Since the first case of coronavirus disease 2019 (COVID-19) was diagnosed, it has been reported in many provinces and cities in China, and some patients have developed severe and critically ill. Severe patients usually have dyspnea and/or hypoxemia one week after the onset, and the severe ones quickly progress to acute respiratory distress syndrome, septic shock, difficult to correct metabolic acidosis, and coagulopathy. Therefore, respiratory support therapy is an important life support measure. Medical workers are at greater risk of being infected by patients when performing respiratory therapy-related procedures. Standard protective measures can minimize the possibility of infection by medical staff, and also reduce the incidence of cross-infection in hospitals. Recently, the Central South Hospital of Wuhan University reported that the infection rate between people in COVID-19 hospital was 41% [1]. At present, domestic medical personnel have infected more than 1,700 cases of COVID-19. During the respiratory therapy, there are a large number of high-risk operations that may cause or aggravate the spread of the virus. To this end, we put forward the following precautionary recommendations for clinically commonly used respiratory therapy operations based on current evidence and domestic conditions (Figure 1), for front-line medical care Staff for reference.

**Summary** Since the diagnosis of the first new type of coronavirus pneumonia, there have been a large number of human-to-human cases, of which more than 1,700 medical staff have been infected. There are a large number of high-risk procedures for respiratory treatment of critically ill patients, such as tracheal intubation, simple respirator-assisted ventilation, non-invasive positive pressure ventilation, high-flow nasal catheter therapy, bronchoscopy, sputum suction, and transport, which can cause or worsen Extensive spread of exhaled virus in the airways. Therefore, we have formulated this precautionary recommendation based on the best current evidence and existing domestic conditions to reduce the risk of infection for medical staff while providing the best treatment for patients.
**Recommendation 1: Strict implementation of standard prevention, personal occupational protection, and isolation of patients.**

The transmission source of COVID-19 is mainly infected patients, and the transmission route is mainly respiratory droplets and contact transmission. High-concentration aerosol exposure in a closed environment may also cause transmission\(^2\). Standard precautions\(^3\) should be routinely applied in all areas of the hospital\(^4\), and patients should be isolated from contact and droplets. Patients who have not established an artificial airway should wear medical surgical masks. The World Health Organization (WHO) guidelines recommend that medical personnel should perform airborne prevention when performing treatments that can generate aerosols\(^5\). According to Guangzhou’s experience in combating SARS, room ventilation is very important. The ICU gas update rate is more than 12 times per hour. When the exhaust port is near the patient’s bedside and the air supply port is at the entrance of the medical staff, it has a good protective effect. According to the relevant guidelines\(^5,6\), three levels of protection are recommended when performing respiratory therapy-related operations in isolation wards. Operators are recommended to wear round caps, medical N95 protective masks (closed inspection should be done after wearing), work clothes, goggles Protective face screen, latex gloves, medical protective clothing (can be added with disposable impermeable isolation clothing), shoe covers / boot covers, and medical protective hoods if necessary. Secondary care should be used when caring for patients recovering (negative nucleic acid tests twice).

When conditions are limited and ventilation equipment such as central air conditioning is required to be turned off, the following measures should be taken when using general wards to treat non-invasive or (and) invasive COVID-19 patients.

1. Patients are managed centrally, and non-invasive ventilation or invasive ventilation patients are isolated in a single room. When there is no condition, no more than 2 intubated patients are admitted to each ward. Patients with non-invasive ventilation and invasive ventilation should not be placed in the same room. The isolation ward for mechanically ventilated patients should be planned in a corner room with good ventilation.
2. Open windows daily for ventilation.
3. Use 2000 mg / L chlorine-containing disinfectant to wipe the instruments and the bed around the room twice a day.
4. Continuously turn on the air sterilizer, and intermittently sterilize by ultraviolet light when possible.
5. Close the door before and after entering and leaving the ward.
6. Minimize the length of stay in the isolation ward and reduce medical staff access.

**Recommendation 2: Use measures to reduce aerosol diffusion during nasal high-flow oxygen therapy, such as patients wearing medical surgical masks.**

Gas flow exceeding the patient’s inspiratory flow is an important feature of nasal high flow nasal cannula (HFNC). High flow can provide sufficient oxygen supply and dead space scouring of the upper airway\(^7\). At 45 L / min, the upper airway dead space gas can be washed away within 500 ms\(^8\). Hui et al.\(^9\) monitored the diffusion distance of exhaled gas at high nasal flow in an in vitro model and found that, The diffusion distance of exhaled breath increases with the increase of gas flow. In addition, the patient’s cough can also significantly increase the expiratory distance, and wearing a mask (especially the N95 mask) to the simulated person can significantly reduce the expiratory distance\(^10\). COVID-19 patients often have cough symptoms. Therefore, we recommend that these patients wear medical surgical masks and try to breathe closed mouth and nose when using HFNC (Figure 2). In addition, the research results show that the loose connection of high-flow nasal catheter is an
A significant reason for the increase in the patient's expiratory distance is the significant increase of the patient's expiratory distance during high-flow nasal catheter therapy (HFNC). Therefore, when using HFNC, attention should be paid to tightly connecting the nasal catheter. Due to the weight of the tube itself in clinical use, the nasal tube is pulled to cause displacement, and the tube can be fixed by a clip or a lanyard to reduce the weight of the tube. The principle of selecting a high-flow nasal obstruction catheter model is that the diameter of the catheter should be less than or equal to 50% of the patient's nostril.

**Suggestion 3: Use a closed mask and a virus-filtering heat and moisture exchanger (HME) during non-invasive ventilation, or use a dual-line ventilator that can place filters on the inspiratory and expiratory ends; masks fit tightly to the face to avoid unintentional leaks.**

**Set the ventilator to standby before wearing and removing the mask.**

During non-invasive ventilation, the exhaled gas of patients in the negative pressure ward can diffuse to a range of 1 m. Due to the different leak holes in the mask, the diffusion distance of exhaled air is different, and the diffusion distance will increase with the increase of the set pressure. In vivo studies have shown that non-invasive ventilation can increase the surface deposition of droplets with an average diameter > 10 μm beyond the range of 20 cm. In view of the contagiousness and transmission of the new coronavirus similar to severe acute respiratory syndrome (SARS), we refer to the prevention recommendations of SARS: medical staff should take three-level protective measures when caring for non-invasive ventilation patients. When using single-pipe non-invasive ventilation, you should avoid using a mask with an exhalation valve (Figure 3A), try to use a closed mask with an exhalation valve and HME with virus filtering in series (Figure 3B), and avoid using a heated humidifier; if the patient does not need to use a humidified humidifier, such as long-term use of non-invasive ventilation (> 24 h) and cannot tolerate non-invasive ventilation for drinking, oral care, sputum and other operations, and combined bacterial infections, patients with thick airway secretions can consider using a dual circuit ventilator with non-invasive ventilation function, because it can heat and humidify the inhaled gas and can install a virus filter on the expiratory end (Figure 3C), thereby reducing non-invasiveness. Aerosols in patient's exhaled breath during ventilation pollute indoor environment. No matter what kind of ventilator is used, pay close attention to the condition of the filter during use. If pollution or condensate deposits cause poor ventilation of the ventilator and the patient's exhalation resistance increases, the filter should be replaced in time. During non-invasive ventilation, a tight fit between the mask and the face should be ensured to reduce unintentional leaks. When the patient needs to sputum, he should stop taking off the mask in time. When there is sputum in the mask, he should clean it up and wipe it with 75% alcohol. To prevent the patient's droplets or exhaled aerosol from polluting the environment, the ventilator can be set to standby before wearing and removing the mask. The results of a recent large-scale study of acute hypoxic respiratory failure showed that the use of high-flow nasal catheters instead of ordinary oxygen therapy during the non-invasive ventilation interval can significantly improve the success rate of non-invasive ventilation. Therefore, it is suggested that under conditions, non-invasive ventilation and high-flow nasal catheters can be used alternately to increase patient comfort and increase the success rate of non-invasive ventilation.
Recommendation 4: When using a simple respirator, ensure that the method and strength of the fixed mask are correct, and avoid breathing out of sync; a virus filter is connected between the mask and the simple respirator.

Manual ventilation of a simple respirator is a high-risk operation for droplet or aerosol transmission \(^{17}\). In a simulation study, it was found that the improper fit of the simple respirator mask and the patient's face is important for the dispersion of the droplet or aerosol. Reason \(^{18}\), which prompts us that manual operation is required for skilled personnel to maintain a close fit and breathing synchronization. The research results also suggest that the tandem breathing filter between the mask and the simple respirator can significantly reduce the patient's flight when properly operated. Foam or exhaled aerosol leak. It is recommended to add a filter between the simple respirator and the mask or artificial airway during use (Figure 4) to reduce the spread of the virus in the patient's airway to the indoor air. The simple respirator should be dedicated to the person, and it should be usually arranged next to the bed of the patient with artificial airway, and should be wiped and disinfected with 75% alcohol after each use, and wiped with 75% alcohol before final disinfection. Sterilization.

Recommendation 5: It is recommended to use a visual bronchoscope with an electronic screen for bronchoscopy. Before the examination, sedation is appropriate (muscle relaxants can be used for mechanically ventilated patients), and preventive measures to reduce the aerosol diffusion of patients, such as patients wearing masks, oral cavity

Negative pressure air attracts or keeps the breathing circuit closed. For patients undergoing non-invasive ventilation, it is recommended to choose a mask with a
The indications for bronchoscopy should be strictly grasped to avoid unnecessary operations. In addition to the measures to regulate the management of bronchoscopes during use \[19\], three levels of protection should be carried out, and operators should wear powered positive pressure air purification hoods \[20\] when conditions permit. Before bronchoscopy, appropriate sedation (muscle relaxants can be used in patients with mechanical ventilation) to reduce cough and sputum and intolerance. Patients without artificial airways should wear a mask to cover the mouth when under nasal aspirator under full local anesthesia (Figure 5). If necessary, a negative pressure suction tube can be added to form a local negative pressure to clear the cough droplets from the patient \[18\]. For patients who are receiving non-invasive ventilation, a non-invasive ventilation mask with a bronchoscope inlet can be replaced after the bronchoscopy through the inlet, which can ensure the patient's ventilation and oxygenation needs while performing bronchoscopy, thereby avoiding ventilation or oxygen during the examination. Combined deterioration \[21\], \[22\]; At the same time, the use of a mask can minimize the pollution of the patient's droplets or exhaled aerosols (Figure 6). If such a mask is not available, a three-way connector can be used to connect the mask of a simple respirator and insert a bronchoscope through the suction hole (Figure 7A). Patients with artificial airways can pass the suction tube at the suction hole of the extension tube of the breathing circuit to maintain the tightness of the circuit (Figure 7B), reducing the risk of patients exhaling aerosol. Immediately after the bronchoscopy, insert a 75% alcohol bottle for negative pressure suction to clean and disinfect the bronchoscope suction tube, wipe the surface of the bronchoscope with 75% alcohol, and then seal the bronchoscope with a sealed bag and send it for sterilization.

**Recommendation 6:** A video laryngoscope or a video bronchoscope is recommended for tracheal intubation, a rapid induction anesthesia program using sedatives and muscle relaxants to reduce cough intensity, and implement measures to reduce patient aerosol spread, such as Wear a mask on the patient when the negative pressure in the tracheal bronchoscopy channel to provide complete bronchoscopy while ensuring respiratory support.
tube is suctioning or intubating through the nose. Masks with tracheal intubation or bronchoscopy can be used to perform nasal tracheal intubation with noninvasive ventilation for respiratory support. Before tracheotomy of a patient, the risks and benefits should be carefully weighed. The balloon pressure of the artificial airway should be maintained at 25 ~ 30 cmH$_2$O and the balloon pressure should be monitored regularly.

The results of a retrospective systematic review show that tracheal intubation, non-invasive ventilation, tracheotomy, and manual ventilation before tracheal intubation during medical activities can increase the risk of SARS infection in health care-related personnel. A consistent conclusion was reached: tracheal intubation has a significant correlation with it. Although the quality of the studies included in this study was low, due to the development of the SARS epidemic and time constraints at the time, it was less feasible to conduct a high-quality prospective randomized controlled study, so the authors believe that this systematic review study There is still a certain reference value in the prevention of COVID-19 transmission.

The results of some model studies show that, regardless of the presence or absence of artificial airways, the diffusion distance of the patient’s gas when coughing is significantly affected by the intensity of the cough. For example, the normal cough can be sprayed at a distance of (860 ± 93) mm when not intubated, and moderate cough. The time distance is (298 ± 43) mm. In addition, when continuous negative pressure suction (~45 kPa) is placed in the mouth or intubation during coughing, the aerosol dispersion can be reduced by more than 32%.

The results of this study suggest that when performing aerosol-prone treatments such as tracheal intubation, the patient’s cough intensity should be appropriately suppressed, such as the use of sedatives or even muscle relaxants to reduce the outward diffusion of aerosols in the patient’s body while intubating. The use of visual laryngoscopes and suction of negative pressure in the mouth and trachea can reduce the risk of exposure of medical personnel. For example, patients can wear masks and suction of negative pressure during nasal tracheal intubation (Figure 5).

For transnasal tracheal intubation, it is recommended to choose visual nasal tracheal intubation under the guidance of a bronchoscope. This method can keep the operator and the patient relatively far away, and may reduce the risk of the operator being exposed to the aerosol coughed by the patient. The Guangzhou Institute of Respiratory Diseases has independently developed a non-invasive mask with a tracheal intubation or bronchoscopy channel (Figure 6), which can ensure that patients receive non-invasive ventilation while inserting a bronchoscope through the channel and guiding transnasal tracheal intubation. Compared with the conventional intubation process, this method can significantly reduce the incidence of hypoxemia during tracheal intubation in critically ill patients with respiratory failure. In addition, the mask can also seal the airway when dealing with respiratory infectious diseases, and it can play a good role in protecting medical personnel. Medical personnel can wear positive-pressure air purification hoods for intubation when conditions permit. Tracheotomy is a high risk factor for infection of medical staff. To reduce tracheotomy, you should consider appropriately lengthening the tube time for oral or nasal intubation. Before tracheotomy, you should carefully weigh the risks and benefits and do three-level protection.

After the establishment of an artificial airway (tracheal intubation or tracheotomy), the pressure of the balloon should be maintained at 25 ~ 30 cmH$_2$O (1 cmH$_2$O = 0.098 kPa) and the balloon pressure gauge should be used routinely (every 6 ~ 8 h) to ensure effective ventilation and reduce air pollution caused by aspiration and air leakage due to inadequate airbag sealing. At the same time, it reduces airway mucosal compression damage caused by excessive inflation of the airbag.

**Recommendation 7: Sputum suction on demand, without frequent replacement of closed sputum suction devices, can be used continuously for 1 week.**

The results of a retrospective analysis of SARS showed that caregivers who had sputum suction before and during intubation had a four-fold increased risk of SARS infection than caregivers who had not performed sputum suction, the authors believe Some caregivers did not know that they were caring for SARS patients and failed to provide proper protection. This reminds us that even in the face of suspected patients, medical personnel should take personal protection when suctioning. We recommend that patients with invasive ventilation use a closed sputum suction device. Before use, ensure that the device is tightly connected without damage; it is worth noting that the closed sputum tube does not need to be replaced regularly. Use sterile saline or sterilized injection after each sputum suction. Rinse with water through the side flushing holes (Figure 8). The closed sputum suction tube can be used continuously for 1 week before considering replacement. Sputum should be sucked as
needed, and the signs of sputum suction should be evaluated regularly, such as coughing, auscultation of sputum, and ventilator monitoring showing increased airway pressure and decreased tidal volume.

**Figure 8** Guidelines for flushing closed sputum suction devices

**Recommendation eight:** Keep the breathing circuit closed during mechanical ventilation, and configure virus filters on both the inspiratory and expiratory ends; it is recommended to use a disposable double-heated guidewire breathing circuit. The breathing circuit does not need to be replaced routinely when there is no obvious pollution. A ventilator using an air compressor or turbocharger should routinely check its own virus filter and replace it regularly.

Relevant research results show that the aerosol particles discharged by the filter at the exhalation end are 160 times higher than the aerosol particles discharged with the filter. Medical personnel’s exposure to second-hand or exhaled aerosolization drugs and patient droplets accounts for more than 45% of iatrogenic drug damage. Therefore, during mechanical ventilation in patients with COVID-19 pneumonia, it is recommended to add a virus filter to the exhalation end of the breathing circuit to reduce the pollution of the patient’s exhaled air to the environment. It should be noted that some ventilators are equipped with reusable high-efficiency filters, such as PB840, PB980, etc. In general, there is no need to add an additional filter, just add an additional one on the exhalation side when inhaling. Filters; most ventilators are not equipped with exhalation filters, such as Dräger, Siemens, etc., virus filters should be routinely added to the exhalation end, based on the condensate residue on the filter and the patient’s exhalation resistance. Whether the filter needs to be replaced, if the exhalation resistance is increased or airway occlusion occurs (Figure 9). When changing the filter, the speed should be increased to reduce the pollution of the patient’s exhaled air to the environment. Avoid disconnection of the ventilator tube during the use of the ventilator, and it is not necessary to replace it routinely if there is no obvious contamination of the ventilator tube. Research results show that frequent replacement of the breathing circuit has a tendency to increase ventilator associated pneumonia (VAP). It also increases the risk of exposure of the virus in the patient’s airways to the surrounding environment. The condensate formed in the ventilator tube may carry viruses. To avoid or reduce the generation of condensate, you can choose a single-use dual-circuit heating guide wire tube. Only when using a pipe without a heating wire, a condensate collecting cup should be added to the ventilator pipe and poured in time. The condensed water needs to be harmlessly treated. The internal gas path of ventilator is disinfected, such as Dräger Savina, Wellcom esprit and other ventilators and air compressors with internal virus filters should be replaced routinely. COVID-19 patients should be replaced immediately after use. Other ventilators that use central oxygen and central air supply use sterile medical gas, and both the inspiratory and expiratory sides of the ventilator are equipped with virus filters, and the patient’s exhaled virus returns to the internal circuit of the ventilator. It is unlikely that internal airway disinfection is required.
Figure 9 Figure 9A shows the monitoring and waveform of the ventilator during normal use, and Figure 9B shows the increase in expiratory resistance: peak airway pressure and end-expiratory pressure increase, respiratory system compliance decreases, the expiratory airflow time is significantly prolonged and insufflation Ventilator alarm shows air trap

Recommendation Nine: Try to avoid mechanically ventilated patient transfers and make adequate preparations if necessary.

Preparations should be made before the transfer is carried out, and the transfer route should be planned in advance. The ventilator-related preparation operations include cleaning the condensate in the breathing circuit and the patient's airway and oral secretions, transferring parts of the ventilator connection circuit to prevent accidental disconnection, and adding a virus filter between the ventilator circuit and the endotracheal tube. The functional HME (Figure 10) does not need to be removed when a closed suction device is available. Appropriate sedation during transport can reduce man-machine confrontation and avoid irritating cough. It is recommended to use disposable tubing and treat as medical waste immediately after use. At the same time, comprehensively disinfect the ventilator, including using 75% alcohol or 1000 mg/L chlorine-containing disinfectant to wipe the surface of the ventilator and oxygen tank, and for sensors, exhalation valves, etc., soak with 75% alcohol for 30 minutes.

Figure 10 Transfer ventilator plus temperature and humidity exchanger with virus filter function

Recommendation 10: Use ventilator pressure support (PSV) for voluntary breathing test (SBT) before weaning for patients with invasive ventilation. Avoid using T-tube method.

Explain with patients before extubation and prepare sequential respiratory support equipment in advance. Operators take three levels of protection. An artificial nose is recommended after tracheotomy for patients withdrawn from mechanical ventilation.

The 2017 ATS withdrawal guideline recommends PSV for SBT based on moderate quality evidence. The results of a recent multicenter randomized controlled study by Subira et al. showed that PSV (30 min) had a higher success rate of extubation than the T tube (2 h). For the transmission prevention of COVID-19, the PSV method has more sealing performance than the T-tube method and reduces the risk of aerosol spread. Before extubation, communicate with the patient to explain the operation purpose and process to get cooperation, and prepare sequential respiratory support equipment. Removal of tracheal intubation will inevitably stimulate cough and sputum in patients. In addition to routine operations during extubation, negative pressure will be added to the
mouth to attract and cover treatment towels or disposable bedspreads to prevent droplets from spreading (Figure 11). Patients with chronic cardiopulmonary disease should fully evaluate cardiopulmonary compensatory function and choose noninvasive or HFNC sequential support ventilation. Operators use three-level protection measures, and those with conditions can wear powered positive pressure air purification hoods.

Patients with tracheostomy may need to retain the incision cannula for a period of time after disengagement from mechanical ventilation, so an artificial nose is recommended to provide airway warming. If the patient has airway protection, the balloon should be fully deflated. If necessary, oxygen therapy can be provided by the upper airway after the balloon is deflated; if the patient needs to keep the balloon inflated to prevent accidental inhalation, the gas-cut mask can be used. Connected to the venturi device and buckled on the artificial nose to provide oxygen therapy.

**Recommendation 11: Reduce unnecessary chest physiotherapy and sputum machine-assisted sputum operation in the acute phase to promote aerosol dispersal.**

The results of in vivo studies by Simonds et al. showed that physical therapy can increase the generation of droplets with an average diameter> 10 μm and can be deposited within 1 m of the surrounding environment. Although retrospective studies have shown that chest physiotherapy does not increase the risk of SARS infection among caregivers, it may benefit from strict protective measures. Therefore, given the fact that it increases droplet production, unnecessary chest physiotherapy should be avoided. For those who really need treatment, medical staff should take precautions and wear masks to patients. Patients may cough and expectorate during drainage. Patients without artificial airways are recommended to wear medical surgical masks. Patients with sputum use tissue paper to cover their noses and noses and wipe them clean. Those with artificial airways use closed suction devices. And timely suction of negative pressure in the mouth and nose.

**Recommendation twelve: Patients with pure COVID-19 should try to avoid unnecessary aerosol inhalation treatment.**

When patients with COPD or asthma do need to inhale, dry powder inhaler and pressure dosing inhaler + mist storage tank are preferred; mechanical ventilator recommends using vibrating screen atomizer, placed at the air inlet end of the humidification tank No need to remove. The virus filter on the exhalation side of the nebulizer should not be removed.

Aerosol aerodynamic results show the spread of influenza virus, influenza patients expectorated aerosols, 65% of influenza virus RNA present in an aerodynamic diameter of <4 μm in the aerosol particles, and these gas both sol particles can be inhaled into the body and may be similar to coronavirus infections. Although the drug aerosol diffused during atomization has a lower risk of transmitting disease than the aerosol particles discharged.
from the patient, the aerosol generated during atomization can carry the virus carried by the patient's exhaled gas, so it should be reduced during the outbreak. Nebulization is necessary to reduce the risk of aerosol particulate transmission. Some research results show that even when using spray nebulization inhalation treatment in a negative pressure ward, with the increase of shallow and fast breathing, the maximum distance of aerosol particles from the side hole of the nebulizer mask increases (0.45 ~ 0.80 m) \(^{32}\). Therefore, if it is necessary to inhale, it is recommended that patients with spontaneous breathing use an active inhalation-driven nebulization device (such as a dry powder inhaler) or a metered dose inhalation device (such as a pressure metered dose inhaler (pMDI)), both. After inhalation, wipe the mouth and mouth with 75% alcohol. When using pMDI, it is recommended to use a mist storage tank, which is for the exclusive use of mist storage tanks. The final disinfection of the mist storage tank can be soaked with 75% alcohol. For mechanically ventilated patients requiring inhalation therapy, it is recommended to use a vibrating screen nebulizer and place the T tube at the intake end of the humidifier tank of the ventilator \(^{33}\) (Figure 12). It is placed in the circuit for the next use. When nebulizing, the medicine only needs to be placed in the nebulizer cup through the nebulizer opening. If the nebulization treatment takes a long time (> 30 min) or many times (4 ~ 6 times / d), it is recommended to add a virus filter on the ventilator's air end during nebulization to prevent the nebulization medicine from entering the ventilator and affecting the ventilator. Performance, closely observe changes in airway resistance. Health care professionals should follow the precautionary measures recommended for aerosol inhalation treatment.

![Figure 12 Placement of vibrating screen atomizer](image)

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