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Does obesity improve the prognosis of patients with community-acquired pneumonia? Insights from the MIMIC-IV database

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ABSTRACT

Objective: Positive associations between body mass index (BMI) and clinical outcomes have been found and are called "obesity paradox". However, whether obesity has protective effects on critically ill patients with community-acquired pneumonia (CAP) remains unclear. Herein, this study aims to investigate the association of BMI with outcomes in critically ill patients with CAP.

Methods: This cohort study analyzed patients with CAP requiring ICU admission from the Medical Information Mart for Intensive Care (MIMIC)-IV database. Patients were categorized as underweight, normal weight, overweight and obese group. Study outcomes included 90-day mortality, sepsis development, acute kidney injury (AKI) occurrence, length of hospital stay (LOS), length of ICU stay and mechanical ventilation. Multivariate regression models and restricted cubic spline (RCS) regression were performed to analyze the impact of BMI on study outcomes adjusting for possible confounding variables.

Results: A total of 2874 eligible patients were enrolled in this study. The study population had a median age of 67.0 years with a male predominance (54.9 %). The underweight group had the highest mortality rate, while the obese group exhibited lowest rates. Obese was significantly associated with a longer length of ICU stay, duration of ventilation, and an increased risk of AKI. RCS analysis further confirmed a L-shaped relationship between BMI and 90-day mortality, with the lowest mortality risk observed at a BMI range of 33–35 kg/m^2. The incremental benefit of increasing BMI plateaued at 34 kg/m^2.

Conclusions: A relationship between obesity and mortality was identified in critically ill patients wi1th CAP. Notably, our study uniquely reveals that the relationship between BMI and 90-day mortality is non-linear, and there is no additional mortality-reducing benefit associated with increasing BMI levels among individuals with a BMI exceeding 34 kg/m^2.

1. Introduction

Over the past two decades, the prevalence of obesity has risen sharply. Obesity is linked to a higher risk of various chronic conditions, including cardiovascular disease, diabetes mellitus, and cancer [1,2]. Numerous studies have clearly shown that body mass index (BMI) was associated with mortality, with different diseases affecting mortality rates in distinct ways [3]. Compared to individuals of normal weight, obese people face a significantly greater risk of dying [4,5]. However, an interesting phenomenon known as the "obesity paradox" has been observed in patients with severe acute conditions like heart failure, coronary heart disease, and diabetes [6,7]. This paradox suggests that, in certain patient groups, a higher BMI might actually be linked to better health outcomes.

However, the effect of BMI on the prognosis of pneumonia remains controversial. Some research indicates no significant differences in mortality or ICU admission rates among different BMI groups in patients with community-acquired pneumonia (CAP) [8,9]. On the other hand, other studies have found that obese patients with CAP may have a lower mortality risk. For instance, a meta-analysis by Nie et al. proposed that while obese individuals are at a higher risk of developing pneumonia, they might have a reduced mortality risk once they contract it [7]. Several other studies also support the "obesity paradox," showing a positive effect on mortality in patients with CAP [10,11]. Despite these varying findings, there is a general consensus that underweight individuals are at an increased risk of dying from CAP [12].

Furthermore, patients with severe CAP, namely those with life-threatening conditions that require intensive medical intervention

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and continuous monitoring in the intensive care unit (ICU), are highly prone to various clinical complications and even death. However, currently, few studies have focused on the impact of obesity on mortality and the incidence of complications in these populations. In addition, current literature on the long-term mortality outcomes of obesity in CAP is limited, with most studies limited to short-term follow-up (<30 days) [13,14]. Thus, the aim of this study is to investigate the impact of BMI on the prognosis of severe CAP by accessing clinical complication and mortality of patients admitted to the ICU.

2. Methods

2.1. Data sources

The study utilized data from the Medical Information Mart for Intensive Care (MIMIC)-IV database (version 3.1), a publicly accessible repository containing deidentified health records of critical care patients admitted to Beth Israel Deaconess Medical Center between 2008 and 2022 [15]. This comprehensive database contains data for over 65,000 patients admitted to an ICU and over 200,000 patients admitted to the emergency department. Authorized access to the anonymized dataset (Record ID: 69360995) was obtained by certified researcher Chuyu Zhong, who supervised the standardized data extraction process. As the MIMIC-IV database has previously undergone institutional review board evaluation by the Institutional Review Boards of Beth Israel Deaconess Medical Center and the Massachusetts Institute of Technology and contains only predeidentified clinical information, this secondary analysis required neither additional ethical approval nor patient consent, in compliance with the principles of ethical research practices using existing deidentified data.

2.2. Study population

This retrospective cohort study investigated patients with CAP requiring ICU admission, as defined by the American Thoracic Society/Infectious Diseases Society of America (ATS/IDSA) guidelines. The inclusion criteria were patients over 18 years old requiring admissions to the ICU with an ICD-9/10 code of pneumonia within the top 10 diagnoses and must receive pneumonia-related antibiotics treatment within the first 72 h of hospital admission. Notably, the MIMIC-IV database prioritizes diagnostic coding by economic burden rather than clinical relevance. Additional, stringent exclusion criteria were applied to ensure the integrity and reliability of the analysis. Patients with missing data over 30 % were excluded. Subsequent to the application of these criteria, a total of 2874 patients were included in the study (Fig. 1).

2.3. Data collection

Demographic characteristics, clinical severity indices (including Simplified Acute Physiology Score II [SAPSII]), physiological parameters (blood pressure, heart rate, respiratory rate, temperature), hematological/biochemical laboratory values (i.e. hemoglobin, red blood cell count [RBC], platelet, and white blood cell count [WBC]), comorbidities (i.e. diabetes mellitus, chronic obstructive pulmonary disease [COPD], hypertension, and cancer), and mechanical ventilation status were extracted from the MIMIC-IV database within the initial 24 h of ICU admission. BMI was calculated based on weight and height measured at admission. Data integration encompassed critical care information systems, electronic health records, and bedside monitoring devices, with mortality outcomes verified through linkage to the US Social Security System. All analyses adhered to PhysioNet's data access protocols, utilizing read-only access to ensure dataset integrity [15].

2.4. Clinical outcomes

The primary objective of this study was to examine the association of BMI on the 90-day mortality. Secondary objectives included analyses on the association of BMI on sepsis development, acute kidney injury (AKI) occurrence, length of hospital stay (LOS), length of ICU stay and mechanical ventilation.

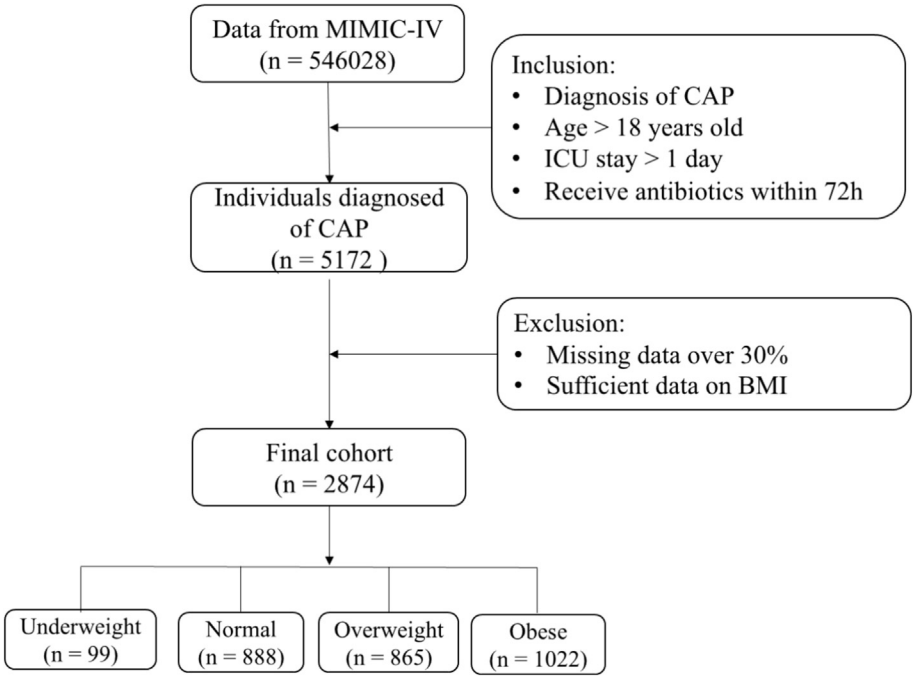

Fig. 1. The flow of the enrolled patients throughout the study.

2.5. Statistical analysis

Unless stated otherwise, categorical variables are expressed as number (percentage) and continuous variables as median (interquartile range (IQR)). To analyze the association of BMI with clinical outcomes, the intention-to-treat population was subdivided in 4 subgroups based on the criteria from WHO: (i) underweight (<18.5 kg/m^2), (ii) normal weight (18.5–24.9 kg/m^2), (iii) overweight (25–29.9 kg/m^2), and (iv) obese (≥30 kg/m^2). Multivariate regression models were used to analyze associations between BMI classes and outcomes of interest. Unadjusted and adjusted estimates of the effect sizes and corresponding 95 % confidence intervals (CI) were determined using either linear, logistic or Cox proportional hazards regressions, as appropriate (normal weight group served as base reference). All multivariate models were adjusted for the same variables based on clinical expertise and prior literature [8,16]: age, sex, smoking, cancer, COPD, heart failure, renal disease, hypertension, diabetes, heart rate, respiratory rate, temperature, systolic blood pressure, blood urea nitrogen, serum glucose, WBC and SAPSII. The restricted cubic spline (RCS) regression with three knots was used to investigate the nonlinear association of the continuous variable BMI on outcomes of interest, respectively. All statistical analyses were performed using R version 4.4.2 and tests were done at a two-sided 5 % significance level with two-sided 95 % confidence intervals.

3. Results

3.1. Patient characteristics

A total of 2874 eligible patients were enrolled in this study. Table 1 presents the baseline characteristics stratified by BMI subgroups. The study population had a median age of 67.0 years with a male predominance (54.9 %). Most patients were either normal weight (30.9 %) or obesity (35.6 %). Patients with obesity had higher rates of hypertension (39.3 %), chronic nephrosis (22.5 %), hyperlipidemia (37.9 %), heart failure (38.9 %) and diabetes mellitus (37.8 %), compared to those of normal or underweight. Notably, the underweight group observed the highest malignancy prevalence (23.2 % vs 12.4–19.3 % in other groups). Pneumonia severity, as assessed by SAPSII scores, showed comparable distributions across BMI subgroups, with approximately half of the patients demonstrating SAPSII scores exceeding 40. The median SAPSII score was 40.0 (IQR: 31.0–50.0) across all groups.

3.2. BMI and 90-day mortality

Kaplan-Meier analysis demonstrated significant differences in 90-day mortality rates across BMI subgroups (log-rank $P < 0.001$). The underweight group had the highest mortality rate, while the obese group

Table 1
Baseline characteristics of the included patients.

	Overall (N = 2874)	Underweight (N = 99)	Normal weight (N = 888)	Overweight (N = 865)	Obese (N = 1022)	P value
Demographic						
Age (years)	67.0 (55.0, 78.0)	74.0 (61.0, 85.0)	69.0 (55.0, 82.0)	68.0 (57.0, 80.0)	65.0 (55.0, 74.0)	<0.001
Male, n (%)	1577 (54.9 %)	44 (44.4 %)	484 (54.5 %)	533 (61.6 %)	516 (50.5 %)	<0.001
Smoking, n (%)	408 (14.2 %)	17 (17.2 %)	135 (15.2 %)	126 (14.6 %)	130 (12.7 %)	0.336
Weight (kg)	78.4 (65.4, 93.9)	47.0 (42.0, 52.2)	63.0 (56.7, 70.0)	79.0 (71.3, 86.0)	100.0 (88.8, 112.3)	<0.001
Height (cm)	168.0 (160.0, 178.0)	165.0 (157.0, 173.0)	168.0 (162.8, 175.0)	170.0 (163.0, 178.0)	168.0 (160.0, 178.0)	0.006
BMI (kg/m^2)	27.4 (23.5–32.4)	17.4 (16.4, 17.9)	22.5 (20.9, 23.7)	27.3 (26.1–28.6)	34.5 (32.0–38.5)	<0.001
Clinical severity						
SAPSII	40.0 (31.0, 50.0)	43.0 (34.0, 56.0)	39.0 (31.0, 50.0)	40.0 (31.0, 51.0)	40.0 (31.0, 50.0)	0.036
Vital signs						
Heart rate (beats/min)	92.0 (80.0, 108.0)	97.0 (81.0, 110.0)	92.0 (79.0, 108.0)	93.0 (80.0, 109.0)	91.0 (80.0, 106.0)	0.178
SBP (mmHg)	117.0 (101.0, 137.0)	118.0 (101.0, 137.0)	117.5 (102.0, 136.0)	118.0 (101.0, 137.0)	117.0 (100.0, 137.0)	0.796
DBP (mmHg)	59.0 (50.0, 69.0)	58.0 (50.0, 69.0)	58.0 (50.0, 69.0)	59.0 (51.0, 69.0)	59.0 (49.0, 69.0)	0.785
MBP (mmHg)	76.0 (65.0, 89.0)	80.0 (66.0, 90.0)	78.0 (66.0, 90.0)	76.0 (65.0, 88.0)	76.0 (63.0, 88.0)	0.187
Respiratory rates (breath/min)	21.0 (17.0, 25.0)	21.0 (17.0, 25.0)	21.0 (16.0, 25.0)	21.0 (17.0, 26.0)	21.0 (17.0, 25.0)	0.769
SpO_2 (%)	97.0 (94.0, 100.0)	98.0 (93.0, 100.0)	97.0 (94.0, 100.0)	97.0 (94.0, 100.0)	96.0 (93.0, 99.0)	<0.001
Temperature (°C)	36.8 (36.5, 37.2)	36.7 (36.4, 37.1)	36.8 (36.4, 37.1)	36.8 (36.5, 37.3)	36.9 (36.6, 37.3)	<0.001
Laboratory Parameters						
WBC (10^9/L)	13.6 (9.6, 18.6)	14.1 (9.7, 20.1)	13.5 (9.3, 18.6)	13.5 (9.6, 18.4)	13.8 (9.8, 18.8)	0.563
RBC (10^9/L)	3.6 (3.1, 4.2)	3.5 (3.2, 3.9)	3.6 (3.1, 4.1)	3.7 (3.2, 4.1)	3.7 (3.2, 4.3)	0.003
BUN (mg/dL)	25.0 (16.0, 42.0)	25.0 (15.0, 38.0)	23.0 (15.0, 38.5)	26.0 (16.0, 42.0)	27.0 (17.0, 46.0)	<0.001
Glucose (mg/dL)	148.0 (119.0, 201.0)	145.0 (110.0, 173.0)	141.0 (114.0, 186.5)	148.0 (120.0, 203.0)	158.0 (125.0, 214.0)	<0.001
Lymphocyte (10^9/L)	1.0 (0.6, 1.6)	1.0 (0.4, 1.8)	1.0 (0.6, 1.7)	1.0 (0.6, 1.7)	0.9 (0.5, 1.6)	0.186
Neutrophil(10^9/L)	9.9 (6.5, 14.4)	9.4 (6.6, 13.2)	9.8 (6.2, 14.3)	9.9 (6.4, 14.4)	10.3 (6.7, 14.5)	0.248
Lactate (mmol/L)	2.0 (1.3, 3.2)	2.1 (1.4, 3.4)	2.0 (1.3, 3.2)	2.0 (1.3, 3.0)	2.0 (1.3, 3.2)	0.741
CRP (mg/L)	133.9 (62.9, 221.1)	118.8 (62.9, 232.2)	133.5 (62.9, 217.4)	150.4 (64.7, 223.9)	126.2 (54.8, 217.4)	0.214
Comorbidities						
Hypertension, n (%)	1046 (36.4 %)	32 (32.3 %)	305 (34.3 %)	307 (35.5 %)	402 (39.3 %)	0.092
Renal disease, n (%)	588 (20.5 %)	15 (15.2 %)	154 (17.3 %)	189 (21.8 %)	230 (22.5 %)	0.014
Cancer, n (%)	483 (16.8 %)	23 (23.2 %)	171 (19.3 %)	162 (18.7 %)	127 (12.4 %)	<0.001
Diabetes, n (%)	801 (27.9 %)	12 (12.1 %)	170 (19.1 %)	233 (26.9 %)	386 (37.8 %)	<0.001
Hyperlipemia, n (%)	952 (33.1 %)	15 (15.2 %)	249 (28 %)	301 (34.8 %)	387 (37.9 %)	<0.001
Heart failure, n (%)	1023 (35.6 %)	23 (23.2 %)	304 (34.2 %)	298 (34.5 %)	398 (38.9 %)	0.005
COPD, n (%)	651 (22.7 %)	26 (26.3 %)	202 (22.7 %)	186 (21.5 %)	237 (23.2 %)	0.668
Outcomes						
90-day mortality, n (%)	1039 (36.2 %)	55 (55.6 %)	340 (38.3 %)	303 (35.0 %)	341 (33.4 %)	<0.001
Sepsis, n (%)	2479 (86.3 %)	83 (83.8 %)	753 (84.8 %)	740 (85.5 %)	903 (88.4 %)	0.100
AKI, n (%)	2336 (81.3 %)	68 (68.7 %)	652 (73.4 %)	696 (80.5 %)	920 (90.0 %)	<0.001
Mechanical ventilation, n (%)	2704 (94.1 %)	93 (93.9 %)	833 (93.8 %)	809 (93.5 %)	969 (94.8 %)	0.662
LOS (days)	11.7 (7.1, 19.7)	9.3 (6.2, 17.1)	11.3 (7.0, 18.7)	11.7 (6.9, 18.6)	12.2 (7.6, 21.6)	0.006
Length of ICU stay (days)	5.5 (2.8, 10.1)	4.6 (2.5, 8.7)	5.0 (2.6, 9.6)	5.1 (2.8, 9.7)	6.2 (3.0, 11.7)	<0.001

Abbreviations: AKI = Acute Kidney Injury; BMI = Body Mass Index; BUN = Blood Urea Nitrogen; CRP = C-Reactive Protein; COPD = chronic obstructive pulmonary disease; DBP = Diastolic Blood Pressure; ICU = Intensive Care Unit; LOS = Length of Stay; MBP = Mean Blood Pressure; SAPSII = Simplified Acute Physiology Score II; RBC = Red Blood Cell; SBP = Systolic Blood Pressure; SpO2: Percutaneous Arterial Oxygen Saturation; WBC = White Blood Cell.

exhibited lowest rates (Fig. 2). Specifically, 55.6 % of underweight patients died within 90 days of admission, which was 1.5 times higher than the 38.3 % mortality rate observed in the normal weight group. Multivariate Cox regression analysis revealed that underweight group had a significantly higher risk of death compared to normal weight group (HR: 1.36, 95 % CI: 1.02–1.81), as depicted in Table 2. In contrast, no statistically significant difference in mortality risk was found for overweight or obese group. RCS analysis further confirmed a L-shaped relationship between BMI and 90-day mortality, with the lowest mortality risk observed at a BMI range of 33–35 kg/m^2 (Fig. 3A).

3.3. BMI and LOS & length of ICU stay

The median LOS for underweight, normal weight, overweight, and obese groups was 9.3 (IQR: 6.2–17.1), 11.3 (IQR: 7.0–18.7), 11.7 (IQR: 6.9–18.6), and 12.2 (IQR: 7.6–21.6) days, respectively. The obese group had the longest LOS, though multivariate linear regression analysis found no statistically significant differences among BMI subgroups. Similarly, there was also no significant differences in RCS analysis (Fig. 3B). Notably, multivariate linear regression analysis showed that the obese group had a longer length of ICU stay compared to normal weight group ($p = 0.004$). RCS analysis also indicated a trend of increasing length of ICU stay with higher BMI (Fig. 3C).

3.4. BMI and mechanical ventilation

The incidence of mechanical ventilation was similar across BMI groups, at approximately 94 %. Among patients requiring mechanical ventilation, the duration of ventilation was influenced by BMI. Multivariate linear regression found that the obese group had a longer duration of ventilation compared to normal weight group ($p = 0.040$), and RCS analysis revealed a trend of prolonged ventilation duration with increasing BMI (Fig. 3D and Fig. 3E).

3.5. BMI and sepsis & AKI

The incidence of sepsis did not differ significantly across BMI groups, and multivariate logistic regression found no statistically significant differences. However, RCS analysis suggested a linear trend (Fig. 3F). In contrast, the incidence of AKI varied markedly among BMI groups, with the highest rate (90.0 %) observed in the obese group and the lowest (68.7 %) in the underweight group. Multivariate logistic regression analysis demonstrated that overweight and obese groups had a higher risk of AKI compared to normal weight group. RCS analysis further supported this finding, showing an increased risk of AKI with higher BMI (Fig. 3G).

4. Discussion

In this study, a L-shaped relationship of BMI with 90-day mortality was observed–slight obesity was associated with lowest risk to death. RCS analysis indicates that once BMI exceeds 34 kg/m^2, further increases in BMI do not confer additional survival benefits and may even elevate mortality risk. Specifically, no significant improvement in outcomes observed for BMIs above this threshold compared to the 30–34 kg/m^2 range. However, both obese categories (BMI 30–34 kg/m^2 and ≥ 34 kg/m^2) demonstrate superior survival outcomes relative to normal weight patients. While no correlation between obesity and either LOS or mechanical ventilation requirements were observed, obesity was associated with prolonged length of ICU stay and extended mechanical ventilation duration. Additionally, obese patients exhibited a higher risk of AKI and sepsis, though this complication did not translate into increased mortality.

Our research findings align with those of previous studies, indicating that obese patients with CAP generally exhibit a relatively lower mortality risk. A meta-analysis by Nie, encompassing 13 cohort studies, demonstrated that overweight and obese patients had a significantly

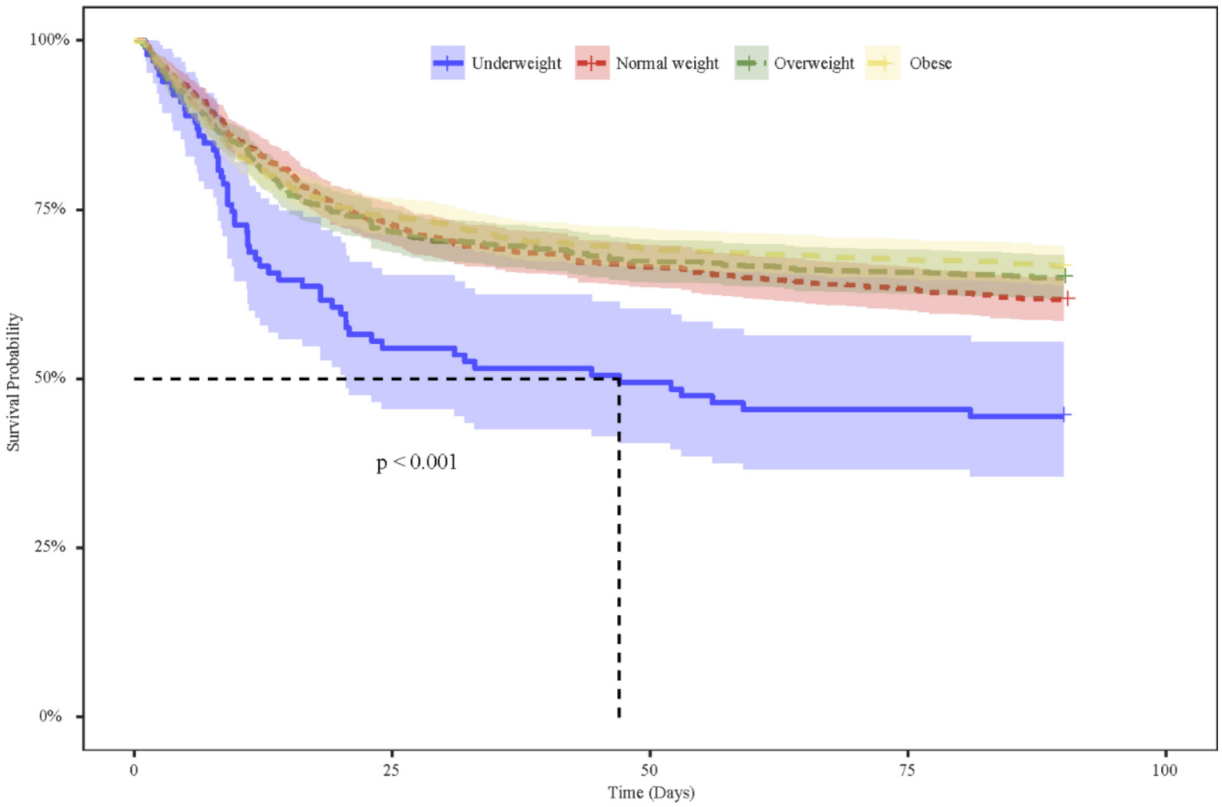

Fig. 2. Kaplan–Meier curve of survival according to different body mass index classes.

Table 2
Multivariate regression analyses of clinical outcomes by BMI[a].

	BMI	Underweight [a]	Overweight [a]	Obese [a]
90-day mortality	0.99 (0.98, 0.99)	1.36 (1.02, 1.81)	0.92 (0.78, 1.07)	0.90 (0.77, 1.05)
Sepsis	1.03 (1.01, 1.05)	0.80 (0.45, 1.50)	0.98 (0.74, 1.30)	1.25 (0.94, 1.67)
AKI	1.09 (1.07, 1.11)	0.65 (0.40, 1.08)	1.46 (1.15, 1.86)	3.38 (2.58, 4.46)
Mechanical ventilation	1.01 (0.98, 1.03)	1.18 (0.52, 3.19)	0.95 (0.64, 1.41)	1.07 (0.71, 1.60)
Duration of ventilation	1.22 (0.55, 1.90)	−14.71 (−39.96, 10.55)	0.99 (−10.40, 12.39)	11.77 (0.56, 22.98)
LOS	0.07 (−0.01, 0.15)	−1.83 (−4.68, 1.02)	−0.16 (−1.45, 1.13)	0.64 (−0.63, 1.90)
Length of ICU stay	0.10 (0.06, 0.14)	−1.14 (−2.71, 0.42)	0.03 (−0.67, 0.74)	1.02 (0.32, 1.71)

Abbreviations: AKI = Acute Kidney Injury; BMI = Body Mass Index; ICU = Intensive Care Unit; LOS = Length of Stay.
[a] : vs. normal weight.

reduced risk of death compared to individuals with underweight [7]. Similarly, a prospective study involving 763 patients revealed that obese patients had a markedly lower 6-year mortality rate than those of normal weight [17]. Collectively, these studies suggest that obesity is associated with a more favorable prognosis in patients with CAP. However, it is crucial to note that the relationship between BMI and mortality risk is not linear. In other words, a higher BMI does not necessarily equate to a lower risk of death. A prospective observational study by Kim reported that once patients reached grade II obesity (BMI ≥ 35 kg/m^2), further increases in BMI did not confer additional prognostic benefits [16,18], a finding consistent with our study's observations. Additionally, in this study, obese patients were younger and smoked less, which could account for their relatively lower mortality rate. Notably, this trend persisted even after adjusting for age and smoking status, suggesting other factors may also contribute.

Studies across various patient populations have consistently demonstrated favorable outcomes for obese individuals, including those undergoing surgery [19], receiving chronic hemodialysis [20], hospitalized with heart failure or myocardial infarction [21], and those with CAP [4,16]. One prevailing hypothesis attributes this survival advantage to obesity's impact on the immune system and inflammatory state during acute infections [7]. Chronic inflammation associated with obesity modulates both pro-inflammatory and anti-inflammatory biomarkers, potentially conferring long-term prognostic benefits [22]. For instance, adipose tissue contains elevated receptors for tumor necrosis factor (TNF)-α, a marker of pneumonia severity, which may inhibit TNF-α activity [23]. Additionally, adipokines secreted by adipocytes play crucial roles in the immune response. Leptin, for example, regulates T-cell responses, while adiponectin exhibits anti-inflammatory properties that may mitigate lung inflammation [13]. These benefits may become evident when patients reach obesity. Another theory connects the “obesity paradox” with lean muscle mass. Obese individuals typically possess greater lean muscle mass alongside increased fat stores, which may contribute to reduced mortality rates. Unfortunately, relying exclusively on BMI makes it impossible to differentiate between fat and lean muscle mass. Studies have shown that weight loss correlates with poorer prognosis and higher mortality, while muscle mass is inversely associated with death risk [24]. After adjusting for muscle mass, the impact of

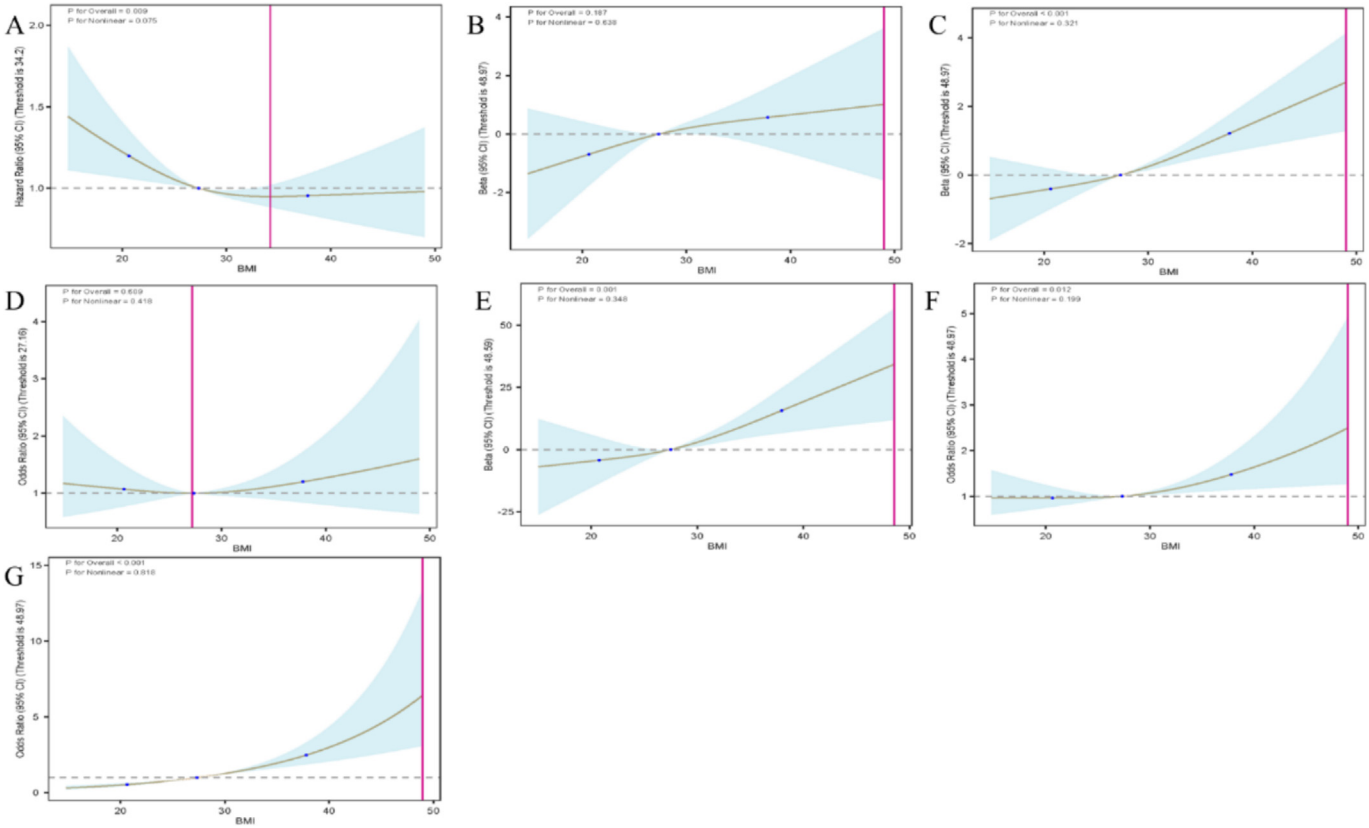

Fig. 3. Restricted cubic spline curve for (A) 90-day mortality, (B) LOS, (C) Length of ICU stay, (D) Mechanical ventilation, (E) Duration of ventilation, (F) Sepsis, and (G) AKI.

BMI on mortality diminishes [25]. Data further reveal that individuals with central obesity but normal BMI exhibit elevated mortality rates [26,27]. Consequently, obesity may lower mortality by enhancing muscle mass; however, morbidly obesity may not further augment muscle mass or survival advantages. The role of inflammation and the immune effect of obesity are both interesting research fields, worthy of further study to fully understand their clinical impacts [18].

When evaluating the results of this study, several potential limitations should be noted. First, we did not collect data on the temporal changes in body weight and composition within our study cohort. Consequently, we cannot rule out the possibility of body weight fluctuations over time. Second, our study primarily involved elderly patients. As such, our findings may not be generalizable to younger populations. Similarly, the study focused exclusively on patients with CAP who required admission to ICU. Therefore, the results do not pertain to patients with CAP managed in outpatient settings. Thirdly, although multivariate adjustments and subgroup analyses were used to account for potential confounding factors, some variables, such as nutritional support strategies between obese and non-obese patients with CAP and their respective impacts, were not available in the database that may influence the results, leaving room for residual confounding factors. Additionally, the study was conducted at a single center, limiting the generalizability of the findings to broader populations. Finally, due to the data source, we were unable to investigate the specific pathogens involved. Despite these limitations, the study has notable strengths. It included a large, well-characterized cohort of critically ill patients with CAP, representative of those typically treated in emergency departments. We assessed clinically relevant complications, such as AKI, which serves as a reliable marker of short-term outcomes. Importantly, all results were rigorously adjusted for major confounders, including smoking status, cancer, and comorbidities associated with malnutrition.

5. Conclusion

Obesity is associated with a reduced mortality rate in critically ill patients with CAP. However, it is worth noting that when a patient's BMI reaches 34 kg/m^2, an increase in BMI will not further reduce the risk of death.

CRediT authorship contribution statement

Chuyu Zhong: Writing – original draft, Data curation, Conceptualization. **Qingqiang Zeng:** Formal analysis, Conceptualization. **Jingtai Hu:** Writing – review & editing, Formal analysis.

Consent for publication

Not applicable.

Ethics approval and consent to participate

The MIMIC-IV databases have received ethical approval from the Institutional Review Boards at Beth Israel Deaconess Medical Center and Massachusetts Institute of Technology. As the databases do not contain protected health information, a waiver of informed consent was included in the approval from the Institutional Review Boards at Beth Israel Deaconess Medical Center and Massachusetts Institute of Technology. Therefore, this manuscript does not involve a research protocol requiring approval by the relevant institutional review board or ethics committee. All methods in this study were carried out in accordance with relevant guidelines and regulations (declarations of Helsinki).

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None.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

Not applicable.

Data availability

Publicly available data sets were analyzed in this study. These data can be found here: https://physionet.org/about/database/.

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