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Design and engineering application of medical oxygen supply system in novel coronavirus pneumonia treatment hospital

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Abstract

Respiratory supporting, as an important medical treatment for new coronavirus pneumonia patients, must be effectively guaranteed by medical oxygen supply. However, the medical oxygen system designed and configured by the existing hospitals according to the current specifications cannot meet the oxygen needs for patients with new coronavirus pneumonia. This paper aimed to study the design of medical oxygen system in new coronavirus pneumonia emergency hospital. By investigating the oxygen treatment plan for the novel coronavirus pneumonia patients in the health emergency hospital, the oxygen treatment characteristics of different patients were studied. The oxygen characteristics of different respiratory support terminals were explored to study the oxygen demands of new coronavirus pneumonia emergency hospitals. Through calculating flow rates of medical gas system air source referring to ‘technical code for medical gases engineering’, the proportion coefficient of severe patients converted into respiratory distress patients was introduced, and the model of calculating flow rates of medical oxygen system air source in emergency hospital was proposed. The cases were verified in a typical health emergency hospital that the developed calculation flow model of medical oxygen source met the demands of hospital oxygen. The outcomes provide a reference for the design and construction of medical oxygen in such health emergency hospitals.

1. Introduction

With the spread of novel coronavirus pneumonia since December 2019, the Chinese government has urgently reconstructed and built temporary emergency infectious disease hospitals in Wuhan and other places, in order to strengthen the treatment of infected patients \cite{1}. As the critical patients need 100% oxygen, the oxygen demand of the patients in critically condition is more than 10 times, resulting in the oxygen consumption of the emergency hospital being reached more than 10 times of the peak daily consumption \cite{2}. In such cases, the problem of insufficient medical oxygen supply is very prominent.

On March 3, 2020, the General Office of the National Health Commission and the Office of the State Administration of Traditional Chinese Medicine had issued the ‘Novel Coronavirus Pneumonia Diagnosis and Treatment Program (Trial Version 7)’. The novel coronary pneumonia patients have been classified into light, normal, heavy, and critical Type 4 category. General treatment should promptly give effective oxygen therapy measures, including nasal duct, mask oxygen and nasal high-flow oxygen therapy \cite{3,4}. In the treatment of severe and critical cases, respiratory support includes:

- Oxygen therapy: the severe patients should receive nasal catheter or face mask for oxygen inhalation, and timely be assessed whether the respiratory distress syndrome and/or hypoxemia are relieved;
- Nasal high-flow oxygen therapy or non-invasive mechanical ventilation: when the patients cannot be relieved from the respiratory distress syndrome and/or hypoxemia after standard oxygen therapy, it can be considered to use nasal high-flow oxygen therapy or non-invasive mechanical ventilation. If the condition can be not improved or even worsen within a short time (1–2 h), organ intubation and invasive mechanical ventilation should be performed in time;
- Invasive mechanical ventilation;

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● Salvage treatment: for patients with severe acute respiratory distress syndrome (ARDS), prone position ventilation should be used for more than 12 h per day, and ECMO should be considered as soon as possible.

Novel coronavirus pneumonia patients usually need oxygen therapy, especially in critically ill patients, which require high flow oxygen supply equipment to receive oxygen [5,6]. The general hospital medical oxygen supply system cannot meet the demand of temporary large flow. In order to solve the problem of medical oxygen supply, the emergency designated hospital has to expand the medical oxygen supply system temporarily. For example, the Wuhan JinYinTan Hospital has been increased by two sets of liquid oxygen tank (storage capacity 10 m³) and vaporizer (vaporization capacity 500Nm³/h) oxygen supply facilities, and the Wuhan Red Cross Hospital has also added two sets. Considering the high demands for medical oxygen for the treatment of novel coronavirus pneumonia, the new Fire God Mountain Hospital and Thunder God Mountain Hospital had both increased the design capacity of the oxygen supply system which was much larger than the national standards of “Technical code for medical gases engineering” (GB 50751–2012) [7] and ‘Code for design of Infectious Disease Hospital’ (GB 50849–2014) [8]. Due to the lack of data on the oxygen demands of hospitals for acute respiratory infectious disease, the medical oxygen configuration varies greatly among hospitals.

To answer this question, by investigating the oxygen treatment plan for the novel coronavirus pneumonia patients in the health emergency hospital, the oxygen treatment characteristics of different patients were studied, and the oxygen characteristics of different respiratory support terminal equipment were combined to study the oxygen demand of new coronavirus pneumonia emergency hospital. Based on the formula of calculating flow rate of medical gas system air source in ‘technical code for medical gases engineering’, the proportion coefficient of severe patients converted into respiratory distress patients was introduced, and the model of calculating flow rate of medical oxygen system air source in emergency hospital was proposed.

This study aims to explore the medical oxygen system of the novel coronavirus pneumonia hospital, and discuss the medical oxygen supply and system configuration of the hospital. The work is expected provide reference for future design and construction of such hospitals.

2. Methodology

2.1. Medical oxygen terminal ventilation

From the “Novel Coronavirus Pneumonia Diagnosis and Treatment Program (Trial Version 7)”, the oxygen equipment used to treat patients with novel coronary pneumonia mainly includes standard oxygen therapy (general oxygen inhalation), high-flow oxygen therapy equipment, non-invasive ventilator, and invasive ventilator.

1) Standard oxygen therapy generally has low flow and low concentration oxygen. Ordinary nasal ducts are usually with an oxygen flow of 1–6L/min and concentration of 24–32%; ordinary masks and venturi masks inhale oxygen are with a flow of up to 10L/min and concentration of up to 50%. With reference to the provisions of Appendix B [7] of GB 50751 and Article 10.4.2 [8] of GB 50849, the average flow rate at the terminal of standard oxygen therapy can be 4–6 L/min.

2) High-flow nasal cannula oxygen therapy (HFNC) Fig. 1, as a new breathing support technology, has been widely used in clinical in recent years. The treatment equipment mainly includes air-oxygen mixer, humidification therapeutic apparatus, high-flow nasal congestion and connecting respiratory pipeline, which can provide patients with a relatively constant oxygen concentration (21%–100%), temperature (31–37 °C) and humidity of high-flow (8–80L/min) oxygen, and the oxygen through the nasal congestion treatment with good comfort [9]. For patients with respiratory distress and/or hypoxemia, the range of ventilation flow is 30–60L/min commonly. Due to the different physical conditions of each patient, the oxygen absorption concentration is different [10]. Generally, the oxygen concentration is around 50% because of the human body cannot continuously inhale high concentration oxygen for a long time [11]. The average flow rate of the oxygen terminal of the high-flow oxygen therapy instrument can be 15–30L/min.

3) Non-invasive ventilator, connected through mouth-nose mask, nasal mask, full-face mask, etc., is mostly used for patients with mild-to-moderate, using continuous positive pressure ventilation CPAP, BIPAP and other breathing modes. The pressure level and ventilation volume are high, generally 40–60L/min, and the oxygen concentration is set according to the patient’s physical

![Fig. 1. Operation process of high-flow nasal cannula oxygen therapy [9].](image)
conditions [12]. The average flow rate of the oxygen terminal of the non-invasive ventilator can be 15–30L/min. (4) Invasive ventilator, is mostly used for invasive mechanical ventilation through oral, nasal endotracheal intubation or tracheotomy. There are many ventilation modes commonly used for patients with severe respiratory failure. The oxygen ventilation volume is generally below 30 L/min because of the good airtightness of the pipeline [13]. The oxygen concentration is set according to the patient’s physical condition, so the critical value is generally high. Some integrated leak compensation of invasive ventilator can also be used for non-invasive mechanical ventilation, and then the ventilation volume will increase [14]. The invasive ventilator’s average flow rate of the oxygen terminal can also be 15–30L/min.

For the above mentioned breathing support methods, the oxygen terminals should consider the average flow, and the terminal interface design needs to meet the peak flow requirements of the device. Some of the ventilator peak flow requirements reach 200L/min [15].

2.2. Characteristics of oxygen supply in patients with novel coronary pneumonia

The novel coronary pneumonia admission hospital in Wuhan are mainly appointed to treat severe, critically ill and ordinary patients, and the makeshift hospitals are mainly for treating light patients. Treating serious patients and critically ill patients in the novel coronary pneumonia hospital require 100% oxygen [16]. According to the “Novel Coronavirus Pneumonia Diagnosis and Treatment Program (Trial Version 7)”, if standard oxygen inhalation is ineffective in critically ill patients, it needs to be changed to a high-flow oxygen therapy instrument or a ventilator to inhale oxygen. Referring to the data of patients with novel coronavirus pneumonia released by Hubei Province and Wuhan City at 24:00 on February 18, 2020, 57805 cases were still being treated in the hospital across the country, 50633 cases in Hubei (43471 cases in Wuhan), while the severe cases reached the peak, 11977 cases in China, 9562 cases in Hubei (9289 cases in Wuhan, 1957 cases in critical illness), the cumulative death cases are 2004, and 1921 cases in Hubei province (1497 cases in Wuhan) [17]. The cumulative probability of conversion from severe conversion to critical illness is about 36.1%. Though some serious patients have not developed into critically ill patients, they have developed into respiratory distress, and still need to use high-flow oxygen therapy equipment or ventilator to inhale oxygen. However, there is no statistical data currently. Based on the survey by the authors, the proportion of the serious patients who develop into respiratory distress patients (including critically ill patients) is about 45%–55%.

2.3. Computational model of gas source flow

Combining with the actual conditions of hospital patients at fixed points, the oxygen demand of patients, the proportion coefficient (θ) of severe patients converted into respiratory distress patients was introduced, based on the equation of calculating flow rate of medical gas system air source in ‘technical code for medical gases engineering’ [7]. The model of gas source flow of medical oxygen system is proposed as follows:

\[ Q = (q_1 \eta_1 \cdot (1 - \theta) \cdot n_1) + (q_1 \eta_1 \theta n_1) + (q_2 \eta_1 \eta_2 n_2) + \sum Q_{oth} \]

\[ Q \text{—— Calculated flow of gas source (L/min); } \]
\[ q_1 \text{—— Standard oxygen therapy average flow (L/min), recommended values is 5–6L/min; } \]
\[ q_2 \text{—— High-flow oxygen delivery average flow (L/min), recommended values is 15–25L/min; } \]
\[ q_3 \text{—— Average flow per terminal of ICU bed (L/min), recommended values is 20–30L/min; } \]

\[ n_1 \text{—— Number of beds in ward; } \]
\[ n_2 \text{—— Number of oxygen terminals in ICU; } \]
\[ \eta_1 \text{—— Coefficient of simultaneous use of oxygen terminal in ward, recommended values of 0.7–0.9; } \]
\[ \eta_2 \text{—— Coefficient of simultaneous use of oxygen terminal in ICU, recommended values of 0.8–1.0; } \]

\[ \theta \text{—— The proportion of serious patients converted into respiratory distress patients (Proportion of patients using high-flow oxygen therapy), recommended values of 0.30–0.45 for novel coronary pneumonia. For other acute respiratory infectious diseases, it is taken according to specific conditions, and the proportion of critically ill patients admitted to hospitals is the larger; } \]
\[ Q_{oth} \text{—— Operating room gas, other oxygen terminal gas, it can be calculated according to the “Technical code for medical gas engineering” (GB 50751-2012), and it is recommended to use the coefficient } \eta \text{ according to the actual value. } \]

3. Results

3.1. Wuhan JinYinTan Hospital

JinYinTan Hospital is one of the first batch of novel coronary pneumonia treatment and designated hospitals in Wuhan. At present, there are about 822 beds, including 1 ICU care unit, 3 intensive care units and 17 general infectious ward care units for novel coronary pneumonia patients, and about 40 beds per care unit. The hospital has 110 ventilators and 100 high-flow oxygen therapy equipment. According to the survey, except for the patients who will be discharged from the hospital, all other patients basically receive oxygen.

In order to meet the oxygen transport of novel coronary pneumonia patients, the hospital has renovated the original medical oxygen system, adding 2 sets of liquid oxygen tanks (storage capacity 10 m³), and vaporizer (vaporization capacity 500Nm³/h) oxygen supply facilities. The original 2 sets of liquid oxygen tanks (storage capacity 5 m³) and the vaporizer (150Nm³/h) oxygen supply facilities are set as backup gas sources. According to the investigation, the renovated medical oxygen supply system can meet the oxygen demands, and the daily medical liquid oxygen consumption in hospital is 7–9 m³.

According to Section 2.2 of the gas source calculation flow model, the comparisons are made with traditional designs, including the design flow of medical oxygen system, liquid oxygen tank capacity, vaporizer vaporization amount, and medical liquid oxygen consumption per day. The results are shown in Table 1 and Table 2.

From Tables 1 and 2, it can be seen that based on the calculation model, the error is within 20% when the liquid oxygen consumption per day of the hospital is compared with the actual data, indicating that the

| Table 1 Calculation parameter setting of medical oxygen model in Wuhan JinYinTan hospital. |
|-----------------|-------|-----------------|-------|
| Number of beds in ward | 802   | Coefficient of simultaneous use of oxygen terminal in ward | 0.7   |
| Number of oxygen terminals in ICU | 26    | Coefficient of simultaneous use of oxygen terminal in ICU | 0.8   |
| Standard oxygen therapy average flow (L/min) | 5     | The proportion of serious patients converted into respiratory distress patients | 0.26 |
| High-flow oxygen delivery average flow (L/min) | 17    | Other oxygen terminal gas per ICU bed (L/min) | 400   |
| Average flow per terminal of ICU bed (L/min) | 20    |

Notes:

a: The proportion of serious patients converted into respiratory distress patients is based on the actual number of high-flow oxygen supply equipment.

b: Oxygen consumption of other oxygen equipment is estimated data.
values of the model and parameters are correct. In addition, the calculation deviations are positive, and thus it’s safe for the oxygen supply system. Restricted by the medical conditions of the hospital, the proportion of serious patients that converted into respiratory distress patients is based on the actual number of high-flow oxygen supply equipment. From the perspective of better ensuring the treatment of patients, the number of high-flow oxygen supply equipment should be further increased. Therefore, it is suggested to take the recommended values for such engineering designs. The average flow of oxygen terminal in Table 1 and 2 is taken as the lower limit of the recommended value, which is more accurate for calculating the total consumption of liquid oxygen. The selection of engineering designs can be taken as the middle and upper limit of the recommended values. The configuration of liquid oxygen tank and vaporizer is consistent with the calculation model, which basically meets the oxygen demands of hospital under current conditions.

3.2. Fire God Mountain Hospital

Wuhan Fire God Mountain Hospital has a total construction area of 33100 m$^2$ and a total number of beds of 1000 beds (including 30 beds in the ICU center). It has Building 1 and Building 2. Building 1 is a single-story building, consisting of 9 single-story nursing units, a medical technology building and an ICU center, and each nursing unit has 24 wards. Building 2 is a two-story building and is divided into 4 groups, consisting of 8 nursing units, each of which has 24 wards. According to related reports, as of 23:20 on February 12, the Fire God Mountain Hospital has admitted more than 1000 patients [18]. The medical oxygen system is equipped with 8 horizontal liquid oxygen tanks with a single tank of 10 m$^3$, and the tank body is designed with a pressure bearing capacity of 1.0 MPa; the supply of liquid oxygen is completed by the tank car. The liquid oxygen plant is equipped with two vaporizers, one for use and one for standby. The rated flow of a single vaporizer is 5000Nm$^3$/h.

According to the gas source calculation flow model in Section 2.2, the comparison results are shown in Tables 3 and 4. According to the survey data, the statistics of daily consumption of liquid oxygen in Fire God Mountain Hospital is demonstrated in Fig. 2.

From Tables 3 and 4, based on the model calculation, the results are consistent with the verification result of Jinyintan hospital, verifying that the values from the model and parameters are correct. For the deviations between the calculation results and the actual vaporizer configuration, it is inferred that on the one hand, the proportion of serious patients converted into respiratory distress patients is based on the actual number of high-flow oxygen supply equipment. This is limited by medical conditions and the value is relatively small. As a result, it is suggested to select according to the recommended values. For other parameters, the selections for engineering design can be based on the recommended values of the middle and upper limits. When adopting the upper limit of the recommended value in the model, the designed vaporization capacity of the vaporizer is 1364 Nm$^3$/h, which meet the two-day liquid oxygen storage capacity. In this case, the total volume of the liquid storage tank of 75.5 m$^3$ is needed. On the other hand, as a temporary new emergency hospital, Fire God Mountain Hospital had been completed within 10 days, covering the design, procurement, construction and application. Due to the Spring Festival holiday in China and equipment supply cycle restrictions, many equipment has to only use existing inventory, like 10 m$^3$ horizontal liquid oxygen tank and Vaporizer of 5000Nm$^3$/h.

4. Discussions

4.1. The reserve of medical oxygen source

According to GB 50751–2012, the codes address that the main source of medical oxygen should be set or reserved to meet the gas consumption for one week or more, and should be at least not less than 3 days. The novel coronary pneumonia hospitals have a large amount of oxygen and high utilization rates. As an emergency measure, there are more oxygen systems used for reconstruction and expansion in a short time, while the medical oxygen equipment reserves are limited. Therefore, a reasonable reserve amount should be determined according to the production and distribution capabilities of medical oxygen production enterprises in surrounding areas. The recommended reserve amount is not less than 2 days of gas consumption, and the designated hospitals with unfavorable distribution conditions are suggested to increase the oxygen reserve.

4.2. Suggestions on selection of typical medical oxygen systems

According to engineering practice and case study in this study, some suggestions are summarized here, regarding to selecting the appropriate medical oxygen systems:

1) The selection of oxygen terminals should be able to meet the peak flow requirements of using a ventilator or high-flow oxygen therapy instrument;
2) The design of oxygen pipeline and accessories in the ward should meet the flow requirements of all beds in the ward using ventilator or high-flow oxygen therapy instrument at the same time;
3) In the intensive care unit (ICU) of the ward area, the oxygen system should meet the flow requirements of all beds in the care unit using the ventilator or high-flow oxygen therapy instrument at the same time;

| Table 2 | Comparison between the calculation model and actual values in Wuhan Jinyintan hospital. |
|---------|--------------------------------------------------------------------------------------------|
| Actual medical gas equipment configuration and operation data | Model calculation results | Notes |
| Configure volume of liquid oxygen tank(m$^3$) | 2*10 | The original (2*5m$^3$) tank is spare | Calculated flow of oxygen system(L/min) | 5375 |
| Configure vaporization amount of vaporizer (Nm$^3$/h) | 2*500 | One use, one preparation | Design volume of liquid oxygen tank(m$^3$) | 25.5 |
| Actual consumption of liquid oxygen per day(m$^3$) | 7-9 | Survey statistics | 2 days of gas consumption |

| Table 3 | Calculation parameter setting of medical oxygen model in Fire God Mountain Hospital |
|---------|-----------------------------------------------------------------------------------|
| Number of beds in ward | $n_1$ | Coefficient of simultaneous use of oxygen terminal in ward | $\eta_1$ | 0.7 |
| Number of oxygen terminals in ICU | $n_2$ | 60 | Coefficient of simultaneous use of oxygen terminal in ICU | $\eta_2$ | 0.8 |
| Standard oxygen therapy average flow(L/min) | $q_1$ | 5 | The proportion of serious patients converted into respiratory distress patients | $\theta$ | 0.25 |
| High-flow oxygen delivery average flow(L/min) | $q_2$ | 17 | Other oxygen terminal gas(L/min) | $Q_{\text{set}}$ | 500 |
| Average flow per terminal of ICU bed(L/min) | $q_3$ | 20 | | | |
4) The general nursing unit in the ward area can be calculated according to the gas source calculation flow model in this section. The recommended value of the parameter θ is 0.30–0.45;

5) The medical liquid oxygen storage tank air supply system is adopted. If using an air-temperature Vaporizer, the Vaporizer type is calculated according to the gas source calculation flow model provided in this study. The system flow rate should be considered, as well as the system air leakage rate.

6) When the existing hospital is transformed into a designated hospital, the medical oxygen system should be expanded and transformed referring to the above calculation model to adapt the system to local conditions. Given it is difficult for the existing hospital oxygen system supply pipe network and terminal pipes to be completed in a short time, it is recommended that when the system safety permits, increase the gas supply pressure to ensure the oxygen terminal pressure and flow.

5. Conclusion

This study analyzes and discusses the characteristics of oxygen terminal gas consumption through exploring the characteristics of novel coronary pneumonia treatment and the demands for medical oxygen in emergency designated hospitals. Based on the “Technical code for medical gases engineering” (GB50751-2012), a computational model of medical oxygen source for novel coronary pneumonia treatment is proposed. Combined with the clinical treatment needs, the model is applied to recommend the design parameters of medical oxygen system. Through the investigation of the actual oxygen consumption data of two typical designated hospitals, Jinyintan hospital and Fire God Mountain Hospital, the correctness of the recommended values of the model and design parameters are verified. The work can provide guidance for the reconstruction of the emergency oxygen supply system of the designated hospitals to fight against the epidemic situation, and provide reference for the design and construction of the medical oxygen system for similar hospitals.

The study introduces the proportion of serious patients converted into respiratory distress patients θ, which is used to correct the difference in the amount of oxygen used by different patients for respiratory support, so that the calculation results of medical oxygen source correctly reflect the actual oxygen demand. According to the research, the proportion of serious patients converted into respiratory distress patients (Proportion of patients using high-flow oxygen therapy), recommended values is 0.30–0.45 for novel coronary pneumonia, and the higher the proportion of critically ill patients admitted to the hospital is the larger value.

By analyzing the characteristics of the use of various oxygen terminal equipment, as well as different respiratory support treatment plans for patients with new coronary pneumonia, the average flow of oxygen at various oxygen therapy terminals is obtained, which is used to calculate the design and selection of the air source of the oxygen system. The recommended average flow rate flow model in this section. The recommended average flow rate of standard oxygen therapy is 5–6L/min; the recommended average flow rate of high-flow oxygen delivery is 15–25L/min; and the coefficient of simultaneous use of oxygen at the end of the ward is recommended to be 0.7–0.9. The recommended average flow rate of each terminal of the ICU bed is 20–30L/min; the coefficient of simultaneous use of ICU oxygen terminal is recommended to be 0.8–1.0. These research data provide guidance for the construction of the oxygen supply system of the new coronary pneumonia treatment hospital, and avoid the mismatch between the scale of the oxygen supply system and the actual operation demand.

Discussion on the medical oxygen supply reserves of hospitals for the treatment of new coronary pneumonia. Due to the large oxygen consumption and high utilization rate of the designated hospitals for new coronary pneumonia treatment, as an emergency measure, there are many reconstructions and expansions and new oxygen systems in a short period of time, and medical oxygen equipment reserves are limited. The recommended reserve should not be less than the gas consumption for 2 days, and the designated hospitals with unfavorable distribution conditions are recommended to increase the oxygen reserve.

Author statement

I have made significant contributions to the conceptualization, methodology, Project administration, resources, and writing-review and editing of the work;
I have approved the final version. I agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Author contributions

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Jianping Lei: Methodology, writing-review and editing.
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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] A. Jyl, Y.A. Zhi, A. Qw, et al., The epidemic of 2019-novel-coronavirus (2019-nCoV) pneumonia and insights for emerging infectious diseases in the future[J], Microb. Infect. 22 (2) (2020) 80–85.
[2] Pengpeng, Novel coronavirus infection prevention and control work in Hubei held seventeenth press conference[EB/OL], Wuhan Pulmonary Hospital(Wuhan tuberculosis prevention and treatment institute) (2020) 2.
[3] F. Yu, L. Du, D.M. Ojcius, et al., Measures for diagnosing and treating infections by a novel coronavirus responsible for a pneumonia outbreak originating in Wuhan, China[J], Microb. Infect. 22 (2) (2020).
[4] Released by National Health Commission & National Administration of Traditional Chinese Medicine on March, Diagnosis and treatment protocol for novel coronavirus pneumonia (trial version 7)[J], Chinese Med J (2020) 133.
[5] Yu-hao Liu, Feng Li , Wei Jiang, et al. Oxygen Metabolism Score Directed Respiratory Support for 2019 Novel Coronavirus Pneumonia[J]. Social ence Electronic Publishing.
[6] M. Pfeifer, S. Ewig, T. Voshaar, et al., Position paper for the state-of-the-art application of respiratory support in patients with COVID-19[J], Respiration 99 (6) (2020) 1–21.
[7] National Health Commission of the People’s Republic of China. Technical code for medical gas engineering (GB 50751-2012)[S], China Planning Press, 2012.
[8] Health and Family Planning Commission of the People’s Republic of China. Code for Design of Infectious Disease Hospital(GB50849-2014)[S], China Planning Press, 2014.
[9] Respiratory Critical Care Medicine Group, Respiratory Disease Branch, Chinese Medical Association. Expert consensus on the clinical application of nasal high-flow humidified oxygen therapy in adults [J], Chin. J. Tuberc. Respir. Dis. 42 (2) (2019) 83–91.
[10] Rémi Coudroy, Angéline Jamet, P. Petua, et al., High-flow nasal cannula oxygen therapy versus noninvasive ventilation in immunocompromised patients with acute respiratory failure: an observational cohort study[J], Ann. Intensive Care 6 (1) (2016) 45.
[11] R. Miguel-Montanes, D. Hajiage, J. Messika, et al., Use of high-flow nasal cannula oxygen therapy to prevent desaturation during tracheal intubation of intensive care patients with mild-to-moderate hypoxemia, [J], Critical Care Medicine 43 (3) (2015) 574–583.
[12] Chuan-Li Shao, Xue-Feng Gu, Bin Lu, BiPAP non-invasive ventilator in the treatment of pulmonary encephalopathy[J], Journal of Huaihai Medicine (2010).
[13] Xue-Mei Liang, Xiao-Ya Cai, Zhen Wang, et al., Meta-analysis of Comprehensive Nursing Measures for Non-invasive Ventilator in the Treatment of COPD with Respiratory Failure[J], medical information, 2019.
[14] Zhuang Ma, Liang Shi, Yong-Jun Hua, et al., Clinical analysis of invasive mechanical ventilation with bilevel positive airway pressure non-invasive ventilator[J], Chin. J. Respir. Crit. Care Med. (2008).
[15] National Medical Products Administration. Terminal Units for Medical Gas Piping Systems - Part 1: Terminal Units for Use with Compressed Medical Gases and Vacuum(VY 0801.1-2010)[S], China Standard Press, 2012.
[16] Guo-jun He, Yi-jiao Han, Qiang Fang, et al., Clinical experience of high-flow nasal cannula oxygen therapy in severe COVID-19 patients[J], J. Zhejiang Univ. 49 (2) (2020).
[17] Hubei Provincial Health Committee.Information on novel coronavirus pneumonia epidemic in Hubei province [EB/OL].February 19, 2020.
[18] Xing-wei Sun.The total number of confirmed patients in Fire God Mountain Hospital is more than 1000[N]. People’s Liberation Army.February 13, 2020.