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Surviving 2019 novel coronavirus pneumonia: A successful critical case report

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ABSTRACT

Background: . An outbreak of acute respiratory illness was proved to be infected by a novel coronavirus, officially named Coronavirus Disease 2019 (COVID-19) from World Health Organization (WHO), was confirmed first in Wuhan, China, and has become endemic worldwide, which was a serious threaten to public health all over the world. Herein, we reported a successful critical case of COVID-19 and shared our experience of treatment, which would do a favor for other COVID-19 patients.

Case summary: . A 65-year-old man, Wuhan citizen, was infected by COVID-19, and his pulmonary lesions progressed quickly in five days. On admission to Tongji Hospital, Wuhan, China, the immediate arterial blood gas(ABG) analysis showed the PaO2/FiO2(P/F) ratio was 134.4mmHg, moderate acute respiratory distress syndrome(ARDS) was diagnosed. Emergency tracheal intubation was performed, and the initial ventilator mode and parameters were set up based on the lung-protective ventilation strategy, but the P/F ratio could not be improved, and then the prone position ventilation was carried out for four consecutive days, as long as 16 hours every day, the P/F ratio rose to 180mmHg approximately, which still did not reach to the standard of extubation. And then we found that it was complicated with acute cor pulmonale(ACP) by ultrasound examination, dobutamine and diuretic were used for the treatment of ACP caused by ARDS successfully, and the P/F ratio went up to about 250mmHg. Seven days later after admission, the endotracheal intubation was successfully removed, after extubation, High-Flow nasal cannula(HFNC) oxygen therapy was used as a sequential strategy to prevent reintubation. Ultimately, he was discharged on day 34 after admission.

Conclusion: . Our case presented the treatment process of a critical COVID-19. Effective therapy was crucial to heal COVID-19, and organ function support therapy, especially the cardiorespiratory function support therapy, was the core of treatment.

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Introduction

Since December, 2019, an increasing number of cases of novel coronavirus (2019-nCoV) pneumonia (NCP) have been identified in Wuhan, Hubei Province, China,[1–3] officially named Coronavirus Disease 2019 (COVID-19) from World Health Organization (WHO). The number of COVID-19 patients increased quickly in China and other countries in the world, including American, Italy, France, Iran and so on. Currently, more than 11,000,000 laboratory-confirmed cases in the world have been reported. The latest public health information from Chinese Centers for Disease Control(CDC) shows, under the great efforts of Chinese government, many effective strategies were made, and large numbers of COVID-19 patients in China have been cured. Unfortunately, in many other countries, the caseload of COVID-19 was still huge, and raised a global health emergency, and World Health Organization (WHO) has made the assessment that COVID-19 can be characterized as a pandemic. Therefore, COVID-19 has become the common enemy of all mankind. Herein, we reported a successful critical case of COVID-19 in Tongji Hospital, Wuhan, China, and shared our experience of treatment, which would do a favor for other COVID-19 patients.

Case report

On February 4th, 2020, a 65-year-old man, Wuhan citizen, began with low-grade fever, about 38°C, dry cough, shortness of breath, combined with chest CT scans finding and oropharyngeal swab real-time reverse-transcription–polymerase-chain-reaction (RT-PCR) assay for 2019-nCoV, he was diagnosed with COVID-19 and treated

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in a local community hospital. He got oxygen therapy, ganciclovir for antiviral treatment, cefamandole to prevent bacterial infection, nevertheless, he still had a fever, and shortness of breath was aggravating, even felt dyspnea, chest CT scans were rechecked on February 15th and February 20th, respectively (Figs. 1 and 2), which showed the localized patchy clouding opacity was increasing rapidly, on February 22th, he was transferred to Tongji hospital at one AM. He has no special medical history. After admission to Tongji hospital, the initial physical examination revealed axillary temperature was 36.4°C, blood pressure was 142/89 mmHg, pulse was 91 bpm, respiratory rate was 40 breath/min, and SpO2 was 95% when he was breathing supplement oxygen at 10L/min, and dyspnea was obvious. The arterial blood gas(ABG) analysis was carried out immediately and showed pH was 7.408, PCO2 32.6mmHg, PaO2/FiO2(P/F) ratio 134.4mmHg, and lactate 3.31mmol/L, which means acute respiratory failure, lung ultrasound was carried out at once, and severe lung edema and consolidation located in dorsal and basal segment of lower lobe were found, combined with the newest chest CT scans findings, moderate acute respiratory distress syndrome(ARDS) was diagnosed. Considering the rapid progressing pulmonary lesions, emergency tracheal intubation was performed, based on the lung-protective ventilation strategies,[4] the initial ventilator mode was synchronized intermittent mandatory ventilation(SIMV), tidal volume 400ml, about 5ml/kilogram weight, positive end-expiratory pressure(PEEP) 10-12cmH2O, FiO2 80%, frequency 18 breath/min, and then, SpO2 was about 95%, respiratory rate was 18 to 22 breath/min. The laboratory results showed white blood cell count(WBC) was obvious high, $17.56*10^9$/L, neutrophil ratio 93.3%, lymphocyte ratio 4.2%, and C-reactive protein (CRP) 56.3 mg/L and interleukin-6(IL-6) 39.21pg/ml, serum creatinine 65umol/L, aspartate aminotransferase (AST) 23 U/L, alanine aminotransferase (ALT) 35 U/L, and lactate dehydrogenase (LDH) 441 U/L, albumin 29.1g/L, NT-proBNP 626pg/ml. And the oropharyngeal swab tested still positive for 2019-nCoV by rRT-PCR assay. The IgM and IgG of 2019-nCoV were significantly high, 132.59AU/ml and 111.81AU/ml, respectively.

Under the treatment of mechanical ventilation(MV), the P/F ratio could not be improved and serum lactate was still high, therefore, on the day of admission, the prone position ventilation was performed from seventeen o'clock PM to eight o'clock AM next day for four consecutive days, as long as 16 hours every day (Fig. 3). Considering the influence of sedation and analgesia during the prone position ventilation, in order to maintain hemodynamic stability, bedside invasive hemodynamic monitoring was carried out, including central venous pressure(CVP) monitoring and arterial blood pressure(ABP) monitoring, at the same time, every day we used ultrasound to evaluate this patient's cardiac function, effective circulatory blood volume, and pulmonary interstitial edema, rigid fluid management was implemented by recording urine volume per hour and fluid balance every 24 hours. At the second day after the prone position ventilation therapy, the P/F ratio went up to about 150mmHg at the supine position,

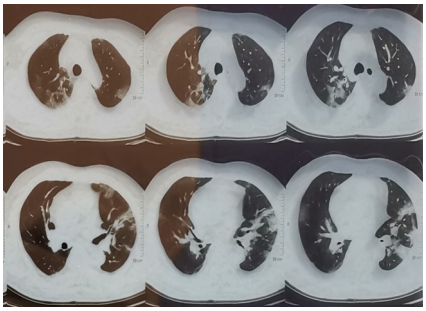

Fig. 1. Chest CT images on February 15th. Chest CT images showed a few confluent ground-glass opacities about pleura in peripheral bilateral lungs. CT, computed tomography.

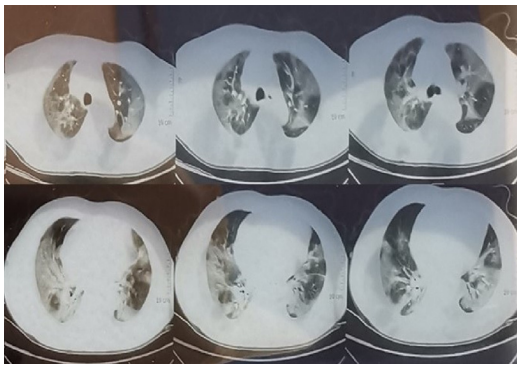

Fig. 2. Chest CT images on February 20th. Chest CT images showed a wide range of confluent ground-glass opacities about pleura and fissure in peripheral bilateral lungs. CT, computed tomography.

while approximate 180mmHg at the prone position. However, to the fourth day, the P/F ratio did not increase more, by the ultrasound examination, we found that the inferior vena cava was filled with no obvious respiratory variability, the right ventricular was satiate, CVP was in a high level, 14mmHg to 15mmHg, which means circulatory blood volume was overload, and estimated pulmonary artery pressure(PAP) reached to 45-50mmHg by tricuspid regurgitation speed, which means it was complicated with acute cor pulmonale(ACP). Based on the findings of ultrasound scans, we adjusted this patient's therapeutic regimen, diuretics were used to achieve the goal of being negative fluid balance, meanwhile, we used dobutamine to improve right ventricular function and optimize ventricular artery coupling at a dose of 2ug/(kg*min), and heart rate was below 90bpm with no arrhythmia. After that, the P/F ratio increased obviously, about 230mmHg at the supine position, while approximate 250mmHg at the prone position, and chest x ray presented that pulmonary lesions were clearly reduced compared to last time (Figs. 4 and 5), and bedside ultrasound scans found that PAP declined to about 30mmHg gradually, the respiratory variability of inferior vena cava was 30%, CVP went down to 7mmHg. By these aggressive treatments above, the pulmonary function and cardiac function were improved significantly.

At the seventh day after admission, oxygenation was satisfied and hemodynamic was stable, the mental status and muscle force recovered, the endotracheal intubation was successfully removed. After extubation, High-Flow nasal cannula(HFNC) oxygen therapy was used as sequential strategy to prevent reintubation. HFNC oxygen therapy was withdrew on day 12 after admission, and supplemental oxygen was discontinued on day 29 after admission.

Fig. 3. Prone position ventilation was performed in this COVID-19 patient for four consecutive days, as long as 16 hours every day. COVID-19, Coronavirus Disease 2019.

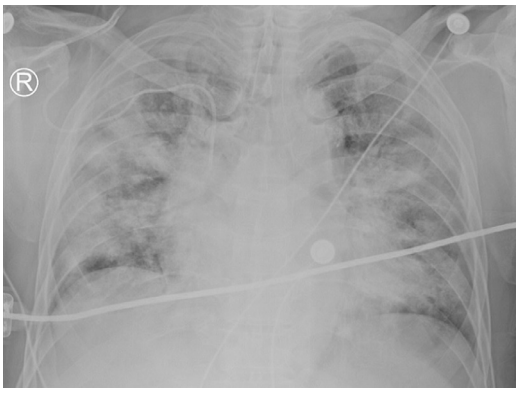

Fig. 4. Chest X ray on February 24th. Anteroposterior chest radiograph showed multifocal ground-glass opacities in bilateral lungs, especially the right lung.

Fig. 5. Chest X ray on February 26th. Anteroposterior chest radiograph showed patchy ground-glass opacities in bilateral lungs, mainly located in the lower lung zones.

The results of 2019-nCoV of oropharyngeal swabs by rRT-PCR assay were repeatedly negative on day 22, 24 and 29 after admission. The patient's clinical condition improved gradually, apart from intermittent exertional dyspnea. He was discharged on day 34 after admission.

Discussion

We reported this critical case of COVID-19 in Tongji Hospital, Wuhan, China. In accordance with early reported critical cases, this case presented some similar clinical characteristics, including fever, cough, shortness of breath, dyspnea and severe hypoxemia,[1,2] and the chest CT scans showed bilateral infiltrating pneumonia, mainly located in the edge of lungs,[5,6] which means nonuniformity of lung injury, and progressed diffusely later, ARDS was diagnosed clearly. It has been proved that there are some therapeutic strategies for ARDS, such as recruitment maneuvers, the prone position ventilation therapy, however, for ARDS caused by COVID-19, it had some own clinical characteristics. Recruitment maneuvers have been demonstrated to be no ideal response to ARDS caused by COVID-19.[7] As an important rescuing strategy for ARDS, the validity of the prone position ventilation therapy has been demonstrated by large numbers of research.[8,9] The prone position ventilation therapy had the ability to correct nonuniformity of lung injury, facilitate the alveolar recruitment in the gravity-dependent lung region, which had been verified by ultrasound, and then improve hypoxemia and hypercapnia.[10] Early research showed that it would achieve optimal clinical effects when the prone position ventilation therapy lasted for above 12 hours every times,[11] therefore, in this case, the prone position ventilation therapy was performed for 16 hours every times.

HFNC, a novel device, could deliver fully humidified, high-flow oxygen (up to 60 L/min) through a nasal cannula. By delivering the gas at given flow rates in excess of the patient's peak inspiratory flow rate, HFNC provides a constant FiO2. In addition, a flow-dependent effect of continuous positive airway pressure has been observed, which is similar to PEEP. Last, the high gas flow may provide an upper airways deadspace washout effect, create an oxygen reservoir within the upper airways, reduce inspiratory resistance and work of breathing.[12] Compared with noninvasive ventilator, HFNC could provide greater comfort for patients, avoid excessive tidal volume, which would lead to worse outcome in patients with ARDS. After extubation, HFNC oxygen therapy had presented the ability to reduce the risk of reintubation and postextubation respiratory failure,[13,14] and there was research showed that HFNC was safe enough during the current COVID-19 outbreak.[15]

ARDS often was complicated with ACP, characteristiced by acute pulmonary arterial hypertension and right ventricular dysfunction, even failure,[16] these clinical features also were observed in this case. Possible mechanisms included pulmonary vasoconstriction caused by hypoxemia and hypercapnia, vascular collapse between alveoli after numbers of alveolar collapse. Prone position ventilation therapy could facilitate the alveolar recruitment, improve hypoxemia and hypercapnia, as a result, reduced PAP and protected right ventricular function.[17] Meanwhile, dobutamine, a $\beta 1$ adrenoceptor agonist, has been demonstrated to be able to optimize ventricular artery coupling and improve right ventricular function by increasing heart rate and myocardial contractility.[18] In our case, the prone position ventilation therapy, combining with dobutamine and diuretic, reduced acute pulmonary arterial hypertension caused by COVID-19 successfully.

In summary, this case presented the treatment process of a critical COVID-19. Effective therapy was crucial to reduce the mortality of COVID-19, and organ function support therapy, especially the cardiorespiratory function support therapy, was the core of treatment.

Additional contributions

We thank the patient for providing permission to share his information.

Declaration of Competing Interest

The authors declare no conflicts of interest relevant to this article.

References

1. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. *JAMA*. 2020;323:1061–1069.
2. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. *Lancet*. 2020;395:507–513.
3. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al. A Novel Coronavirus from Patients with Pneumonia in China, 2019. *New Engl J Med*. 2020;382:727–733.
4. Petrucci N, De Feo C. Lung protective ventilation strategy for the acute respiratory distress syndrome. *Cochrane Database Syst Rev*. 2013;2013(2):CD003844.
5. Yoon SH, Lee KH, Kim JY, Lee YK, Ko H, Kim KH, et al. Chest radiographic and CT findings of the 2019 novel coronavirus disease (COVID-19): analysis of nine patients treated in Korea. *Korean J Radiol*. 2020;21:494–500.
6. Wei J, Xu H, Xiong J, Shen Q, Fan B, Ye C, et al. 2019 Novel coronavirus (COVID-19) pneumonia: serial computed tomography findings. *Korean J Radiol*. 2020;21:501–504.
7. Chen L, Del Sorbo L, Grieco DL, Junhasavasdikul D, Rittayamai N, Soliman I, et al. Potential for lung recruitment estimated by the recruitment-to-inflation ratio in acute respiratory distress syndrome. A clinical trial. *Am J Respir Crit Care Med*. 2020;201:178–187.
8. Scholten EL, Beitler JR, Prisk GK, Malhotra A. Treatment of ARDS with prone positioning. *Chest*. 2017;151:215–224.
9. Kallet RH. A comprehensive review of prone position in ARDS. *Respir Care*. 2015;60:1660–1687.
10. Guerin C, Gattinoni L. Assessment of oxygenation response to prone position ventilation in ARDS by lung ultrasonography. *Intensiv Care Med*. 2016;42:1601–1603.

11. Hu SL, He HL, Pan C, Liu AR, Liu SQ, Liu L, et al. The effect of prone positioning on mortality in patients with acute respiratory distress syndrome: a meta-analysis of randomized controlled trials. *Crit Care*. 2014;18:R109.
12. Maggiore SM, Idone FA, Vaschetto R, Festa R, Cataldo A, Antonicelli F, et al. Nasal high-flow versus Venturi mask oxygen therapy after extubation. Effects on oxygenation, comfort, and clinical outcome. *Am J Respir Crit Care Med*. 2014;190:282–288.
13. Hernandez G, Vaquero C, Gonzalez P, Subira C, Frutos-Vivar F, Rialp G, et al. Effect of postextubation high-flow nasal cannula vs conventional oxygen therapy on reintubation in low-risk patients: a randomized clinical trial. *JAMA*. 2016;315:1354–1361.
14. Hernandez G, Vaquero C, Colinas L, Cuena R, Gonzalez P, Canabal A, et al. Effect of postextubation high-flow nasal cannula vs noninvasive ventilation on reintubation and postextubation respiratory failure in high-risk patients: a randomized clinical trial. *JAMA*. 2016;316:1565–1574.
15. Loh NW, Tan Y, Taculod J, Gorospe B, Teope AS, Somani J, et al. The impact of high-flow nasal cannula (HFNC) on coughing distance: implications on its use during the novel coronavirus disease outbreak. *Can J Anaesth*. 2020;67:893–894.
16. Fougeres E, Teboul JL, Richard C, Osman D, Chemla D, Monnet X. Hemodynamic impact of a positive end-expiratory pressure setting in acute respiratory distress syndrome: importance of the volume status. *Crit Care med*. 2010;38:802–807.
17. Jozwiak M, Teboul JL, Anguel N, Persichini R, Silva S, Chemla D, et al. Beneficial hemodynamic effects of prone positioning in patients with acute respiratory distress syndrome. *Am J Respir Crit Care Med*. 2013;188:1428–1433.
18. Acosta F, Sansano T, Palenciano CG, Falcon L, Domenech P, Robles R, et al. Effects of dobutamine on right ventricular function and pulmonary circulation in pulmonary hypertension during liver transplantation. *Transpl Proc*. 2005;37:3869–3870.