ARTICLE

Clinical Research

The impact of obesity on COVID-19 complications: a retrospective cohort study

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Abstract

Background Obesity is an epidemic in New York City, the global epicenter of the coronavirus pandemic. Previous studies suggest that obesity is a possible risk factor for adverse outcomes in COVID-19.

Objective To elucidate the association between obesity and COVID-19 outcomes.

Design Retrospective cohort study of COVID-19 hospitalized patients tested between March 10 and April 13, 2020.

Setting SUNY Downstate Health Sciences University, a COVID-only hospital in New York.

Participants In total, 684 patients were tested for COVID-19 and 504 were analyzed. Patients were categorized into three groups by BMI: normal (BMI 18.50–24.99), overweight (BMI 25.00–29.99), and obese (BMI ≥ 30.00).

Measurements Primary outcome was 30-day in-hospital mortality, and secondary outcomes were intubation, acute kidney injury (AKI), acute respiratory distress syndrome (ARDS), and acute cardiac injury (ACI).

Results There were 139 patients (27%) with normal BMI, 150 patients who were overweight (30%), and 215 patients with obesity (43%). After controlling for age, gender, diabetes, hypertension, and qSOFA score, there was a significantly increased risk of mortality in the overweight (RR 1.4, 95% CI 1.1–1.9) and obese groups (RR 1.3, 95% CI 1.0–1.7) compared with those with normal BMI. Similarly, there was a significantly increased relative risk for intubation in the overweight (RR 2.0, 95% CI 1.2–3.3) and obese groups (RR 2.4, 95% CI 1.5–4.0) compared with those with normal BMI. Obesity did not affect rates of AKI, ACI, or ARDS. Furthermore, obesity appears to significantly increase the risk of mortality in males (RR 1.4, 95% CI 1.0-2.0, $P = 0.03$), but not in females (RR 1.2, 95% CI 0.77–1.9, $P = 0.40$).

Conclusion This study reveals that patients with overweight and obesity who have COVID-19 are at increased risk for mortality and intubation compared to those with normal BMI. These findings support the hypothesis that obesity is a risk factor for COVID-19 complications and should be a consideration in management of COVID-19.

Introduction

The first case of coronavirus disease 2019 (COVID-19) emerged from Wuhan, China in December 2019. This new strain of coronavirus quickly spread globally, and COVID-19 was classified as a pandemic by the World Health Organization in March 2020. The United States (U.S.), and

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in particular New York City (NYC), eventually became the epicenter of severe acute respiratory syndrome coronavirus 2 [1].

Chronic conditions are associated with adverse outcomes in COVID-19. One such factor may be obesity [1], which has reached epidemic proportions in the U.S. and exacts a significant toll on the American healthcare system. In 2017, the Centers for Disease Control and Prevention reported that 42.4% of the American population was diagnosed with obesity [2]. The prevalence of obesity is particularly high in certain populations, such as non-Hispanic blacks and Hispanics [2]. These groups have also been reported to be disproportionately affected by the COVID-19 pandemic [3].

Previous studies have implicated obesity as a risk factor in severe COVID-19 outcomes, such as invasive mechanical ventilation [4], severe pneumonia [5], and increased hospitalizations [6]. Various mechanisms may be involved, including restrictive lung disease, lipo-toxicity, and induction of a proinflammatory state [7]. However, there is limited information describing the association between obesity and mortality in COVID-19, particularly in vulnerable racial and ethnic minority populations. The purpose of this study is to elucidate the association between obesity and COVID-19 outcomes in a designated COVID-19-only center in East Flatbush, a community in Brooklyn, New York whose population is estimated to be 88% black and 34% obese [8].

Methods

Study design

This is a retrospective cohort study of patients tested for COVID-19 at SUNY Downstate Health Sciences University in New York, designated by Governor Andrew Cuomo as a COVID-only hospital. Testing was conducted via nasopharyngeal swab and subsequent reverse-transcription polymerase chain reaction (RT-PCR). The Cepheid machine was used for automation of RT-PCR. Data were collected and deidentified for all hospitalized patients through the Healthbridge Electronic Medical Health Record system. The Downstate institutional review board approved this study for publication.

Subjects

This study cohort had 684 patients who were tested for COVID-19 and 504 patients were ultimately used for analysis. The population included patients 18 years of age or older who were admitted from March 10th to April 13th 2020. Patients were excluded from the study if their COVID-19 test was negative; if body mass index (BMI) was not recorded in the electronic medical record or if the patient was underweight (defined as a BMI < 18.50 kg/m^2); and if they were still admitted to the hospital at the end of the study period. See Fig. 1 for exclusion criteria breakdown.
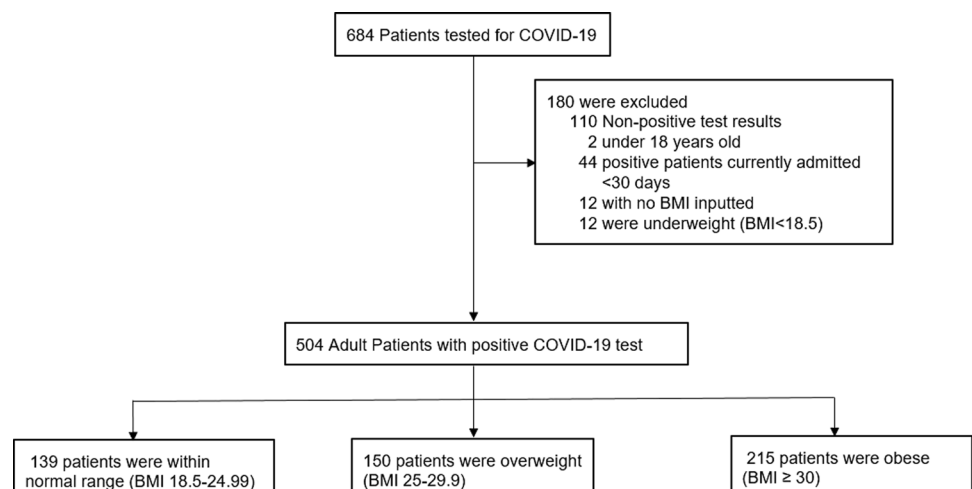
Primary predictors

Obesity was defined by BMI, calculated as weight (kilograms)/height^2 (meters). Patients were categorized into three groups: normal (BMI 18.50–24.99 kg/m^2), overweight (BMI 25.00–29.99 kg/m^2), and obese (BMI ≥ 30.00 kg/m^2). As mentioned above, underweight patients (BMI < 18.50 kg/m^2) were excluded.

Covariates

Covariates were age, sex, diabetes mellitus, hypertension, and the quick sequential organ failure assessment (qSOFA) score measured on patient admission. Data were self-

Fig. 1 Study population criteria. Cohort was divided into three groups based off BMI (Body Mass Index).

reported by the patient and added to the electronic record by the health care provider. qSOFA was defined as one point for each of the following criteria: altered mental status with Glasgow Coma Scale <15, tachypnea with respiratory rate greater than or equal to 22, and hypotension with systolic blood pressure less than or equal to 100. qSOFA scores were dichotomized at a cutoff of 2 since patients with scores of 2 or greater have a higher risk of mortality [9].

Outcomes

The primary outcome was 30 day in-hospital mortality, while the secondary outcomes included intubation status, acute kidney injury (AKI), Acute Respiratory Distress Syndrome (ARDS), and acute cardiac injury (ACI). Acute kidney injury was diagnosed using the kDIGO criteria [10], while ARDS was defined by the Berlin criteria [11]. Acute cardiac injury was defined as elevation of troponin levels above the 99% of the upper reference limit occurring within 30 days of COVID-19 diagnosis.

Statistical analysis

Differences in demographics and clinical characteristics were compared across the three BMI groups, using χ^2 or Fisher's exact tests for categorical variables and Kruskal–Wallis for continuous variables. Characteristics statistically significant at the 0.10 alpha level in bivariate analyses were included into the multivariable regression model [12]. Log-binomial regression models were used to determine whether any of the BMI groups was associated with an increase in the relative risk of outcomes upon adjustment for covariates. All statistical analysis was performed using SAS Studio 3.8 software.

Results

Table 1 shows the baseline characteristics of the study population. The mean age of the cohort was 68, with 316 (63%) patients greater than 65 years old. In this cohort, 263 (52%) were male and 454 (90%) were black. Baseline comorbidities included diabetes in 269 (53%) and hypertension in 416 patients (83%). There were 139 patients (27%) with normal BMI, 150 patients with overweight (30%), and 215 patients with obesity (43%). The mean age of the group with obesity was 63, while the normal range and groups with overweight were 70 and 71, respectively.

After controlling for all covariates, there was a significantly increased risk of mortality in the patients with overweight (RR 1.4, 95% CI 1.1–1.9, $P = 0.003$) and patients with obesity (RR 1.3, 95% CI 1.0–1.7, $P = 0.04$) compared with those with normal BMI (Table 2). Similarly,

there was significantly increased relative risk for intubation in the patients with overweight (RR 2.0, 95% CI 1.2–3.3, $P = 0.01$) and patients with obesity (RR 2.4, 95% CI 1.5–4.0, $P = 0.001$) compared with the normal group (Table 3). Obesity did not demonstrate an association with AKI, ACI, or ARDS.

Subgroup analyses were also performed based on sex and age. A significantly increased risk of mortality was found in the group with obesity (RR 1.4, 95% CI 1.0–2.0, $P = 0.03$) compared with the normal BMI group in male patients, but not in female patients (RR 1.2, 95% CI 0.77–1.9, $P = 0.40$) (See Appendix Table 1). Similarly, there was significantly increased relative risk for intubation in the group with obesity (RR 2.5, 95% CI 1.4–4, $P = 0.003$) compared with the normal BMI group in male patients, but not in female patients (RR 2.3 95%, CI 0.93–5.9, $P = 0.07$) (See Appendix Table 2). Age-stratified analyses demonstrate that among those 65 or older, being overweight significantly impacts mortality (RR 1.5, 95% CI 1.2–2.0, $P = 0.002$) (See Appendix Table 3). In addition, among 45–64 year olds and those 65 years or older, obesity significantly impacts intubation (RR 3.0, 95% CI 1.1–8.0, $P = 0.03$ and RR 2.1, 95% CI 1.1–3.8, $P = 0.02$), respectively (See Appendix Table 4).

Discussion

This study revealed that obesity is independently associated with adverse outcomes in COVID-19 patients when controlled for age, gender, hypertension, diabetes, and qSOFA score. Both groups with an elevated BMI showed an increased probability for mortality and intubation compared to the patients with normal BMI.

To our knowledge, this is the first large study to show the increased risk for mortality in this patient subset. The mechanism of this association is unclear but may be related to lipo-toxicity and the proinflammatory state induced by obesity. The excess free fatty acids induce lipo-toxicity, causing damage to organs such as the liver and pancreas. This leads to impairment of insulin receptors, contributing to insulin resistance, hypertriglyceridemia, and the progression to metabolic syndrome [13]. Furthermore, obesity creates a proinflammatory state, with increased expression of cytokines such as tumor necrosis factor alpha and interleukin-6, as well as acute phase reactants like C-reactive protein (CRP) and amyloid antigen [13]. These cytokines cause damage to vascular endothelium, accelerating hypertension via renin-angiotensin-aldosterone system activation, atherosclerosis, and even thrombosis. Obesity has also been implicated in impairment of the adaptive immune response against influenza and other viruses [7].

Table 1 Characteristics of the study population at baseline according to BMI category (n = 504).

Characteristic	Total n = 504	Normal n = 139 (27%)	Overweight n = 150 (30%)	Obese n = 215 (43%)	p value
Age – mean ± sd	68 ± 15	70 ± 16	71 ± 13	63 ± 14	<0.001
<45 yrs	33 (7%)	9 (6%)	7 (5%)	17 (8%)	<0.001
45–64 yrs	155 (31%)	34 (24%)	28 (19%)	93 (43%)	
≥65	316 (63%)	96 (69%)	115 (77%)	105 (49%)	
Male sex– n (%)	263 (52%)	84 (60%)	84 (56%)	95 (44%)	0.006
Race					0.64
Black	454 (90%)	126 (91%)	132 (88%)	196 (91%)	
White	20 (4%)	8 (6%)	7 (5%)	5 (2%)	
Asian	2 (0.4%)	1 (1%)	0	1 (0.5%)	
Hispanic	3 (0.6%)	0	1 (1%)	2 (1%)	
Unknown	25 (5%)	4 (3%)	10 (7%)	11 (5%)	
Comorbidities					
Diabetes	269 (53%)	72 (52%)	85 (57%)	112 (52%)	0.63
Hypertension	416 (83%)	102 (73%)	127 (85%)	187 (87%)	0.003
Hyperlipidemia	174 (35%)	38 (27%)	55 (37%)	81 (38%)	0.11
Coronary Artery Disease	96 (19%)	30 (22%)	39 (26%)	27 (13%)	0.003
COPD	41 (8%)	7 (5%)	9 (6%)	25 (12%)	0.05
Asthma	41 (8%)	4 (3%)	12 (8%)	25 (12%)	0.009
Chronic kidney disease	81 (16%)	21 (15%)	28 (19%)	32 (15%)	0.59
ESRD[a]	65 (13%)	18 (13%)	24 (16%)	23 (11%)	0.34
qSOFA ≥ 2[b]	156 (31%)	51 (33%)	48 (32%)	57 (37%)	0.12
Current or Former Smoker	71 (14%)	16 (12%)	28 (19%)	27 (13%)	0.06
Outcomes					
Intubation	113 (22%)	17 (12%)	36 (24%)	60 (28%)	0.002
Acute kidney injury	95 (19%)	31 (22%)	31 (21%)	33 (15%)	0.21
Acute cardiac injury	160 (32%)	40 (29%)	49 (33%)	71 (33%)	0.66
ARDS[c]	91 (18%)	18 (13%)	28 (19%)	45 (21%)	0.16
Mortality	219 (43%)	51 (37%)	81 (54%)	87 (40%)	0.006

[a]End stage renal disease.

[b]Quick sequential organ failure assessment.

[c]Acute respiratory distress syndrome.

Table 2 Adjusted relative risks for association between BMI category and mortality.

Predictor	Relative risk (95% CI)	p value
Overweight	1.4 (1.1–1.9)	0.003
Obese	1.3 (1.0–1.7)	0.04
Age	–	–
45 – 64 yrs	2.7 (1.0–6.9)	0.04
≥65	4.5 (1.8–11)	0.002
Male	1.3 (1.0–1.5)	0.03
Diabetes	1.1 (0.92–1.3)	0.31
Hypertension	0.81 (0.66–1.0)	0.06
qSOFA ≥ 2	1.2 (0.96–1.4)	0.12

Table 3 Adjusted relative risks for association between BMI category and intubation.

Predictor	Relative risk (95% CI)	p value
Overweight	2.0 (1.2–3.3)	0.0
Obese	2.4 (1.5–4.0)	<0.001
Age	–	–
45–64 yrs	2.1 (0.81–5.7)	0.12
≥65	2.0 (0.77–5.3)	0.15
Male	1.3 (0.95–1.8)	0.10
Diabetes	1.2 (0.87–1.7)	0.24
Hypertension	0.76 (0.48–1.2)	0.23
qSOFA ≥2	0.86 (0.59–1.3)	0.43

This study's findings are consistent with previous studies that demonstrate an association between obesity and invasive mechanical ventilation [4]. This may be related to excess adipose tissue in the upper respiratory tract that results in obstruction of the airway and quicker progression to hypoxia. Patients with obesity also have increased intraabdominal pressure and a restrictive chest wall, resulting in decreased forced expiratory volume and forced vital capacity as well as decreased diaphragm contractility [7]. This contributes to lung dysfunction and subsequent desaturations leading to intubation.

Covariate analysis showed both age and the male gender to be significant independent predictors of mortality when controlling for other confounders. The stratified analysis showed that younger patients with obesity between 45–64 years of age have a relative risk of 3 for intubation compared with younger patients with normal BMI, while patients ages 65 or older have a comparably lower relative risk of 2.1. These results support the idea that obesity is raising the risk for COVID-19 complications in younger populations. Previous studies support this hypothesis, as it has already been shown that patients with obesity under the age of 60 are more likely to get admitted to acute and critical care settings [14].

Stratification by sex reveals worse outcomes in males over females, with higher risks of both mortality and intubation in males with obesity. This discrepancy may be related to anatomic variation: males tend to have more visceral fat, while females have more subcutaneous fat. Visceral fat has been shown to induce an inflammatory state with elevated CRP levels, while studies have shown that subcutaneous adipose tissue could be protective and lowers risk of mortality [15].

Demographic data reveals that most of the patients in this study reside in East Flatbush (See Appendix Fig. 1), a neighborhood with a higher rate of obesity (34%) compare with Brooklyn overall (27%) and NYC (24%) (8). Factors that may contribute to this include lower income and limited access to higher determinants of health and healthy lifestyle options. For example, in East Flatbush, 80% of adults report eating one serving of fruits or vegetables per day (compared with 87% in NYC), and 32% report drinking one or more 12-ounce sugary drinks per day (vs 23% in NYC) [8]. The East Flatbush neighborhood also has a low density of supermarkets compared with bodegas, which have less healthy food options [8]. Of note, the prevalence of obesity in the admitted patients in our study (43%) is higher than the average in the East Flatbush community (34%). This may support the hypothesis that obesity increases rate of hospital admissions in COVID-19 [6].

This study has some limitations. Due to the observational nature of the study design, the potential for unmeasured residual confounding exists. Rates of all-cause mortality and intubation may be influenced by many other factors, such as socioeconomic disparities, advance directives and healthcare decisions, access to health insurance, dependence on public transportation, and overcrowding. Also, our study population is predominantly African American, a group with higher reported rates of obesity and other comorbidities [16], and may not be representative of the general U.S. population.

Despite these limitations, this study also has notable strengths: it is among the first to show an association between mortality and obesity, and uses relative risks as opposed to odds ratio, which is often computed in other studies and can exaggerate the risk ratio. Future research should address other risk factors and comorbidities that make COVID-19 patients high-risk, further clarifying healthcare decisions for the physician. We believe that this study supports the hypothesis that obesity is a risk factor for COVID-19 complications and should be considered by healthcare providers to dictate prevention and management of this virus.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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