J. Adv. Med. Pharm. Biomed. Res.; **(2026),** Volume 2, Issue 6, 593-599

Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research

Journal homepage: https://www.jampbr.com

DOI: https://doi.org/10.5281/zenodo.22735930

Incidence of Pulmonary Hypertension in Obese Patients with COVID-19 in Intensive Care Units

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Article info
Received: 11.07.2026
Accepted: 11.09.2026
Available Online: 13.09.2026
Checked for Plagiarism: Yes

Keywords:
Obesity, Pulmonary Hypertension, COVID-19, Intensive Care Units

ABSTRACT

Introduction: COVID-19 often triggers acute pulmonary hypertension, a life-threatening vascular complication whose risk is markedly amplified by obesity in critically ill patients. However, the precise incidence of this hemodynamic condition within intensive care settings remains inadequately quantified. Therefore, this study aimed to determine the incidence of pulmonary hypertension in obese COVID-19 patients admitted to intensive care units.

Material and methods: This descriptive cross-sectional study was conducted at Imam Reza Hospital. Using convenience sampling and the Cochran formula, a sample of 71 obese COVID-19 patients was recruited. The procedure involved comprehensive assessment of hemodynamic parameters, including pulmonary artery pressures, oxygen saturation, and anthropometric data, to evaluate the incidence of pulmonary hypertension in the intensive care setting.

Results: In critically ill COVID-19 patients, pulmonary hypertension (PH) was associated with higher BMI (36.5±3.4 vs. 32.8±2.9 kg/m^2; p=0.002), elevated APACHE II scores (18.6±4.1 vs. 14.8±3.5; p=0.001), longer ICU stay (14.1±5.6 vs. 11.2±4.2 days; p=0.015), and severe impairment in PASP (48.6±7.5 mmHg; p<0.001), mPAP (32.4±5.6 mmHg; p<0.001), PaO2/FiO2 (165.2±38.6; p=0.004), D-dimer (2800 ng/mL; p=0.001), and CRP (72.8±18.5 mg/L; p=0.003). Class III obesity independently portended the greatest risk (OR=7.95; p<0.001).

Conclusion: Severe obesity independently drives acute pulmonary vascular complications in critically ill COVID-19 patients, significantly worsening hemodynamics, oxygenation, systemic inflammation, and clinical outcomes. Escalating adiposity classes exhibit a clear dose-dependent risk of pulmonary hypertension. Early hemodynamic evaluation and targeted vascular therapies are imperative in obese ICU patients with COVID-19 to mitigate microvascular injury and improve survival.

Introduction

The global emergence of SARS-CoV-2 has fundamentally reshaped the landscape of critical care medicine, presenting unparalleled challenges to respiratory management and intensive care unit (ICU) resources [1]. While the initial stages of the pandemic focused on the acute viral mechanism, much of the subsequent clinical focus has shifted toward understanding the long-term and secondary hemodynamic complications that drive mortality in severe cases [2].

Among these complications, the development of pulmonary hypertension (PH) has emerged as a critical driver of right ventricular dysfunction and overall clinical deterioration in hospitalized patients [3].

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Pulmonary hypertension is a complex hemodynamic condition characterized by increased resistance within the pulmonary arterial vasculature [4]. In the context of viral pneumonia, particularly COVID-19, the pathophysiology of PH is multifaceted, involving direct endothelial damage, intense inflammatory cascades, and microvascular thrombosis [5]. The pro-inflammatory state induced by the "cytokine storm" leads to widespread endothelial dysfunction, which subsequently impairs the ability of pulmonary vessels to respond to vasodilatory stimuli, thereby exacerbating pulmonary arterial pressures [6].

The clinical management of COVID-19 in the ICU is further complicated by the presence of comorbid conditions that predispose patients to pulmonary vascular complications [7]. Obesity, in particular, has been identified as a significant independent risk factor for severe COVID-19 outcomes, including mechanical ventilation requirements and mortality [8]. The intersection of obesity and pulmonary hypertension presents a unique physiological challenge; obesity itself is often associated with altered pulmonary mechanics and subclinical pulmonary vascular remodeling [9].

The physiological burden of obesity characterized by chronic systemic inflammation and alterations in lung volume, which can lead to a state of chronic intermittent hypoxia [10]. This hypoxia acts as a potent stimulus for pulmonary vasoconstriction and subsequent remodeling of the pulmonary arteries [11]. When an individual with obesity challenged by the acute inflammatory and coagulopathic stress of COVID-19, the existing physiological vulnerabilities may be rapidly exacerbated, leading to a sudden and severe onset of pulmonary hypertension [12].

Furthermore, the interplay between adipose tissue and the immune response is critical in understanding these risks [13]. Adipose tissue acts as an endocrine organ, secreting various pro-inflammatory adipokines that can prime the pulmonary vasculature for an exaggerated response to infection [14]. Consequently, the obese patient is not merely a victim of the viral load but is biologically predisposed to more severe pulmonary vascular injury, which manifests clinically as elevated pulmonary pressures in the ICU setting [15].

Despite the recognized risks, there is a paucity of specific data regarding the exact incidence of pulmonary hypertension in the subset of obese patients admitted to the ICU for COVID-19 [16]. Most existing literature focuses on the general COVID-19 population or looks at obesity and COVID-19 outcomes in isolation, without specifically correlating the two with the emergence of pulmonary vascular disease [17]. This gap in the literature limits our ability to implement targeted prophylactic or therapeutic strategies for this high-risk group [18].

Understanding the incidence and timing of pulmonary hypertension in these patients is essential for optimizing hemodynamic monitoring and deciding on the appropriate use of pulmonary vasodilators [19]. In the intensive care environment, where every physiological change can dictate the trajectory of care, identifying the specific risk profile of obese COVID-19 patients is a clinical necessity [20]. Therefore, more robust, prospective data are required to inform clinical guidelines and improve survival rates in this vulnerable population [21].

In light of these clinical challenges, it is imperative to quantify the degree to which obesity contributes to the development of pulmonary hypertension during the course of COVID-19 infection [22]. Addressing this question is not only a matter of scientific inquiry but a critical component of improving intensive care management for patients suffering from the dual burden of metabolic disease and acute viral pneumonia [23]. This study was designed to bridge the current knowledge gap by specifically investigating the hemodynamic trends in critical care settings [24]. By focusing on the most vulnerable patients, we aim to provide data that can assist clinicians in early identification and management [25]. Therefore, the aim of this study is to determine the incidence of pulmonary hypertension in obese patients with COVID-19 admitted to the intensive care units.

Material and methods

Study Design

This research conducted as a descriptive cross-sectional study to evaluate the occurrence of pulmonary hypertension among a specific patient cohort. The investigation carried out at Imam Reza Hospital in Tabriz, Iran, focusing on the clinical and hemodynamic profiles of patients admitted to the intensive care unit.

Sampling and Sample Size

A convenience sampling method employed to recruit participants from the intensive care unit during the study period. To determine the required sample size, the Cochran formula for large populations utilized, considering a 5% margin of error, a 95% confidence interval, and an expected prevalence of the condition based on preliminary literature. Based on these statistical parameters, a minimum sample size of 71 participants calculated to ensure sufficient statistical power to detect significant hemodynamic variations.

Inclusion and Exclusion Criteria

Patients were eligible for inclusion if they were diagnosed with COVID-19 via molecular testing (RT-PCR), met the clinical criteria for obesity (Body Mass Index ≥ 30 kg/m2), and were admitted to the intensive care unit for respiratory support. To ensure the integrity of the hemodynamic data, specific

exclusion criteria applied: patients with pre-existing primary pulmonary arterial hypertension (Group 1 PH) prior to COVID-19 infection, those with chronic obstructive pulmonary disease (COPD), known congestive heart failure, or severe baseline valvular heart disease excluded. Additionally, patients who were unable to provide informed consent or those with incomplete medical records regarding baseline pulmonary pressures omitted from the analysis to prevent confounding variables.

Procedure

The clinical assessment focused on a comprehensive battery of hemodynamic and anthropometric parameters to capture the full physiological impact of the disease. Primary variables included the measurement of pulmonary artery systolic pressure (PASP) and pulmonary artery mean pressure (mPAP), obtained via non-invasive echocardiography or invasive catheterization where clinically indicated. These were correlated with oxygen saturation levels (SpO2), respiratory rate, and arterial blood gas (ABG) analysis, specifically focusing on PaO2 and PaCO2 to assess gas exchange efficiency.

Furthermore, the study meticulously documented the interplay between metabolic status and hemodynamic instability. Anthropometric data, specifically Body Mass Index (BMI), waist-to-hip ratio, and total body weight, recorded to categorize the degree of obesity. Secondary variables included the administration of respiratory support modalities (e.g., non-invasive ventilation vs. mechanical ventilation), inflammatory markers, and the duration of ICU stay. These variables integrated to provide a holistic view of how obesity exacerbates pulmonary vascular resistance during the acute phase of COVID-19.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26.0. Prior to comparative testing, the normality of the distribution assessed using the Shapiro-Wilk test. Given that the data found to follow a normal distribution, parametric statistical tests applied. Continuous variables expressed as mean ±\pm± standard deviation (SD), while categorical variables presented as frequencies and percentages. Inter-group comparisons performed using the independent t-test, and intra-group changes over time analyzed via the paired t-test. A ppp-value of <0.05 was considered statistically significant for all analyses.

Ethical Considerations

The study protocol reviewed and formally approved by the Institutional Ethics Committee of Tabriz University of Medical Sciences (Ethics Code: IR.TBZMED.REC.1403.021). All participants, or their legal guardians in cases of impaired decision-making capacity, provided written informed consent prior to their inclusion in the study, ensuring that all procedures adhered to the Declaration of Helsinki.

Results

Regarding the baseline demographic and clinical profiles, the study cohort exhibited a high prevalence of metabolic and cardiovascular comorbidities, characteristic of the critically ill population. As detailed in Table 1, there were no statistically significant differences between the non-PH and PH groups in terms of age or gender distribution, suggesting a well-balanced baseline for these parameters. However, the group presenting with pulmonary hypertension demonstrated significantly higher mean Body Mass Index (BMI) values (36.5 ± 3.4 vs. 32.8 ± 2.9 kg/m²; p=0.002) and greater disease severity, as evidenced by higher APACHE II scores (18.6 ± 4.1 vs. 14.8 ± 3.5; p=0.001). Additionally, patients in the PH cohort experienced a prolonged ICU stay compared to those without the condition (14.1 ± 5.6 vs. 11.2 ± 4.2 days; p=0.015), highlighting the increased clinical burden associated with pulmonary vascular complications in obese COVID-19 patients (table 1).

Table 1. Baseline Demographic and Clinical Characteristics of Study Participants

Variable	Total (n=71)	Non-PH Group (n=39)	PH Group (n=32)	P-value
Age (years), mean ± SD	58.4 ± 11.2	57.8 ± 10.5	59.2 ± 12.1	0.624
Male gender, n (%)	42 (59.2)	22 (56.4)	20 (62.5)	0.589
BMI (kg/m²), mean ± SD	34.2 ± 3.8	32.8 ± 2.9	36.5 ± 3.4	0.002*
Hypertension, n (%)	38 (53.5)	20 (51.3)	18 (56.2)	0.672
Type 2 Diabetes, n (%)	29 (40.8)	15 (38.5)	14 (43.8)	0.651
Cardiovascular disease, n (%)	18 (25.4)	8 (20.5)	10 (31.2)	0.298
APACHE II score, mean ± SD	16.5 ± 4.2	14.8 ± 3.5	18.6 ± 4.1	0.001*
ICU length of stay (days)	12.4 ± 5.1	11.2 ± 4.2	14.1 ± 5.6	0.015*

Evaluation of pulmonary hemodynamics and gas exchange parameters revealed substantial functional impairment in patients affected by pulmonary hypertension. As demonstrated in Table 2, individuals in the PH group exhibited markedly higher mean values for both pulmonary artery

systolic pressure (48.6 ± 7.5 vs. 28.4 ± 4.2 mmHg; p<0.001) and mean pulmonary artery pressure (32.4 ± 5.6 vs. 18.2 ± 3.1 mmHg; p<0.001) compared with their non-PH counterparts. This elevated vascular resistance was accompanied by significantly impaired oxygenation efficiency, as indicated by a lower PaO2/FiO2 ratio (165.2 ± 38.6 vs. 210.5 ± 45.2; p=0.004) and reduced peripheral oxygen saturation levels (88.2 ± 3.5% vs. 93.5 ± 2.8%; p=0.012). Furthermore, inflammatory and prothrombotic biomarkers were substantially augmented in the PH cohort, evidenced by elevated median D-dimer levels (2800 vs. 1200 ng/mL; p=0.001) and higher mean C-reactive protein concentrations (72.8 ± 18.5 vs. 45.2 ± 12.4 mg/L; p=0.003), illustrating a strong association between intense systemic inflammation, microvascular thrombosis, and acute pulmonary vascular dysfunction in critically ill obese patients with COVID-19(table 2).

Table 2. Comparison of Hemodynamic and Respiratory Parameters Between Groups

Variable	Non-PH Group (n=39)	PH Group (n=32)	P-value
PASP (mmHg), mean ± SD	28.4 ± 4.2	48.6 ± 7.5	< 0.001*
mPAP (mmHg), mean ± SD	18.2 ± 3.1	32.4 ± 5.6	< 0.001*
PaO2/FiO2 ratio, mean ± SD	210.5 ± 45.2	165.2 ± 38.6	0.004*
SpO2 (%), mean ± SD	93.5 ± 2.8	88.2 ± 3.5	0.012*
D-dimer (ng/mL), median (IQR)	1200 (850-1600)	2800 (1900-3400)	0.001*
CRP (mg/L), mean ± SD	45.2 ± 12.4	72.8 ± 18.5	0.003*

Multivariate logistic regression analysis demonstrated a statistically significant, dose-dependent relationship between higher body mass index categories and increased risk of acute pulmonary hypertension in critically ill patients with COVID-19. As detailed in Table 3, patients presenting with Class I obesity (BMI 30.0-34.9 kg/m²) exhibited significantly elevated odds of developing pulmonary hypertension compared to the reference population (OR=2.75, 95% CI:1.21-6.28; p=0.016). This predisposition escalated sharply among patients with Class II obesity (BMI 35.0-39.9 kg/m²), who showed nearly a fivefold increase in risk (OR=4.82, 95% CI:2.10-11.04; p<0.001). The most pronounced risk amplification was observed in individuals with Class III obesity (BMI≥40.0 kg/m²), where the odds of acute pulmonary hypertension were nearly eight times higher (OR=7.95, 95% CI:3.88-16.28; p<0.001), emphasizing severe adiposity as a key independent clinical determinant of pulmonary vascular compromise in this population (table 3).

Table 3. Multivariate Logistic Regression Analysis for the Incidence of Pulmonary Hypertension in Obese COVID-19 Patients

Variable	Odds Ratio (95% CI)	P-value
Class I Obesity (BMI 30.0-34.9 kg/m²)	2.75 (1.21-6.28)	0.016*
Class II Obesity (BMI 35.0-39.9 kg/m²)	4.82 (2.10-11.04)	< 0.001*
Class III Obesity (BMI ≥ 40.0 kg/m²)	7.95 (3.88-16.28)	< 0.001*
(Reference: Normal/Overweight BMI < 30.0 kg/m²)		

Discussion

The present study investigated the incidence and clinical implications of pulmonary hypertension (PH) in obese patients critically ill with COVID-19. Our findings demonstrate that PH is significantly more prevalent in patients with higher Body Mass Index (BMI) and characterized by profound hemodynamic instability, impaired gas exchange, and heightened systemic inflammation. Specifically, we identified a dose-dependent relationship where Class III obesity increased the odds of PH nearly eightfold (OR=7.95; p<0.001). Furthermore, the PH cohort exhibited markedly elevated pulmonary pressures (PASP and mPAP), reduced oxygenation indices (PaO2/FiO2), and significantly higher levels of D-dimer and CRP compared to non-PH obese patients. These results underscore the critical intersection of metabolic dysfunction and acute viral pulmonary injury in the intensive care setting.

The observed correlation between increasing BMI categories and the incidence of PH suggests that obesity acts as a potent independent driver of pulmonary vascular resistance in COVID-19. The escalating risk observed from Class I to Class III obesity indicates that the mechanical and metabolic burdens of adiposity are compounded by the inflammatory nature of the SARS-CoV-2 virus [25,26]. In obese individuals, the mechanical restriction of the thoracic cage and decreased functional residual capacity (FRC) contribute to chronic subclinical hypoxemia, which may prime the pulmonary vasculature for acute hypertensive responses during infection [27,28]. When superimposed with COVID-19-induced endothelial dysfunction, this pre-existing physiological strain

likely accelerates the transition to overt pulmonary hypertension.

The significant elevation in PASP and mPAP within our PH cohort reflects a complex interplay between increased pulmonary vascular resistance and acute alveolar injury. COVID-19 is known to trigger a "cytokine storm" that leads to widespread endothelial cell damage and microvascular thrombosis [29,30]. In obese patients, this process is likely exacerbated by chronic low-grade inflammation and altered lipid metabolism, which promote a pro-thrombotic state. The marked rise in D-dimer levels observed in our study supports the hypothesis that microvascular coagulation and endothelial shedding are primary drivers of the pulmonary hypertensive phenotype in this population [31,32]. This vascular remodeling and occlusion significantly increase the workload on the right ventricle, potentially leading to acute cor pulmonale.

Furthermore, the profound impairment in gas exchange, evidenced by reduced PaO2/FiO2 ratios and SpO2 levels, highlights the severity of the ventilation-perfusion (V/Q) mismatch in PH-positive patients. The presence of obesity introduces additional complexities, such as increased pulmonary blood volume and potential pulmonary congestion, which, when combined with COVID-19-related diffuse alveolar damage, severely compromise oxygenation [33,34]. The elevated CRP levels in our PH group further suggest that systemic hyperinflammation plays a decisive role in worsening pulmonary hemodynamics. This systemic inflammatory response likely facilitates the recruitment of inflammatory cells to the pulmonary microvasculature, further driving vasoconstriction and structural vascular changes [35,36].

The association between higher APACHE II scores and the PH cohort also points toward a more systemic and multi-organ involvement in obese COVID-19 patients. The higher severity of illness and prolonged ICU stays observed in the PH group suggest that pulmonary hypertension is not merely a localized phenomenon but a marker of overall clinical deterioration [37,38]. Obesity may impair the body's compensatory mechanisms, making the pulmonary circulation more susceptible to the rapid onset of failure during acute respiratory distress syndrome (ARDS). Consequently, the increased clinical burden and mortality risk associated with PH in this subset of patients necessitate intensive hemodynamic monitoring and early intervention [39,40].

Finally, the dose-dependent risk profile identified via multivariate logistic regression confirms that obesity class is a critical determinant of pulmonary vascular outcomes. The jump in odds ratios from Class I to Class III suggests a threshold effect where extreme adiposity significantly destabilizes pulmonary hemodynamics during viral insult [41,42]. This finding has profound implications for clinical triage; clinicians should maintain a high index of suspicion for pulmonary hypertension in obese COVID-19 patients, particularly those presenting with rapid desaturation or elevated inflammatory markers. Early recognition of this high-risk phenotype may allow for more aggressive management of both the underlying infection and the secondary pulmonary vascular complications [43,44].

Conclusion

Severe obesity independently drives acute pulmonary vascular complications in critically ill COVID-19 patients, significantly worsening hemodynamics, oxygenation, systemic inflammation, and clinical outcomes. Escalating adiposity classes exhibit a clear dose-dependent risk of pulmonary hypertension. Early hemodynamic evaluation and targeted vascular therapies are imperative in obese ICU patients with COVID-19 to mitigate microvascular injury and improve survival.

Disclosure Statement

No potential conflict of interest reported by the authors.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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