Obesity and COVID-19 Severity in a Designated Hospital in Shenzhen, China

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OBJECTIVE

Patients with obesity are at increased risk of exacerbations from viral respiratory infections. However, the association of obesity with the severity of coronavirus disease 2019 (COVID-19) is unclear. We examined this association using data from the only referral hospital in Shenzhen, China.

RESEARCH DESIGN AND METHODS

A total of 383 consecutively hospitalized patients with COVID-19 admitted from 11 January 2020 to 16 February 2020 and followed until 26 March 2020 at the Third People's Hospital of Shenzhen were included. Underweight was defined as a BMI <18.5 kg/m^2, normal weight as 18.5–23.9 kg/m^2, overweight as 24.0–27.9 kg/m^2, and obesity as ≥28 kg/m^2.

RESULTS

Of the 383 patients, 53.1% were normal weight, 4.2% were underweight, 32.0% were overweight, and 10.7% were obese at admission. Obese patients tended to have symptoms of cough ($P = 0.03$) and fever ($P = 0.06$) compared with patients who were not obese. Compared with normal weight patients, those who were overweight had 1.84-fold odds of developing severe COVID-19 (odds ratio [OR] 1.84, 95% CI 0.99–3.43, $P = 0.05$), while those who were obese were at 3.40-fold odds of developing severe disease (OR 3.40, 95% CI 1.40–2.86, $P = 0.007$), after adjusting for age, sex, epidemiological characteristics, days from disease onset to hospitalization, presence of hypertension, diabetes, cardiovascular disease, chronic obstructive pulmonary disease, liver disease, and cancer, and drug used for treatment. Additionally, after similar adjustment, men who were obese versus those who were normal weight were at increased odds of developing severe COVID-19 (OR 5.66, 95% CI 1.80–17.75, $P = 0.003$).

CONCLUSIONS

In this study, obese patients had increased odds of progressing to severe COVID-19. As the severe acute respiratory syndrome coronavirus 2 may continue to spread worldwide, clinicians should pay close attention to obese patients, who should be carefully managed with prompt and aggressive treatment.

On 30 January 2020, the World Health Organization (WHO) declared the novel coronavirus epidemic, now named coronavirus disease 2019 (COVID-19), a Public Health Emergency of International Concern. As of 3 April 2020, there were 82,858 confirmed, diagnosed cases in China, though the disease has now spread rapidly worldwide, infecting close to 2 million people. Rapid information and knowledge

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Table 1—Characteristics of 383 patients with SARS-CoV-2/COVID-19 by groups of BMI

Characteristics	BMI, kg/m^2 Underweight (n = 16, 4.2%)	Normal (n = 203, 53.1%)	Overweight (n = 123, 32.0%)	Obesity (n = 41, 10.7%)	P value
Age, years, median (IQR)	35.5 (28–60)	50 (36–62)	50 (37–61)	48 (39–54)	0.13
Sex, females/males, n (% males)	14/2 (12.5)	127/76 (37.4)	50/73 (59.4)	9/32 (78.1)	<0.001
Men, n (row %)	2 (1.1)	76 (41.5)	73 (39.9)	32 (17.5)	—
Women, n (row %)	14 (7.0)	127 (63.5)	50 (25.0)	9 (4.5)	—
Epidemiological information, n (%)					
From Hubei	6 (37.5)	118 (58.1)	72 (58.5)	19 (46.3)	0.10
Not been to Hubei, but infected by individuals from Hubei	8 (50)	72 (35.5)	42 (34.2)	14 (34.2)	
Without any clear contact history	2 (12.5)	13 (6.4)	9 (7.3)	8 (19.5)	
Personal disease history, n (%)					
Diabetes					
No	16 (100)	192 (94.6)	115 (93.5)	38 (92.7)	0.82
Yes	0 (0)	11 (5.4)	8 (6.5)	3 (7.3)	
Hypertension					
No	15 (93.8)	174 (85.7)	104 (84.6)	32 (78.1)	0.46
Yes	1 (6.3)	29 (14.3)	19 (15.5)	9 (22)	
Cardiovascular disease					
No	15 (93.8)	185 (91.1)	109 (88.6)	39 (95.1)	0.67
Yes	1 (6.3)	18 (8.9)	14 (11.4)	2 (4.9)	
Liver disease					
No	14 (87.5)	196 (96.6)	118 (95.9)	35 (85.4)	0.15
Yes	2 (12.5)	7 (3.5)	5 (4.1)	6 (14.6)	
Cancer					
No	16 (100)	200 (98.5)	122 (99.2)	40 (97.6)	0.72
Yes	0 (0)	3 (1.5)	1 (0.8)	1 (2.4)	
COPD					
No	14 (87.5)	187 (92.1)	112 (91.1)	38 (92.7)	0.86
Yes	2 (12.5)	16 (7.9)	11 (8.9)	3 (7.3)	
Initial symptoms, n (%)					
Fever					
No	6 (37.5)	64 (31.5)	41 (33.3)	5 (12.2)	0.06
Yes	10 (62.5)	139 (68.5)	82 (66.7)	36 (87.8)	
Cough					
No	11 (68.8)	135 (66.5)	70 (56.9)	18 (43.9)	0.03
Yes	5 (31.3)	68 (33.5)	53 (43.1)	23 (56.1)	
Fatigue					
No	15 (93.8)	192 (94.6)	119 (96.8)	41 (100)	0.36
Yes	1 (6.3)	11 (5.4)	4 (3.3)	0 (0)	
Headache					
No	16 (100)	198 (97.5)	120 (97.6)	41 (100)	0.84
Yes	0 (0)	5 (2.5)	3 (2.4)	0 (0)	
Diarrhea					
No	16 (100)	199 (98)	120 (97.6)	37 (90.2)	0.09
Yes	0 (0)	4 (2)	3 (2.4)	4 (9.8)	
Sore throat					
No	16 (100)	201 (99)	121 (98.4)	41 (100)	0.81
Yes	0 (0)	2 (1)	2 (1.6)	0 (0)	
Nasal congestion					
No	16 (100)	201 (99)	121 (98.4)	41 (100)	0.81
Yes	0 (0)	2 (1)	2 (1.6)	0 (0)	
Disease progression, days, median (IQR)					
From onset to hospitalization	4 (1–5)	3 (2–6)	4 (2–7)	4 (2–6)	0.52
From onset to dyspnea	—	8 (4–10)	6.5 (3.5–8.5)	8 (3–11)	0.49
From onset to ARDS	—	9.5 (7–11)	8 (6–10)	7.5 (4–11.5)	0.51
From onset to manifestation as severe	—	13 (10–21)	13 (8–18)	15.5 (10–20)	0.74
From onset to mechanical ventilation	—	10 (7–15)	9 (6.5–12.5)	8 (4–12)	0.88
From onset to viral clearance of nasal swab	14.5 (10–21)	14 (9–18)	15 (10–22)	14 (9–20)	0.14
From onset to discharge	25.5 (15–29.5)	23 (17.5–31)	27 (19–36)	23.5 (19.5–32)	0.17

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Table 1—Continued

Characteristics	BMI, kg/m^2 Underweight (n = 16, 4.2%)	Normal (n = 203, 53.1%)	Overweight (n = 123, 32.0%)	Obesity (n = 41, 10.7%)	P value
Treatment, n (%)					
Lopinavir/ritonavir	8 (50)	148 (72.6)	87 (70.7)	30 (73.2)	0.29
Favipiravir	2 (12.5)	7 (3.4)	5 (4.1)	1 (2.4)	0.32
Need ICU care	0 (0)	16 (7.8)	14 (11.4)	5 (12.2)	0.36
Invasive mechanical ventilation	0 (0)	16 (7.8)	14 (11.4)	5 (12.2)	0.36
Extracorporeal membrane oxygenation	0 (0)	1 (0.5)	1 (0.8)	1 (2.4)	0.62
Severity, n (%)					
Nonsevere	16 (100)	164 (80.8)	87 (70.7)	25 (61.0)	0.001
Severe	0 (0)	39 (19.2)	36 (29.3)	16 (39.0)	
Death, n (%)					
No	16 (100)	202 (99.5)	122 (99.2)	40 (97.6)	0.42
Yes	0 (0)	1 (0.5)	1 (0.8)	1 (2.4)	

ARDS, acute respiratory distress syndrome; ICU, intensive care unit.

sharing are top priorities for disease control and prevention. Thus far, early reports suggest that persons with epidemiological history (i.e., came from Hubei province, China), older age, and chronic medical conditions have a higher risk for severe illness from this virus. However, many other demographic and clinical characteristics of this novel coronavirus and how these factors might affect disease progression remain unclear (1).

Previous studies suggest that obesity is associated with poorer immune response and outcomes in patients with respiratory disease (2,3). Thus, we explored the hypothesis that higher BMI is a risk factor for progression to severe COVID-19, independent of common risk factors.

RESEARCH DESIGN AND METHODS

Study Design and Participant Criteria

In the current study, data from all consecutively hospitalized patients from 11 January 2020 to 21 February 2020 at the Third People's Hospital of Shenzhen were collected. The Third People's Hospital of Shenzhen is the only referral hospital authorized by the government in Shenzhen City to care and treated for COVID-19 patients. The diagnosis of COVID-19 was based on the WHO interim guidance (4).

All patients were followed until 26 March 2020. Information of epidemiological, clinical, laboratory, and radiological characteristics and of the treatment and progression of the disease were obtained from electronic medical records. All patients with COVID-19 were carefully treated, and their data were collected by nurses, physicians, or other medical staff at the hospital. There was no missing information for all variables of interest in this study (5–16). We declare that no data related to obesity and COVID-19 severity from patients in our hospital have been published, submitted, or are in press. This study was approved by the Ethics Committee of The Third People's Hospital of Shenzhen (institutional review board number 2020 108). Most patients provided written informed consent, except for three critically ill patients who died of COVID-19. Of these three patients, one patient's informed consent was signed by his family member and the other two patients' informed consents were waived.

Epidemiological information of any exposure to the source of transmission (Wuhan or other cities in Hubei Province) within the previous 14 days were collected and categorized into three groups: *1*) from Hubei; *2*) not been to Hubei, but infected by individuals from Hubei; or *3*) without any clear contact history. Anthropometric measures including standing height and body weight were measured at admission, with light indoor clothing and no shoes. Height was measured to the nearest 0.1 cm, and weight was measured to the nearest 0.1 kg. BMI was calculated as weight divided by height, expressed as kilogram per square meter. The Chinese-specific cut-offs for general adiposity were used, with underweight defined as BMI $<$18.5 kg/m^2, normal weight as BMI 18.5–23.9 kg/m^2, overweight as BMI 24.0–27.9 kg/m^2, and general obesity as BMI $\geq$28.0 kg/m^2 (17).

Confirmation of COVID-19

The presence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was detected by the real-time reverse transcription PCR method (18). Two pairs of primers targeting the open reading frame 1ab and the nucleocapsid protein (N) were amplified and examined. The corresponding sequences for open reading frame 1ab were 5′-CCCTGTGGGTTTTACACTTAA-3′ (F), 5′-ACGATTGTGCATCAGCTGA-3′ (R), and 5′-CY3-CCGTCTGCGGTATGTGGAAAGGTTATGG-BHQ1–3′ (probe), and those for N were 5′-GGGGAACTTCTCCTGCTAGAAT-3′(F), 5′-CAGACATTTTGCTCTCAAGCTG-3′(R), and 5′-FAM-TTGCTGCTGCTTGACAGATT-TAMRA-3′(probe). Each sample was run in triplicate with positive and negative control sets as suggested. These diagnostic criteria were based on the guideline from the National Centers for Disease Control and Prevention of China. The key laboratory of the Shenzhen Centers for Disease Control and Prevention reconfirmed the samples that identified as positive for COVID-19.

Outcome Assessment

The outcome of this study was progression to severe COVID-19. As per the national guidelines for community-acquired pneumonia and the diagnosis and treatment plan for new coronavirus in China (19,20), all patients were classified into severe or mild cases based on results from chest radiography, clinical examination, and symptoms. Patients with mild symptoms (i.e., fever, cough, expectoration, and other upper respiratory tract symptoms) and without

Table 2—Characteristics of 383 patients with SARS-CoV-2/COVID-19 by status of progression to severe COVID-19

Characteristics	Nonsevere (n = 292, 76.2%)	Severe (n = 91, 23.8%)	P value
Age, years, median (IQR)	44.5 (34–57)	61 (52–65)	<0.001
Male, *n* (%)	125 (42.8)	58 (63.7)	<0.001
Epidemiological information, *n* (%)			
From Hubei	160 (54.79)	55 (60.44)	0.04
Not been to Hubei, but infected by individuals from Hubei	112 (38.36)	24 (26.37)	
Without any clear contact history	20 (6.85)	12 (13.19)	
Personal disease history, *n* (%)			
Diabetes			
No	282 (96.58)	79 (86.81)	0.001
Yes	10 (3.42)	12 (13.19)	
Hypertension			
No	255 (87.33)	70 (76.92)	0.02
Yes	37 (12.67)	21 (23.08)	
Cardiovascular diseases			
No	274 (93.84)	74 (81.32)	0.001
Yes	18 (6.16)	17 (18.68)	
Liver disease			
No	277 (94.86)	86 (94.51)	0.54
Yes	15 (5.14)	5 (5.49)	
Cancer			
No	291 (99.66)	87 (95.6)	0.01
Yes	1 (0.34)	4 (4.4)	
COPD			
No	273 (93.49)	78 (85.71)	0.03
Yes	19 (6.51)	13 (14.29)	
Initial symptoms, *n* (%)			
Fever			
No	104 (35.62)	12 (13.19)	<0.001
Yes	188 (64.38)	79 (86.81)	
Cough			
No	187 (64.04)	47 (51.65)	0.03
Yes	105 (35.96)	44 (48.35)	
Fatigue			
No	279 (95.55)	88 (96.7)	0.77
Yes	13 (4.45)	3 (3.3)	
Headache			
No	284 (97.26)	91 (100)	0.21
Yes	8 (2.74)	0 (0)	
Diarrhea			
No	285 (97.6)	87 (95.6)	0.30
Yes	7 (2.4)	4 (4.4)	
Sore throat			
No	288 (98.63)	91 (100)	0.58
Yes	4 (1.37)	0 (0)	
Nasal congestion			
No	289 (98.97)	90 (98.9)	1.00
Yes	3 (1.03)	1 (1.1)	
Disease progression, days, median (IQR)			
From onset to hospitalization	3 (1–6)	4 (2–7)	0.01
From onset to discharge	22 (16–30)	33.5 (24–41)	<0.001
Death, *n* (%)			
No	292 (100)	88 (96.7)	0.01
Yes	0 (0)	3 (3.3)	

abnormalities or with mild changes on chest radiography were classified as nonsevere (21). A mild change in chest radiography is defined by multiple, small patchy shadows and interstitial changes, mainly in the outer zone of the lung and under the pleura. Severe COVID-19 was defined by the presence of any of the following conditions: *1*) significantly increased respiration rate of ≥30 times/minute; *2*) hypoxia, i.e., oxygen saturation (resting state) ≤93%; *3*) blood gas analysis, i.e., partial pressure of oxygen/fraction of inspired oxygen ≤300 mmHg; or *4*) the occurrence of respiratory or other organ failure that required intensive care unit monitoring and treatment, or shock.

Moreover, for the confirmed cases in Shenzhen, nasal swab samples were collected every 3 days and evaluated by the quantitative PCR (qPCR) assay. The duration of positive viral test results was defined as the time from the day of disease onset to the day of virus clearance. Viral clearance was defined as the presence of two consecutive negative results in qPCR detection for SARS-CoV-2 antigens at an interval of 24 h. The first day of these two consecutive days were used as the clearance day. Patients were discharged from hospital after the clearance of COVID-19.

Statistical Analysis

Categorical variables were described as frequency and percentages, and continuous variables as mean and SD or median and interquartile range (IQR). Means for continuous variables were compared using independent group *t* tests when the data were normally distributed; otherwise, the Mann-Whitney test was used. Comparison of categorical variables was done using the χ^2 test or the Fisher exact test, if the cell counts were small. Multivariable logistic regression was used to explore factors associated with the severity of disease, using odds ratios (ORs) and 95% CIs. Potential confounders considered in the regression model included age (per year), sex (female/male), epidemiological characteristics (from Hubei, not been to Hubei, but infected by individuals from Hubei, or without any clear contact history), days from disease onset to hospitalization, hypertension (yes/no), diabetes (yes/no), cardiovascular disease (yes/no), chronic obstructive pulmonary disease (yes/no), liver disease (yes/no) and cancer (yes/no), and drugs used for treatment (lopinavir/ritonavir, favipiravir, and others), as appropriate. All variables included in the multivariable regression were categorized as shown in Table 1. All statistical analyses were performed using STATA/SE version 16.0 software

Table 3—Association between BMI and progression to severe disease in 383 patients with SARS-CoV-2/COVID-19

BMI, kg/m^2	Number/total number (%)	Age-adjusted model ORs (95% CIs)	*P* value	Multivariable model† ORs (95% CIs)	*P* value
Total					
18.5–23.9	39/203 (19.2)	1.00		1.00	
24–27.9	36/123 (29.3)	1.78 (1.00–3.21)	0.05	1.84 (0.99–3.43)	0.05
28+	16/41 (39.0)	3.35 (1.47–7.63)	0.004	3.40 (1.40–8.26)	0.007
Men					
18.5–23.9	20/76 (26.3)	1.00			
24–27.9	23/73 (31.5)	1.91 (0.84–4.33)	0.12	1.98 (0.78–5.00)	0.15
28+	15/32 (46.9)	5.4 (1.93–15.09)	0.001	5.66 (1.80–17.75)	0.003
Women					
18.5–23.9	19/127 (15.0)	1.00			
24–27.9	13/50 (26)	1.76 (0.74–4.22)	0.20	1.64 (0.63–4.29)	0.31
28+	1/9 (11.1%)	0.58 (0.07–5.24)	0.63	0.70 (0.07–7.20)	0.76

†Adjusted for age, sex, epidemiological characteristics, days from disease onset to hospitalization, presence of hypertension, diabetes, cardiovascular disease, COPD, liver disease, and cancer, and drug used for treatment, as appropriate.

(StataCorp, College Station, TX). A two-sided *P* value of <0.05 was considered statistically significant.

RESULTS

A total of 383 patients aged 18 years or above were admitted to the Third People's Hospital of Shenzhen from 11 January 2020 to 16 February 2020, and they were followed until 26 March 2020. More than 80% of the severe cases occurred within 2 weeks of hospitalization. Of the 383 patients, 53.1% were normal weight, 4.2% were underweight, 32.0% were overweight, and 10.7% were obese. The obesity group had a higher percentage of men than the other BMI groups (78.1% versus 12.5–59.4%, $P < 0.001$). Moreover, men had a higher prevalence of obesity than women (17.5% versus 4.5%). Obese patients also tended to have cough ($P = 0.03$) and fever ($P = 0.06$) as initial symptoms, compared with nonobese patients, but they were comparable in terms of other symptoms ($P = 0.09$–0.81), epidemiological characteristics ($P = 0.10$), personal disease history ($P = 0.15$–0.82), and disease progression or treatment ($P = 0.14$–0.88) (Table 1).

Of these 383 patients, 91 (23.8%) progressed to severe COVID-19. There were no patients who developed severe COVID-19 in the underweight group. More overweight or obese patients progressed to severe cases, with 39 (19.2%) severe cases in the normal weight group, 36 (29.3%) in the overweight group, and 16 (39.0%) in the obese group ($P = 0.001$) (Table 1). As of 26 March 2020, three patients (0.78%) died of COVID-19, with one (0.49%) in the normal weight group, one (0.81%) in the overweight group, and one (2.44%) in the obese group (Table 1).

Table 2 shows that patients who were older, male, from Hubei, and had preexisting diseases (including diabetes, hypertension, cardiovascular disease, cancer, chronic obstructive pulmonary disease [COPD]), and had fever and cough as initial symptoms tended to develop severe COVID-19 (*P* from <0.001 to 0.04). Moreover, compared with nonsevere patients, patients with severe disease had longer duration from disease onset to hospitalization (median [IQR], 3 [1–6] versus 4 [2–7] days) and stayed in the hospital longer (median [IQR], 22 [16–30] versus 33.5 [24–41] days). Three deaths occurred in the severe group, and no deaths occurred in the nonsevere group (Table 2).

Because no patients developed severe COVID-19 in the underweight group, the underweight group was not included in the analyses in Table 3. Table 3 shows that after adjusting for age, sex, epidemiological characteristics, days from disease onset to hospitalization, disease history, and drugs used for treatment, compared with the normal weight group, those who were overweight had 1.84-fold odds of developing severe COVID-19 (OR 1.84, 95% CI 0.99–3.43, $P = 0.05$), while those who were obese were at 3.40-fold odds of developing the disease (OR 3.40, 95% CI 1.40–8.26, $P = 0.007$). Although the result for sex interaction was not significant ($P = 0.11$), the association appeared to be more pronounced in men than in women. After similar adjustment, the ORs (95% CIs) for overweight and obese patients versus normal weight patients was 1.64 (0.63–4.29) and 0.70 (0.07–7.20) in women, respectively, and 1.98 (0.78–5.00) and 5.66 (1.80–17.75) in men, respectively (Table 3).

Because the presence of underlying diseases, such as diabetes, hypertension, and cardiovascular disease, might also mediate the association between BMI and severe COVID-19, we conducted a sensitivity analysis adjusting for these diseases. The results attenuate slightly, with the ORs (95% CIs) for severity being 4.99 (1.66–15.0) in men and 3.12 (1.31–7.42) for obesity in all patients. The presence of these diseases accounted for about 3% of the effect of BMI on disease severity, with the r^2 increasing by 3% (from 0.2199 to 0.2268) after this adjustment.

CONCLUSIONS

In this case series study of COVID-19 patients in Shenzhen, we found that obesity, especially in men, significantly increased the risk of developing severe COVID-19. During the first 2 months of the pandemic, of 383 patients aged 18+ years hospitalized with COVID-19 in Shenzhen, the prevalence of overweight ($24 \leq$ BMI < 28 kg/m^2) and obese (BMI ≥ 28 kg/m^2) patients was 32% and 10.7%, respectively. Compared with patients with normal weight, patients who were obese were at increased odds of progressing to severe disease, and the association remained significant after adjusting for comorbidities and other risk factors. In addition, further subanalysis demonstrated that men with BMI ≥ 28 kg/m^2 had more than threefold

increased odds of progression to severe COVID-19, with almost half of the obese male patients developing severe COVID-19. The association in women was less clear due to the small number of obese women in the study sample. Moreover, obese patients also tended to have typical upper respiratory tract infection symptoms, such as fever and cough. No significant differences were found in terms of the duration of disease progression and drugs used for treatment between the different BMI groups.

It is plausible that obesity might increase the risk of severe COVID-19, as previous studies have shown that excessive weight gain $\geq$18 kg might increase the risk of developing community-acquired pneumonia (22,23) and may impede lung function. Obese patients allocate a disproportionately high percentage of total body oxygen consumption to their respiratory work, leading to a reduction in functional residual capacity and expiratory volume (24,25). A subsequent ventilation-perfusion abnormality can decrease ventilatory reserve and predispose the obese to respiratory failure after even mild pulmonary challenges (26,27). Moreover, individuals with obesity are at increased risk of developing pulmonary emboli and aspiration pneumonia (28) and may develop a sustained increase in arterial carbon dioxide tension due to chronic daytime hypoventilation. Patients with obesity were more likely to need an intensive care unit for acute lung injury and to have prolonged mechanical ventilation and hospital stay when compared with normal weight patients (27,29–31). In summary, the exact mechanisms remain elusive and are probably multifactorial, stemming from mechanical alterations of the airways and lung parenchyma, to systemic and airway inflammatory and metabolic dysfunction that adversely influences pulmonary function and/or response to therapy. In addition to the detrimental effects on lung function, obesity is a confirmed cause of diabetes and cardiovascular disease, leading to higher overall mortality (32–34). In our study, patients with a BMI $\geq$28 kg/m^2 were at increased odds of developing a severe case of COVID-19, which remained significant in the multivariable analysis after adjustment for reported comorbidities. Neither being overweight nor obese has previously been identified as an increased risk of developing severe COVID-19 in humans (35–38). Our study is the first to show that obesity is an important risk factor for disease progression, though this has also been supported in animal studies. A previous study showed that obese mice infected with influenza virus had a sixfold higher fatality ratio and diminished pulmonary expression of proinflammatory cytokines (tumor necrosis factor α, interleukin 6, and interferon α and β) than nonobese mice (39).

Over two-thirds of obese patients in our study received antiviral medications. However, most patients in Shenzhen initiated treatment $>$48 h after the onset of symptoms. Although obese and nonobese patients did not differ in the median time from onset of symptoms to hospitalization, overweight or obese patients were more likely to be treated slightly later, compared with normal weight patients (Table 1).

Our study is subject to several limitations. First, as this study includes all confirmed patients with COVID-19 in a city outside of the epidemic centers of China (i.e., Hubei or Wenzhou), the sample size is not large. However, our hospital is the only government-mandated COVID-19 treatment hospital in Shenzhen and, thus, would represent patients in the region. Second, although smokers are more likely to develop pneumonia, data on smoking status in our patients were not available. We did adjust for the presence of COPD in the model to partly alleviate these confounding effects from smoking, and the results did not change. Thus, the influence of smoking, if any, should not be substantial. Third, our study is hypothesis generating and does not represent a definitive prospective study. The causal inference between obesity and progression to severe COVID-19 should be examined in further studies. Fourth, as this is a case series study of all adult patients with COVID-19 admitted to a referral hospital instead of a prospective population-based cohort study, we cannot calculate the relative risk of developing COVID-19 and cannot estimate whether obese individuals are more likely to develop the infection. Fifth, due to the small number of patients with diabetes and other pre-exiting diseases in our case series, the associations of these diseases with disease progression could not be assessed. Sixth, the current study did not have enough statistical power to exclude a small or moderate effect of obesity on disease progression. Only 9 women and 32 men were defined as obese at admission; thus, our analysis was underpowered in women. However, in obese men, even the lower limit of the 95% CI reached 1.80, suggesting an important adverse effect of obesity on disease progression. Finally, as a limited number of pediatric patients have been diagnosed in Shenzhen thus far, we have only included adult patients in this study. Effects of obesity on coronavirus infection or disease progression in children are yet to be reported (5–16).

In summary, obesity, an increasingly common chronic disease globally, was significantly associated with progression to severe COVID-19 in adults hospitalized with SARS-CoV-2 infection. As COVID-19 may continue to spread worldwide, clinicians should pay close attention to obese patients. Obese patients should be carefully monitored and managed with prompt and aggressive treatment.

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