Body mass index linked to short-term and long-term all-cause mortality in patients with acute myocardial infarction

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ABSTRACT

Purposes of study This study aimed to elucidate the relationship between obesity and short-term and long-term mortality in patients with acute myocardial infarction (AMI) by analysing the body mass index (BMI).

Study design A retrospective cohort study was performed on adult intensive care unit (ICU) patients with AMI in the Medical Information Mart for Intensive Care III database. The WHO BMI classification was used in the study. The Kaplan-Meier curve was used to show the likelihood of survival in patients with AMI. The relationships of the BMI classification with short-term and long-term mortality were assessed using Cox proportional hazard regression models.

Results This study included 1295 ICU patients with AMI, who were divided into four groups according to the WHO BMI classification. Our results suggest that obese patients with AMI tended to be younger (p<0.001), be men (p=0.001) and have higher blood glucose and creatine kinase (p<0.001) compared with normal weight patients. In the adjusted model, compared with normal weight AMI patients, those who were overweight and obese had lower ICU risks of death HR=0.64 (95% CI 0.46 to 0.89) and 0.55 (0.38 to 0.78), respectively, inhospital risks of death (0.77 (0.56 to 1.09) and 0.61 (0.43 to 0.87)) and long-term risks of death (0.78 0.64 to 0.94) and 0.72 (0.59 to 0.89). On the other hand, underweight patients had higher risks of short-term(ICU or inhospital mortality) and long-term mortality compared with normal weight patients (HR=1.39 (95% CI 0.58 to 3.30), 1.46 (0.62 to 3.42) and 1.99 (1.15 to 3.44), respectively).

Conclusions Overweight and obesity were protective factors for the short-term and long-term risks of death in patients with AMI.

INTRODUCTION

Acute myocardial infarction (AMI) plays an important role in the death of patients with cardiovascular disease worldwide.[1] Large numbers of patients with AMI are admitted to intensive care units (ICUs) each year.[2] Paying greater attention to the risk factors for ICU patients with AMI can help clinicians to identify high-risk patients and rapidly make appropriate clinical judgements.[3] This would help to reduce the short-term and long-term mortality rates of ICU patients with AMI.

The ongoing developments of electronic products and the increased mechanisation of society are resulting in people increasingly preferring high-calorie fast foods and sedentary lifestyles, which is making obesity a huge global public burden. The global prevalence of obesity reportedly increased threefold between 1975 and 2016.[4] Although studies have demonstrated that obesity is an important factor in increasing all-cause mortality and multiple chronic comorbidities (eg, diabetes, stroke and hypertension), the effects of obesity on the treatment and prognosis of ICU patients with AMI remain unclear.[4 5]

The body mass index (BMI) is a measure that combines height and weight to classify obesity.[6] Our aim in this study was to determine whether obesity (ie, a high BMI) is related to the short-term and long-term risks of death in patients with AMI. This study obtained patient data from the latest critical care Medical Information Mart for Intensive Care III (MIMIC-III) database.

METHODS

Database

The data source was a free open-access database (V.1.4 of the MIMIC-III database), which contains information on more than 40 000 patients admitted to ICUs at the Beth Israel Deaconess Medical Centre (Boston, Massachusetts, USA) and the Massachusetts Institute of Technology (Cambridge, Massachusetts, USA) from June 2001 to October 2012.[7] We completed the required courses for use of the application database and obtained the corresponding certificate. Requirement for individual patient consent was waived because the project did not impact clinical care and all protected health information was deidentified. What is more, our study was performed in compliance with the Declaration of Helsinki, which describes the ethical principles for medical research involving human subjects.

Study population

Patients who were first admitted to an ICU (if there were multiple admissions for the same patient) and diagnosed with AMI according to ICD-9 were enrolled. Those who were younger than 18 years and had more than 5% missing data were excluded from the analysis.

Based on the WHO classification for BMI, all participants in our study were divided into four weight categories: normal weight (BMI ≥18.5 and <25 kg/m^2), underweight (BMI <18.5 kg/m^2),

overweight (BMI ≥25 kg/m^2 and <30 kg/m^2) and obese (BMI ≥30 kg/m^2).[8]

Data extraction

We used the official MIMIC-III tutorial to construct the study database using PostgreSQL (V.13.0, PostgreSQL Global Development Group) and used Structure Query Language to extract the following variables: demographic parameters (eg, age, sex and race), first ICU (eg, coronary care unit, cardiac surgery recoveryunit, medical ICU, surgical ICU or thoracic surgery ICU), admission type (eg, elective, emergency or urgent), blood glucose, laboratory parameters (eg, calcium, creatine kinase (CK), creatine kinase isoenzymes (CK-MB), lactate dehydrogenase (LDH) and troponin T), intervention-associated information (eg, percutaneous coronary intervention (PCI), heart bypass surgery (bypass), intra-aortic balloon pump (IABP) and mechanical ventilation), vasopressor use, aspirin, clopidogrel, atorvastatin and streptokinase use (drug use) and scoring systems (eg, Sequential Organ Failure Assessment (SOFA) and Acute Physiology Score III (APSIII)). BMI was calculated as the weight in kilograms divided by the square of the height in metres. If a variable (eg, blood glucose) was measured more than once for the same patient with AMI, we used the first value.

Outcomes

The primary outcomes in this study were short-term ICU and inhospital mortality rates. The secondary outcome was the long-term mortality, which we determined using the 'EXPIRE' in the MIMIC-III database. EXPIRE includes both deaths within the hospital and deaths recorded by matching the patient to the Social Security Master Death Index records from the US government. The follow-up time for long-term mortality started at patient's admission and followed for at least 3 months.

Statistical analysis

Univariate analyses were applied to all of the study variables. Shapiro-Wilk tests were used to assess the distribution of variables.[9] Non-normally distributed continuous variables were reported as medians with IQRs and the Kruskal-Wallis rank-sum test or the Mann-Whitney U test were used to compare these data. All classified variables were expressed as numbers and percentages, and they were compared using the χ^2 test or Fisher's exact probability method. Survival analysis was performed using Kaplan-Meier curves.[10] The Cox proportional hazard regression model was used to examine the effects of various factors on short-term and long-term mortality rates. Schoenfeld residuals were used to test the proportional risk assumption.

We additionally performed analyses stratified by age, APSIII, LDH, glucose, PCI and bypass use to identify any confounding influences on ICU mortality. We also performed analyses stratified by age, APSIII, LDH, glucose, marital status, first-careunit type, vasopressor use, PCI and bypass use to identify any confounding influences on inhospital mortality. Finally, subgroup analyses were performed for long-term mortality based on age, APSIII, SOFA score, CK-MB, LDH, glucose, troponin T, sex, marital status, first-careunit type, mechanical ventilation, vasopressor, IABP, PCI and bypass use.

R software (V.4.0.3) and SPSS software (V.27.0) were used for all statistical analyses. A p value of <0.05 in two-sided tests was deemed significant.

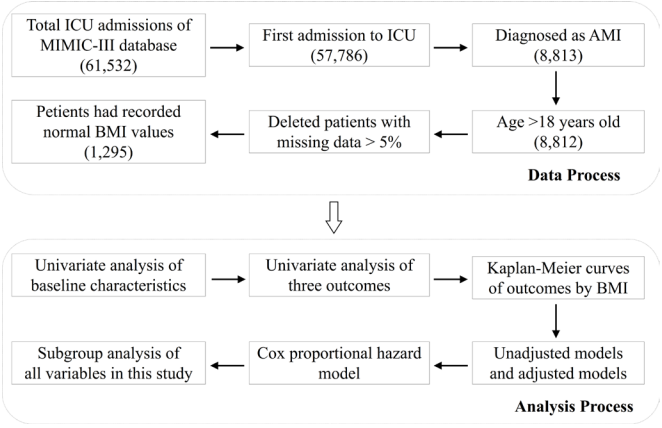

Figure 1 Flowchart of study cohort selection. BMI, body mass index.

RESULTS

Patient characteristics

This study extracted 1295 patients with AMI from the MIMIC-III database (figure 1). The baseline characteristics of the patients stratified by BMI quartiles are presented in table 1. Non-normal weight (underweight, overweight and obese) patients were younger than normal weight patients (median=65.00 (IQR=46.00–71.00), 70.00 (60.00–78.00), 66.00 (58.00–75.00) and 73.50 (62.25–82.00), p<0.001). Blood glucose increased gradually with the BMI quartile (median=133.60 (IQR=116.45–164.02), 142.03 (121.78–177.60) and 150.00 (123.50–190.25), p<0.001). CK-MB was higher in overweight and obese patients than in normal weight patients (median=254.00 (IQR=121.00–757.50), 230.00 (127.00–684.00) and 187.50 (92.00–447.00), p<0.001) but lower in underweight patients (161.00 (IQR=67.00–395.00) and 187.50 (IQR=92.00–447.00), p<0.001). The trend of LDH was similar to that of CK-MB. There were higher proportions of male overweight and obese patients than male normal weight patients (71.8%, 68.6% and 62.2%, respectively; p=0.001).

Outcomes

The primary outcome was the short-term (ie, in ICU and inhospital) all-cause mortality. The ICU mortality rate of all patients in this study was 17.9% (232 of 1295). As indicated in table 2, we found that the ICU mortality rate was similar to the inhospital mortality rate.

The long-term all-cause mortality rate of all patients was 49.9% (647 of 1295). As indicated in table 2, the long-term mortality rates of overweight and obese patients with AMI were much lower than that of normal weight patients with AMI (48.3%, 45.2% and 56.2%, respectively; p=0.001). However, the ICU mortality rate was higher for underweight patients with AMI than for normal weight patients with AMI (76.2% and 56.2%, respectively; p=0.001).

Survival analysis and Cox proportional hazard regression model

The short-term and long-term Kaplan-Meier survival curves are shown in figure 2, which indicate that the overweight and obese groups had a significant survival advantage compared with their other-weight counterparts. After log-rank test, p values were all less than 0.05 in different outcomes. The Cox proportional hazard regression models showed that the relationships between BMI and the risks of death were similar to the trends found in the single-factor analyses (table 3). After adjusting for all of the

Table 1 Charateristics of patients stratified by BMI quartiles

Variables	BMI (kg/m^2)				
N=1295	**BMI1(n=386)**	**BMI2 (n=21)**	**BMI3 (n=339)**	**BMI4 (n=449)**	**P value**
Age (years)	73.50 (62.25,82.0)	65.00 (46.00,71.0)	70.00 (60.00,78.0)	66.00 (58.00,75.0)	<0.001
SOFA	5.00 (3.00,8.0)	5.00 (4.00,7.0)	5.00 (2.00,8.0)	5.00 (3.00,8.0)	0.222
APSIII	49.00 (37.00,63.7)	57.00 (47.00,69.0)	45.00 (32.50,62.0)	48.00 (35.00,64.0)	0.020
Blood glucose (mg/dL)	133.60 (116.45,164.0)	133.78 (115.00,162.2)	142.03 (121.78,177.6)	150.00 (123.50,190.2)	<0.001
Calcium (mg/dL)	8.60 (8.00,9.1)	8.50 (7.80,9.5)	8.50 (8.00,9.0)	8.60 (8.10,9.1)	0.642
CK (IU/L)	187.50 (92.00,447.0)	161.00 (67.00,395.0)	254.00 (121.00,757.5)	230.00 (127.00,684.0)	<0.001
CK-MB (ng/mL)	9.00 (4.00,27.0)	9.00 (4.00,20.0)	12.00 (5.00,58.5)	10.00 (5.00,39.0)	0.008
LDH (IU/L)	309.50 (225.25,499.0)	287.00 (193.00,480.0)	370.00 (251.00,589.0)	343.00 (240.00,546.0)	0.005
TroponinT (ng/mL)	0.34 (0.09,1.2)	0.21 (0.02,1.3)	0.43 (0.08,1.6)	0.36 (0.07,1.5)	0.365
Sex=male/female	240/146 (62.2/37.8)	8/13 (38.1/61.9)	315/124 (71.8/28.2)	308/141 (68.6/31.4)	0.001
Admission_type					0.068
Elective	17 (4.4)	0 (0.0)	16 (3.6)	10 (2.2)	
Emergency	359 (93.0)	21 (100.0)	406 (92.5)	434 (96.7)	
Urgent	10 (2.6)	0 (0.0)	17 (3.9)	5 (1.1)	
Insurance=private/government	67/319 (17.4/82.6)	7/14 (33.3/66.7)	119/320 (27.1/72.9)	142/307 (31.6/68.4)	<0.001
Marital status					<0.001
Married	187 (48.4)	10 (47.6)	260 (59.2)	255 (56.8)	
Unmarried (single)	71 (18.4)	6 (28.6)	77 (17.5)	95 (21.2)	
Separated/divorced/widowed	118 (30.6)	5 (23.8)	85 (19.4)	76 (16.9)	
Others	10 (2.6)	0 (0.0)	17 (3.9)	23 (5.1)	
Race					0.005
White	278 (72.0)	16 (76.2)	312 (71.1)	343 (76.4)	
Black	29 (7.5)	2 (9.5)	14 (3.2)	25 (5.6)	
Asian	14 (3.6)	0 (0.0)	12 (2.7)	3 (0.7)	
Hispanic or Latino	65 (16.8)	3 (14.3)	101 (23.0)	78 (17.4)	
First_careunit					0.005
CCU	140 (36.3)	8 (38.1)	229 (52.2)	204 (45.4)	
CSRU	106 (27.5)	5 (23.8)	94 (21.4)	102 (22.7)	
MICU	103 (26.7)	5 (23.8)	80 (18.2)	110 (24.5)	
SICU	25 (6.5)	3 (14.3)	24 (5.5)	19 (4.2)	
TSICU	12 (3.1)	0 (0.0)	12 (2.7)	14 (3.1)	
Vasopressor=0/1	135/251 (35.0/65.0)	9/12 (42.9/57.1)	170/269 (38.7/61.3)	161/288 (35.9/64.1)	0.626
Ventilation=0/1	166/220 (43.0/57.0)	7/14 (33.3/66.7)	195/244 (44.4/55.6)	176/273 (39.2/60.8)	0.346
IABP=0/1	361/25 (93.5/6.5)	21/0 (100.0/0.0)	400/39 (91.1/8.9)	409/40 (91.1/8.9)	0.262
Drug=0/1	184/202 (47.7/52.3)	10/11 (47.6/52.4)	175/264 (39.9/60.1)	189/260 (42.1/57.9)	0.137
PCI=0/1	295/91 (76.4/23.6)	15/6 (71.4/28.6)	292/147 (66.5/33.5)	337/112 (75.1/24.9)	0.006
Bypass=0/1	295/91 (76.4/23.6)	19/2 (90.5/9.5)	332/107 (75.6/24.4)	322/127 (71.7/28.3)	0.127

Non-normal continuous variables were presented as median (IQR). Categorical variables were presented as number (precentage %). BMI1: 18.5 kg/m^2≤BMI<25.0 kg/m^2, BMI2: <18.5 kg/m^2, BMI3: 25.0 kg/m^2≤BMI<30.0 kg/m^2, BMI4: >30.0 kg/m^2.

APSIII, acute physiology score III; BMI, body mass index; Bypass, heart bypass surgery; CCU, coronary care unit; CK, creatine kinase; CK-MB, creatine kinase isoenzymes; CSRU, cardiac surgery recoveryunit; IABP, intra-aortic balloon pump; LDH, lactate dehydrogenase; MICU, medical intensive care unit; PCI, percutaneous coronary intervention; SICU, surgical intensive care unit; SOFA, sequential organ failure assessment; TSICU, thoracic surgery intensive care unit.

Table 2 Outcomes of patients stratified by BMI quartiles

Variables	BMI (kg/m^2)				
N=1295	**BMI1 (n=386)**	**BMI2 (n=21)**	**BMI3 (n=339)**	**BMI4 (n=449)**	**P value**
ICU mortality	303/83 (78.5/21.5)	15/6 (71.4/28.6)	367/72 (83.6/16.4)	378/71 (84.2/15.8)	0.067
Length of ICU stay (days)	4.00 (2.00,8.0)	4.00 (3.00,10.0)	4.00 (2.00,9.0)	4.00 (2.00,9.0)	0.350
Inhospital mortality	303/83 (78.5/21.5)	15/6 (71.4/28.6)	367/72 (83.6/16.4)	378/71 (84.2/15.8)	0.067
Length of hospital stay (days)	11.00 (6.00,17.0)	14.00 (7.00,17.0)	10.00 (6.00,17.0)	11.00 (6.00,19.0)	0.534
Long-term mortality	169/217 (43.8/56.2)	5/16 (23.8/76.2)	227/212 (51.7/48.3)	246/203 (54.8/45.2)	0.001
Length of death by dod (days)	90.00 (30.25, 482.7)	90.00 (19.00, 122.0)	90.00 (90.00, 1440.0)	90.00 (90.00, 1440.0)	0.001

Nonnormal continuous variables were presented as median (IQR). Categorical variables were presented as number (precentage %).

BMI, body mass index; dod, these deaths include both deaths within the hospital and deaths identified by matching the patient to the social security master death index.

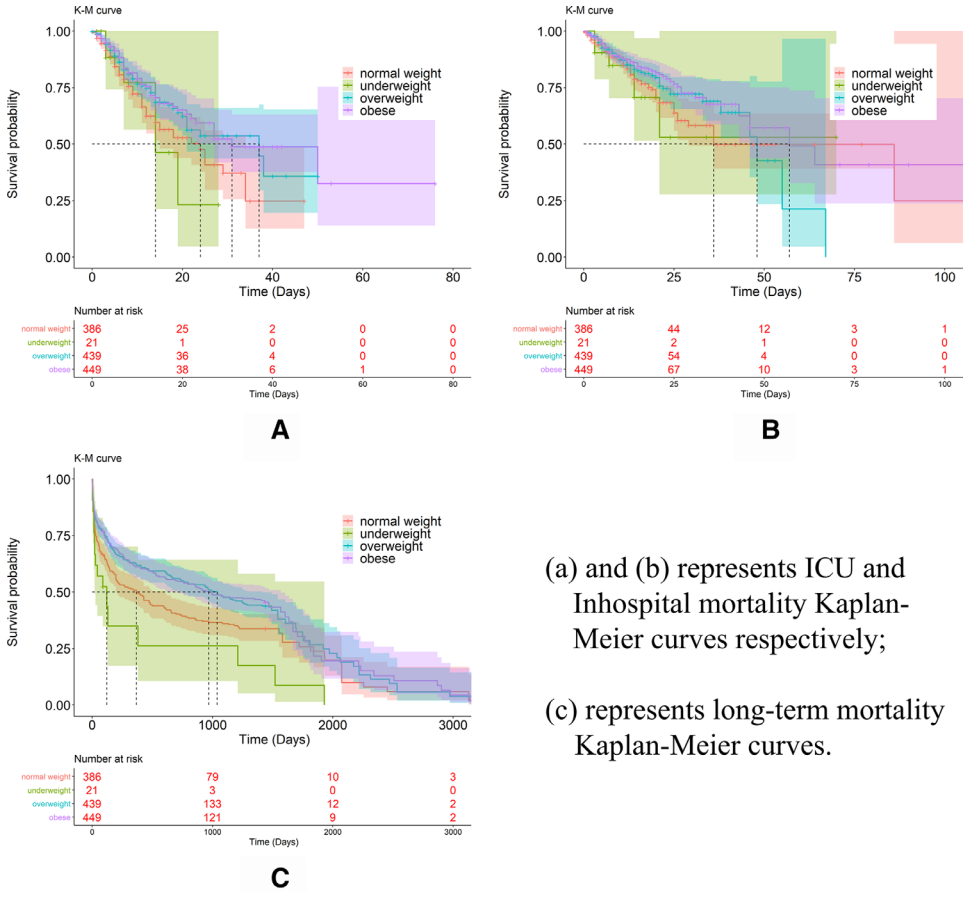

Figure 2 Kaplan-Meier curves of short-term and long-term mortality by BMI category. BMI, body mass index; ICU, intensive care unit.

listed covariates, BMI was always an important protective factor affecting the short-term and long-term all-cause AMI mortality rates (p<0.001, p=0.028 and p<0.001, respectively). The short-term and long-term mortality rates were lower in overweight patients with AMI than in their normal weight counterparts (HR=0.64 (95% CI 0.46 to 0.89), 0.77 (0.56 to 1.09) and 0.78 (0.64 to 0.94), respectively). Compared with normal weight patients, obese patients had reduced short-term and long-term risks of death (HR=0.55 (95% CI 0.38 to 0.78), 0.61 (0.43 to 0.87) and 0.72 (0.59 to 0.89), respectively). In contrast, the short-term and long-term mortality risks were higher in underweight patients than in normal weight patients (HR=1.39 (95% CI 0.58 to 3.30), 1.46 (0.62 to 3.42) and 1.99 (1.15 to 3.44), respectively).

Moreover, as shown in figure 3, HR values gradually decreased with the BMI category increases in short-term and long-term mortality. All Cox models complied with the proportional risk assumption after Schoenfeld residuals diagnosis, the results are shown as online supplemental figure S1–3, and p values were all greater than 0.05.

Subgroup analyses

The relationships between short-term and long-term mortality rates and BMI quartiles in different subgroups are presented in online supplemental table S1. In the subgroup analysis of ICU mortality, a significant interaction was found for stratification according to age (p for interaction=0.004). The HR trends were opposite in overweight and obese patients in two different age groups: HR=0.49 (95% CI 0.25 to 0.96) and 0.57 (0.31 to 1.05) for persons under the age of 69, 0.68 (0.47 to 0.99) and 0.56 (0.37 to 0.84) for persons over the age of 69.

Furthermore, the subgroup analysis of Inhospital mortality identified an interaction for stratification according to LDH (p interaction=0.015). The HR trends differed between patients with lower LDH (<1000 IU/L) and those with higher LDH (≥1000 IU/L). However, no interaction was found in the subgroup analysis of long-term mortality.

DISCUSSION

Summary of research results

This study explored whether the BMI category is an important risk factor for the short-term and long-term mortality rates of patients with AMI. Our research results are summarised as follows: First, the Kaplan-Meier curves and Cox proportional hazards regression models showed that patients of overweight and obese AMI were more likely than normal weight patients to survive. In contrast, underweight patients with AMI had a lower survival probability than normal weight patients. Second, blood glucose increased with the BMI category, being higher in underweight patients than in normal weight patients. Third, the changing trends of CK and LDH with the BMI category were similar. Fourth, women constituted a larger proportion of underweight patients with AMI, whereas men predominated in the groups of overweight and obese patients with AMI. Finally, in this retrospective cohort study, marital status, ethnicity, first-careunit (p=0.005) and PCI use (p=0.006) differed among the BMI categories.

Table 3 The association between BMI and short-term or long-term mortality

	BMI (kg/m^2)	
	HR (95%CIs)	P value
(a) ICU mortality		
Model 1		
BMI1: 18.5 kg/m^2≤BMI<25.0 kg/m^2	Ref.	
BMI2:<18.5 kg/m^2	1.15 (0.50 to 2.63)	0.742
BMI3: 25.0kg/m^2≤BMI<30.0 kg/m^2	0.69 (0.50 to 0.95)	0.023
BMI4:>30.0 kg/m^2	0.64 (0.46 to 0.88)	0.006
Model 2		
BMI1: 18.5 kg/m^2≤BMI<25.0 kg/m^2	Ref.	
BMI2:<18.5 kg/m^2	1.14 (0.49 to 2.64)	0.762
BMI3: 25.0kg/m^2≤BMI<30.0 kg/m^2	0.69 (0.51 to 0.96)	0.027
BMI4:>30.0 kg/m^2	0.70 (0.50 to 0.97)	0.031
Model 3		
BMI1: 18.5 kg/m^2≤BMI<25.0 kg/m^2	Ref.	
BMI2:<18.5 kg/m^2	1.39 (0.58 to 3.30)	0.457
BMI3: 25.0kg/m^2≤BMI<30.0 kg/m^2	0.64 (0.46 to 0.89)	0.009
BMI4:>30.0 kg/m^2	0.55 (0.38 to 0.78)	<0.001
(b) Inhospital mortality		
Model 1		
BMI1: 18.5 kg/m^2≤BMI<25.0 kg/m^2	Ref.	
BMI2:<18.5 kg/m^2	1.15 (0.50 to 2.64)	0.738
BMI3: 25.0 kg/m^2≤BMI<30.0 kg/m^2	0.81 (0.59 to 1.11)	0.186
BMI4:>30.0 kg/m^2	0.70 (0.51 to 0.96)	0.028
Model 2		
BMI1: 18.5 kg/m^2≤BMI<25.0 kg/m^2	Ref.	
BMI2:<18.5 kg/m^2	1.24 (0.54 to 2.86)	0.615
BMI3: 25.0kg/m^2≤BMI<30.0 kg/m^2	0.83 (0.60 to 1.14)	0.251
BMI4:>30.0 kg/m^2	0.78 (0.57 to 1.08)	0.142
Model3		
BMI1: 18.5 kg/m^2≤BMI<25.0 kg/m^2	Ref.	
BMI2:<18.5 kg/m^2	1.46 (0.62 to 3.42)	0.390
BMI3: 25.0 kg/m^2≤BMI<30.0 kg/m^2	0.77 (0.56 to 1.09)	0.143
BMI4:>30.0 kg/m^2	0.61 (0.43 to 0.87)	0.006
(c) Long-term mortality		
Model 1		
BMI1: 18.5 kg/m^2≤BMI<25.0 kg/m^2	Ref.	
BMI2:<18.5 kg/m^2	1.68 (1.01 to 2.80)	0.044
BMI3: 25.0 kg/m^2≤BMI<30.0 kg/m^2	0.73 (0.60 to 0.88)	0.001
BMI4:>30.0 kg/m^2	0.71 (0.59 to 0.86)	<0.001
Model 2		
BMI1: 18.5 kg/m^2≤BMI<25.0 kg/m^2	Ref.	
BMI2:<18.5 kg/m^2	2.26 (1.34 to 3.79)	0.002
BMI3: 25.0 kg/m^2≤BMI<30.0 kg/m^2	0.80 (0.66 to 0.98)	0.028
BMI4:>30.0 kg/m^2	0.84 (0.69 to 1.03)	0.094
Model 3		
BMI1: 18.5 kg/m^2≤BMI<25.0 kg/m^2	Ref.	
BMI2:<18.5 kg/m^2	1.99 (1.15 to 3.44)	0.013
BMI3: 25.0 kg/m^2≤BMI<30.0 kg/m^2	0.78 (0.64 to 0.94)	0.012
BMI4:>30.0 kg/m^2	0.72 (0.59 to 0.89)	0.002

(a) and (b) represent ICU and inhospital mortality. (c) represents long-term mortality. Models were derived from Cox proportional hazards regression models. Model 1: unadjusted. Model 2: adjusted for age, sex and race. Model 3: adjusted for age, SOFA, APSIII, blood glucose, calcium, CK, CK-MB, LDH, troponinT, sex, admission_type, insurance, marital status, race, first_careunit, ventilation, vasopressor, IABP, drug, PCI, bypass.
APSII, Acute Physiology Score III; BMI, body mass index; CK, creatine kinase; CKMB, creatine kinase isoenzymes; IABP, intra-aortic balloon pump; ICU, intensive care unit; LDH, lactate dehydrogenase; PCI, percutaneous coronary intervention; SOFA, Sequential Organ Failure Assessment.

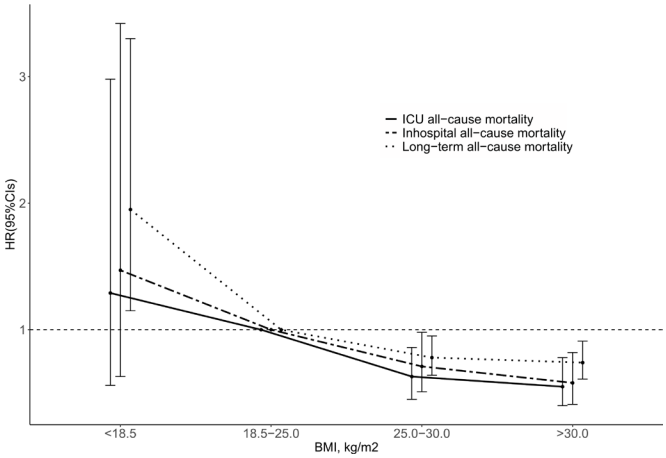

Figure 3 Short-term and long-term all-cause mortality according to BMI category. BMI, body mass index; ICU, intensive care unit.

Possible explanations for the present findings

We now provide possible explanations for our observations, in the same order as they are listed in the previous paragraph. First, previous studies have found obesity to be an important risk factor for hyperglycaemic, hypertension and almost all types of cardiovascular disease.[11] Moreover, obesity was related to inflammation, oxidative stress, impaired fibrinolysis and platelet aggregation. This means that obesity has a negative impact on cardiovascular diseases and so can also be assumed to be an important contributing factor to cardiovascular diseases. However, the existing evidence indicates that obesity has a positive effect on the prognosis of cardiovascular patients, which represents an 'obesity paradox'.[12]

Second, we found significant differences in blood glucose at different BMIs (p<0.001). Furthermore, we found no significant interaction between BMI category and short-term or long-term mortality in blood glucose subgroups. Combined with the above results, we speculate that the blood glucose does not impact the prognosis of patients with AMI, nor is it a risk factor for short-term and long-term mortality.

It had been reported that the correlation between BMI category and mortality depends on age, being more pronounced in older adults.[13] However, in our study, the underweight, overweight and obese patients with AMI were younger than the normal weight patients, and we found no significant interaction between BMI category and short-term or long-term mortality in most subgroups. Age had a significant interaction between different BMI categories and ICU mortality (p=0.004), and overweight patients older than 69 years had smaller changes in BMI risk (HR=0.68 (95% CI 0.47 to 0.99) and 0.49 (0.25 to 0.96)), while obese patients had larger changes (HR=0.56 (95% CI 0.37 to 0.84) and 0.57 (0.31 to 1.05)). We found that age had little effect on mortality across the different BMI categories, especially on the long-term mortality. This means that being overweight or obese at different ages is a protective factor for mortality, while being underweight is a risk factor. Further prospective studies are needed to confirm these surprising associations.

Third, we found a moderately significant interaction between BMI category and inhospital mortality in LDH subgroups (p=0.015). Overweight and obese patients with AMI had much lower risks of inhospital death, while the other results were not significant. Moreover, CK and LDH showed similar trends in our study. Previous studies have found that patients with AMI

generally have elevated LDH and CK.[14 15] In other words, our results suggest that both enzymes are more likely to be elevated in overweight and obese patients with AMI, whereas obesity is more protective in patients with AMI against inhospital mortality. Based on these results, we hypothesised that there are protective mechanisms that regulate CK and LDH in overweight and obese patients, thereby reducing damage to the myocardial cells.

Fourth, the sex ratio differed significantly between the different BMI categories (p=0.001), which suggests that men are more likely to be obese, while women find it easier to lose weight. The results of all of the subgroup analyses indicated that sex did not significantly interact with the relationship between BMI category and long-term mortality, and hence that sex was not a risk factor among patients with AMI in different BMI categories. The above results indicate that patients with AMI of different sexes and BMIs should receive different treatments in order to achieve better curative effects.

Finally, marital status, ethnicity, first-careunit and PCI use differed significantly between the different BMI categories. However, there was no significant interaction between BMI category and short-term or long-term mortality. This suggests that BMI is a protective factor for short-term and long-term mortality despite differences in the population information for different BMIs and PCI use.

Strengths and limitations of the study

The results of observational studies, even those with large samples and good designs, may be affected by residual confounders and causal inversions. This may explain why underweight people showed higher short-term and long-term mortality rates. The causal relationships between BMI categories and short-term and long-term mortality rates in patients with AMI should be of considerable interest to many researchers.

The MIMIC-III database was selected for our study, and its largeness and inclusion of important critical care data provided strong evidence for our results.[16] In addition, we conducted a precise data grouping and data cleaning process, which made the research more representative and convincing,[17] thereby increasing the clinical value of our findings. Moreover, the results of our study indicated that admitting patients with AMI to the ICU and the follow-up period were beneficial to reducing their short-term and long-term mortality rates, by increasing nutrition and resisting consumption during treatment.

CONCLUSIONS

The present analysis of information in the MIMIC-III database has indicated that overweight and obese patients with AMI have advantageous baseline characteristics and longer hospital stays in short-term and long-term mortality. The results suggest that BMI is an independent risk factor for short-term and long-term all-cause mortality and is linked to adverse clinical outcomes in patients with AMI.

LIMITATIONS

Of course, our study was subjected to some limitations. First, the presence of a correlation does not indicate causation. Both low and high BMIs are associated with mortality, and so it cannot be directly inferred that an abnormal BMI increases the mortality risk. For example, patient oedema would cause a pseudo increase in BMI, but there are also many other conditions that can lead to weight loss and abnormally low BMI. The physical condition of patients with AMI, rather than their BMI, may have been responsible for the decreased mortality rate in overweight and obese patients observed in the present study.

Second, patients with a high BMI may receive more attention when they are hospitalised[18] in order to prevent the adverse effects of their high BMI. This could explain why the patients with AMI with a higher BMI had lower short-term and long-term mortality rates.

Third, we also wondered if obesity might trigger other regulatory mechanisms that protect heart cells from damage.[19–21] For example, some previous molecular biology experiments have suggested that obese patients may have more protective regulators for sustaining life.[22 23] However, further experiments are needed to obtain evidence for these speculations.

Finally, BMI might not be a complete representation of the institutional status of a patient.[24] For example, whether visceral fat affects mortality remains to be seen. It could be that a more representative indicator is needed to replace BMI when assessing body fat in patients in order to obtain a more accurate picture of their fat status and give them better treatments.

Main messages

- This study is the first to investigate the relationship between body mass index (BMI) and short-term or long-term mortality in patients with acute myocardial infarction (AMI) in critical care units using data from Medical Information Mart for Intensive Care III database.
- Our study researches multiple outcomes, all of which concluded that overweight and obesity are protective factors for mortality of patients with AMI, while underweight patients led to the opposite conclusion, that is to say, there is an 'obesity paradox' in short-term or long-term mortality of patients with AMI.
- By observing the disordered relationship between BMI and mortality of patients with AMI, we find that HR values corresponding to BMI class do not decrease equally in short-term or long-term mortality, which may indicate that there is a nonlinear relationship between BMI and mortality of patients with AMI.

Current research questions

- Although our study has found an 'obesity paradox' between body mass index (BMI) and mortality among people with acutemyocardial infarction (AMI), the exact cause is unclear and does not propose a better solution.
- The data of Medical Information Mart for Intensive Care III database is not new and rich enough, so the whole population data with a larger time span should be considered for further study.
- The cause-and-effect relationship between BMI and mortality in patients with AMI is not clear, and we should consider other further research methods, such as randomised controlled trials, mendelian randomisation and so on.

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