2.34)	0.54 (0.33–0.90)*

AMI indicates acute myocardial infarction; CABG, coronary artery bypass surgery; OR, odds ratio; and PCI, percutaneous coronary intervention.

\*Marked a statistically significant estimate.

†Logistic regressions adjusted for trends, age groups, sex, type of acute myocardial infarction and in-hospital complication of heart failure, atrial fibrillation, cardiogenic shock, or death.

**Table 3. Multivariable-Adjusted ORs and 95% CIs for Receiving Cardiac Procedures During Hospitalization for an Initial AMI According to Sex and Age in Patients With STEMI and NSTEMI: Worcester Heart Attack Study**

	Trends	Sex groups		Age groups, y			
		Men (n=1681)	Women (n=1154)	<55 (n=617)	55-64 (n=611)	65-74 (n=565)	≥75 (n=1042)
STEMI							
Unadjusted models							
Echocardiography	1.32 (1.21-1.44)*	Reference	1.25 (0.93-1.67)	Reference	1.14 (0.80-1.64)	1.11 (0.75-1.65)	1.59 (1.08-2.32)*
Cardiac catheterization	1.07 (0.95-1.20)	Reference	0.31 (0.21-0.46)*	Reference	0.36 (0.13-1.04)	0.24 (0.08-0.68)*	0.04 (0.02-0.10)*
PCI	1.04 (0.96-1.14)	Reference	0.41 (0.30-0.56)*	Reference	0.54 (0.33-0.90)*	0.47 (0.28-0.80)*	0.15 (0.10-0.24)*
Adjusted models†							
Echocardiography	1.38 (1.26-1.51)*	Reference	1.22 (0.89-1.69)	Reference	1.05 (0.72-1.53)	0.92 (0.60-1.41)	1.40 (0.90-2.17)
Cardiac catheterization	1.00 (0.86-1.15)	Reference	0.65 (0.40-1.03)	Reference	0.36 (0.12-1.05)	0.27 (0.09-0.80)*	0.06 (0.02-0.16)*
PCI	0.99 (0.90-1.10)	Reference	0.63 (0.45-0.89)*	Reference	0.56 (0.33-0.95)*	0.57 (0.33-1.00)*	0.25 (0.15-0.41)*
NSTEMI							
Unadjusted models							
Echocardiography	1.32 (1.24-1.41)*	Reference	1.14 (0.93-1.40)	Reference	1.23 (0.93-1.76)	1.52 (1.10-2.09)*	1.86 (1.41-2.46)*
Cardiac catheterization	1.16 (1.09-1.23)*	Reference	0.40 (0.33-0.50)*	Reference	0.54 (0.29-1.00)*	0.25 (0.14-0.45)*	0.05 (0.03-0.09)*
PCI	1.0 (0.94-1.06)	Reference	0.48 (0.39-0.58)*	Reference	0.61 (0.44-0.84)*	0.41 (0.30-0.56)*	0.17 (0.13-0.23)*
Adjusted models†							
Echocardiography	1.43 (1.33-1.53)*	Reference	1.11 (0.89-1.38)	Reference	1.13 (0.81-1.59)	1.20 (0.85-1.69)	1.38 (1.00-1.88)*
Cardiac catheterization	1.07 (0.99-1.16)	Reference	0.51 (0.39-0.65)*	Reference	0.54 (0.29-1.03)	0.33 (0.18-0.60)*	0.08 (0.05-0.13)*
PCI	0.94 (0.88-1.00)	Reference	0.53 (0.43-0.66)*	Reference	0.62 (0.44-0.88)*	0.53 (0.38-0.75)*	0.28 (0.20-0.38)*

CABG indicates coronary artery bypass surgery; NSTEMI, non-ST-segment-elevation myocardial infarction; OR, odds ratio; PCI, percutaneous coronary intervention; and STEMI, ST-segment-elevation myocardial infarction.

\*Marked a statistically significant estimate.

†Logistic regressions adjusted for trends, age groups, sex, type of acute myocardial infarction (AMI) and in-hospital complication of heart failure, atrial fibrillation, cardiogenic shock, or death.

**Table 4. Trends in Procedure Usage During Hospitalization for an Initial AMI According to Sex: Worcester Heart Attack Study**

		Study years			Changes over time, %
		2005	2011	2018	
Noninvasive procedures					
Echocardiography	Sexes				
	All patients	61.0	65.2	92.2	31.2
	Men	59.7	62.1	93.1	33.4
	Women	62.6	69.9	90.1	27.5
Exercise treadmill test	All patients	4.5	2.6	3.4	-1.1
	Men	3.8	3.6	3.1	-0.7
	Women	5.2	1.1	4.1	-1.1
Invasive procedures					
Cardiac catheterization	All patients	73.1	75.3	89.6	16.5
	Men	81.9	82.9	92.4	10.5
	Women	63.0	64.0	83.5	20.5
PCI	All patients	58.1	57.3	65.0	6.9
	Men	68.8	65.4	71.0	2.2
	Women	45.8	45.2	52.1	6.3
CABG	All patients	4.1	6.9	11.0	6.9
	Men	4.2	8.2	11.1	6.9
	Women	4.0	4.8	10.7	6.7

Changes over time was calculated as the absolute percentage difference between 2018 and 2005. AMI indicates acute myocardial infarction; CABG, coronary artery bypass surgery; and PCI, percutaneous coronary intervention.

≥75 years (Table 2). When changes in patient demographic and clinical factors during the years under study were controlled for, the odds of echocardiography and CABG surgery use increased by 41% (95% CI, 33%–49%) and 17% (95% CI, 7%–29%), respectively (Table 4).

## DISCUSSION

In this community-based study of 2835 patients with an initial AMI across a span of 15 years, we found a similar utilization of noninvasive cardiac procedures in the age and sex groups examined (except for higher echocardiography use in older patients) but a greater use of invasive procedures (cardiac catheterization, PCI, CABG surgery) in men and in younger patients compared with women and older patients. We also found that, between 2005 and 2018, the use of echocardiography and CABG surgery increased in each of the age groups and both sexes examined, while the use of cardiac catheterization and PCI increased faster in women and older patients.

### Use of Cardiac Procedures According to Sex

Among patients who were admitted to the hospital for an initial AMI between 2005 and 2018, we found that the use of cardiac catheterization, PCI, and CABG surgery was lower in women than in men. Our findings

showed a continued discrepancy between the sexes in the receipt of invasive cardiac procedures as noted in several prior studies. For example, data from >14 000 patients hospitalized with NSTEMI in Canada between 1999 and 2008 showed that, compared with men, women were less likely to have undergone coronary angiography.<sup>32</sup>

We had previously shown lower use of cardiac catheterization and CABG surgery in women than in men among residents of the Worcester metropolitan area hospitalized with AMI in 6 annual periods between 1990 and 1999.<sup>33</sup> More recent data, including findings from the VIRGO (Variations in Recovery: Role of Gender on Outcomes of Young AMI Patients) study, which was performed between 2008 and 2012 and included 1465 patients hospitalized with AMI, and from the National Inpatient Sample between 2004 and 2015, which included >7 million patients hospitalized with AMI, continued to show a lower use of coronary angiography and PCI among women compared with men, consistent with the results of the present study.<sup>34,35</sup>

The reasons for the less aggressive management of AMI among women than men are likely multifactorial. However, a lack of typical chest pain and delays in seeking acute medical care among women may not result in indications for the receipt of coronary angiography or coronary reperfusion therapy, which are symptom and time dependent.<sup>36</sup> This observation may, in part, explain the similar use of echocardiography and exercise stress testing in the present study

**Table 5. Trends in Procedure Usage During Hospitalization for an Initial AMI According to Age: Worcester Heart Attack Study**

		Study years			Changes over time, %
		2005	2011	2018	
Noninvasive procedures					
Echocardiography	Age groups, y				
	<55	55.3	56.1	96.5	41.2
	55–64	61.4	52.4	96.1	34.7
	65–74	59.1	67.0	87.2	28.1
	≥75	64.1	77.3	89.0	24.9
Exercise treadmill test	<55	4.3	0.0	3.5	−0.8
	55–64	1.1	1.0	2.9	1.8
	65–74	7.8	2.2	6.4	−1.4
	≥75	4.1	5.2	1.0	−3.1
Invasive procedures					
Cardiac catheterization	<55	96.8	92.9	98.8	2
	55–64	92.1	90.5	96.1	4
	65–74	87.0	85.7	92.6	5.6
	≥75	50.4	50.6	72.0	21.6
PCI	<55	84.0	82.7	83.7	−0.3
	55–64	75.0	69.5	68.9	−6.1
	65–74	65.2	61.5	63.8	−1.4
	≥75	38.4	33.1	46.0	7.6
CABG	<55	3.2	4.1	4.7	1.5
	55–64	2.3	8.6	14.6	12.3
	65–74	8.7	9.9	16.0	7.3
	≥75	2.9	5.8	8.0	5.1

Changes over time was calculated as the absolute percentage difference between 2018 and 2005. AMI indicates acute myocardial infarction; CABG, coronary artery bypass surgery; and PCI, percutaneous coronary intervention.

between women and men, procedures for which indications usually do not depend on the presence of chest pain symptoms.

The clinical outcomes following an AMI in women are usually poorer, including higher death and complication rates compared with men.<sup>32,35,37</sup> The lower utilization of invasive revascularization procedures in women may partially explain these worse outcomes. Our findings continue to highlight the need to close these gaps in hospital management practices between men and women in the setting of AMI.

### Use of Cardiac Procedures According to Age

We found a higher percentage of older patients who received echocardiography compared with younger patients during their hospitalization for a first AMI (74.7% in patients aged ≥75 years versus 65.2% in patients aged <55 years); this higher use remained after multivariable adjustment. The greater use of echocardiography in older as compared with younger patients was likely related to higher rates of clinically significant in-hospital complications, such as heart failure and

cardiogenic shock among older patients, which required frequent left ventricular function evaluation.

In contrast, the use of invasive cardiac procedures, both diagnostic and therapeutic, was lower in patients aged ≥75 years. The lower use of cardiac catheterization, despite a higher frequency of in-hospital heart failure and cardiogenic shock, might suggest more conservative management practices for older patients. The frequency of coronary revascularization (by either PCI or CABG surgery) was 86.1% in patients aged <55 years but only 42.6% in patients aged ≥75 years. We also observed a dose–response pattern, namely, the older the patients were, the lower the chance of these patients undergoing invasive cardiac procedures (Table 1). We also observed that a higher percentage of patients aged 55 to 74 years underwent CABG surgery as a means of revascularization compared with patients aged <55 years. However, this higher use in those aged 55 to 74 years was attenuated and no longer statistically significant after controlling for several potentially confounding factors (Table 2).

The lower rates of undergoing cardiac catheterization and subsequent coronary revascularization in older patients are likely attributable to multiple factors,



both patient- and physician-related. Older patients tend to have more complex coronary lesions that are less amenable to revascularization, and they are more likely to be frail and have complex comorbidities, making invasive procedures riskier.<sup>38</sup> These observations correlate with a higher rate ( $\approx 10\%$ ) of CABG surgery, which is usually indicated for complex coronary lesions, in patients aged 55 to 74 years, observed in the present study, compared with only 5% in patients aged  $<55$  years. Older patients are also more likely to have contraindications associated with long-term antiplatelet therapy and a higher risk of bleeding, which may limit the revascularization strategy chosen.

Despite this background, revascularization in patients aged  $>75$  years who developed an AMI, with and without cardiogenic shock, has been consistently associated with benefits on survival in multiple studies.<sup>39–42</sup> Thus, the lower frequency of coronary revascularization observed in patients aged  $\geq 75$  years in our study calls for further investigation and specific practice guidelines on the appropriateness of invasive management in this high-risk patient population.

### Trends in the Use of Cardiac Procedures

We found that the use of diagnostic and therapeutic, both invasive and noninvasive, cardiac procedures increased between 2005 and 2018. Of note, there was no statistically significant interaction between time and sex or age groups except for the use of echocardiography in different age groups. Thus, other observed between-group differences in terms of trends in the use of the other examined procedures might not be statistically significant.

We found that the rate of increase in the use of cardiac catheterization and PCI observed in the present study was faster in women than in men, albeit not statistically significant. During the 13-year period under study, the absolute increases were 20.5% and 6.3% among women in terms of the use of cardiac catheterization and PCI compared with only 10.5% and 2.2% in men, respectively. On the other hand, changes in the frequency of echocardiography, exercise stress testing, and CABG surgery were not significantly different between women and men during the period under study. The greater increases in the use of several procedures in women during the years under study suggest positive trends in standardizing the care for women and for men during hospitalization for AMI. Improvements in door-to-balloon time, and the establishment of cardiac centers of excellence, as shown in our prior studies, might have helped streamline patient's hospital care and increased access to invasive diagnostic and therapeutic procedures for patients who developed an AMI.<sup>43</sup>

We observed an increase in the use of echocardiography across age groups, from 50% to 60% in 2005

to  $\approx 90\%$  in 2018. Patients aged 55 to 64 years (from 2.3% in 2005 to 14.6% in 2018) and patients aged 65 to 74 years (from 8.7% in 2005 to 16.0% in 2018) experienced an increase in CABG surgery use, while the use of PCI remained relatively stable between 60% and 70% during this period. In contrast, patients aged  $\geq 75$  years experienced an increase, despite lower utilization rates, in both PCI and CABG surgery during the period under study.

Although not being statistically significant in our study, age-specific differences in the use of coronary revascularization have been previously reported in the published literature. Commercial data from 469 827 patients, hospitalized with AMI from over 750 hospitals in the United States between 2000 and 2016, showed an increase in coronary revascularization among patients aged  $\geq 75$  years with the fastest rates occurring among the oldest patients.<sup>44</sup> The increase in the use of coronary revascularization among older patients was likely the result of the availability of recent data, which show considerable benefit and safety of both PCI and CABG surgery among appropriately selected older patients.<sup>45</sup>

It is noteworthy that in our additional analyses of patients who developed either a STEMI or an NSTEMI, trends over time, sex, and age differences in the use of cardiac procedures (echocardiography, cardiac catheterization, and PCI) were similar in patients who experienced either a STEMI or an NSTEMI (Table 3). After multivariable adjustment, trends over time, sex, and age differences in cardiac procedure use were similar in patients who developed either a STEMI or an NSTEMI.

### Study Implications

Our study highlights the ongoing need for improvements in the management of AMI in women and older individuals. Recognition of disparities in the management of patients with heart disease, especially in the administration of cardiac diagnostic and interventional procedures, has increased recently in professional organizations. In the past 3 years, the American Heart Association and the American College of Cardiology have released several clinical guidelines on the diagnosis, management, and prevention of cardiac disease with statements specifically focusing on women and older patients.<sup>46</sup> These are important steps to mitigate the disparities in care for women and older patients with acute and chronic forms of heart disease. In addition, medical education and training should focus on recognizing and addressing discrepancies in acute cardiac care, and quality measures for cardiac centers of excellence should include metrics in health care disparities.

### Study Strengths and Limitations

The strengths of this study include its large, community-based perspective, which allowed us to

describe the use of cardiac procedures, and changes over time therein, in different age groups and men and women among those hospitalized with a first AMI. The patients included in this passive disease surveillance study were rigorously and independently ascertained and validated, and the data collected were comprehensive, which allowed us to adjust for important factors that may have affected the use of different cardiac procedures. On the other hand, this central Massachusetts study population was primarily of White race, which limited our ability to examine the use of cardiac procedures in patients of different races and ethnicities. In addition, because of the small number of exercise stress tests and CABG surgeries performed, estimates for its use in different subgroups might not be stable. Finally, the use of logistic regression analysis to examine changes over time in the use of selected procedures might not perfectly depict the underlying probability, especially for procedures that were commonly or uncommonly used. Future studies should focus on recent trends in the use of specific cardiac procedures and their appropriateness of indication.

## CONCLUSIONS

Women and older patients who were hospitalized for an initial AMI at several tertiary care medical centers in central Massachusetts were less likely to have received invasive diagnostic and therapeutic procedures during their index hospitalization, including cardiac angiography, PCI, and CABG surgery, than men and younger patients. However, each of these groups experienced a greater increase in the receipt of these invasive procedures during the period under study compared with men and younger patients, respectively.

## ARTICLE INFORMATION

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### Disclosures

None.

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