The impact of body mass index on mechanical ventilation and outcomes of patients admitted to the hospital with COVID-19

Paloma Molina[1,6], Andrea Terrazas[1,6], Diego Piccolo[3], José de Jesús Méndez[2,6], Luz Ramirez[4,6], Mohamed Ziad[5,6], Joseph Varon[1,2,4-7]

Abstract

***Introduction*: Multiple studies consistently demonstrate a link between higher body mass index (BMI) levels and unfavorable outcomes in individuals with coronavirus disease 2019 (COVID-19). This study aimed to assess the influence of BMI on COVID-19 outcomes and the need for mechanical ventilation.**

***Materials and methods*: From March 2020 to February 2022, we conducted a retrospective cohort study involving adult patients admitted to a single center in Houston, Texas, with COVID-19 infection. Patients were categorized into five groups based on their treatment methods: Group 1 received invasive mechanical ventilation, Group 2 used bilevel positive airway pressure ventilation (BiPAP), Group 3 was on high flow nasal cannula (HFNC), Group 4 utilized both HFNC and BiPAP, and Group 5 included patients in the Intensive Care Unit (ICU) who could manage on room air.**

***Results*: 985 individuals were included in this study with a median age of 55.7 years old (45-67). Overall median BMI was 29.3 kg/m^2 (27-34.5 kg/m^2). Five hundred fifty-four (56.2%) patients were males and 431 (43.8%) females. A total of 798 (81%) survived. Hospitalization survival in underweight patients was 13 (86.7%), normal weight was 143 (81.7%), overweight was 267 (79%), obese class 1 was 191 (84.1%), obese class 2 was 98 (79%), and obese class 3 was 87 (81.3%) (χ2 (5)=3.032, p=0.695). When assessing the need for mechanical ventilation, 160 (16.1%) of all patients required assisted ventilation. In each category: 3 (20%) underweight patients, 25 (16%) normal weight patients, 62 (39%) overweight patients, 33 (21%) obese class 1 patients, 23 (14%) obese class 2 patients, and 14 (9%) obese class 3 patients required ventilation (χ2 (5)=2.613, p=0.759). Analyzing days hospitalized, length of stay in each category was: underweight 6 (5-12) days, normal weight 7 (3-12) days, overweight 6.5 (4-12) days, obese class 1 7 (4-12) days, obese class 2 7.5 (4-14) days, and obese class 3 7 (5-12) days (H(5)=3.207, p=0.632).**

***Conclusions*: In our cohort, BMI was not associated with increased mortality rate, longer hospitalization duration, or need for mechanical ventilation in patients with COVID-19.**

[1.] Universidad Autónoma de Baja California, Tijuana, México
[2.] Universidad Popular Autónoma del Estado de Puebla, Puebla, México
[3.] Universidad de las Américas Puebla, Puebla, México
[4.] Benemérita Universidad Autónoma de Puebla, Puebla, México
[5.] Caribbean Medical University, Willemstad, Curaçao
[6.] Dorrington Medical Associates, Houston, Texas, USA
[7.] The University of Houston College of Medicine, Houston, USA

Address for correspondence:
Joseph Varon, MD, FACP, FCCP, FCCM, FRSM
2219 Dorrington Street, Houston, Texas, 77030, USA
Tel: +1-713-669-1670
Fax: +1-713-669-1671 FAX
Email: jvaron@uh.edu

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Introduction

Numerous studies have consistently shown that higher body mass index (BMI) levels are associated with worse outcomes among individuals infected with coronavirus disease 2019 (COVID-19). (1) Obese individuals, in particular, face an increased risk of developing severe illness, requiring intensive care, and experiencing higher mortality rates compared to those with lower BMI. (2) The relationship between BMI and COVID-19 outcomes is multifaceted and complex. Obesity is known to be associated with chronic inflammation and an increased prevalence of comorbidities such as diabetes, cardiovascular disease, and respiratory conditions. (3) These underlying health conditions may contribute to a poorer prognosis among obese COVID-19 patients. Understanding the correlation between BMI and patient outcomes is crucial for risk stratification and guiding appropriate management strategies. (3) Mechanical ventilation played a critical role in managing severe COVID-19 cases, especially in the intensive care unit (ICU). (4) When COVID-19 patients develop severe respiratory distress, assisted mechanical ventilation may become necessary to support their breathing and ensure adequate oxygenation. However, invasive mechanical ventilation has been associated with worse mortality among COVID-19 patients. (4) Therefore, in the ICU setting, various respiratory support techniques are employed, including bilevel positive airway pressure (BiPAP), high-flow nasal cannula (HFNC), and invasive mechanical ventilation (IMV). (5)

This study aimed to examine the relationship between BMI and COVID-19 patients regarding the need for assisted mechanical ventilation and clinical outcomes.

Methods

Study design and setting

Retrospective cohort analysis was conducted at a single center in the intensive care unit in Houston, Texas. The analysis focused on adult hospital patients diagnosed with COVID-19 between March 2020 and February 2022. The sample was divided into four groups: Group 1 consisted of patients receiving invasive mechanical ventilation, Group 2 comprised patients requiring BiPAP, Group 3 included patients on HFNC, Group 4 consisted of patients using both HFNC and BiPAP, Group 5 included patients in the ICU who were able to be managed on room air, and finally Group 6 included the patients in the ICU managed with a nasal cannula.

Participants

Patients' eligibility was determined using the institution's Meditech electronic medical records (EMR) software. Patients were included in the cohort if they met the following criteria: 1) Detection of severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) ribonucleic acid (RNA) through quantitative reverse transcription polymerase chain reaction (RT-PCR), 2) Severe symptoms requiring admission to the ICU, 3) Need for invasive mechanical ventilation, and 4) Evidence of pulmonary infiltrates on chest imaging. Patients who did not require mechanical ventilation were excluded from this cohort.

BMI category definitions

Patients were categorized based on their BMI as follows: underweight, normal weight, overweight, or obese. Underweight individuals had a BMI of less than 18.5 kg/m^2. Normal-weight individuals had a BMI between 18.5 and less than 24.9 kg/m^2. Overweight individuals had a BMI between 25 and less than 29.9 kg/m^2. Obese individuals had a BMI of 30.0 kg/m^2 or higher. Among the obese category, further subclassification was done: Class I obese individuals had a BMI between 30 and less than 34.9 kg/m^2. Class II obese individuals had a BMI between 35 and less than 39.9 kg/m^2. Class III obese individuals had a BMI of 40 kg/m^2 or higher. These classifications align with the World Health Organization's BMI classifications. (6)

Data collection

We utilized the Meditech™ electronic medical record system within the hospital to collect patient data for the study. This dataset comprised various information such as demographic details, clinical records, laboratory examinations, severity assessments, imaging results, treatment regimens, the use of invasive mechanical ventilation, length of hospitalization, and patient prognoses.

It is important to highlight that before data collection, this study strictly followed ethical protocols and obtained approval from the hospital's Institutional Review Board. All patient data underwent anonymization procedures and was handled with the highest level of confidentiality to safeguard individual privacy.

Statistical analysis

Statistical analysis was conducted by using IBM SPSS Statistics version 24.0. Descriptive statistics, including frequencies and percentages, were used to summarize data. Chi-square, U Mann-Whitney, and Kruskal Wallis tests were used to examine the association between the categorical variables. Statistical significance was defined as a p-value <0.05.

Results

Demographics

This study comprised 985 patients, including 554 (56.2%) males and 431 (43.8%) females. Five hundred and thirty-four (54.2%) patients identified as Hispanic, 194 (19.7%) as Caucasian, 204 (20.7%) as African American, 10 (1%) as Asians, and 29 (2.9%) fell into the "other" category. Out of all participants in this study, 14 (1.4%) were determined to be underweight, 175 (17.8%) were determined to have normal weight, 338 (34.3%) were determined to be overweight, 227 (23%) were determined to be within the obesity class 1, 124 (12.6%) as obesity class 2, and 107 (10.9%) as obesity class 3. The distribution of each sex within BMI classifications can be found in **Figure 1**. The patients' ages ranged between 17 and 95 years old, with a mean age of 55.7 years.

The most common comorbidities found in the cohort were hypertension in 365 (31.1%) individuals and type 2 diabetes mellitus (T2DM) (25.3%). Other comorbidities included were chronic obstructive pulmonary disease (COPD), previous myocardial infarction (MI), congestive heart failure (CHF), peripheral vascular disease (PVD), stroke or transient ischemic attack (TIA), hemiplegia, dementia, liver disease, cancer (both solid tumors as well as leukemia and lymphoma), connective tissue disease, peptic ulcer disease, and acquired immunodeficiency syndrome (AIDS). One hundred fifty-one (41.3%) patients within our sample reported having other comorbidities not listed, and 149 (40.7%) reported having none (**Figure 2**).

Type of ventilatory support according to BMI

In Group 1, out of 985 patients, 160 (16%) required invasive mechanical ventilation. Of these 160 patients, 3 (2%) were classified as underweight, 25 (16%) as normal weight, 62 (39%) as overweight, 33 (21%) as having class I obesity, 23 (14%) as class II obesity, and 14 (9%) as class III obesity ($\chi 2$ (5)=2.613, p=0.759). Group 2 consisted of 10 patients who required BiPAP (1%). Within Group 2, 5 patients were overweight (50%), 1 had class I obesity (10%), and 4 had class III obesity (40%). No patients were underweight, normal weight, or within class II obesity. In Group 3, 139 patients (14%) required the utilization of HFNC. Out of these, 2 (1%) were underweight, 20 (14%) were of normal weight, 48 (35%) were overweight, 33 (24%) fell into the class I obesity classification, 22 (16%) in class II obesity, and 14 (10%) in class III obesity. Group 4 consisted of 57 individuals (15.6%) who were managed using both BiPAP and HFNC. Among them, 9 (16%) were classified as having a normal weight, 14 individuals (25%) were classified as overweight, 17 individuals (30%) were within the class I obesity, 8 individuals (14%) were within class II obesity, and 9 individuals (16%) were within class III obesity. Group 5 was made up of 198 patients (20%) who were managed on room air only. From this group, 6 (3%) were underweight, 46 (23%) were of normal weight, 62 (31%) were overweight, 47 (24%) were found to be within class I obesity, 22 (11%) as class II obesity, and 15 (8%) as class III obesity. Lastly, Group 6 was composed of 401 (41%) patients managed with nasal cannula, from which 3 (1%) were underweight, 69 (17%) had a normal weight, 137 were overweight, 95 (24%) were found in class 1 obesity, 48 (12%) within class 2 obesity, and 49 (12%) as class 3 obesity. A summary of this data can be found in **Figure 3**.

Mortality

Seven hundred and ninety-eight (81%) patients survived hospitalization, while 187 (19%) expired. Fifty-seven (13.2%) females and 130 (23.5%) males died (p<0.001). Two (14.3%) patients were underweight, 32 (18.3%) had a normal weight, 71 (21%) were overweight, 36 (15.9%) were obese class 1, 26 (21%) were obese class 2, and 20 (18.7%) were obese class 3 ($\chi 2$ (5)=3.032, p=0.695) (**Table 1**)

Only 1 (1.6%) patient on room air was overweight and died (p=0.773). From the group of patients with nasal cannula, 4 (5.8%) patients had normal weight, 4 (2.9%) were overweight, and 3 (6.1%) obese class 3 died (p=0.322). In the high-flow nasal cannula group, 2 (10%) had a normal weight, 1 (2.1%) was overweight, 1 (3%) had obesity class 1, and 1 (7.1%) had obesity class 3. Additionally, 5 (3.6%) did not show a significant difference (p=0.491). However, the other groups exhibited a higher mortality rate. This included the group that used HFNC and BiPAP simultaneously, 3 (33.3%) patients with normal weight, 6 (42.9%) overweight, 7 (41.2%) obesity class 1, 4 (50%) obesity class 2, and 1 (11.1%) obesity class 3 died (p=0.497). In the BiPAP group, 5 (55.6%) of the patients were overweight, 1 (11.1%) had obesity class 1, and 3 (33.3%) had obesity class 3 (p=0.248). Finally, the IMV group exhibited the highest mortality, with 2 (66.7%) underweight patients, 23 (92%) with normal weight, 53 (85.5%) overweight, 27 (81.8%) obesity class 1, 22 (95.7%) obesity class 2, and 12 (85.7%) obesity class 3 (p=0.846). However, no statistically significant difference was found between clinical outcomes and BMI. The data can be seen in **Figure 4**.

BMI, hospital stay, and severity scales

We aimed to determine if there was a correlation between BMI and hospital length of stay (LOS) and found no correlation between these two variables ($\chi 2$ (5)=3.207, p=0.632)). In addition, we aimed to determine if BMI influenced the total number of days until patients were intubated and the number of intubated days and found no correlation as well. We also found no correlation between BMI and scoring systems (Acute Physiology and Chronic Health Evaluation [APACHE] II and quick Sequential Organ Failure Assessment [qSOFA]).

Discussion

This study aimed to investigate the impact of BMI on COVID-19 outcomes in a cohort of patients admitted to the ICU. The primary outcomes examined were mortality, hospitalization duration, and the need for mechanical ventilation. Contrary to prior publications, our results indicated that BMI was not significantly associated with higher mortality rates, longer hospitalization periods, or the need for mechanical ventilation among patients with COVID-19. We did, however, find that there was a relationship between weight classification and the type of ventilation required. Patients in higher weight classifications (overweight, class 1, class 2, and class 3 obesity) were more likely to require invasive mechanical ventilation as compared to those with normal weight or underweight.

The study also highlighted the obesity paradox, which refers to the counterintuitive benefits of obesity on mortality in certain populations. While this study did not find a statistically significant correlation between BMI and mortality, other investigations have shown that obesity did play a role in the severity of SARS-CoV-2 infection, particularly affecting patients with a BMI of 35 or higher. (6,7)

Not surprisingly, patients on room air oxygen had a low mortality rate (1.6%), regardless of their BMI, suggesting that those not requiring additional oxygen support had better overall health or less severe respiratory conditions. For patients receiving nasal cannula and HFNC, mortality rates varied across different BMI categories. Still, the differences were not statistically significant, indicating that BMI alone may not be a strong predictor of mortality in patients utilizing these types of oxygen supplementation.

A recent French study revealed a high prevalence of patients with obesity and severe obesity requiring invasive mechanical ventilation due to SARS-CoV-2 infection. (8) This study demonstrated different distributions of SARS-CoV-2 patients across BMI categories, with a lower prevalence of patients with a BMI≥35 kg/m^2 reported in one study compared to another. (8,9)

While mortality rates showed variability across different BMI categories in certain groups, the lack of statistically significant associations suggested that BMI alone may not be a strong predictor of mortality in these specific circumstances. (10,11) As a result, healthcare professionals should consider other relevant factors when assessing patient outcomes and making treatment decisions. Further research involving larger sample sizes and other influencing factors is needed to comprehensively understand mortality in these patient groups.

Conclusions

Our results indicate that BMI does not significantly correlate with higher mortality rates, longer hospital stays, or the need for invasive mechanical ventilation among COVID-19 patients. While higher BMI levels may influence the need for mechanical ventilation, BMI alone may not predict mortality or severity reliably. However, our study did reveal a notable connection between weight classification and the type of ventilation required, with higher weight classifications being linked to an increased likelihood of needing invasive mechanical ventilation.

Conflicts of interest

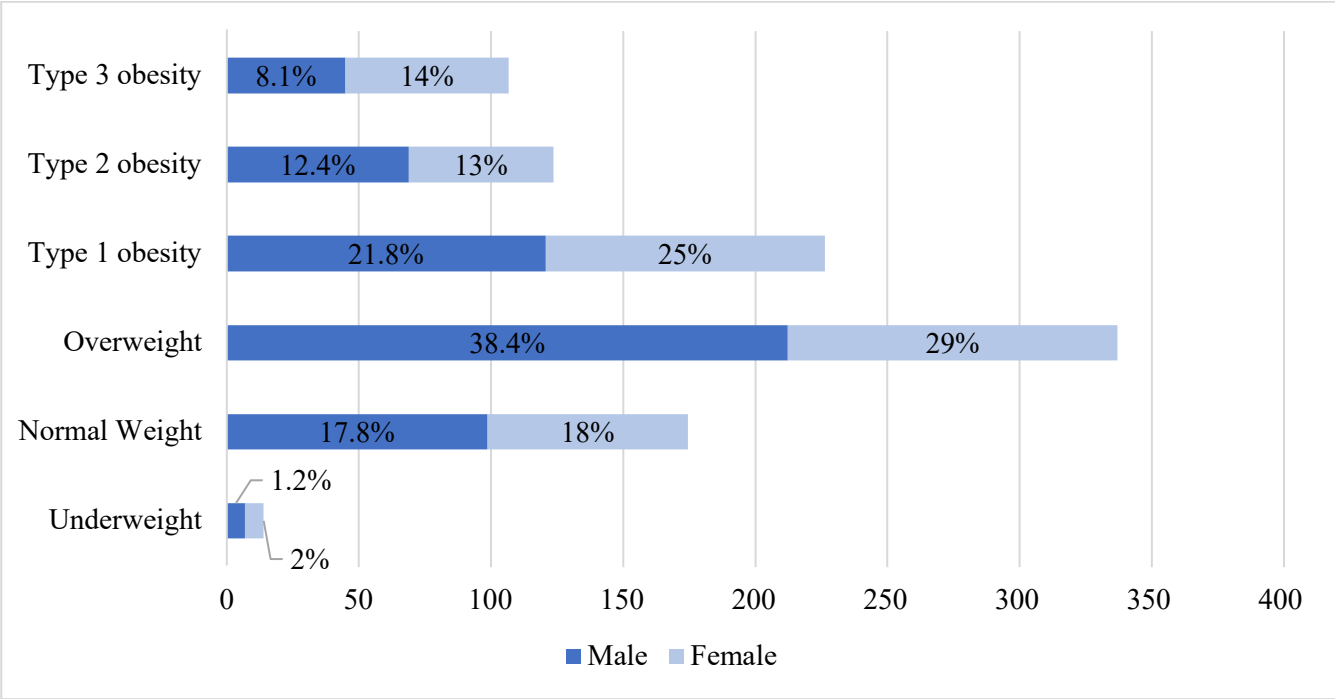
The authors have no conflicts of interest in the preparation of this manuscript. This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors. This work was presented as an oral presentation at the Society of Critical Care Medicine Annual Congress in San Francisco, California, in January 2023.

Table 1. Patients who did not survive hospitalization

	Underweight	Normal weight	Overweight	Obese class 1	Obese class 2	Obese class 3	Total	U Man-Withney
Room air	0	0	1	0	0	0	1	p=0.773
	0%	0%	100%	0%	0%	0%	0.54%	
Nasal cannula	0	4	4	0	0	3	11	p=0.322
	0%	36%	36%	0%	0%	27%	5.91%	
HFNC	0	2	1	1	0	1	5	p=0.491
	0%	40%	20%	20%	0%	20%	2.69%	
BiPAP	0	0	5	1	0	3	9	p=0.248
	0%	0%	56%	11%	0%	33%	4.84%	
HFNC+BiPAP	0	3	6	7	4	1	21	p=0.497
	0%	14%	29%	33%	19%	5%	11.29%	
IMV	2	23	53	27	22	12	139	p=0.846
	1%	17%	38%	19%	16%	9%	74.73%	

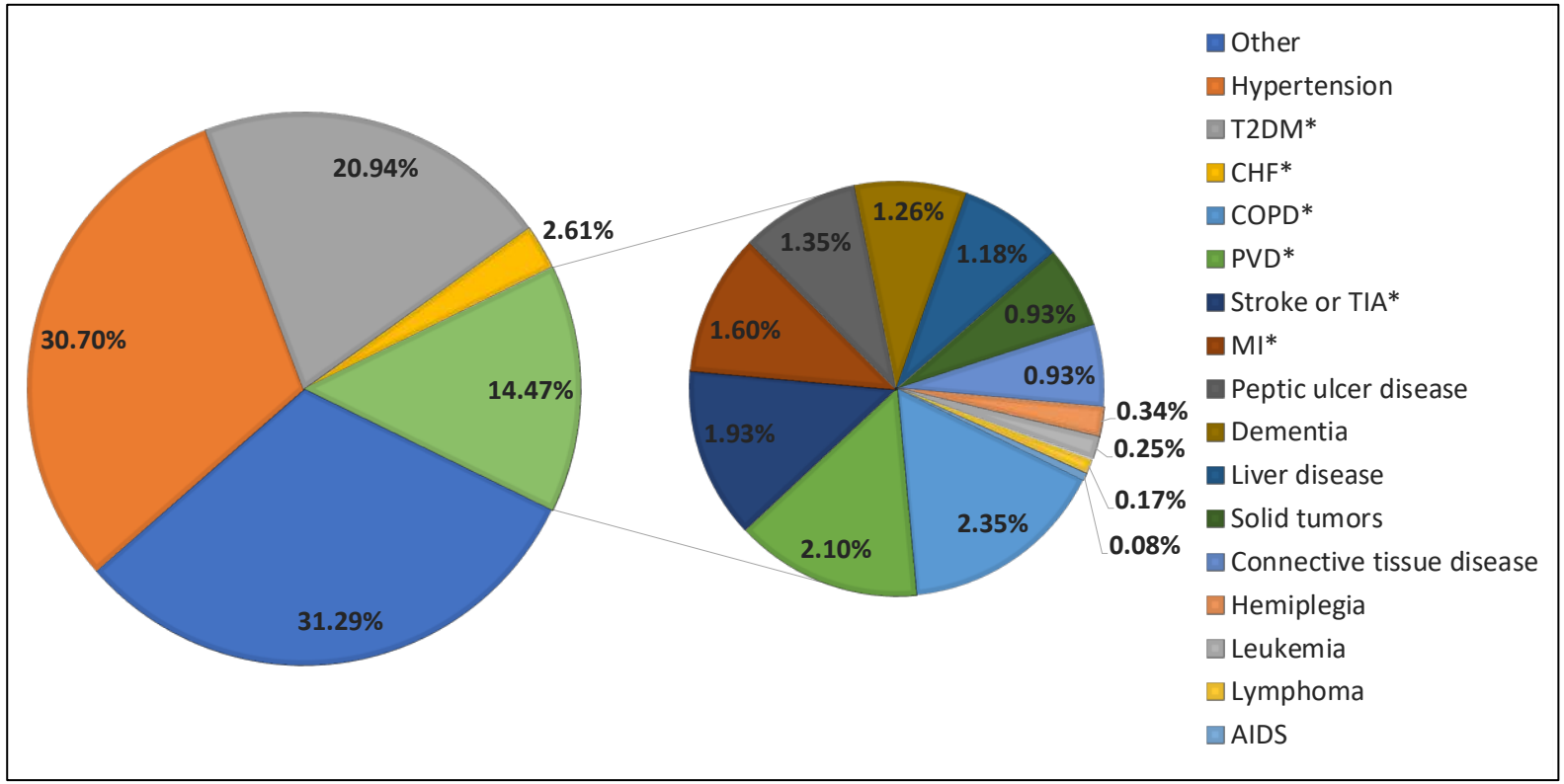
Legend: HFNC=high flow nasal cannula; BiPAP=bilevel positive airway pressure; IMV=invasive mechanical ventilation.

Figure 1. Distribution of BMI according to gender



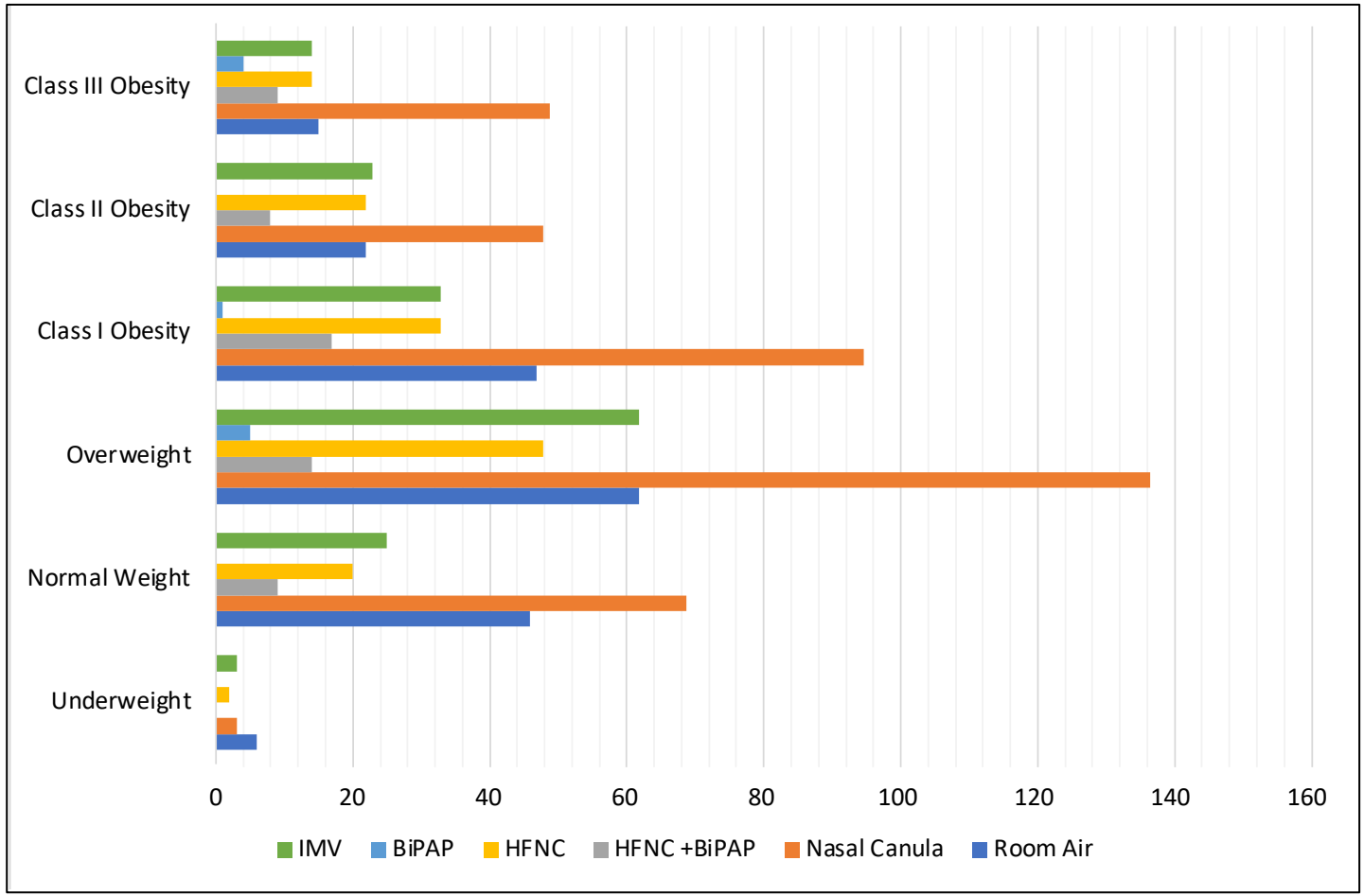
Legend: BMI=body mass index.

Figure 2. Patient comorbidities



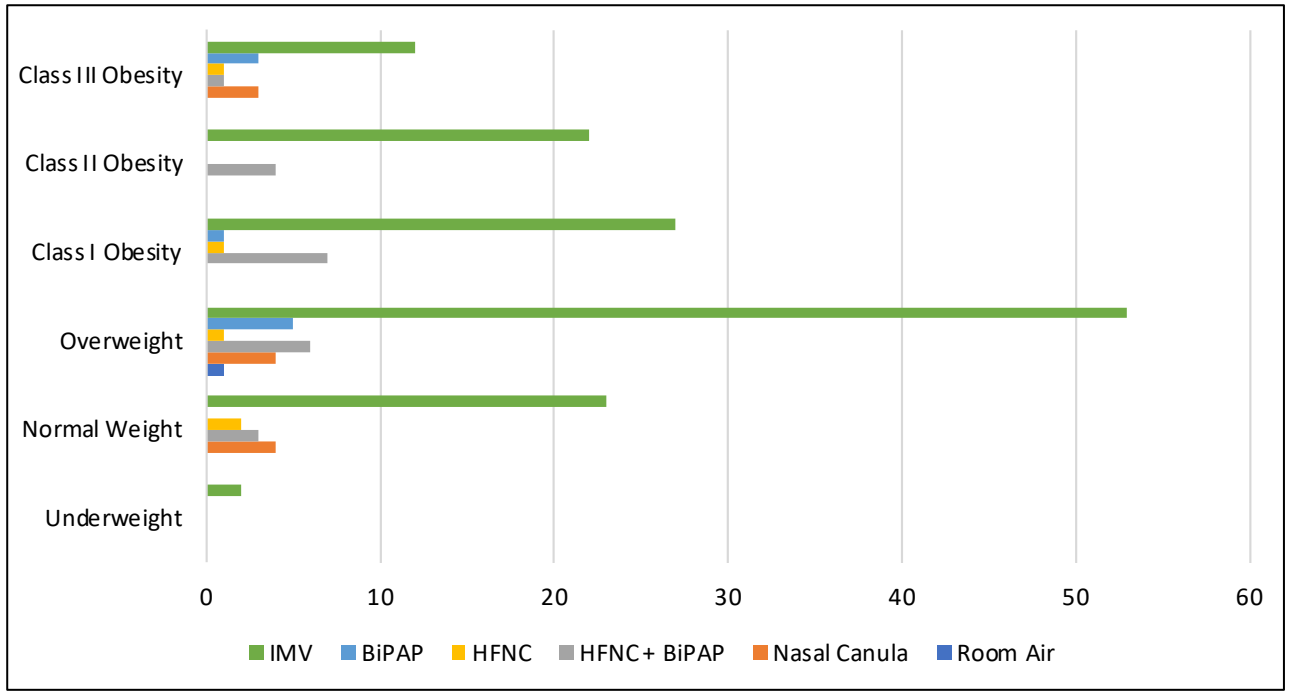
Legend: T2DM=type 2 diabetes mellitus; CHF=congestive heart failure; COPD=chronic obstructive pulmonary disease; PVD=peripheral vascular disease; TIA=transient ischemic attack; MI=myocardial infarction; AIDS=acquired immunodeficiency syndrome.

Figure 3. BMI and type of ventilatory support



Legend: BMI=body mass index; IMV=invasive mechanical ventilation; BiPAP=bilevel positive airway pressure; HFNC=high-flow nasal cannula.

Figure 4. Mortality according to ventilation device used and BMI



Legend: BMI=body mass index; IMV=invasive mechanical ventilation; BiPAP=bilevel positive airway pressure; HFNC=high-flow nasal cannula.

References

1. Kim RY, Glick C, Furmanek S, Ramirez JA, Cavallazzi R. Association between body mass index and mortality in hospitalized patients with community-acquired pneumonia. ERJ Open Res 2021;7:00736-2020.
2. Varon J, Hussaini N. Extreme obesity in the intensive care unit. World Nutr J 2023;7:8-9.
3. Girn T, Akinwale D, Ramirez C, Almaguer A, Said MZ-M, Emeaba N, et al. Impact of BMI on mortality, mechanical ventilation, and length of stay in COVID-19 patients. Crit Care Med 2023;51:184.
4. Hendren NS, de Lemos JA, Ayers C, Das SR, Rao A, Carter s, et al. Association of body mass index and age with morbidity and mortality in patients hospitalized with COVID-19. Circulation 2021;143:135-44.
5. Kooistra EJ, de Nooijer AH, Claassen WJ, Grondman I, Janssen NAF, Netea MG, et al. A higher BMI is not associated with a different immune response and disease course in critically ill COVID-19 patients. Int J Obes (Lond) 2021;45:687-94.
6. Plataki M, Pan D, Goyal P, Hoffman K, Choi JMK, Huang H, et al. Association of body mass index with morbidity in patients hospitalized with COVID-19. BMJ Open Respir Res 2021;8:e000970.
7. Nuttall FQ. Body mass index: obesity, BMI, and health: a critical review. Nutr Today 2015;50:117-28.
8. Carter C, Aedy H, Notter J. COVID-19 disease: non-invasive ventilation and high frequency nasal oxygenation. Clin Intgr Care 2020;1:100006.
9. Guglielmi V, Colangeli L, Scipione V, Ballacci S, Di Stefano M, Hauser L, et al. Inflammation, underweight, malignancy and a marked catabolic state as predictors for worse outcomes in COVID-19 patients with moderate-to-severe disease admitted to internal medicine unit. PLoS One 2022;17:e0268432.
10. Simonnet A, Chetboun M, Poissy J, Raverdy V, Noulette J, Duhamel A, et al. High prevalence of obesity in severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) requiring invasive mechanical ventilation. Obesity (Silver Spring) 2020;28:1195-9.
11. Palaiodimos L, Kokkinidis DG, Li W, Karamanis D, Ognibene J, Arora S, et al. Severe obesity, increasing age and male sex are independently associated with worse in-hospital outcomes, and higher in-hospital mortality, in a cohort of patients with COVID-19 in the Bronx, New York. Metabolism 2020;108: 154262.
12. Kim TS, Roslin M, Wang JJ, Kane J, Hirsch JS, Kim EJ, et al. BMI as a risk factor for clinical outcomes in patients hospitalized with COVID-19 in New York. Obesity (Silver Spring) 2021;29:279-84.
13. Wu X, Li C, Chen S, Zhang X, Wang F, Shi T, et al. Association of body mass index with severity and mortality of COVID-19 pneumonia: a two-center, retrospective cohort study from Wuhan, China. Aging (Albany NY) 2021; 13:7767-80.
14. Yang Y, Wang L, Liu J, Fu S, Zhou L, Wang Y. Obesity or increased body mass index and the risk of severe outcomes in patients with covid-19: a protocol for systematic review and meta-analysis. Medicine (Baltimore) 2022;101 :e28499.
15. Kompaniyets L, Goodman AB, Belay B, Freedman DS, Sucosky MS, Lange SJ, et al. Body mass index and risk for COVID–19–related hospitalization, intensive care unit admission, invasive mechanical ventilation, and death — United States, March–December 2020. MMWR Morb Mortal Wkly Rep 2021; 70:355-61.
16. Ruan Q, Yang K, Wang W, Jiang L, Song J. Clinical predictors of mortality due to covid-19 based on an analysis of data of 150 patients from Wuhan, China. Intensive Care Med 2020; 46:846-8.
17. Li X, Xu S, Yu M, Wang K, Tao Y, Zhou Y, et al. Risk factors for severity and mortality in adult COVID-19 inpatients in Wuhan. J Allergy Clin Immunol 2020;146:110-8.
18. Nie W, Zhang Y, Jee SH, Jung KJ, Li B, Xiu Q. Obesity survival paradox in pneumonia: a meta-analysis. BMC Med 2014;12:61.
19. Littleton SW, Tulaimat A. The effects of obesity on lung volumes and oxygenation. Respir Med 2017;124:15-20.
20. Pouwels S, Ramnarain D, Aupers E, Rutjes-Weurding L, van Oers J. Obesity may not be associated with 28-day mortality, duration of invasive mechanical ventilation and length of intensive care unit and hospital stay in critically Ill patients with severe acute respiratory syndrome coronavirus-2: a retrospective cohort study. Medicina (Kaunas) 2021;57:674.
21. Chang R, Elhusseiny KM, Yeh Y-C, Sun W-Z. Covid-19 icu and mechanical ventilation pa-

patient characteristics and outcomes—a systematic review and meta-analysis. PLoS One 2021;16:e0246318.
22. Najafabadi BT, Rayner DG, Shokraee K, Shokraie K, Panahi P, Rastgou P, et al. Obesity as an independent risk factor for COVID-19 severity and mortality. Rev Cochrane Database Syst Rev 2023;5:CD015201.
23. Richardson S, Hirsch JS, Narasimhan M, Crawford JM, McGinn T, Davidson KW. Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York City area. JAMA 2020;323:2052-9.

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