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Original Research

Clinical Characteristics, Outcomes, and Epidemiological Trends of Patients Admitted With Type 2 Myocardial Infarction

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A B S T R A C T

Background: Type 2 myocardial infarction (T2MI) was first established as a unique entity in 2007. However, its clinical features are not well characterized. This study aimed to determine the clinical characteristics, predictors of mortality, and hospitalization trends of patients with T2MI.

Methods: The National Inpatient Sample database was queried for patients hospitalized in the United States with T2MI (January 2018 to December 2019). Data were used to assess baseline characteristics, primary diagnoses, predictors of mortality, and hospitalization and mortality trends of T2MI.

Results: During the 24-month study period, 1,789,485 (76%) patients were admitted with type 1 myocardial infarction (T1MI) and 563,695 (24%) were admitted with T2MI. Patients with T2MI were more likely to be older (71 vs 68 years; $P < .001$) and female (47.5% vs 38.3%; $P < .001$), with fewer comorbidities related to coronary atherosclerosis. African Americans were the only race with a significantly higher rate of hospitalization for T2MI (15.9% vs 11.6%; $P < .001$). The predictors of mortality were similar in both the T2MI and T1MI cohorts. Sepsis (23.47%), hypertensive heart disease (15.35%), and atrial arrhythmias (4.49%) were the most common principal diagnoses for T2MI. T2MI hospitalizations trended consistently upward during the study period. Monthly in-hospital mortality rates were consistently higher for T2MI versus T1MI ($P < .001$).

Conclusions: T2MI is a unique and heterogeneous clinical entity. Despite increased awareness, there is a lack of standardization of medical management and timing for revascularization, even as mortality rates remain persistently elevated compared with T1MI. Certain demographics, including African Americans, may be disproportionately affected.

Introduction

A joint consensus paper released by the American College of Cardiology and the European Society of Cardiology in 2007 divided myocardial infarction (MI) into 5 subtypes based on etiology (Table 1). MI caused by an imbalance between myocardial oxygen supply and demand unrelated to acute coronary atherothrombosis or subsequent to a revascularization procedure was deemed a type 2 MI (T2MI).[1]

Despite this new classification adopted in 2007, T2MI was not assigned a unique *International Classification of Diseases, Tenth Edition, Clinical Modification* (ICD-10-CM) code until October 2017. Since the inception of its use in billing, the National Inpatient Sample (NIS) database has used ICD-10-CM codes to collect information on the characteristics and outcomes of patients admitted with a diagnosis of T2MI.

Most studies describing the characteristics of patients with T2MI agree that they tend to be older, female, and have more chronic comorbidities.[2-7] However, there tends to be a significant discrepancy in reported hospitalization and mortality trends, associated comorbidities, and outcomes.[2-8]

In the present study, we used the most recent data available from the NIS database (January 2018 to December 2019) to compare patients admitted to the hospital with a diagnosis of T2MI with patients admitted with a diagnosis of type 1 MI (T1MI). We hypothesized that the baseline characteristics and predictors of increased mortality would be significantly different between the groups. We also hypothesized that the number of T2MI hospitalizations would increase as the awareness of T2MI increased and that mortality rates would not improve over time given the lack of standardization of management of T2MI.

Abbreviations: CABG, coronary artery bypass graft; CAD, coronary artery disease; ESRD, end-stage renal disease; ICD-10-CM, *International Classification of Diseases, Tenth Edition, Clinical Modification*; MI, myocardial infarction; NIS, National Inpatient Sample; NSTEMI, non–ST-elevation myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction; T1MI, type 1 myocardial infarction; T2MI, type 2 myocardial infarction.

Keywords: mortality; National Inpatient Sample; outcomes; type 2 myocardial infarction.

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Table 1. Classification of MI and myocardial injury based on the Fourth Universal Definition of Myocardial Infarction.

MI type	Definition
Type 1 MI	Caused by atherothrombotic CAD and usually precipitated by atherosclerotic plaque rupture or erosion.
Type 2 MI	Mismatch between oxygen supply and demand. Because of a wide variety of causes. CAD may or may not be present.
Type 3 MI	MI detected by autopsy examination in cases where biomarkers are not obtained before death, or the patient suffers cardiac death, with new ischemic ECG changes or ventricular fibrillation (but not biomarkers) detected before death.
Types 4 and 5 MI	MI following PCI or CABG and reflecting myocardial injury related to the procedure itself, periprocedural issues, or complications <48 h after the procedure.
Myocardial injury	At least 1 elevated cardiac troponin above the 99th percentile but without the signs of ischemia. Considered acute if there is a rise or fall in troponin values.

In the clinical setting, the classification of MI and myocardial injury can be subtle. In addition to meeting the criteria for acute myocardial injury, in which there is a rise and fall of troponins with at least 1 value above the 99th percentile, those with types 1 or 2 MI must also have evidence of ischemia, defined as the presence of symptoms of ischemia, new ischemic ECG findings, pathologic Q wave development, imaging evidence consistent with the new loss of viable myocardium, or (in the case of type 3 MI), ischemia found on autopsy. Autopsy evidence of ischemia because of acute atherothrombosis still meets the criteria for type 1 MI. Troponin level criteria for coronary procedure–related (types 4 and 5) MI are arbitrarily defined as being at least 5 to 10 times of the 99th percentile upper reference limit.

CABG, coronary artery bypass graft; CAD, coronary artery disease; ECG, electrocardiogram; MI, myocardial infarction; PCI, percutaneous intervention.

Methods

Data source

Data were obtained from the NIS database files. The NIS is part of the Healthcare Cost and Utilization Project. It is a family of health care databases and related software tools developed through a federal/state/industry partnership sponsored by the Agency for Healthcare Research and Quality.

Considered the largest publicly available all-payer inpatient health care database in the United States, the NIS database yields national estimates of inpatient hospital stays. It consists of a stratified sample of discharges from all hospitals in the Healthcare Cost and Utilization Project, equal to approximately 20% of all discharges in US community hospitals. When weighted, it estimates >35 million hospitalizations per year nationally. Because the database contains deidentified patient information, the study was deemed exempt from the need for institutional review board approval by our institution.

Study population

We analyzed the NIS databases from 2018 to 2019 to identify all patients aged >18 years admitted with a diagnosis of MI. The subjects were then divided into 2 groups (Figure 1). The first group consisted of patients admitted with a diagnosis of T2MI using the ICD-10-CM code 121.A1. This code was explicitly assigned to T2MI in October 2017. The second group included patients admitted with T1MI and was defined as the combination of non–ST-segment elevation MI (NSTEMI) and ST-segment elevation MI (STEMI) and identified using the ICD-10-CM codes I21 and I22, respectively (Supplemental Table S1). Patients who had a diagnosis of both T1MI and T2MI were excluded from our analysis.

Patient and hospital variables

Baseline characteristics were obtained using variables provided by the NIS databases. These consisted of demographic characteristics (eg, age, sex, and race) and Elixhauser clinical comorbidities as defined by the Agency for Healthcare Research and Quality along with other relevant clinical comorbidities using the *International Classification of Diseases, Tenth Revision* codes.[9] Procedures such as percutaneous coronary intervention (PCI) and coronary artery bypass graft (CABG) were identified using the *International Classification of Diseases, Tenth Revision,* Procedure Coding System codes (Supplemental Table S1).

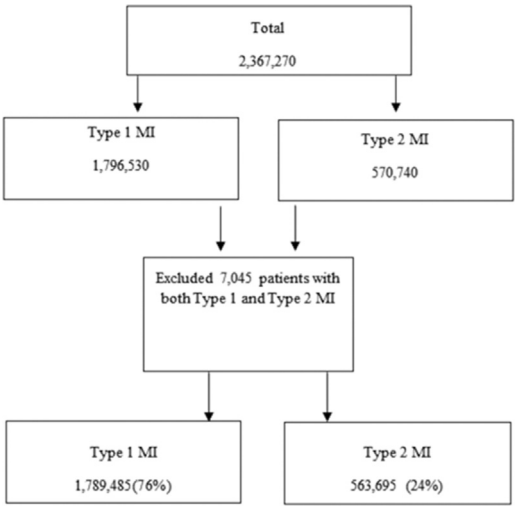


Figure. 1. Patient population selection. The National Inpatient Sample database was queried over a 24-month period (January 2018 to December 2019) for all patients admitted with MI and divided into T1MI (which includes all STEMI and NSTEMI codes) and T2MI (which does not have a subdivision within ICD-10-CM diagnostic codes). ICD-10-CM, *International Classification of Diseases, Tenth Edition, Clinical Modification*; MI, myocardial infarction; NSTEMI, non–ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction; T1MI, type 1 myocardial infarction; T2MI, type 2 myocardial infarction.

Outcomes definition

We primarily sought to determine baseline characteristics (including age, sex, race, comorbidities, etc), common primary admission diagnoses, and predictors of all-cause in-hospital mortality (mortality) in T2MI. The secondary outcomes included temporal trends in T2MI hospitalizations and mortality, as well as procedural (ie, PCI and CABG) and coronary angiography rates.

Statistical analysis

Discharge weight provided by the NIS was applied to unweighted data to infer national estimates. Weighted data were used in all analyses. We used descriptive statistics to summarize the distribution of baseline parameters and hospital characteristics. Continuous variables are expressed as means and standard deviations. Categorical variables are expressed as absolute values and percentages. To ascertain differences between patients with T1MI and T2MI, we used the Pearson χ^2 test, Fisher exact test, independent t test, and Mann-Whitney U test, as appropriate.

Binary-logistic regression was used to explore the association between the type of MI and inpatient outcomes. We conducted a univariable analysis, and variables significantly associated with our outcomes ($P < .1$) were included in our multivariable model to adjust for potential confounders.

All statistical analyses were conducted using SPSS Statistics 27.0 (IBM Corp). All P values were 2-sided, and statistical significance was defined as $P < .05$.

Results

A total of 2,353,180 adults with MI were admitted during the 24-month study period, of which 1,789,485 (76%) were diagnosed with T1MI and 563,695 (24%) were diagnosed with T2MI.

Baseline characteristics

Patients with T2MI tended to be older and have a higher proportion of women than those with T1MI. Most patients with T2MIs and T1MIs were White (Table 2). African Americans had a significantly higher percentage of hospitalizations for T2MI versus T1MI. In terms of comorbidities, those admitted for T2MI were more likely to have congestive heart failure, pulmonary hypertension, end-stage renal disease (ESRD), cancer, chronic lung or liver disease, anemia, or atrial arrhythmias. Those with T2MI were also less likely to have preexisting conditions associated with unstable coronary plaque formation, such as diabetes mellitus, hypertension, hyperlipidemia, coronary artery disease, or smoking (Table 2). Among the in-hospital complications queried for in this study, rates of acute kidney injury showed the largest difference between the 2 groups, occurring at double the rate in T2MI (Table 2).

Table 2. Baseline characteristics for type 1 and type 2 MI.

	Type 1 MI (n = 1,789,485)	Type 2 MI (n = 563,695)	P value
Demographic characteristic			
Age, y	68 ± 13	71 ± 14	<.001
Female sex	686,220 (38.30%)	267,815 (47.50%)	<.001
Race			
White	1,266,405 (72.70%)	386,155 (70.20%)	<.001
Black	201,840 (11.60%)	87,530 (15.90%)	<.001
Hispanic	156,775 (9.00%)	43,790 (8.00%)	<.001
Comorbidities			
Diabetes mellitus	757,795 (42.30%)	228,555 (40.50%)	<.001
Hypertension	1,064,430 (59.50%)	311,345 (55.20%)	<.001
Obesity	349,410 (19.50%)	94,925 (16.80%)	<.001
Hyperlipidemia	1,162,310 (65.00%)	272,950 (48.40%)	<.001
Smoking	842,705 (47.10%)	221,660 (39.30%)	<.001
Chronic liver disease	48,160 (2.70%)	31,930 (5.70%)	<.001
Chronic lung disease	358,135 (20.00%)	165,170 (29.30%)	<.001
End-stage renal disease	420,640 (23.50%)	201,775 (35.80%)	<.001
Pulmonary hypertension	112,290 (6.30%)	69,065 (12.30%)	<.001
Heart failure	637,995 (35.70%)	261,745 (46.40%)	<.001
Coronary artery disease	1,397,500 (78.10%)	263,200 (46.70%)	<.001
Peripheral vascular disease	58,830 (3.30%)	15,455 (2.70%)	<.001
Atrial arrhythmias	412,305 (23.00%)	203,405 (36.10%)	<.001
Anemia	81,605 (4.60%)	49,885 (8.80%)	<.001
Solid cancer	63,190 (3.50%)	40,635 (7.20%)	<.001
Blood cancer	22,280 (1.20%)	14,230 (2.50%)	<.001
Hospitalization			
PCI	598,130 (33.40%)	7145 (1.30%)	<.001
CABG	145,430 (8.10%)	2035 (0.40%)	<.001
Cardiac arrest	67,805 (3.80%)	15,105 (2.70%)	<.001
Acute kidney injury	315,265 (17.60%)	199,975 (35.50%)	<.001
Shock	3475 (0.20%)	695 (0.10%)	<.001
Length of stay, d	5 ± 7	7 ± 8	<.001
Discharge disposition			
Routine	1,007,790 (56.3%)	223,015 (39.6%)	<.001
Transfer to short-term hospital	130,785 (7.3%)	18,885 (3.4%)	<.001
Transfer to SNF, ICF, or other	263835 (14.8%)	160,825 (28.5%)	<.001
Home health care	239,740 (13.4%)	106,945 (19%)	<.001
Against medical advice	21,545 (1.2%)	7995 (1.4%)	<.001

Values are mean ± SD or n (%).
CABG, coronary artery bypass graft; ICF, intermediate care facility; MI, myocardial infarction; PCI, percutaneous coronary intervention; SNF, skilled nursing facility.

Patients admitted for T2MI were less likely to undergo coronary computed tomography, coronary angiography, CABG, or PCI during the same hospitalization, compared with patients with T1MI. The length of stay was higher for patients with T2MI. Patients with T2MI were more likely to be transferred to a skilled nursing (or similar) facility or receive home health care and less likely to be transferred to a short-term hospital (Table 2, Supplemental Table S2).

Primary diagnoses associated with T2MI

Of those admitted with a diagnosis of T2MI, 497,730 patients (88.3% of all T2MI admissions) were admitted with T2MI as a secondary diagnosis. The most common primary diagnoses among patients admitted with T2MI were sepsis (23.47%), hypertensive heart disease (15.35%), and atrial arrhythmias (4.49%) (Table 3, Figure 2).

Mortality

Despite a higher prevalence of comorbidities associated with unstable coronary plaque in the T1MI group, both the T2MI and T1MI groups had similar predictors of in-hospital mortality (Table 4). In the T2MI group, the top preexisting conditions associated with increased mortality were cancer, chronic liver disease, stroke, and ESRD, respectively. The strongest predictors in the T1MI group included, stroke, cancer, ESRD, and chronic liver disease, respectively. Patients who underwent PCI or CABG during the same admission had the lowest risk of in-hospital mortality in both T2MI and T1MI groups (Table 4, Figure 3).

In terms of complications, cardiac arrest, followed by acute kidney injury, cancer, shock, and stroke carried the strongest risk of associated in-hospital mortality (Table 4, Figure 3).

Temporal trends in hospitalizations and mortality

The number of patients admitted with either type of MI trended up during the study period and had a significant seasonal variation, peaking in the months from December to March and declining to yearly lows between June and September (Figure 4). When adjusted for seasonal variation, T1MI hospitalizations trended slightly down during the study period; however, this was not statistically significant (P = .38).

Conversely, T2MI hospitalizations trended up during the study period, at a seasonally adjusted rate of 1.82% per month (Central Illustration). The percentage of cases with T2MI contributing to the total of MI hospitalizations also increased during the study period, from 21.07% in January 2018 to 27.61% in December 2019 (Figure 4). The rate of in-hospital mortality was higher for T2MI than T1MI for any given month during the study period (Supplemental Table S3). The monthly mortality rate for T1MI trended down, whereas the monthly mortality rate for T2MI trended up during the study period. The average monthly mortality rate was 6.81% for T1MI and 8.53% for T2MI. In December 2019, T1MI in-hospital mortality fell to a 2-year low of 2555 (3.3%), whereas T2MI in-hospital mortality nearly doubled to a 2-year high of 5400 (18.26%).

Table 3. Principal diagnoses associated with type 2 myocardial infarction.

Rank	Principal diagnosis	n (%)
1	Sepsis	116,805 (23.47%)
2	Hypertensive heart disease	76,395 (15.35%)
3	Atrial arrhythmia	22,325 (4.49%)
4	Acute respiratory failure	9710 (1.95%)
5	Acute kidney injury	9520 (1.91%)
6	Pneumonia	9005 (1.81%)
7	Hypertensive emergency	8370 (1.68%)
8	Gastrointestinal hemorrhage	7330 (1.47%)
9	Pulmonary embolism	6310 (1.27%)
10	Hypertensive urgency	3790 (0.76%)

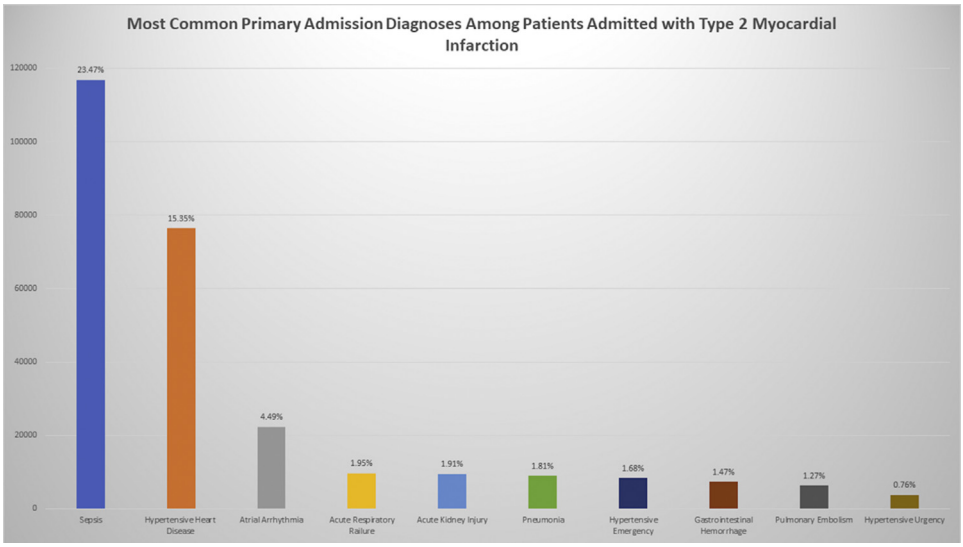


Figure. 2. Most common primary admission diagnoses among admitted patients with type 2 myocardial infarction. Sepsis was the most common primary diagnosis associated with type 2 myocardial infarction, followed by hypertensive heart disease and atrial arrhythmias.

However, the number of hospitalizations of either MI type did not change significantly during this month.

Discussion

In this large US national data set analysis of patients with T2MI, we report several interesting and novel findings. We found that patients with T2MI tended to be older, female, and had fewer preexisting conditions traditionally associated with arterial atherosclerosis. In the vast majority of admissions, T2MI was a secondary diagnosis, with the most common primary associated diagnoses being sepsis, followed by hypertensive heart disease and atrial arrhythmias. African Americans were the only race to have a greater percentage of T2MI hospitalizations compared with T1MI. The use of coronary angiography, as well as revascularization with CABG or PCI, was much lower in the T2MI group. Despite large differences in baseline characteristics, serious chronic comorbidities, such as cancer and prior stroke, were the top predictors of mortality in both groups. The number of T2MI hospitalizations trended consistently upward during the study period, as did the percentage of T2MIs contributing to the total number of MI hospitalizations. In-hospital mortality rates were consistently higher for T2MI than for T1MI across all study months.

We found that patients with T2MI were older, more likely to be female, and more medically complex with a higher prevalence of serious

Table 4. Adjusted predictors of inpatient mortality for type 1 and type 2 MI.

	Type 1 MI		Type 2 MI	
	aOR (95% CI)	*P* value	aOR (95% CI)	*P* value
Demographic characteristic				
Age	1.029 (1.030-1.029)	<.001	1.018 (1.019-1.017)	<.001
Female sex	1.014 (1.000-1.028)	.050	0.947 (0.927-0.968)	<.001
Comorbidities				
Diabetes mellitus	1.019 (1.004-1.033)	.010	0.874 (0.854-0.894)	<.001
Hypertension	0.672 (0.662-0.682)	<.001	0.682 (0.666-0.698)	<.001
Obesity	0.741 (0.726-0.756)	<.001	0.725 (0.701-0.750)	<.001
Smoking	0.771 (0.759-0.782)	<.001	0.665 (0.649-0.682)	<.001
Hyperlipidemia	0.580 (0.572-0.589)	<.001	0.669 (0.654-0.685)	<.001
Coronary artery disease	0.613 (0.604-0.622)	<.001	0.754 (0.736-0.773)	<.001
Peripheral vascular disease	1.103 (1.142-1.066)	<.001	1.100 (1.032-1.173)	.004
Chronic lung disease	1.099 (1.081-1.117)	<.001	1.136 (1.109-1.164)	<.001
End-stage renal disease	1.619 (1.588-1.651)	<.001	1.622 (1.572-1.673)	<.001
Anemia	0.782 (0.759-0.805)	<.001	0.747 (0.718-0.778)	<.001
Chronic liver disease	1.458 (1.411-1.507)	<.001	1.654 (1.589-1.721)	<.001
Heart failure	0.937 (0.921-0.954)	<.001	0.805 (0.781-0.829)	<.001
Pulmonary hypertension	0.908 (0.886-0.930)	<.001	0.923 (0.893-0.954)	<.001
Stroke	1.812 (1.734-1.893)	<.001	1.643 (1.542-1.750)	<.001
Atrial arrhythmia	1.172 (1.155-1.189)	<.001	1.163 (1.137-1.189)	<.001
Solid cancer	1.713 (1.669-1.758)	<.001	2.183 (2.115-2.253)	<.001
Blood cancer	1.437 (1.375-1.501)	<.001	2.013 (1.915-2.117)	<.001
Hospitalization				
PCI	0.553 (0.542-0.563)	<.001	0.492 (0.428-0.566)	<.001
CABG	0.493 (0.476-0.510)	<.001	0.452 (0.349-0.585)	<.001
Cardiac arrest	14.851 (14.566-15.141)	<.001	14.133 (13.617-14.668)	<.001
Acute kidney injury	3.708 (3.655-3.761)	<.001	2.746 (2.687-2.807)	<.001
Stroke	1.187 (1.124-1.254)	<.001	1.650 (1.523-1.788)	<.001
Shock	1.879 (1.688-2.092)	<.001	2.137 (1.744-2.618)	<.001

aOR, adjusted odds ratio; CABG, coronary artery bypass graft; MI, myocardial infarction; PCI, percutaneous coronary intervention.

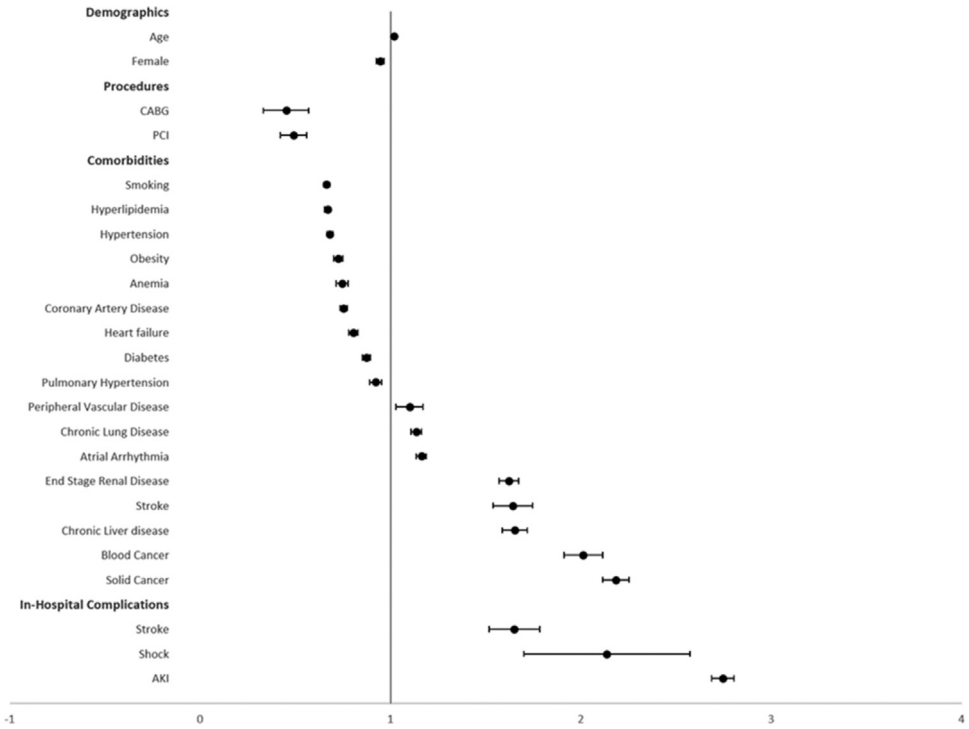


Figure. 3. Adjusted predictors of all-cause mortality among patients with type 2 myocardial infarction. Similar to the T1MI cohort, mortality in this group was much more strongly associated with noncardiovascular conditions such as chronic liver and renal disease and cancer. AKI, acute kidney injury; CABG, coronary artery bypass graft; PCI, percutaneous intervention.

chronic conditions, such as congestive heart failure, pulmonary hypertension, and ESRD. We also demonstrated that diseases generally considered unrelated to unstable coronary plaque are the primary reason for admission in patients with T2MI. Both these findings have been fairly well established in the literature and are confirmed in this much larger study population.[2,3,5,6,10-14] In this study, T2MI was a secondary diagnosis in nearly 90% of cases, suggesting that patients tend to present with T2MI and not because of it. It may also suggest that in many cases, myocardial injury, such as can occur in hyperinflammatory states like sepsis, is being improperly coded as T2MI. This practice can have a significant potential negative impact on hospital readmission rates and subsequent reimbursement.[15]

Although the systemic diseases that trigger T2MI may sometimes act like a "stress test," revealing underlying obstructive coronary artery disease (CAD), in many cases, the death of myocardial tissue is entirely unrelated to the obstructed coronary arteries. In fact, some studies have shown that only roughly half of the patients with T2MI have obstructive CAD when evaluated with coronary angiography.[4,16,17] Because this group tends to be so hetergeneous, there is greater uncertainty regarding the management of these patients, especially regarding the timing of invasive procedures. Several recent prospective studies have attempted to address this problem. The Determining the Mechanism of Myocardial Injury and Role of Coronary Disease in Type 2 Myocardial Infarction trial found that of the 100 trial participants with T2MI, approximately 30% had obstructive CAD and one-third had left ventricular dysfunction, which for the most part was previously unrecognized.[18] The authors conclude that patients with T2MI may benefit from earlier coronary imaging and the initiation of guideline therapies where appropriate. The Defining the Prevalence and characteristics of Coronary Artery Disease Among Patients with Type 2 Myocardial Infarction Using CT-FFR trial is actively recruiting and hoping to address a similar question regarding the use of imaging to determine the prevalence of obstructive CAD in patients with T2MI.

In the present study, approximately 1 in 9 patients with T2MI underwent diagnostic coronary angiography, 1 in 77 received coronary stenting, and 1 in 250 received a CABG. Although a causative relationship cannot be inferred in this highly selected subgroup of patients, when these procedures were performed, they were associated with significantly lower mortality in patients with T2MI. Clinically, the underlying cause of the oxygen supply and demand mismatch should be the primary therapeutic target. The low rates of coronary angiography in T2MI seen in the current study and in other published reports likely underscores the uncertainty many clinicians may feel regarding its benefit in this demographic. The question of whether patients with T2MI, or a subset of these patients with certain risk factors, would benefit from earlier diagnostic imaging and/or revascularization has not yet been clearly elucidated in the literature but is under active investigation. The Appropriateness of Coronary Investigation in Myocardial Injury and Type 2 Myocardial Infarction trial is currently underway to address the question of whether patients with myocardial injury or T2MI benefit from early invasive testing (coronary angiography within 5 days) compared with conservative management (functional testing within 14 days at the clinician's discretion).[19] As our understanding of T2MI continues to evolve, further studies will be needed to help inform our management of this heterogeneous and complex group of patients.

African Americans were the only ethnic cohort with a greater percentage of T2MI hospitalizations than T1MI hospitalizations. Previous literature looking at racial disparities in the management of acute MI has shown mixed data regarding revascularization rates for African Americans compared with other racial cohorts, although a recent nationwide study by Alkhouli et al[20] demonstrated a proportional increase in African Americans undergoing revascularization over the last several decades.[21-24] When presentation is stratified by STEMI versus NSTEMI, studies have shown decreased revascularization rates and longer median times to revascularization in African Americans presenting with NSTEMI.[21,24] Although there are likely many reasons for these decreased revascularization rates in African Americans, such as an increased prevalence of cardiometabolic comorbidities in this group, it is important to note that the previously mentioned studies either did not differentiate

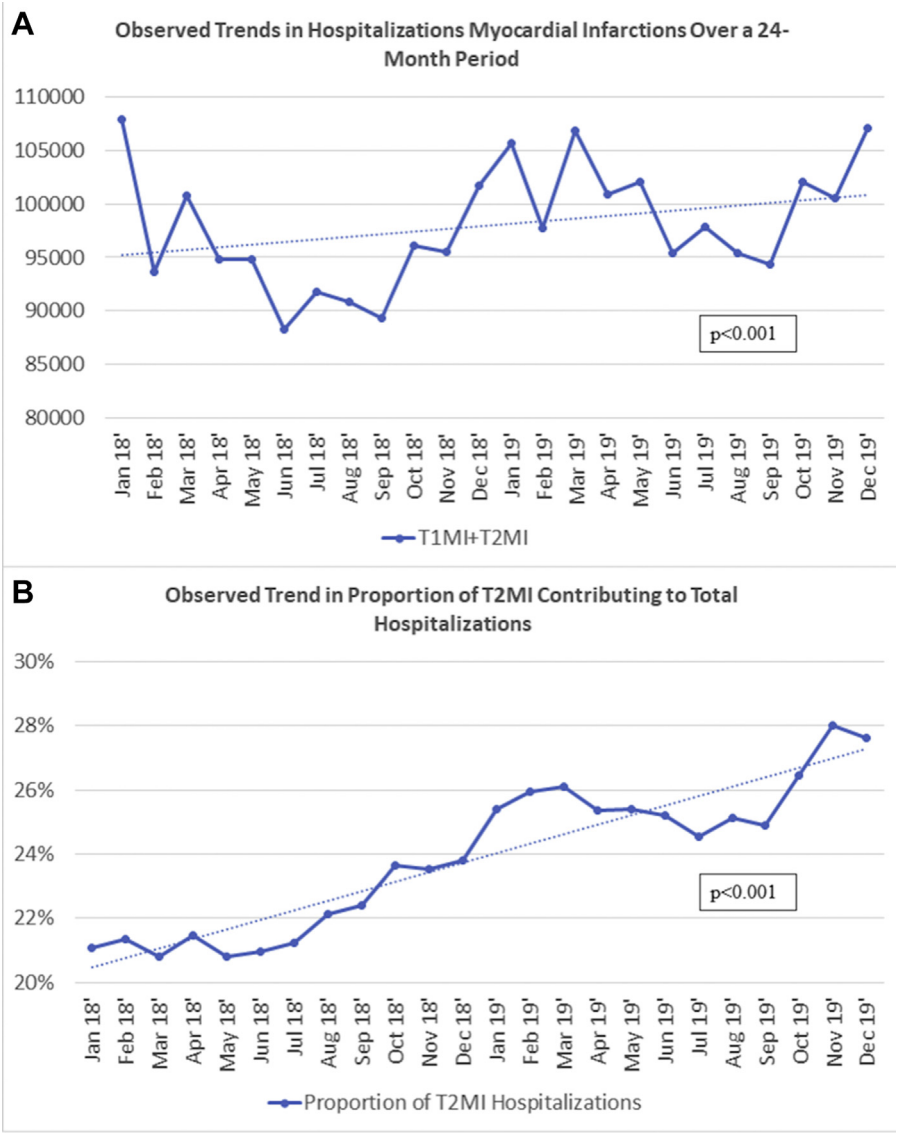
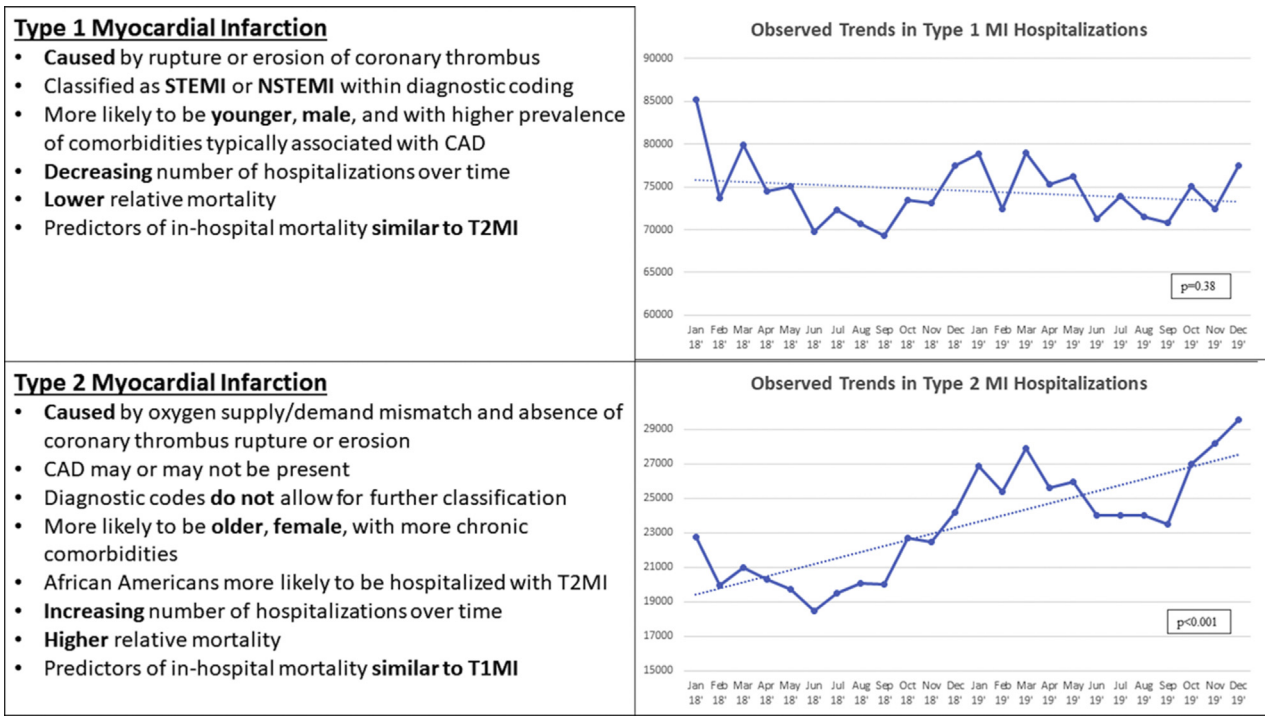


Figure. 4. Observed trends in monthly hospitalizations for MIs and the proportion of hospitalizations comprising T2MIs. Total hospitalizations for MI (**A**) trended up at a seasonally adjusted rate of 0.26% per month and the percent of total hospitalizations comprised of T2MI (**B**) admissions over the 24-month study period. The percent of admissions comprising T2MIs consistently increased over the study period. MI, myocardial infarction; T1MI, type 1 myocardial infarction; T2MI, type 2 myocardial infarction.

between T2MI and T1MI or purposefully excluded T2MI. Based on the present findings, because African Americans are more likely to present with T2MI, which is also much more likely to be coded as an NSTEMI in the *International Classification of Diseases, Ninth Revision* or older coding systems, this may in part explain the decreased revascularization rates in this cohort. Our study adds to the current literature by presenting a data set that, to our knowledge, is the largest such study accounting for T2MI hospitalizations in African Americans.

Despite fairly large differences in baseline characteristics, the predictors of in-hospital mortality for both T2MI and T1MI were remarkably similar. In fact, the top 5 predictors of in-hospital mortality were the same in both groups, although in a slightly different order, and included chronic comorbidities such as cancer, stroke, ESRD, and chronic liver disease. The present study therefore reaffirms prior work showing that in the era of reperfusion therapy for T1MI and improved management of CAD risk factors, the main drivers of in-hospital mortality are chronic, noncardiovascular conditions, rather than the risk factors that predispose to unstable coronary plaque itself. These chronic comorbidities that typically carry a poor prognosis are more prevalent in T2MI. This is likely a main contributing factor to why the mortality rate for T2MI was higher than that for T1MI for any given month in the study period and did not improve over time. This is consistent with the findings of the review by DeFilippis et al,[4] which has shown that most current studies have demonstrated increased mortality in patients with T2MI in both short- and long-term follow-up than in patients with T1MI, although a few studies have shown that this difference attenuated when looking at cardiovascular mortality alone.[2,11]

What little data that exist on the temporal trends of T2MI has shown wide variability, with reported incidence rates in the literature ranging from 2% to 58% of all cases with MI.[2,4-6] Similar to what was seen in the present study, the vast majority of current literature often demonstrates a much larger proportion of patients with T1MI than T2MI. Although we demonstrated that the proportion of cases with T2MI that contribute to total MI hospitalizations is rapidly growing, likely because of increased awareness of T2MI both as a unique pathophysiologic entity and the ICD-10-CM code itself, the reason behind this large skew in the data toward T1MI is not entirely clear. One obvious potential contribution includes improper understanding and differentiation among T1MI, T2MI, and myocardial injury. Contributing to this discrepancy is the incongruency between the Fourth Universal Definition of MI, which appropriately states that the terms STEMI and NSTEMI can apply to both MI types,



Central Illustration. Comparison of characteristics, outcomes, and trends in hospitalization and mortality in patients with type 1 myocardial infarction (T1MI) and type 2 myocardial infarction (T2MI). Trends in hospitalization for T1MI (top) and T2MI (bottom) during the 24-month study period. As shown in the graphs, the number of hospitalizations for T2MI saw a clear trend upward in contrast to T1MI hospitalizations. CAD, coronary artery disease; NSTEMI, non–ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction.

and current ICD-10-CM codes where these terms apply exclusively to T1MI.[25,26] At least 1 study has found that the number of T2MIs improperly coded as NSTEMI (and therefore T1MI) is as high as 30%.[27] When applied to the current study, this alone would serve to nearly double the number of T2MI hospitalizations. A recent study by McCarthy et al[28] showed approximately 14% decline in T1MI hospitalizations following the introduction of the T2MI ICD-10-CM code in 2017, largely driven by a reduction in hospitalizations where T1MI was coded as a secondary diagnosis. This large change in favor of T2MI likely indicates ascertainment bias because of patients with T2MI previously being incorrectly coded as T1MI, and the large rise in T2MI hospitalizations seen in the present study is likely in part because of a continuation of improvement of this ascertainment bias. However, this cannot totally account for the rise in T2MI hospitalizations because the rise in T2MI hospitalizations far outpaced the fall in T1MI hospitalizations. The cause of the rise in T2MI hospitalizations is likely multifactorial and largely driven by other factors, such as increased use of high sensitivity troponins and the misdiagnosis of myocardial injury as T2MI.[15,29]

Study limitations

The limitations of the present study include those of any retrospectively collected data set, such as possible erroneous diagnosis or diagnostic misclassification. These factors may have been more pronounced in data from the NIS because of the fact that T2MI was only assigned an ICD-10-CM code as of October 2017 and there was an initial lack of awareness among clinicians. Widespread confusion in the differences between ICD-10-CM and classification of T2MI and the Fourth Universal Definition of MI as previously discussed were also likely a factor. Because not all patients in the study underwent coronary angiography, it is possible that some patients diagnosed with T2MI really had T1MI. The NIS database is also not able to objectively capture some factors. For example, some patient characteristics, such as race, are self-reported, potentially leading to reporting bias. Additionally, the database only captures procedures performed during the same admission, which may lead to sampling bias. For instance, the urgency for coronary imaging or revascularization is typically less with T2MI, which may lead to more of these procedures being performed electively at a later date. Similarly, because out-of-hospital mortality is not captured in the data set, this likely leads to the underreporting of mortality rates.

Conclusions

In this large national study, we found T2MI to be a unique entity compared with T1MI in terms of baseline characteristics, outcomes, and epidemiological trends. Specifically, patients presenting with T2MI were more likely to be older and female. Unlike other racial groups, a greater proportion of African Americans present with T2MI than T1MI. Patients with T2MI also tended to be sicker with more chronic comorbidities not directly related to atherosclerotic disease, which in turn were the strongest predictors of mortality in both MI types. The number of hospitalizations for T2MI appears to be increasing at a significantly faster rate and is associated with higher mortality than T1MI. The use of coronary angiography and revascularization with PCI or CABG remains drastically lower in patients with T2MI but is associated with a significantly lower risk of in-hospital mortality.

The natural history and drivers of poor outcomes for T2MI found in this study are still imperfectly understood. Further studies may help determine whether a specific subset of patients with T2MI would benefit

from earlier coronary imaging and revascularization. How and whether these findings should affect the management of patients with T2MI warrants further prospective clinical trials.

Declaration of competing interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethics statement

The research reported has adhered to the relevant ethical guidelines.

Supplementary material

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