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Obesity is a Major Risk Factor for Hospitalization in Community-Managed COVID-19 Pneumonia

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Abstract

Objective: We aimed to investigate whether the stratification of outpatients with coronavirus disease 2019 (COVID-19) pneumonia by body mass index (BMI) can help predict hospitalization and other severe outcomes.

Patients and Methods: We prospectively collected consecutive cases of community-managed COVID-19 pneumonia from March 1 to April 20, 2020, in the province of Bergamo and evaluated the association of overweight (25 kg/m² ≤ BMI < 30 kg/m²) and obesity (≥ 30 kg/m²) with time to hospitalization (primary end point), low-flow domiciliary oxygen need, noninvasive mechanical ventilation, intubation, and death due to COVID-19 (secondary end points) in this cohort. We analyzed the primary end point using multivariable Cox models.

Results: Of 338 patients included, 133 (39.4%) were overweight and 77 (22.8%) were obese. Age at diagnosis was younger in obese patients compared with those overweight or with normal weight (P < .001), whereas diabetes, dyslipidemia, and heart diseases were differently distributed among BMI categories. Azithromycin, hydroxychloroquine, and prednisolone use were similar between BMI categories (P > .05). Overall, 105 (31.1%) patients were hospitalized, and time to hospitalization was significantly shorter for obese vs over- or normal-weight patients (P < .001). In the final multivariable analysis, obese patients were more likely to require hospitalization than nonobese patients (hazard ratio, 5.83; 95% CI, 3.91 to 8.71). Results were similar in multiple sensitivity analyses. Low-flow domiciliary oxygen need, hospitalization with noninvasive mechanical ventilation, intubation, and death were significantly associated with obesity (P < .001).

Conclusion: In patients with community-managed COVID-19 pneumonia, obesity is associated with a higher hospitalization risk and overall worse outcomes than for nonobese patients.
February 23. The highest rates of infection and death in Italy were registered in this province, unfortunately making this area the ideal epidemiologic setting to study COVID-19.

We aimed to examine the association of increased body mass index (BMI; calculated as the weight in kilograms divided by the height in meters squared) with hospitalization and severe outcomes in a nonhospital setting of COVID-19 pneumonia. We collected all consecutive cases of community-managed COVID-19 pneumonia during the early weeks of the pandemic (March 1 to April 20, 2020) from a large cohort of residents in the province of Bergamo followed up by 35 primary care providers and evaluated the association of overweight and obesity with time to hospitalization (primary end point), domiciliary low-flow oxygen need, noninvasive mechanical ventilation (NIV), intubation, and death due to COVID-19 (secondary end points).

**PATIENTS AND METHODS**

**Setting and Data Sources**

We conducted a prospective observational cohort study in the province of Bergamo area, Italy. Study participants were recruited from the adult general population (aged ≥18 years) among approximately 40,000 residents followed up by 35 primary care providers and evaluated the association of overweight and obesity with time to hospitalization (primary end point), domiciliary low-flow oxygen need, noninvasive mechanical ventilation (NIV), intubation, and death due to COVID-19 (secondary end points).

**Case Ascertainment and Variables Assessed**

Incident cases of COVID-19 pneumonia were collected during the study period, that is, the early phases of pandemic in Lombardy. All adults with at least 2 of the following 4 symptoms (temperature ≥37.5°C, cough, pleuritic chest pain, and dyspnea) with pneumonia documented using computed tomography (CT) between March 1, 2020, and April 20, 2020, were included in the study. Patients were tested using reverse transcriptase–polymerase chain reaction (RT-PCR) assay for SARS-CoV-2 when clinically indicated by the local health authority. Patients not fulfilling these criteria, including asymptomatic or low-symptomatic cases without pneumonia, even if positive for SARS-CoV-2 at RT-PCR, were excluded. Patients with acute respiratory distress syndrome and/or requiring hospitalization and/or respiratory support at onset were not included. Patients with evidence of bacterial pneumonia (ie, clear imaging signs of bacterial pneumonia according to the radiologic report) were also excluded.

Patients were treated for COVID-19 infection according to medical judgment, following a shared protocol provided by the referral hospital Giovanni XXIII of Bergamo, which included hydroxychloroquine (HCQ), 200 mg, 12 hours apart for the first 2 doses, then 200 mg/day for 5 or more days; oral azithromycin, 500 mg/day, for 5 or more days; oral cefixime, 400 mg/day, for 5 or more days; oral prednisolone or equivalents, 5 to 25 mg/day, for 5 or more days; and subcutaneous enoxaparin, 4000 U/day, until mobilization or resolution of phlebitis. In general, patients started treatment with azithromycin with or without HCQ, and cefixime was added after 5 days if no improvement was seen, in case of macrolide allergy, or in addition to previous treatments in patients 65 years or older or with 1 or more comorbid condition. Prednisolone and enoxaparin were added according to clinical judgment.

General practitioners were allowed to prescribe domiciliary low-flow oxygen therapy to patients with oxygen saturation less than 93% at rest while breathing ambient air documented by pulse oximeter (<90% for patients affected by chronic obstructive pulmonary disease) or heart rate greater...
than 22 beats/min. Data for patient demographic characteristics, baseline co-morbid conditions, presenting symptoms, oxygen saturation while breathing ambient air at presentation, historical and current medication list, low-flow oxygen prescription by the general practitioners, inpatient hospitalization, invasive and noninvasive ventilator use data, and death were collected.

The study was conducted according to Strengthening the Reporting of Observational Studies in Epidemiology guidelines for cohort studies. This study was conducted in compliance with the Good Clinical Practice protocol and the Declaration of Helsinki principles and was approved by the local institutional review board.

**BMI Assessment**

The most recent patient weight and height during the 12 months preceding the index date (diagnosis of pneumonia) were collected, and BMI was calculated as described. Patients were stratified by BMI as normal weight (BMI <25 kg/m²), overweight (25 kg/m² ≤ BMI <30 kg/m²), and obese (≥30 kg/m²), according to the World Health Organization definitions.17

**Study End Points**

The primary end point was the time from the index date to hospitalization due to COVID-19 (time-to-event outcome). Secondary end points were time from the index date to death due to COVID-19 and the associations of BMI categories with hospitalization, domiciliary low-flow oxygen need, NIV, intubation, and death during the observation period.

**StatisticalAnalyses**

Categorical data were summarized as percentage, significant difference, or associations of BMI categories with secondary end points, or other clinical features were analyzed using χ² test or Fisher exact tests, when appropriate. Continuous variables were presented as mean ± SD or median and interquartile range, depending on normality demonstrated using the Kolmogorov-Smirnov test. Comparisons were performed using either Student t test for independent samples (2 tailed) or with analysis of variance comparisons with Bonferroni correction when the mean values of the 3 BMI categories were being compared.

Cox proportional hazard regression models were used to estimate the association between obesity and hospitalization (primary end point). Patients without a primary end point event had their data censored on May 31, 2020. An initial multivariable Cox regression model included as covariates demographic factors, comorbid conditions at diagnosis, and treatment for community-managed COVID-19 pneumonia. A Cox regression model including as covariates only those with significant P values at univariate analysis was performed and reported. The estimated distribution of hospitalization and death was performed using the Kaplan-Meier method and log-rank test. Multiple imputation was used to handle missing data, and model estimates and standard errors were calculated using Rubin’s rules.18

All analyses were performed using JMP Pro package (SAS Institute Inc) and SAS System for Windows, version 9.4 (SAS Institute), and P<.05 was considered statistically significant for all analyses.

**RESULTS**

**Clinical Presentation and Specific Treatments**

Of the 341 consecutive patients, 3 were excluded because patients did not meet the study criteria (ie, evidence of bacterial pneumonia on CT). A total of 338 patients were included in the analysis. Distributions of BMI ranged from 17.0 to 41.4 kg/m² (Supplemental Figure 1, available online at http://www.mayoclinicproceedings.org); 133 (39.4%) patients were overweight and 77 (22.8%) patients were obese.

Baseline demographic and clinical features are described in Table 1. Age at diagnosis was younger in obese (BMI ≥30 kg/m²) patients compared with overweight (25 kg/m² ≤ BMI <30 kg/m²) and normal-weight (BMI <25 kg/m²) patients (P<.001 in both cases by direct comparison), while...
the prevalence of male sex increased with higher BMI ($P<.001$ for both obese and overweight vs normal-weight patients, by direct comparisons). Diabetes, dyslipidemia, and heart disease were differently distributed among the BMI categories. By direct comparison, diabetes was more frequent in normal-weight compared with overweight patients, while dyslipidemia was more frequent in overweight compared with normal-weight patients ($P<.001$ for both). Heart diseases were higher in obese compared with overweight patients and in normal-weight compared with overweight patients ($P=.001$ and $P=.02$, respectively).

The proportions of patients reporting headache, syncope/presyncope, dyspnea at rest, and oxygen desaturation ($<93\%$ while breathing ambient air) progressively increased with the increasing of BMI categories, while rhinorrhea/nasal obstruction progressively decreased (Table 2). Overall, approximately $42.0\%$ ($142/338$) of patients underwent nasal swab testing for RT-PCT confirmation, and all of them had positive results.

The cumulative frequency of each drug used during the observation period for the treatment of COVID-19 pneumonia is reported in Table 2. Virtually all patients used azithromycin, more than half used HCQ, and approximately one-third used a low-medium dose of oral prednisolone or equivalents. Overall, no difference was observed among BMI categories, with the exception of paracetamol.

### Table 1. Demographic Characteristics and Baseline Comorbid Conditions of Patients With Community-Managed COVID-19 Pneumonia by BMI

| Characteristic                          | All Patients (N=338) | Normal-Weight Patients (BMI <25 kg/m²) (n=133) | Overweight Patients (BMI ≥25 kg/m²) (n=128) | Obese Patients (BMI ≥30 kg/m²) (n=77) | $P^b$ |
|----------------------------------------|----------------------|-----------------------------------------------|--------------------------------------------|--------------------------------------|-------|
| Age at diagnosis (y), mean ± SD        | 65.7±13.1            | 66.5±14.9                                     | 67.4±11.6                                  | 61.3±12.1                            | .003  |
| Male sex, % (no.)                      | 59.4 (201)           | 45.9 (61)                                     | 67.2 (86)                                  | 70.1 (54)                            | <.001 |
| Body weight (kg), mean ± SD            | 79.8±17.4            | 66.2±9.5                                      | 82.4±12.1                                  | 99.0±15.0                            | <.0001|
| Height (m), mean ± SD                  | 1.8±0.09             | 1.7±0.09                                      | 1.7±0.09                                   | 1.7±0.10                             | .612  |
| Ethnicity, White, % (no.)              | 91.4 (309)           | 90.2 (120)                                    | 89.8 (115)                                 | 96.1 (74)                            | .421  |
| Smoking, current or former, % (no.)    | 26.9 (91)            | 28.7 (37)                                     | 31.3 (40)                                  | 18.1 (14)                            | .119  |
| Packyears, mean ± SD                   | 18±6                 | 20±7                                           | 17±6                                       | 16±4                                 | .112  |
| No comorbid conditions, % (no.)        | 110 (37)             | 143 (19)                                      | 8.6 (11)                                   | 9.1 (7)                              | .284  |
| Diabetes, % (no.)                      | 24.3 (82)            | 33.8 (45)                                     | 14.8 (19)                                  | 23.4 (18)                            | .002  |
| Blood hypertension, % (no.)            | 45.23 (153)          | 48.9 (65)                                     | 39.8 (51)                                  | 48.1 (37)                            | .293  |
| Angiotensin-converting enzyme inhibitors, % (no.) | 14.2 (48)            | 17.3 (23)                                     | 10.9 (14)                                  | 14.3 (11)                            | .339  |
| Angiotensin II receptor blockers, % (no.) | 9.8 (33)              | 9.8 (13)                                      | 10.2 (13)                                  | 9.1 (7)                              | 9670  |
| Dyslipidemia, % (no.)                  | 27.8 (94)            | 18.1 (24)                                     | 37.5 (48)                                  | 28.6 (22)                            | .002  |
| Heart diseases, % (no.)                | 24.9 (83)            | 31.6 (42)                                     | 14.8 (19)                                  | 28.6 (22)                            | .005  |
| Cancer, % (no.)                        | 6.9 (23)             | 7.7 (10)                                      | 6.3 (8)                                    | 6.5 (5)                              | .891  |
| Chronic kidney disease stage ≥3, % (no.) | 2.7 (9)               | 3.0 (4)                                       | 3.9 (5)                                    | 0 (0)                                | .224  |
| Asthma, % (no.)                        | 3.6 (12)             | 6.0 (8)                                       | 1.6 (2)                                    | 2.6 (2)                              | .133  |
| Chronic obstructive pulmonary disease , % (no.) | 10.6 (36)            | 12.8 (17)                                     | 12.5 (16)                                  | 3.9 (3)                              | .091  |

*BMI, body mass index; COVID-19, coronavirus disease 2019; heart disease, chronic heart failure, myocardial infarction, atrial fibrillation.

*bOne-way analysis of variance: cut-off for $P$ value interpretation after Bonferroni correction = .017.

CChronic kidney disease stage 3 corresponds to estimated glomerular filtration rate less than 60 mL/min.
During a median follow-up of 70 days (25%-75%; interquartile range, 55-76 days), 105 (31.1%) patients had a primary end point event (Figure 1A), that is, 18.8% (25/133) of normal-weight (BMI < 25 kg/m²), 17.2% (22/128) of overweight (25 kg/m² ≤ BMI < 30 kg/m²), and 75.3% (58/77) of obese patients (BMI ≥ 30 kg/m²; P < .0001 for both comparisons). Time to hospitalization was significantly shorter for obese compared with both normal- and overweight patients (Figure 1B).

In the crude unadjusted analysis, obese patients were more likely to require hospitalization than nonobese patients (BMI < 30 kg/m²; hazard ratio [HR], 6.21; 95% CI, 4.20 to 9.18). Male patients carried also higher risk (HR, 1.53; 95% CI, 1.01 to 2.31), while HCQ and prednisone use (HR, 0.68; 95% CI, 0.17 to 1.00; and HR, 0.59; 95% CI, 0.38 to 0.92, respectively) were less likely associated with the primary end point in the unadjusted analyses. In the final multivariable analysis, obese patients were more likely to need hospitalization than nonobese patients.

**TABLE 2. Clinical Features at Presentation and Specific Treatments of Patients With Community-Managed COVID-19 Pneumonia by BMI**

| Characteristic | All Patients (N=338) | Normal-Weight Patients (BMI < 25 kg/m²) (n=133) | Overweight Patients (25 kg/m² ≤ BMI < 30 kg/m²) (n=128) | Obese Patients (BMI ≥ 30 kg/m²) (n=77) | P |
|---------------|----------------------|-----------------------------------------------|-------------------------------------------------|--------------------------------------|---|
| **Clinical presenting features** | | | | | |
| Temperature > 37.5°C, % (no.) | 98.5 (333) | 98.5 (131) | 100.0 (128) | 96.1 (74) | .082 |
| Fatigue, % (no.) | 85.5 (289) | 82.0 (109) | 86.7 (111) | 89.6 (69) | .280 |
| Myalgia, % (no.) | 58.9 (199) | 54.9 (73) | 58.6 (75) | 66.2 (51) | .277 |
| Arthralgia, % (no.) | 70.1 (237) | 61.7 (82) | 72.7 (93) | 80.5 (62) | .012 |
| Anorexia, % (no.) | 53.0 (179) | 51.1 (68) | 54.7 (70) | 53.3 (41) | .850 |
| Headache, % (no.) | 29.3 (99) | 23.3 (31) | 21.9 (28) | 52.0 (40) | <.001 |
| Conjunctivitis, % (no.) | 24.9 (84) | 22.6 (30) | 23.4 (30) | 31.2 (24) | .355 |
| Rhinorrhea/nasal obstruction, % (no.) | 40.2 (136) | 51.1 (68) | 35.9 (46) | 28.6 (22) | .003 |
| Hypoxemia, % (no.) | 64.8 (219) | 60.9 (81) | 70.3 (90) | 62.3 (48) | .235 |
| Dysgeusia, % (no.) | 43.8 (148) | 38.4 (51) | 45.3 (58) | 50.7 (39) | .206 |
| Gastrointestinal symptoms, % (no.) | 51.2 (173) | 30.8 (41) | 65.6 (84) | 62.3 (48) | <.001 |
| Syncope/presyncope, % (no.) | 27.2 (92) | 15.8 (21) | 26.6 (34) | 48.1 (37) | <.001 |
| Dry cough, % (no.) | 85.2 (288) | 82.0 (109) | 87.5 (112) | 87.0 (67) | .414 |
| Dyspnea at rest, % (no.) | 75.4 (255) | 61.7 (82) | 77.3 (99) | 96.1 (74) | <.001 |
| Oxygen saturation < 93% in ambient air, % (no.) | 79.6 (269) | 68.4 (91) | 82.8 (106) | 93.5 (72) | <.001 |
| Performed swab test, % (no.) | 42.0 (142) | 32.4 (43) | 32.0 (41) | 75.3 (58) | <.001 |
| Positive swab test, % (no.) | 100.0 (142) | 100.0 (43/43) | 100.0 (41/41) | 100.0 (58/58) | >.99 |
| **Specific treatments** | | | | | |
| Acetaminophen, % (no.) | 95.6 (323) | 91.7 (122) | 99.2 (127) | 96.1 (74) | .013 |
| Nonsteroidal anti-inflammatory drug, % (no.) | 50.9 (172) | 50.4 (67) | 51.6 (66) | 50.7 (39) | .981 |
| HCQ, % (no.) | 54.7 (185) | 60.9 (81) | 50.0 (64) | 52.0 (40) | .179 |
| Azithromycin, % (no.) | 98.5 (333) | 98.5 (131) | 99.2 (127) | 97.4 (75) | .580 |
| Ceftiraxone, % (no.) | 57.4 (194) | 50.4 (67) | 60.2 (77) | 64.9 (50) | .088 |
| Prednisolone, % (no.) | 35.5 (120) | 34.6 (46) | 38.3 (49) | 32.5 (25) | .674 |
| Enoxaparin, % (no.) | 39.9 (135) | 38.4 (51) | 42.2 (54) | 39.0 (30) | .802 |

*BMI, body mass index; domiciliary low-flow O₂ therapy, oxygen administered when saturation was less than 93% at rest while breathing ambient air; COVID-19, coronavirus disease 2019; HCQ, hydroxychloroquine, 200 mg, 12 hours apart for the first 2 doses, then 200 mg/d for 5 or more days; oral ceftiraxone, 400 mg/day for 5 or more days; oral azithromycin, 500 mg/day for 5 or more days; oral prednisolone or equivalents, range, 5 to 25 mg/day for 5 or more days; subcutaneous enoxaparin, 4000 IU/day for 5 or more days until mobilization or resolution of phlebitis.

From February 28, according to Italian national policy, only patients presenting with more severe symptoms were tested using reverse transcriptase-polymerase chain reaction assay for severe acute respiratory syndrome coronavirus 2. Most patients treated at their domicile did not have access to the test.

One-way analysis of variance: cut-off for P value interpretation after Bonferroni correction = .017.

**Study End Points**

During a median follow-up of 70 days (25%-75%; interquartile range, 55-76 days), 105 (31.1%) patients had a primary end point event (Figure 1A), that is, 18.8% (25/133) of normal-weight (BMI < 25 kg/m²), 17.2% (22/128) of overweight (25 kg/m² ≤ BMI < 30 kg/m²), and 75.3% (58/77) of obese patients (BMI ≥ 30 kg/m²; P < .0001 for both comparisons). Time to hospitalization was significantly shorter for obese compared with both normal- and overweight patients (Figure 1B).
patients (HR, 5.83; 95% CI, 3.91 to 8.71), without significant associations of other covariates (Figure 2). Results were similar in multiple sensitivity analyses (Supplementary Table, available online at http://www.mayoclinicproceedings.org).

Among secondary end points, domiciliary low-flow oxygen therapy was needed in 138 (40.8%) patients (Figure 3A), that is, 19.6% (26/133) of normal-weight, 39.8% (51/128) of overweight, and 79.2% (61/77) of obese patients. Hospitalization with NIV was needed in 76 (22.5%) patients (Figure 3B), that is, 11.3% (15/133) of normal-weight, 10.2% (13/128) of overweight, and 62.3% (48/77) of obese patients. Hospitalization in the intensive care unit with intubation was needed in 49 (14.5%) patients (Figure 3C), that is, 6.8% (9/133) of normal-weight, 5.5% (7/128) of overweight, and 42.9% (33/77) of obese patients. Death occurred in 9 (2.7%) patients and in all cases, patients died in the hospital, that is, 3.0% (4/133) of the normal-weight, 0% (0/128) of the overweight, and 6.5% (5/77) of the obese groups (Supplemental Figure 2A, available online at http://www.mayoclinicproceedings.org). Time to death significantly differed in the 3 categories (Log-rank test P<.0001) (Supplemental Figure 2B), significantly lower in obese compared with nonobese patients (P=.0184) (Figure 3D).

DISCUSSION
We reported the risk for hospitalization in patients with community-managed COVID-19 pneumonia by BMI categories, showing that obese patients were more likely to need hospitalization than nonobese patients. Moreover, obese patients had a more severe course, requiring domiciliary low-flow oxygen therapy, NIV, and intubation. Death due to COVID-19 was also higher in obese compared with nonobese patients.

Obesity is a recognized independent predictor of severe H1N1 infection,19,20 and higher BMI has been inconsistently reported as a potential risk factor for severe outcomes of hospitalized patients with COVID-19.

![Figure 1](https://www.mayoclinicproceedings.org)

**FIGURE 1.** A, Association of body mass index (BMI) categories and hospitalization at the end of follow-up in the studied cohort of community-managed coronavirus disease 2019 (COVID-19) pneumonia. B, Time to hospitalization by BMI categories in the studied cohort of community-managed coronavirus disease 2019 pneumonia. Hospitalization rate in obese vs overweight and normal-weight patients was significantly increased at 10 days (65.8% vs 14.8% vs 17.3%; P<.0001), 30 days (75.0% vs 17.2% vs 17.3%; P<.001), and end of follow-up (75.3% vs 17.2% vs 18.8%; P<.0001).
infection. As for hospital cohorts, the prevalence of obesity and overweight was high in community-managed patients with COVID-19 infection and was associated with worst prognoses. Interestingly, overweight/obesity and altered liver function were associated with the probability of prolonged hospitalization in patients with COVID-19 infection, highlighting the role of high BMI as a predictor of worst prognosis in hospitalized patients.

In particular, in our cohort, obesity was associated with higher hospitalization risk and various degrees of respiratory impairment, as shown by the higher need of domiciliary low-flow oxygen therapy, NIV, and intubation during the observation period. This is consistent with several previous reports of hospitalized patients showing the association of obesity with invasive mechanical ventilation, in-hospital mortality, and an overall increased risk for critical illness during the disease course, as shown from a recent meta-analysis.

Interestingly, higher BMI was associated with younger age at diagnosis. This was consistent with a previous observation from Johns Hopkins’ hospitalized patients, showing that obesity can shift severe COVID-19 disease to younger individuals. In community-managed patients, common comorbid conditions such as diabetes, hypertension, renal impairment, and cardiac and pulmonary diseases, which are recognized risk factors for severe COVID-19 infection, were not significantly associated with hospitalization. Consistently, obesity was the only variable associated with hospitalization in the final Cox regression analysis.

Although it is still possible that some amount of unmeasured confounding remains, the correction of the analysis for the most significant confounders and the consistency of results across sensitivity analyses is reassuring. Because the primary outcome of this study (i.e., hospitalization) is different from those of the previous hospital cohort studies (mostly intubation and/or in-hospital death), our findings suggest that pre-existing patient conditions driving hospitalization risk are likely different from those of poor outcomes in hospitalized patients.

This role of obesity in predisposing to worst outcomes in initially noncritical COVID-19 pneumonia leads to several practical considerations. First, for clinicians and patients, active vigilance and more aggressive management should be recommended for obese patients with COVID-19 pneumonia treated in a non-hospital setting. Second, because patients with higher BMI do not only have a higher hospitalization risk, but also a higher need of respiratory support, patients with BMI greater than 30 kg/m² might be preemptively hospitalized regardless of their clinical condition in the attempt to promptly intervene in case of respiratory or general complications.
In non–COVID-19 clinical studies, obesity has been recognized as an independent predictor of acute respiratory distress syndrome in mechanically ventilated critically ill patients. Several studies depicted obesity as a chronic low-grade inflammatory condition. Others showed an effect on pulmonary function, affecting lung volumes and compliance and narrowing the peripheral airways. Because angiotensin-converting enzyme type 2 is highly expressed in adipose tissue, more than in the lungs, it has been hypothesized that SARS-CoV-2 could be able to enter into

**FIGURE 3.** Association of body mass index (BMI) categories and (A) low-flow oxygen (O2) need, (B) hospitalization with noninvasive ventilation (NIV), and (C) intubation at the end of follow-up in the studied cohort of community-managed coronavirus disease 2019 (COVID-19) pneumonia. (D) Time to death by BMI categories in the studied cohort of community-managed COVID-19 pneumonia. Overall, low-flow O2 need, NIV, and intubation at the end of follow-up were significantly higher in obese compared with nonobese patients. Survival rates in obese vs nonobese patients were nonsignificantly different at 10 days (98.7% vs 99.6%; P > .05), while they were significantly different at 30 days (95.3% vs 98.5%; P < .05) and end of follow-up (93.6% vs 98.5%; P < .05). ICU, intensive care unit.
adipocytes, which could become infected, thus contributing to the spreading to other organs, or represent a natural reservoir for the virus, thus leading to a prolonged viral clearance. In addition, obesity may induce alteration in the renin-angiotensin system, promoting further derangement in COVID-19 infection. Ultimately, several factors could contribute to explain the pathophysiology underlying this association, and further investigations are needed to clarify the link between obesity and severe COVID-19 infection.

Patients with mild or moderate COVID-19 infection are usually managed with supportive care at home. Community-managed COVID-19 pneumonia, that is, patients with a moderate illness with clinical and radiologic signs of pneumonia, rely on acetaminophen, nonsteroidal anti-inflammatory drugs, azithromycin, HCQ, enoxaparin, and prednisone. No antiviral treatment or anti-cytokine monoclonal antibodies are used in this setting. No substantial difference has been observed in COVID-19 treatment across BMI categories, and in the multivariate analysis, no significant association between HCQ use and hospitalization has been observed. This result is in line with previous analyses of large cohorts of hospitalized patients, showing no protective effects of HCQ for intubation and/or in-hospital mortality, alone or in combination with azithromycin, and with a recent randomized controlled trial showing that HCQ prophylaxis did not prevent illness after high to moderate risk exposure to SARS-CoV-2.

Our findings showed that obese patients with community-managed COVID-19 pneumonia were more likely to require hospitalization and had an overall more severe course than nonobese patients. Obesity was the only factor among the pre-existing comorbid conditions and treatments for SARS-CoV-2 infection that associated with subsequent hospitalization in this community-managed cohort. Our findings should raise the level of awareness in clinicians and patients on the hospitalization risk in obese patients with COVID-19 pneumonia.

CONCLUSION
Our findings showed that obese patients with community-managed COVID-19 pneumonia were more likely to require hospitalization and had an overall more severe course than nonobese patients. Obesity was the only factor among the pre-existing comorbid conditions and treatments for SARS-CoV-2 infection that associated with subsequent hospitalization in this community-managed cohort. Our findings should raise the level of awareness in clinicians and patients on the hospitalization risk in obese patients with COVID-19 pneumonia.

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SUPPLEMENTAL ONLINE MATERIAL
Supplemental material can be found online at http://www.mayoclinicproceedings.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.
Abbreviations and Acronyms: BMI = body mass index; COVID-19 = coronavirus disease 2019; CT = computed tomography; HCQ = hydroxychloroquine; HR = hazard ratio; ICU = intensive care unit; NIV = noninvasive ventilation; O2 = oxygen; RT-PCR = reverse transcriptase–polymerase chain reaction; SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2

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REFERENCES
1. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020;395(10223):497-506.
2. Guan W, Ni Z, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med. 2020;382(18):1708-1720.
3. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet. 2020;395(10229):1054-1062.
4. Onder G, Rezza G, Brusaferro S. Case-fatality rate and characteristics of patients dying in relation to COVID-19 in Italy. JAMA. 2020;323(18):1775-1776.
5. Grasselli G, Zangrillo A, Zanella A, et al. COVID-19 Lombardy ICU Network. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy region, Italy. JAMA. 2020;323(16):1574-1581.
6. Richardson S, Hirsch J, Narasimhan M, et al. Northwell COVID-19 Research Consortium. Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York City area. JAMA. 2020;323(20):2052-2059.
7. Geleris J, Sun Y, Platt J, et al. Observational study of hydroxychloroquine in hospitalized patients with Covid-19. N Engl J Med. 2020;382(25):2411-2418.
8. Guan W, Liang W, Zhao Y, et al. China Medical Treatment Expert Group for COVID-19. Comorbidity and its impact on 1590 patients with Covid-19 in China a nationwide analysis. Eur Respir J. 2020;55(5):2000547.
9. Zhang J, Deng X, Cao YY, et al. Clinical characteristics of 140 patients infected with SARS-CoV-2 in Wuhan, China. Allergy. 2020;26(7):1703-1731.
10. Du RH, Liang LR, Yang CQ, et al. Predictors of mortality for patients with COVID-19 pneumonia caused by SARS-CoV-2: a prospective cohort study. Eur Respir J. 2020;55(5):2000524.
11. CDC COVID-19 Response Team. Preliminary estimates of the prevalence of selected underlying health conditions among patients with coronavirus disease 2019 - United States, February 12-March 28, 2020. MMWR Morb Mortal Wkly Rep. 2020;69(13):382-386.
12. Petrelli CM, Jones SA, Yang J, et al. Factors associated with hospitalization and critical illness among 4,103 patients with COVID-19 disease in New York City. medRxiv. https://doi.org/10.1101/2020.04.08.20057794.
13. Simonnet A, Chatboun M, Poissy J, et al. Lille COVID-19 and Obesity study group. High prevalence of obesity in severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) requiring invasive mechanical ventilation. Obesity (Silver Spring). 2020;28(7):1195-1199.
14. Dorchety AB, Harrison EM, Green CA, et al. Features of 16,749 hospitalised UK patients with COVID-19 using the ISARIC WHO Clinical Characterisation Protocol. medRxiv. https://doi.org/10.1101/2020.03.23.20075042.
15. Fagiuoli S, Lorini FL, Remuzzi G. Covid-19 Bergamo Hospital Crisis Unit. Adaptations and lessons in the Province of Bergamo. N Engl J Med. 2020;382(21):e71.
16. Ferguson ND, Fan E, Campanota L, et al. The Berlin definition of ARDS: an expanded rationale, justification, and supplemental material. Intensive Care Med. 2012;38(10):1573-1582.
17. World Health Organization. Obesity and overweight. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight. Accessed June 15, 2020.
18. Gladitz J, Rubin Donald B & Multiple Imputation for Nonresponse in Surveys. John Wiley & Sons, Chichester — New York — Brisbane — Toronto — Singapore 1987, 258 S., 6 Abb., € 30.25, ISBN 0271-6232 [book review]. Biometrical J. 1989;31(1):131-132.
19. Louie JK, Acosta M, Winter K, et al. California Pandemic (H1N1) Working Group. Factors associated with death or hospitalization due to pandemic 2009 influenza A(H1N1) infection in California. JAMA. 2009;302(17):1896-1902.
20. Morgan OW, Bramley A, Fowlkes A, et al. Morbid obesity as a risk factor for hospitalization and death due to 2009 pandemic influenza A(H1N1) disease. PLoS One. 2010;5(3):e9694.
21. Hu X, Pan X, Zhou W, et al. Clinical epidemiological analyses of overweight/obesity and abnormal liver function contributing to prolonged hospitalization in patients infected with COVID-19. Int J Obes (Lond). 2020;44(8):1784-1789.
22. Sharma A, Gang A, Rout A, Lavie CJ. Association of obesity with more critical illness in COVID-19. Mayo Clin Proc 2020;95(5):2040-2042.
23. Kass DA, Duggal P, Cirigolari O. Obesity could shift severe COVID-19 disease to younger ages. Lancet. 2020; 395(10236):1544-1545.
24. Gajic O, Dabbagh O, Park PK, et al. US Critical Illness and Injury Trials Group: Lung Injury Prevention Study Investigators (USCIITG-LIPS). Early identification of patients at risk of acute lung injury: evaluation of lung injury prediction score in a multicenter cohort study. Am J Respir Crit Care Med. 2011;183(4):462-470.
25. Peters MC, McGrath KW, Hawkins GA, et al. National Heart, Lung, and Blood Institute Severe Asthma Research Program. Plasma interleukin-6 concentrations, metabolic dysfunction, and asthma severity: a cross-sectional analysis of two cohorts. Lancet Respir Med. 2016;4(7):574-584.
26. Chehimi M, Vidal H, Eljaafari A. Pathogenic role of IL-17-producing immune cells in obesity, and related inflammatory diseases. J Clin Med. 2017;6(7):168.
27. Pellegrino R, Gobba A, Antonelli A, et al. Ventilation heterogeneity in obesity. J Appl Physiol. 2014;116(1):175-181.
28. Holley HS, Milic-Emili J, Beddall MR, Bates DV. Regional distribution of pulmonary ventilation and perfusion in obesity. J Clin Invest. 1967;46(4):475-481.
29. Jones RL, Nzekwu MJU. The effects of body mass index on lung volumes. Chest. 2006;130(3):827-833.
30. Cottini M, Licitra A, Lombardi C, Berti A. Clinical characterization and predictors of IOS-defined small-airway dysfunction in asthma. J Allergy Clin Immunol Pract. 2020;8(3):997-1004.e2.
31. Sanchis-Gomar F, Lavie CJ, Mehra MR, Henry BM, Lippi G. Obesity and outcomes in COVID-19: when an epidemic and pandemic collide. Mayo Clin Proc. 2020;95(7):1445-1453.

32. Centers for Disease Control and Prevention. Interim guidance for implementing home care of people not requiring hospitalization for coronavirus disease 2019 (COVID-19). 2020. https://www.cdc.gov/coronavirus/2019-ncov/hcp/guidance-home-care.html. Accessed June 15, 2020.

33. Rosenberg ES, Dufort EM, Udo T, et al. Association of treatment with hydroxychloroquine or azithromycin with in-hospital mortality in patients with COVID-19 in New York State. JAMA. 2020;323(24):2493-2502.

34. Boulware DR, Pullen MF, Bangdiwala AS, et al. A randomized trial of hydroxychloroquine as postexposure prophylaxis for Covid-19. N Engl J Med. 2020;383(6):517-525.

35. Ai T, Yang Z, Hou H, et al. Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases. Radiology. 2020;296(2):E32-E40.

36. Price-Haywood EG, Burton J, Fort D, Seoane L. Hospitalization and mortality among black patients and white patients with Covid-19. N Engl J Med. 2020;382(26):2534-2543.