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ORIGINAL ARTICLE

Impact of obesity on COVID-19 severity: a Mexican experience

Impacto de la obesidad en la gravedad del COVID-19: una experiencia mexicana

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Abstract

Introduction: *Mexico has a high prevalence of overweight and obesity. Patients suffering from these conditions when infected by coronavirus disease-2019 (COVID-19) are at a higher risk of experiencing a more severe clinical sequence. The present study aimed to assess obesity as an independent risk factor for disease severity and mortality in Mexican patients with COVID-19.* **Methods:** *A prospectively constructed database was analyzed. 1027 patients with COVID-19 infection were divided into categories based on the severity of obesity. Demographic characteristics, obesity-related comorbidities, severity of pulmonary dysfunction, severity scores, the need for hospital admission, oxygen supplementation/mechanical ventilation, and mortality were comparatively analyzed among groups. Chest computed tomography (CT) images were scored according to Yang's classification system. Statistical analysis was performed according to the scaling nature of the variables.* **Results:** *The mean age ± standard deviation of the entire group was 55.4 ± 15.3 years. There were no statistically significant differences between body mass index (BMI) categories regarding the presence of obesity-related complications. Patients with a higher BMI had significantly higher severity scores by CT (rho $_{Spearman's}$ = 0.13; p = 0.005). Patients with higher degrees of obesity required hospitalization and intubation/mechanical ventilation more frequently. However, mortality was similar among groups.* **Conclusion:** *Mexican patients living with obesity who were infected by COVID-19 had a more aggressive disease.*

Keywords: *Obesity. COVID-19. Risk factor.*

Resumen

Introducción: *México tiene una alta prevalencia de sobrepeso y obesidad. Los pacientes que padecen estas condiciones cuando son infectados por COVID-19 tienen un mayor riesgo de experimentar una secuencia clínica más severa. El presente estudio tuvo como objetivo evaluar la obesidad como un factor de riesgo independiente para la severidad de la enfermedad y la mortalidad en pacientes mexicanos con COVID-19.* **Métodos:** *Se analizó una base de datos construida prospectivamente. Se dividió a 1027 pacientes con infección por COVID-19 en categorías basadas en la gravedad de la obesidad. Se analizaron comparativamente entre grupos las características demográficas, las comorbilidades relacionadas con la obesidad, la gravedad de la disfunción pulmonar, las puntuaciones de gravedad, la necesidad de ingreso hospitalario, la suplementación con oxígeno/ventilación mecánica y la mortalidad. Las imágenes de TC torácica se puntuaron según el sistema de clasificación de Yang. El análisis estadístico se realizó de acuerdo con la naturaleza escalar de las variables.*

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Resultados: *La edad media ± DE de todo el grupo fue de 55.4 ± 15.3 años. No hubo diferencias estadísticamente significativas entre las categorías de índice de masa corporal (IMC) en cuanto a la presencia de complicaciones relacionadas con la obesidad. Los pacientes con un IMC más elevado presentaron puntuaciones de gravedad significativamente más altas en la TC (rho de $_{Spearman}$ = 0.13; p = 0.005). Los pacientes con mayor grado de obesidad requirieron hospitalización e intubación/ventilación mecánica con mayor frecuencia. Sin embargo, la mortalidad fue similar entre los grupos.*
Conclusiones: *Los pacientes mexicanos con obesidad infectados por COVID-19 presentaron una enfermedad más agresiva.*

Palabras clave: *Obesidad. COVID-19. Factor de riesgo.*

Introduction

The coronavirus disease-2019 (COVID-19) pandemic has represented a global challenge. Since the severity of the disease is highly variable, it is very important to identify people with the highest vulnerability to acquire the disease, as well as the development of serious illness and death. Initial data showed that elderly individuals, as well as people with type 2 diabetes (T2D) or arterial hypertension (HTN), had an increased risk of developing a more severe disease[1].

Since December 2019, when the COVID-19 disease was declared a pandemic, several studies have found that obesity is an independent risk factor for a worse prognosis[2-7]. Recent data show that the severity of the disease is related to the body mass index (BMI) and that patients with a BMI >35 kg/m^2 often require admission to an intensive care unit (ICU) and respiratory support[5,8].

Mexico has a high prevalence of overweight and obesity[9]. Therefore, a high proportion of Mexican patients infected by COVID-19 may experience a more aggressive disease[10-12]. The present study aims to assess obesity as an independent risk factor for COVID-19 severity and mortality in Mexican patients since previous studies have suggested that comorbidities such as obesity, diabetes, and HTN are risk factors for adverse effects and death[11,12].

Methods

Once the number of COVID-19 patients began to spike in Mexico, our Institution devoted itself to the care of infected patients. A triage section was developed, and facilities were adapted. Ethical approval was given by the ABC Medical Center ethics and investigation committee (ABC-20-27).

A prospective database was constructed with 1027 consecutive patients with COVID-19 infection to keep clinical characteristics, laboratory, and image results, as well as the outcome of our patients. Infected patients who did not have a clear indication for hospitalization were sent home and monitored by periodic phone calls.

For the purpose of the study, all patients seeking medical attention at our Institution for the diagnosis of COVID-19 or suspicious symptoms or signs from March to October 2020 were included.

Inclusion criteria

Patients who tested positive for COVID-19 during the study period.

Exclusion criteria

Patients in whom weight and height had not been obtained during screening.

Patients were divided by degree of obesity into 5 groups: (1) Normal BMI ≤ 25 kg/m^2); (2) Overweight (25-29 kg/m^2); (3) Class 1 Obesity (30-34 kg/m^2); (4) Class 2 Obesity (35-39 kg/m^2); and (5) Class 3 Obesity (≥ 40 kg/m^2).

Demographic characteristics, comorbid conditions, the severity of pulmonary affection, severity scores, the need for hospital admission, oxygen (O_2) supplementation/mechanical ventilation, and mortality were comparatively analyzed among groups.

Computed tomography (CT) images of all hospitalized patients were reviewed and scored by one of the authors (HM) to determine the Chest CT Severity Score as described by Yang et al.[13]. The score corresponds to the percentage of pulmonary involvement due to pneumonia secondary to COVID-19. To calculate this score, the lungs were anatomically divided into segments as follows: right lung: 3-segment upper lobe, 2-segment middle lobe, and 5-segment lower lobe. Left lung: 3-segment upper lobe, 2-segment lingula, and 5-segment lower lobe. The apicoposterior segment of the upper lobe was divided into superior and posterior, and the anteromedial segment of the lower lobe was divided into anterior and medial, giving a total of 20 segments. If the segment was not affected

by pneumonia, the number of points for the score was 0; if the percentage of involvement was less than 50%, 1 point was given; and if it was 50% or higher, the number of points was 2. The severity score by CT was based on a receiver operating characteristic analysis, a cut-off point of 19.5 was suggested to distinguish moderate from severe disease in the original publication, with a sensitivity of 83.3%, a specificity of 94%, a positive predictive value of 75%, and a negative predictive value of 96.3%[4]. We adopted this cut-off point in our study.

For the analysis of outcomes, patients were stratified as follows: (1) ambulatory patients who never required hospitalization; (2) need for hospitalization without O_2 support; (3) need for O_2 supplementation; (4) need for high-flow O_2; (5) need for intubation/mechanical ventilation; and (6) death. The final outcome was considered for the analysis.

Two severity scales were used in the analysis: (1) The MULBSTA score, which is an early warning model for predicting mortality in viral pneumonia based on multinodular infiltrates, lymphocyte ≤ 0.8 × 10^9/L, bacterial coinfection, smoking history, HTN, and age ≥ 60 years[14]. (2) The CALL score, a risk-factor scoring system based on patients' age, comorbidities, lymphocyte count, and serum LDH at presentation that could identify 3 levels of group risk according to their probabilities of progression: those who scored 4-6 points had < 10% probability of progression and were considered low risk (class A), 7-9 points with a 10-40% probability of progression were intermediate risk (class B), and 10-13 points with more than 50% probability were considered high risk (class C). The CALL scores from 4 to 13 points. For lymphocyte scores, the definition of lymphopenia was (a 1.0 × 10^9/L). For LDH, there were 3 levels: No more than 250 U/L (the upper normal limit in our laboratories), between 250 and 500 U/L, and more than 500 U/L[15].

A statistical analysis was performed according to the intrinsic scaling for every included variable. Descriptive and inferential statistics were performed accordingly. All $p < 0.05$ were considered statistically significant.

For the multivariate analyses, a binary logistic regression was used, considering the impact of all included variables regarding death as the target outcome. Several statistical regression models were performed, including enter, forward, and backward stepwise models (with the conditional, likelihood ratio, and Wald methods), considering some statistical criteria (pin 0.05, pout 0.10, iterate 20, and cut 0.05). The variables included in these models were gender, age, BMI, arterial HTN, T2D, MULBSTA, CALL, LDH, ferritin, and leukocyte count.

Results

From March to October 2020, a total of 1027 patients with COVID-19 infection were seen at the ABC Medical Center. The demographic characteristics of the study population are shown in Table 1, and Fig. 1 shows the flowchart of the patient population.

According to the degree of obesity, a total of 26.3% had a normal BMI, 42.8% were overweight, 20.5% had class 1 obesity, 7.1% had class 2, and 3.3% had class 3. The mean ± standard deviation age of the entire group was 55.5 ± 15.3 years. Age was negatively (inversely) correlated to the degree of obesity ($r_{Kendall's\ tau\text{-}b} = -0.144$; $p < 0.0001$), as well as age statistically resulted significantly among BMI groups (Analysis of variance [ANOVA]; $p < 0.0001$). Women had a normal weight or higher BMI in contrast with most men who were predominantly overweight or had Class 1 obesity (Cramer's V $p < 0.0001$; Kendall's tau-b $p = 0.003$). We were not able to demonstrate statistically significant differences among ordinal BMI groups regarding the presence of T2D (Kendall's tau-b; $p = 0.073$), HTN (Kendall's tau-b; $p = 0.37$), OSAS (Kendall's tau-b; $p = 0.094$), ischemic cardiopathy (Kendall's tau-b; $p = 0.29$), and immunosuppression (Kendall's tau-b; $p = 0.07$).

Table 2, and Fig. 2 show how patients with a higher degree of obesity also had significantly higher scores of severity on the chest CT (ANOVA; $p = 0.009$). Moreover, BMI negatively (inversely) correlated to the MULBSTA ($rho_{Spearman's} = -0.15$; $p < 0.0001$) and the CALL ($rho_{Spearman's} = -0.07$; $p = 0.04$) scores. There was a strong correlation between the severity assessed by the MULBSTA and CALLS scores and the severity index of the CT scans (rho Spearman's = 0.32 for MULBSTA and 0.26 for CALLS; $p < 0.0001$ for both contrasts).

Furthermore, patients with higher degrees of obesity also had worse clinical outcomes. As shown in Fig. 3, significant differences related to the need for hospitalization and intubation/mechanical ventilation between normal weight and obesity were observed (12.6 vs. 33.8%, respectively; $p < 0.0001$). In spite of this, mortality was similar among BMIs considered as a continuous (T-test; $p = 0.43$) or ordinal scale (Kendall's tau-b; $p = 0.43$). Death was statistically associated with other clinical variables such as MULBSTA score (ANOVA; $p < 0.0001$), CALLS

Table 1. General characteristics of our studied cohort

Variable	Overall (n = 1027)	Normal BMI (n = 270) (26.3%)	Overweight (n = 440) (42.8%)	Class 1 Obesity (n = 210) (20.4%)	Class 2 Obesity (n = 73) (7.1%)	Class 3 Obesity (n = 34) (3.3%)
Age, mean (SD) years	52 (16.2)	52.6 (19.2)	53 (15.8)	51.2 (14)	48 (13.2)	48.6 (11.6)
< 20 years old, n (%)	8 (0.7)	5 (1.8)	2 (0.4)	0	0	1 (2.94)
20-29 years old, n (%)	70 (6.8)	31 (11.4)	28 (6.3)	7 (3.3)	4 (5.4)	0
30-39 years old, n (%)	184 (17.9)	50 (18.5)	70 (15.9)	40 (19)	17 (23.2)	7 (20.5)
40-49 years old, n (%)	208 (20.2)	37 (13.7)	90 (20.4)	53 (25.2)	18 (24.6)	10 (29.4)
50-59 years old, n (%)	209 (20.3)	40 (4.8)	93 (21.1)	46 (21.9)	20 (27.4)	10 (29.4)
60-69 years old, n (%)	179 (17.4)	47 (17.4)	79 (17.9)	41 (19.5)	8 (10.9)	4 (11.7)
70-79 years old, n (%)	118 (11.4)	36 (13.3)	56 (12.7)	18 (8.5)	6 (8.2)	2 (5.8)
> 80 years old, n (%)	51 (4.9)	24 (8.8)	22 (5)	5 (2.3)	0	0
Males, n (%)	650 (63.3)	137 (50.7)	307 (69.8)	140 (66.7)	46 (63)	20 (58.8)
Females, n (%)	377 (36.7)	133 (49.3)	133 (30.2)	70 (33.3)	27 (37)	14 (41.2)
Weight, mean (SD) kilograms	80 (16.6)	64.2 (9.6)	78 (9.1)	90.5 (10.7)	103.7 (14)	114.7 (16.5)
Height, mean (SD) meters	1.68 (0.1)	1.67 (0.1)	1.69 (0.1)	1.68 (0.1)	1.67 (0.1)	1.63 (0.1)
BMI, mean (SD) kg/m^2	28.3 (5.2)	22.8 (1.8)	27.2 (1.4)	32.2 (1.4)	37.1 (1.4)	42.9 (3.2)
Length of intubation, mean (SD) days	13.3 (10.2)	13.6 (11.9)	13.6 (11)	12.6 (8.2)	13.1 (8.8)	13.7 (8.6)
Length of stay, mean (SD) days	12.7 (10.3)	11 (10.4)	13.1 (10.9)	13.2 (8.9)	13.6 (10.1)	15.2 (10)
Physician (MD) as the main job, n (%)	13 (1.6)	5 (38)	4 (30)	2 (15.3)	1 (7.6)	1 (7.6)
MULBSTA, mean (SD) points	8.3 (3.6)	8.8 (3.5)	8.9 (3.6)	7.6 (3.6)	7.4 (3.5)	6.7 (3.4)
CALL, mean (SD) points	7.9 (2.6)	8 (2.7)	8.1 (2.6)	7.7 (2.5)	7.5 (2.4)	7.5 (2.4)
Days with symptoms, mean (SD)	9.55 (6.1)	10.1 (7.6)	9.7 (6)	9.8 (5)	9.8 (4.2)	9.6 (5.5)
Axillary temperature, mean (SD) Celsius	36.6 (2.1)	36.4 (0.6)	36.6 (0.8)	37 (4.2)	36.7 (0.8)	36.6 (0.9)
Systolic arterial pressure, mean (SD) mmHg	119 (15.3)	118.4 (17.3)	118.9 (13.9)	119.2 (15.3)	120.1 (15.3)	120.6 (17.7)
Diastolic arterial pressure, mean (SD) mmHg	70.3 (10)	69.2 (9.5)	70.1 (9.2)	71.6 (11.4)	71.3 (9.9)	70.6 (12.8)
Oxygen saturation, mean (SD) %	86.1 (9.4)	87.6 (7.6)	85.5 (10)	86.6 (8.8)	83.7 (11.1)	84.4 (11.5)
Length of stay in the ICU, mean (SD) days	14 (12.1)	12.6 (13.5)	13.9 (12.4)	14.2 (10)	17.6 (12.6)	15.5 (9.3)
Deaths, n (%)	54 (5.3)	16 (29.6)	25 (46.2)	10 (18.5)	4 (7.4)	3.7

SD: Standard deviation; BMI: Body mass index.

($p < 0.0001$), severity index by CT scan ($p < 0.0001$), DHL ($p < 0.0001$), D-dimer ($p = 0.028$), ferritin ($p = 0.001$), and leucocyte count ($p = 0.013$). The two-step cluster analysis did not reveal any combinatorial pattern with our significant variables for fatal outcomes in our cohort of patients. The CT-S index was consistently significant across all these models with a statistically significant odds ratio (OR) (Exp B = 1.19; $p = 0.036$).

In the group of patients who never required hospitalization, the prevalence of people with a normal BMI was higher. In a mean follow-up of 1 month, none of them required hospitalization.

Discussion

In our study, we found that people living with obesity have a higher risk of hospitalization, advanced pulmonary

Table 2. Pulmonary severity scores determined by CT scans according to patients' obesity degree in our cohort

WHO Obesity Categories	n	%	Mean	Median	SD	p*
Normal weight	107	22.2	16.2	15	10.8	0.009
Overweight	212	44.1	20.5	21	10.2	
G1 Obesity	106	22.0	20.0	19.5	11.1	
G2 Obesity	36	7.5	19.5	21.5	10.1	
G3 Obesity	20	4.2	21.9	20.5	10.2	
Total/General	481	100	19.41	19	10.6	

*Analysis of variance test. CT: Computed tomography; WHO: World Health Organization; SD: Standard deviation.

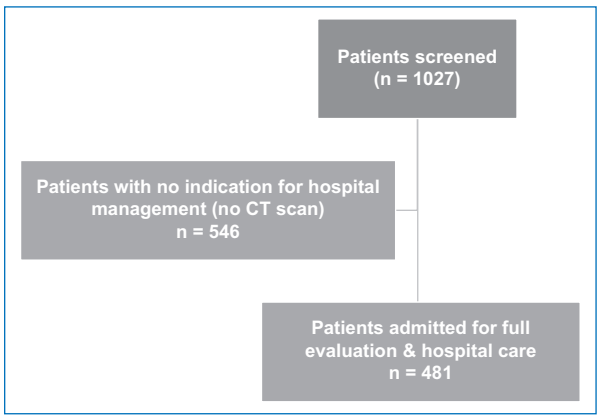

Figure 1. Flowchart of patients.

disease, and the need for intubation when infected by COVID-19 than patients with a normal body weight. This was independent of gender, age, and obesity-associated comorbidities.

In a previous study, the impact of comorbidities such as obesity, diabetes, and HTN as risk factors for adverse effects and death was assessed in 13,842 Mexican patients with laboratory-confirmed severe acute respiratory syndrome-Coronavirus-2 (SARS-CoV-2). Among the SARS-CoV-2-positive cases, 45.3% had at least one comorbidity. The proportion of patients who developed adverse events increased with the number of comorbidities and was higher in the groups with two, three, or more comorbidities[16]. In a similar way, in a retrospective observational analysis carried out in a cohort of 71,103 patients (15,529 tested positive for SARS-Cov-2), the authors demonstrated that obesity was present in 30% of the positive-test non-survivors and was found to be the leading risk factor for death with higher adjusted mortality (hazard ratio = 2.47, 95% confidence interval [CI] 2.04-2.98). Obesity was associated with an increased risk of secondary adverse outcomes, such as pneumonia, hospitalization, invasive mechanical ventilation, and ICU admission[17].

Our findings are also consistent with other previous studies showing that 68.6% of 124 patients from a French cohort with mild obesity (46.7% with BMI >30 kg/m^2) and severe obesity (28.2% with BMI >35 kg/m^2) required invasive mechanical ventilation, and the requirements of mechanical ventilation increased as the BMI also increased. The authors concluded that obesity was an independent risk factor for severity due to SARS-CoV-2[8].

An Italian study of 92 patients designed to evaluate the relationship between the severity of COVID-19 and obesity reported a higher requirement for invasive and non-invasive mechanical ventilation in overweight patients and patients living with obesity, as well as a higher frequency of admission to the ICU. This higher predisposition in patients with obesity to more severe disease was independent of age, gender, and other comorbidities[18].

In a prospective study carried out on 5279 patients in New York City looking for outcomes, of patients admitted to the hospital for COVID-19, the authors identified that in addition to risk factors, such as age, male gender, cardiovascular disease, and kidney disease, any increase in the BMI was related to increased severity of the disease[19].

In a national cohort study of 88,747 veterans in the United States, the authors found that the prevalence of obesity was very high in patients with SARS-CoV-2 (44.8%), that the rates of hospitalization and mechanical ventilation were also higher in patients with obesity, but that obesity was not associated with increased mortality[20]. Most previous studies analyzed the outcomes of hospitalized patients. What is peculiar about our study is that we were able to analyze 200 infected patients who never required hospitalization.

Finally, in a meta-analysis carried out to re-evaluate the relationship between obesity and COVID-19 in 50 studies, with a total of 18,260,378 patients included, obesity was associated with an increased risk of SARS-CoV2 infection (OR: 1.39, 95% CI: 1.25-1.54; $p < 0.00001$) and higher severity, need for admission to the ICU, invasive mechanical ventilation, and mortality[21].

In a meta-analysis published in 2021, Popkin and colleagues also found a close association between obesity

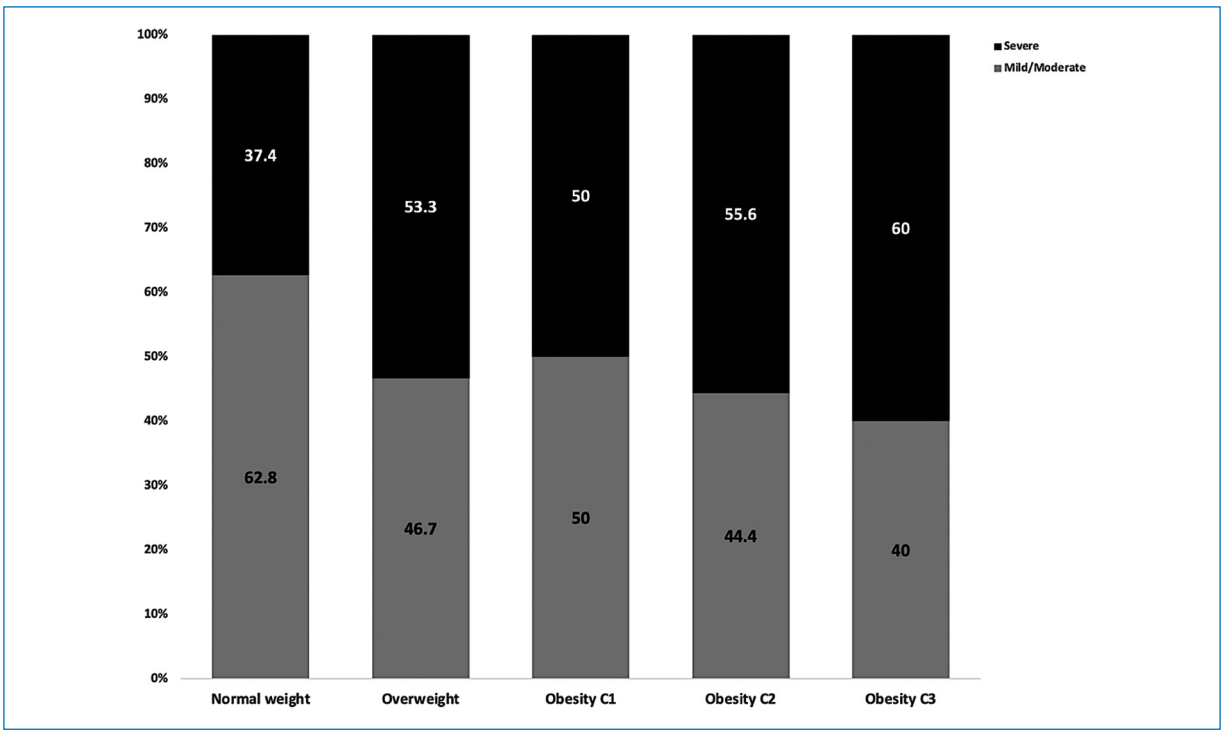

Figure 2. Pulmonary severity is evaluated by computed tomography scan across the different body mass index categories.

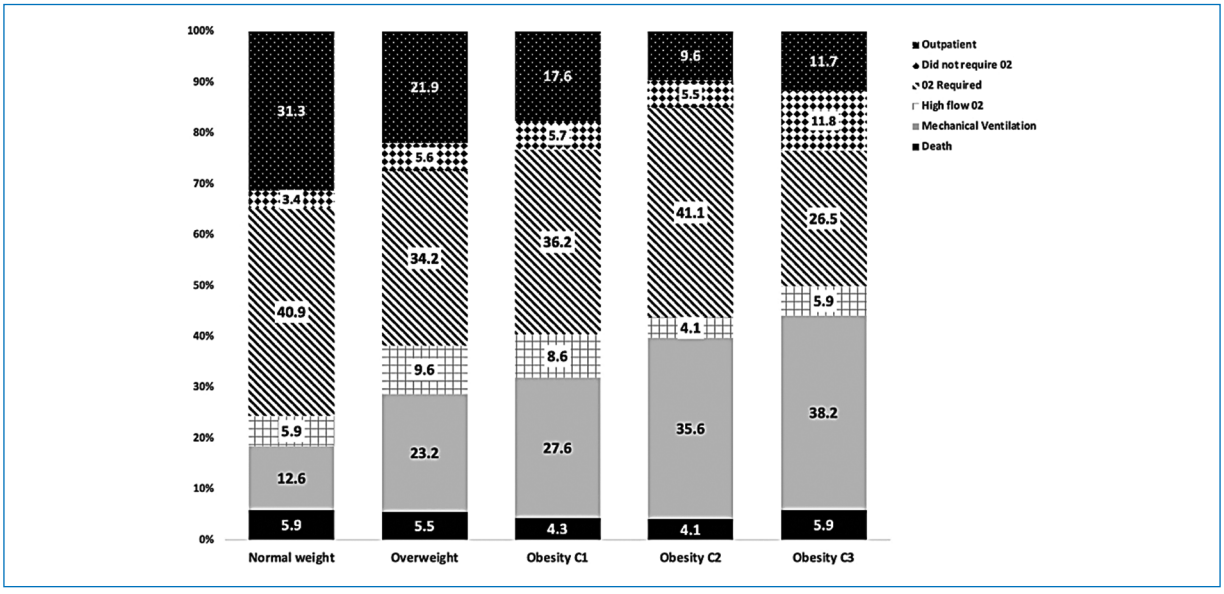

Figure 3. Clinical interventions across the different body mass index categories.

and COVID-19, and in a systematic review of 75 studies (including five case-control studies, 33 retrospective or prospective cohort studies, and 37 observational cross-sectional studies) conducted between January and June 2020, it was shown that people living with obesity had a higher risk of becoming positive for COVID-19, a higher risk of hospitalization, ICU admission, and mortality[22].

The higher predisposition of patients living with obesity to develop a more severe disease may be related to the obesity itself or the occurrence of comorbid diseases such as T2D, HTN, dyslipidemia, and cardiovascular and renal diseases[23]. In our study, all comorbid conditions had a similar distribution in the groups with different obesity categories.

It is known that obesity is a multifactorial disease that is associated with metabolic impairment (including insulin resistance, elevated serum glucose, and altered adipokines) and low-grade inflammation that plays a crucial role in the presentation of severe disease due to COVID-19[23,24].

The increased adipose tissue predisposes to greater infiltration of type 1 macrophages with the consequent production of inflammatory cytokines such as tumor necrosis factor-alpha TNFα, Interleukin (IL)-1β, and IL-6. This condition entails dysregulation of the innate and adaptive immune response in people with obesity, which predisposes them to a greater susceptibility to infections, a more severe evolution of the disease, and a poorer response to treatment[25,26].

Although direct inoculation of the SARS-CoV-2 virus has not been demonstrated in adipose tissue, the expression of the angiotensin-converting enzyme receptor in this tissue is a key element in the viral tropism. Fatty acids, such as cholesterol, are known to be essential in the spread of enveloped RNA viruses, such as respiratory syncytial viruses and influenza. SARS-CoV, the closest relative to SARS-CoV-2, uses cholesterol to facilitate viral budding after binding to protein S at cellular ACE2 receptors; this response allows the spread to other cells[27,28].

It is also likely that the hematogenous spread of the virus toward the adipose tissue through routes that go from adjacent organs to visceral fat deposits such as intrathoracic, epicardial, perirenal, and mesenteric fat, which may prolong the time of virus shedding in humans, may be related to the higher vulnerability of people with obesity to develop a more severe disease[28].

Similarly, patients with obesity may have respiratory dysfunction characterized by an increase in resistance of the respiratory tract, a decrease in expiratory volume and forced capacity, an imbalance in gas exchange, and a decrease in the strength of the respiratory muscles—factors that predispose patients to a higher risk of pneumonia, pulmonary HTN, and cardiac dysfunction. The physical characteristics of people living with obesity also increase the severity and risk of complications from COVID-19. Particularly, obstructive sleep apnea syndrome and other respiratory dysfunctions increase the risk of pneumonia associated with hypoventilation, pulmonary HTN, and cardiac stress. Increased waist circumference and greater body mass raise the difficulty of care in the hospital setting for certain therapies, such as intubation, non-invasive mechanical ventilation, or the prone position. Therefore, the prognosis of patients with obesity and COVID-19 may be complicated by the increasing burden of clinical care among this already vulnerable group[29-31].

Conclusion

We realize that potential confounding variables such as variable body composition among the studied groups, different times from the onset of the disease and the testing, a lack of standard criteria for hospitalization, variable socioeconomic status, and the fact that some patients who were not admitted to the hospital may have been subsequently hospitalized in a different institution should be considered limitations to the study.

Our study found that in a Mexican population, patients with obesity who were infected by COVID-19 had a clinically more aggressive disease characterized by a higher risk of hospitalization, intubation, and mechanical intubation, as well as a more severe pulmonary involvement demonstrated by a CT scan.

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Conflicts of interest

The authors declare no conflicts of interest.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article. Furthermore, they have acknowledged and followed the recommendations as per the SAGER guidelines depending on the type and nature of the study.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

Use of artificial intelligence for generating text. The authors declare that they have not used any type of generative artificial intelligence for the writing of this manuscript nor for the creation of images, graphics, tables, or their corresponding captions.

References

1. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese center for disease control and prevention. JAMA. 2020;323:1239-42.
2. Tadayon Najafabadi B, Rayner DG, Shokraee K, Shokraie K, Panahi P, Rastgou P, et al. Obesity as an independent risk factor for COVID-19 severity and mortality. Cochrane Database Syst Rev. 2023;5:CD015201.
3. Fresán U, Guevara M, Elía F, Albéniz E, Burgui C, Castilla J, et al. Independent role of severe obesity as a risk factor for COVID-19 hospitalization: a Spanish population-based cohort study. Obesity (Silver Spring). 2021;29:29-37.
4. Klang E, Kassim G, Soffer S, Freeman R, Levin MA, Reich DL. Severe obesity as an independent risk factor for COVID-19 mortality in hospitalized patients younger than 50. Obesity (Silver Spring). 2020;28:1595-9.
5. De Araújo MF, Monteiro FP, de Araújo TM, Lira Neto JC, Santos LF, Rolim IL, et al. Individual and mutual effects of diabetes, hypertension, and obesity on acute respiratory distress syndrome mortality rates in clinical patients: a multicentre study. Front Public Health. 2023;11:1219271.
6. Vassilopoulou E, Bumbacea RS, Pappa AK, Papadopoulos AN, Bumbacea D. Obesity and infection: what have we learned from the COVID-19 pandemic. Front Nutr. 2022;9:931313.
7. Bhaskar S, Jovanovic S, Katyal A, Namboodiri NK, Chatzis D, Banach M. Is COVID-19 another case of the obesity paradox? Results from an international ecological study on behalf of the REPROGRAM consortium obesity study group. Arch Med Sci. 2021;19:25-34.
8. 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.
9. Instituto Nacional de Estadística y Geografía, Instituto Nacional de Salud Pública. Encuesta Nacional de Salud y Nutrición 2018-19: resultados Nacionales. Cuernavaca, México: Instituto Nacional de Salud Pública; 2020.
10. John Hopkins University and Medicine. Mortality in the 20 Most Affected Countries Worldwide John Hopkins University, Coronavirus Resource Center. Available from: https://coronavirus.jhu.edu/data/mortality
11. Torres-Ibarra L, Basto-Abreu A, Carnalla M, Torres-Alvarez R, Reyes-Sanchez F, Hernández-Ávila JE, et al. SARS-CoV-2 infection fatality rate after the first epidemic wave in Mexico. Int J Epidemiol. 2022;51:429-39.
12. Camacho Moll ME, Mata Tijerina VL, Silva Ramírez B, Peñuelas Urquides K, González Escalante LA, Escobedo Guajardo BL, et al. Sex, age, and comorbidities are associated with SARS-CoV-2 infection, COVID-19 severity, and fatal outcome in a Mexican population: a retrospective multi-hospital study. J Clin Med. 2023;12:2676.
13. Yang R, Li X, Liu H, Zhen Y, Zhang X, Xiong Q, et al. Chest CT severity score: an imaging tool for assessing severe COVID-19. Radiol Cardiothorac Imaging. 2020;2:e200047.
14. Iijima Y, Okamoto T, Shirai T, Mitsumura T, Sakakibara R, Honda T, et al. MuLBSTA score is a useful tool for predicting COVID-19 disease behavior. J Infect Chemother. 2021;27:84-290.
15. Ji D, Zhang D, Xu J, Chen Z, Yang T, Zhao P, et al. Prediction for progression risk in patients with COVID-19 pneumonia: the CALL score. Clin Infect Dis. 2020;71:1393-9.
16. Kammar-García A, Vidal-Mayo JJ, Vera-Zertuche JM, Lazcano-Hernández M, Vera-López O, Segura-Badilla O, et al. Impact of comorbidities in Mexican SARS-COV-2-positive patients: a retrospective analysis in a national cohort. Rev Invest Clin. 2020;72:151-8.
17. Vera-Zertuche JM, Mancilla-Galindo J, Tlalpa-Prisco M, Aguilar-Alonso P, Aguirre-García MM, Segura-Badilla O, et al. Obesity is a strong risk factor for short-term mortality and adverse outcomes in Mexican patients with COVID-19: a national observational study. Epidemiol Infect. 2021;149:e109.
18. Busetto L, Bettini S, Fabris R, Serra R, Dal Pra C, Maffei P, et al. Obesity and COVID-19: an Italian snapshot. Obesity (Silver Spring). 2020;28:1600-5.
19. Petrilli CM, Jones SA, Yang J, Rajagopalan H, O'Donnell L, Chernyak Y, et al. Factors associated with hospital admission and critical illness among 5279 people with coronavirus disease 2019 in New York City: prospective cohort study. BMJ. 2020;369:m1966.
20. Ioannou GN, Locke E, Green P, Berry K, O'Hare AM, Shah JA, et al. Risk factors for hospitalization, mechanical ventilation, or death among 10 131 US veterans with SARS-CoV-2 infection. JAMA Netw Open. 2020;3:e2022310.
21. Yang J, Ma Z, Lei Y. A meta-analysis of the association between obesity and COVID-19. Epidemiol Infect. 2020;149:e11.
22. Popkin BM, Du S, Green WD, Beck MA, Algaith T, Herbst CH, et al. Individuals with obesity and COVID-19: a global perspective on the epidemiology and biological relationships. Obes Rev. 2020;21:e13128.
23. Singla P, Bardoloi A, Parkash AA. Metabolic effects of obesity: a review. World J Diabetes. 2010;1:76-88.
24. Rasouli N, Kern PA. Adipocytokines and the metabolic complications of obesity. J Clin Endocrinol Metab. 2008;93:S64-73.
25. Ganeshan K, Chawla A. Metabolic regulation of immune responses. Annu Rev Immunol. 2014;32:609-34.
26. McLaughlin T, Ackerman SE, Shen L, Engleman E. Role of innate and adaptive immunity in obesity-associated metabolic disease. J Clin Invest. 2017;127:5-13.
27. Glende J, Schwegmann-Wessels C, Al-Falah M, Pfefferle S, Qu X, Deng H, et al. Importance of cholesterol-rich membrane microdomains in the interaction of the S protein of SARS-coronavirus with the cellular receptor angiotensin-converting enzyme 2. Virology. 2008;381:215-21.
28. Ryan PM, Caplice NM. Is adipose tissue a reservoir for viral spread, immune activation, and cytokine amplification in coronavirus disease 2019? Obesity (Silver Spring). 2020;28:1191-4.
29. Nikniaz Z, Somi MH, Dinevari MF, Taghizadieh A, Mokhtari L. Diabesity associates with poor COVID-19 outcomes among hospitalized patients. J Obes Metab Syndr. 2021;30:149-54.
30. Stefan N, Birkenfeld AL, Schulze MB, Ludwig DS. Obesity and impaired metabolic health in patients with COVID-19. Nat Rev Endocrinol. 2020;16:341-2.
31. Sattar N, McInnes IB, McMurray JJ. Obesity is a risk factor for severe COVID-19 infection: multiple potential mechanisms. Circulation. 2020;142:4-6.