Ventilo

COVID-19

Management protocol on aspects of respiratory support of patients with suspected or confirmed COVID-19

○ Last update 09/04/2020

○ The protocol is based on the most recent data in the literature. Changes could subsequently be made based on the evolution in the number of cases, the possibility of problems accessing ventilators and as the data in medical literature evolves.

Summary

Front-line respiratory support (outside intensive care)

Oxygen therapy: This will be the first and only respiratory support for most hospitalized patients. Oxygen flows will be adjusted to achieve SpO_2 of between 90 and 98%, a large range to limit the number of intervention required from healthcare workers. For COPD patients or patients either with or at risk of developing hypercapnia, the SpO_2 target will be between 88 and 92%.

Automated oxygen titration and monitoring may be useful to reduce the healthcare workers interventions and to optimize oxygenation (more time in the SpO_2 target, less time with hypoxemia/hyperoxemia).

Beyond 6L/min of oxygen (FiO_2 estimated between 45 and 50%) to obtain a SpO_2 reading > 90%, in the event of hemodynamic instability (hypotension, tachycardia) or other organ failure, a transfer to intensive care should be considered. This shall be validated by the intensivist. A discussion on the level of care shall take place quickly as soon as patients are admitted to hospital.

Respiratory supports in intensive care (alternatives to invasive ventilation)

Non-Invasive Ventilation and Nasal High Flow must be reserved for vary specific indications, which shall be validated by the intensivists. It should always be used in a negative pressure room with increased protections (a mask or visor for the patient). The no. 1 objective is not to have to perform emergency intubation on the patient+++

Invasive ventilation: avoid emergency intubations – go with protective ventilation first

Intubation criteria: The main objective is to perform intubation under optimal and non-urgent conditions. The intubation respiratory criteria are regular criteria, but bear in mind that patients shall be intubated rather earlier than later. The oxygenation criteria for intubation in our centre are as follows: SpO_2 < 92% with a FiO_2 at 80% with a Ventimask or high respiratory work of breathing.

Intubation procedure: Intubation must be prepared before entering the patient's room, and all the equipment necessary for intubation must be ready before entering the patient's room. The minimum number of persons necessary shall enter the room for the procedure. Five minutes of preoxygenation is recommended to avoid, if possible, ventilation with Ambu prior to intubation. In the event of ventilation with a mask, use a HEPA filter between the mask and the Ambu, use a Guedel Airway, use small volumes and minimize leaks. The use of rapid sequence intubation and curarization is recommended. Intubation with a video laryngoscope is recommended as a first intention.

Initial ventilator settings: The objective of initial settings is to quickly obtain (without having to remake the adjustments) the protective ventilation settings allowing for adapted ventilation and oxygenation. A heated humidifier should be first put in place with a HEPA filter on the expiratory airway. The recommended initial tidal volume is 4 to 6 ml/Kg $_{PBW}$ and respiratory frequency at least 20/minute (or at least 25/min if a heat and moisture exchanger is used), with an inspiratory flow of 40 to 70L/min. The initial PEEP level shall be set at 6-10 cmH_2O according to hemodynamics and then with a moderate level of PEEP. The SpO_2 sought shall be from 90 to 98%, but if the necessary FiO_2 is > 60%, the SpO_2 sought shall be between 88 and 95%. Plateau pressures should be minimized and always remain at < 30 cmH_2O.

Introduction

According to data that is currently available, approximately 20% of patients with SARS-CoV2 will require hospitalization[1]. 80% of patients have mild forms (asymptomatic or paucisymptomatic and with SpO_2 > 90% in ambient air) and will not have to be hospitalized, in which case management involving home quarantining is recommended[2,3]. 15% of patients will come down with a severe form (pneumonia needing oxygen but not requiring a transfer to intensive care). Finally, 5% of patients will need intensive care management (elevated oxygen requirements that need other respiratory supports, or for the management of other organ failures) (Figure 1). Given the current epidemic, it is recommended that all health-care personnel wear a mask when they meet patients (confirmed cases, of course, but also all patients with respiratory symptoms) or their family[4]. The recommendations proposed for respiratory support are intended to offer the best care to patients based on recommendations, while taking into account the risk of transmission to health-care personnel and therefore minimizing insufficiently validated interventions and situations posing a transmission risk (Figure 2)[5-7].

These recommendations on ventilatory aspects must be accompanied by clear guidelines on the level of care based on the patients' age, their autonomy and comorbidities in view of the very bleak prognosis for some populations and resources that could become limited[8,9]. These issues shall be clarified quickly right at the start of hospitalization.

Front-line respiratory support (outside intensive care)

Oxygen therapy

This will be the first and only respiratory support for most hospitalized patients[10,11]. Oxygen therapy to achieve SpO_2 between 90 and 98% seems to have been adapted. Several recommendations have been published in recent years, proposing different SpO_2 targets of 90-94[12], 92-96[13], 94-98[14,15]. In this context that involves a transmissible respiratory germ pathology and to limit the number of needless interventions, we are proposing a broad target pulse saturation range of 90 to 98% for standard oxygen therapy, which can be delivered with nasal prongs or a mask. For COPD patients or patients either with or at risk of developing hypercapnia, the SpO_2 target will be between 88 and 92%[14].

As numerous studies have shown, it is important to limit periods with hyperoxemia[15-18] to the same extent as hypoxemia, and according to very recent data, the percentage of time within the oxygenation target is inversely proportional to mortality (Figure 3)[15].

Automated oxygen titration and monitoring may be useful to reduce the healthcare workers interventions and to optimize oxygenation (more time in the target, less time with hypoxemia/hyperoxemia)[19, 20].

Some 25 to 30% of hospitalized patients will require intensive care management, which involves closer patient supervision, and in particular, the evolution of oxygen requirements shall be monitored. Clinical deterioration, which is associated with an increase in oxygen requirements or organ failures, often occurs during the second week of evolution[21] and seems to be linked to an immunological inflammatory reaction (a "cytokine storm") or bacterial surinfection, which seems to be less frequent than during flu.

Beyond 6L/min of oxygen (FiO_2 estimated between 45 and 50%)[22] to obtain SpO_2 > 90%, in the event of hemodynamic instability (hypotension, tachycardia) or other organ failure, patients should be transferred to intensive care to allow close monitoring. When high oxygen flow are used, above 4 or 5L / minute, some bench studies show a possible risk of aerosol dispersion when nasal cannulas are used[23]. In this case, the use of an oxygen mask (rather than nasal cannulas) or a protective mask worn by patients as recommended for high-flow oxygen therapy, could reduce the risk of aerosols[24, 25] (Figure 4).

Patients receiving simple oxygen therapy support should wear a mask, if possible[3, 5], at least in the presence of health-care personnel in their room and when being transported outside their room. The generation of aerosols seems quite diminished when patients are wearing surgical masks[26]. Conversely, the wearing of masks by patients can increase lateral aerosols[26].

The level of care shall be discussed quickly as soon as patients are admitted to hospital.

Before patients are transferred to intensive care and before they are in respiratory distress, don't forget to ask them their height and weight, which will make subsequent protective ventilation easier!

Respiratory supports in intensive care (alternatives to invasive ventilation):

The same oxygenation targets shall apply to oxygen therapy cases in intensive care.

Neither non-invasive ventilation, nor high flow nasal canulas are contraindicated in the recommendations of the WHO[2] or the SRLF[4], or in recent reviews[3]. However, the utilization of High Flow Nasal Therapy during COVID-19 remains controversial[27]. In some recommendations, high flow ventilation is present in algorithms prior to intubation and should be used rather than non-invasive ventilation[28]. The use of NIV and high flow should be limited to very specific indications. Practices differ from centre to centre and should be discussed according to the services normally provided. When these supports are used, close supervision is necessary given the high risk of intubation, and objective #1 does state that patients are not to be urgently intubated [2, 3]. Ideally, they should be performed in private negative pressure rooms or with filtered air[4]. These recommendations may evolve if the number of cases increases or if access to ventilators becomes limited.

One important question is balancing the risks for patients receiving sub-optimal management and the risks of transmission to health care personnel[27]. There are risks to patients if NIV or CPAP are not used for classic indications (cardiogenic pulmonary oedema or COPD exacerbation), and in cases of hypoxemia, not using high flow could be considered sub-optimal. Risks to health care personnel, more often than not, are linked to possible quarantine and to the disorganization of the health care system rather than to a vital risk, most often when health care personnel is part of a population less at risk (less than 60 years old). Contrary to coronavirus-SARS which had a high mortality rate close to 10% [29, 30], and even moreso with coronavirus-MERS with a mortality rate of 35%[31], the COVID-19 mortality rate seems to be quite low for health care personnel, particularly among health-care personnel under 60 years of age with no comorbidities[8, 32]. Nonetheless, serious cases involving health care personnel are being increasingly reported, and this possibility must not be overlooked.

When patients are receiving limited care and when a decision has been made not to intubate, these alternatives should not be used due to the risk posed to health care personnel.

Non-invasive ventilation

The use of non-invasive ventilation should be limited to the maximum +++, but could be considered in the case of cardiogenic pulmonary oedema or exacerbation of COPD mainly.

In the event of bilateral pneumonia and high oxygen requirements, which suggests extended evolution duration, the NIV option should be avoided. The success rate of NIV is very low (<25%) in patients with COVID-19, and when NIV fails, the mortality rate is very high[33]. Care should be taken that tidal volumes administered remain low and less than 9.5 mL/kg[34], and that respiratory work of breathing remains moderate to limit elevated trans-pulmonary pressures and patient's self-induced lung injury[35, 36].

The risks of SARS transmission were evaluated during the various respiratory supports, and the risk for NIV was evaluated at 3.1 (1.4, 6.8) (OR, CI)[6].
The risks of aerosol generation were bench tested in various situations. NIV masks with expiratory leaks (single-limb ventilators) are to be avoided[37, 38] (Figure 5). If NIV is the chosen option, it should be done with a double-limb ventilator and an adapted mask positioned to limit leaks, with a HEPA filter on the expiratory airway and with minimized total inspiratory pressure levels (Figure 5). Total inspiratory pressure (PSV + PEEP) should remain under 15 cmH_2O.

Intermittent NIV could be used if the patient has worsening COPD or cystic fibrosis with significant respiratory acidosis, if oxygen requirements are moderate (FiO_2 < 50% to remain within the SpO_2 target values of between 88 and 92%). This remains the care standard and the benchmark treatment, which reduces the mortality rate of these patients[39]. Oxygen therapy with high flow nasal cannulas is an acceptable alternative in this indication[40-42], especially since it requires less manipulation by respiratory therapists as it is continuous therapy, unlike NIV. In this case, a flow limited to 30 or 40L/min should preferably be used.

Patients receiving CPAP at night for diagnosed sleep apnea should receive CPAP when they are hospitalized along with their usual parameters. If possible, this technique should be used in negative pressure rooms. If CPAP devices with single-limb circuits and vented masks are used, bear in mind these are situations with a significant risk of generating aerosols[43] (Figure 5). As an alternative, dual-limb ventilators (Trilogy type) with non-vented masks could be used when possible.

Nasal high flow

Nasal high flow should be used with precautions and after consensus with all of the care teams.

Nasal high flow reduces the respiratory drive of patients in acute respiratory distress and reduces transpulmonary pressure[44] and the associated lesions. Nasal high flow reduces mortality during acute hypoxemia-causing respiratory distress, particularly among patients who are the most hypoxemic[45].

Nasal high flow can be used on patients with significant respiratory requirements or significant breathing efforts[44]. The risks of transmitting SARS were evaluated with high flow and seemed moderate, but there is few available data[6, 46]. Bench data showed that aerosol generation was moderate in nasal high flow, particularly for flows under 40L/min[43, 47] (Figure 7). Conversely, if the cannulas are improperly placed or not tight enough or too small in diameter, the risk of leaks is greater[45]. The main physiological effects relating to a deadspace washout exist at 20L/min[42, 48], but the PEEP effects are lower under 40L/min[42].

When using nasal high flow, there must be certainty that the patient is consenting (do not use on patients who are not cooperative). The flows used should be limited to 30L/min and the maximum FiO_2 used should not exceed 80% to obtain a SpO_2 greater than 92%. The objective is to ensure some leeway to avoid emergency intubations.

To limit the risks of dispersing bioaerosols, the use of surgical masks or visors by patients could be considered (Figure 4).

Invasive ventilation

Intubation criteria

The main objective is to perform intubation under optimal and non-urgent conditions to limit errors and the risks of contaminating healthcare staff and to limit the use of mask ventilation that generates a lot of aerosol. That is why criteria calling for earlier intubation than what is common practice are recommended. The intubation respiratory criteria are regular criteria, but bear in mind that patients shall be intubated rather earlier than later. The oxygenation criteria for intubation are as follows: SpO_2 < 92% with a FiO_2 at 80% with a Ventimask or presence of high work of breathing with risk of high transpulmonary pressures[36].

Intubation procedure

This procedure is among those procedures with the greatest risk of generating particles and infectious transmission[6]. The risk increase is estimated 6.6 in this systematic review, which is based on several studies.

Intubation must be prepared before entering the patient's room, and all of the equipment necessary for the intubation must be ready. Emergency intubation situations must be avoided[5].

A checklist should be available for the rooms of COVID patients and the procedure prepared before the responders (senior intensivist, nurse and respiratory therapist) enter (Figure 8). The number of persons entering the room shall be kept to a minimum, and students should not take part in these risky procedures. The ventilator and the circuits must be prepared in advance. Preoxygenation is recommended to avoid, if possible, Ambu ventilation prior to intubation (which carries a high risk of generating aerosols). Preoxygenation can be done with high flow, if it was used previously, or with a reservoir mask for 3 to 5 minutes. The use of rapid sequence intubation and curarization is recommended[4]. Intubation with a video-laryngoscope is recommended as a first intention.

If manual ventilation is needed if the patient desaturates, a humidifier and electrostatic filter must be positioned between the mask and the Ambu (Figure 9).

Ventilation circuit: a heated humidifier should first be used given the high risk of severe ARDS in these patients[11] and to avoid having to change the circuit after a few days of use. Reducing the dead space is part of the recommendations pertaining to the management of patients with ARDS[49]. In this case, protective ventilation (TV = 6mL/Kg_{PBW} and respiratory rate (RR) of 20/min with a heated humidifier or 25/min with a heat and moisture exchanger) or an ultra-protective ventilation (TV < 6mL/Kg_{PBW} and RR > 25-30) will be required and easier to achieve with minimized deadspace[49, 50]. The objective of using a heated humidifier initially is to avoid having to change the circuit following intubation in the event of severe respiratory acidosis, given the risks of generating droplets each time the circuit is disconnected. A closed suction circuit should be used[49] to reduce the risk of aerosols related to endotracheal suctions[6]. A HEPA filter shall be placed on the expiratory airway of the ventilator[4]. When a heated humidifier is used, a "porous" expiratory circuit reduces water content at the end of the expiratory airway[51] and consequently limits the resistance of expiratory filters[51]. For the same reason, HEPA expiratory filters can be heated specific filters or filters that are not very effective in terms of humidification to avoid retaining water vapours[52]. When the ventilator circuit is disconnected, the endotracheal tube should be clamped during expiration to avoid derecruitment, and ventilation should be stopped prior to disconnection. The recommended sequence is clamping during expiration immediately followed by turning off the ventilator.

Initial ventilator settings

The ventilator settings of patients with COVID-19 may differ from "typical" ARDS. The conclusion of Gattinoni's recent recommendations was: " all we can do ventilating these patients is "buying time" with minimum additional damage: the lowest possible PEEP and gentle ventilation. We need to be patient "[36]. The objective of initial settings is to quickly obtain (without having to remake the adjustments) the protective ventilation settings allowing for adapted ventilation and oxygenation. The proposed settings are based on reduced tidal volumes given the hypothesis that patients intubated for COVID-19 will probably have moderate or severe ARDS[3, 11]. As previously mentioned, several characteristics of the respiratory lesions demonstrate that it is not a "typical" ARDS[36]. Volume-controlled ventilation mode is recommended for the first intention. The recommended initial tidal volume will be 6 ml/Kg_{PBW}. According to data in the literature, initial minute target ventilation for these patients with increased metabolism and often a high temperature should be a minimum of 150 mL/kg_{PBW} [53]. In practice, this initially means respiratory rate of at least 20/minute if a heated humidifier is used or at least 25/minute if a heat and moisture exchanger (HME) is used, which implies using a minimum inspiratory flow of 40 to 70L/min to limit auto-PEEP. These recommendations are based on the ventilation needed for a patient with ARDS since this will most frequently be the case if patients require invasive ventilation. The "VentilO" Smartphone app provides initial settings following intubation based on gender, height/weight, temperature, type of patient and dead space.

Main settings (TV, RR, PEEP, FiO_2)

Tidal volume (TV) = 4-6 mL/kg_{PBW} (**objective to keep Pplat < 30 cmH_2O**, driving pressure < 15 cmH_2O)[49, 54-59] – In the absence of severe acidosis or in the absence of hyperkalemia, ventilation must begin at 6 mL/kg_{PBW}. If not, begin at 8 mL/kg_{PBW} and then decrease quickly to 6 mL/kg_{PBW} after hemodynamic and metabolic stabilization.

Respiratory Rate (RR) for

(i) $PaCO_2$ 40-75 mmHg (with pH > 7.25 if possible) according to the clinical situation, often begin with RR >20 (with a heated humidifier), >25/minute (with a HME) especially if respiratory rate was high prior to intubation, in the event of fever, metabolic acidosis or a situation at risk of metabolic acidosis (oligoanuria, shock…),

(ii) Limit the risk of autoPEP (inspiratory flow of at least 40 L/min to limit IT, especially in the event of autoPEP*). The initial objective is to maintain minute ventilation around 150 mL/kg_{PBW} or more according to the clinical situation[53]. This involves starting with a respiratory rate of 20/minute or 25/minute at least (if the instrumental deadspace is moderate to significant >50 mL or 100 mL, when a HME and connections are used).

Positive End-Expiratory Pressure (PEEP) [49, 60-64]

The usual recommendations for ARDS are the following:

If PaO_2/FiO_2>200 (or SpO_2/FiO_2>235[65]), then set a PEEP at 6 to 12 cmH_2O based on BMI and hemodynamics.

If PaO_2/FiO_2<200 (or SpO_2/FiO_2<235[65]), then set a PEEP according to the EXPRESS strategy[62] (set Tv at 4-8 mL/kg_{PBW}, then increase PEEP until Pplat = 28 cmH_2O) or according to a PEEP/FiO_2 scale [63]. This high PEEP strategy is to be continued in the event of positive effects on oxygenation, in the absence of hemodynamic disruption and if plateau pressure remains at < 30 cmH_2O.

With the respiratory damages related to COVID-19, pulmonary recruitment appears to be heterogeneous and should be evaluated[66]. Given the hemodynamic and pulmonary consequences, if the pulmonary recruitability is low, **moderate PEEP levels should be favored in COVID-19 patients**[36].

Recently, a new mechanics-based index to directly quantify the potential for lung recruitment has been developed, called the Recruitment-to-Inflation ratio (R/I ratio)[67]. The R/I ratio can be calculated automatically from a webpage (https://crec.coemv.ca) (see notes for additional explanations).

Minimize FiO_2 to keep SpO_2 between 88-95% as long as FiO_2 is > 60% to avoid denitrogenation atelectasis[68, 69]. If FiO_2 is < 60%, the target SpO_2 will be the same as during oxygen therapy of a non-intubated patient with COVID (90-98%).

Associated measures

It is recommended that respiratory mechanics measures, particularly **plateau pressure** with a teleinspiratory pause (Pplat to be maintained under 30 cmH_2O), an **autoPEP** with a teleexpiratory pause [49, 55, 70, 71]. Driving pressure can also be measured regularly and should be maintained at under 15 cmH_2O[57], but its usefulness is still being debated[49, 72, 73].

Curares can be used for 24-48 hours for moderate to severe ARDS (PaO_2/FiO_2<150), particularly in the case of patient/ventilator asynchronies such as double triggers[74]. Recent data reveals uncertain impact on mortality[49].

[71,75,76], but curares are still recommended[49], particularly in indications of COVID-19 where it is described that patients have a high respiratory drive. The difficulty in these patients is to maintain prolonged protective ventilation, at least a week in many patients, and prolonged use of could be deleterious with important functional consequences[77]. Strategies using different sedatives, analgesics and neuroleptics should be used.

Prone positioning for moderate to severe ARDS (PaO_2/FiO_2<150), more than 16 h per day[49, 55, 71, 78, 79]. This technique assumes the mobilization of 4 to 6 persons, and each time there is a risk of contamination. It has not been shown in the specific indication of COVID-19 that ventral decubitus reduces mortality and given the risks to healthcare workers, the use of this technique should be limited[36].

Maximum reduction of the deadspace is among the recommendations for the management of ARDS (use of heated humidifier, removal of needless connections) to improve alveolar ventilation (particularly the elimination of CO_2) and to achieve maximum reduction of tidal volumes[49, 59, 80-84]. When ARDS is not present, in certain cases of productive ventilation with reduced tidal volumes and RRs greater than 25, the reduction of the deadspace can also be relevant.

Systematic **recruitment manœuvres** are not recommended[49, 55, 71, 85]. They are to be used carefully in the event of desaturation after derecruitment (e.g., disconnection or endotracheal aspirations), with special care to be taken with hypovolemic or hemodynamically unstable patients. There seem to be cystic forms of COVID-19 with pneumothorax risk according to the first X-ray descriptions.

A **closed aspiration circuit** is also part of ARDS management to avoid repeated derecruitments during endotracheal aspirations[49, 86, 87]. Moreover, during COVID-19, this type of circuit reduces the risk of generating aerosols. The use of veno-venous ECMO can be discussed for selected patients with persistent and severe ARDS (PaO_2/FiO_2 < 80 mmHg in spite of optimized settings)[49, 88-91]. It should only be discussed if the ultraprotective ventilation (TV = 4ml/Kg $_{PBW}$ and RF 30-38/min is impossible to achieve in spite of optimized management, which can occur in 30% of cases[50].

Inhaled NO could be advised if the prone position and curares have been a failure before ECMO is used[49]. Inhaled NO is not recommended for ARDS as a routine measure and outside of these bridge situations leading to ECMO.

The systematic use of **esophageal pressure** monitoring for PEEP settings and transpulmonary pressure monitoring is not recommended[92]. Installing an esophageal probe is a risky procedure, and its use has not been clearly demonstrated, especially in the context of COVID-19 where monitoring should be simplified.

There is insufficient data to recommend the use of **ECCO$_2$R**[49, 58] for ARDS and even less so for COVID-19 since it is a procedure that carries risk of contamination.

The use of corticosteroids for COVID-19 pneumonia is usually not advised[2].

The use of **high-frequency oscillation (HFO)** is very strongly discouraged for ARDS, except possibly as a last resort for patients with refractory hypoxemia (PaO_2/FiO_2 < 60 mmHg for several hours), though no proof exists [49, 55, 58, 71, 93].

Before starting weaning, it is classically recommended that the pathology which led to the intubation be stabilized or resolved[94]. In the case of COVID-19, it is viral pneumonia without antiviral and systemic and pulmonary inflammation without the pathophysiology being well understood. It is therefore probably necessary to be patient before initiating the weaning process[36] and at least wait for a decrease in inflammatory parameters in addition to obtaining adequate oxygenation. For ventilator weaning, T-tube trials must be avoided for spontaneous breathing trials during weaning of COVID-19 patients. Tests with a minimum level of pressure support level or with the 0/0 test while leaving the ventilator connected should be used.

Recommendations for management of the operating room

Several recommendations on the management of COVID-19 patients in the operating room have been published[5, 95]. The main recommendations are as follows:

Preparing the patient and the operating room

Preparation is a must when a patient suspected or confirmed as having COVID-19 is being transferred to the operating room or for procedures at risk of generating aerosols:

i. The operating room should be a negative pressure environment, if possible. At a minimum, the room should be suitably ventilated, and preferably negatively pressurized or isolated with at least 12 air changes/hour.

ii. The patient must wear a face mask while being transported to the operating room.

iii. The personnel involved in patient management must wear PPE as per the hospital's policy for COVID-19.

iv. Hand hygiene must be practiced by personnel before and after all contact with the patient, particularly before putting on and taking off PPE.

v. The number of persons involved in the procedure should be kept to a minimum and personnel replacements avoided during the procedure, if possible.[95]

vi. Regular droplet isolation procedures should be enforced.

vii. Specific disinfection shall be applied after the procedure.

Personal Protective Equipment (PPE) Considerations

(i)Specific PPE components selected for medical procedures that generate aerosols can vary slightly from one hospital to another. However, the underlying principles are the same – protecting healthcare professionals from inhaling and contacting aerosols and droplets that can be generated during the procedure.

PPE components that can be used to achieve this level of protection include:

a. Wearing an N95-certified mask. All healthcare personnel should have an up-to-date fit test;

b. Eye protection either by wearing glasses/goggles or a mask with a disposable visor;

c. Impermeable gown; and

d. Gloves.

(ii) All PPE components soiled during aerosol-generating procedures must be replaced immediately.

(iii) Specific attention must be paid to putting on and taking off PPE to avoid potential exposure and self-contamination. Risk is highest when the PPE is taken off. All healthcare workers participating in aerosol-generating medical procedures must be trained and comfortable with using PPE, including putting it on and taking it off.

(iv) After taking off the PPE, the health-care worker must avoid touching their hair or face before washing their hands.

(v) The PPE must be carefully disposed of in a contact-free garbage can or laundry hamper.[95]

Minimizing aerosol produced

To minimize the aerosol generated when accessing airways, some factors merit consideration:

i. Respiratory tract management should be reserved for the most experienced anesthetist, if possible.

ii. A high-efficiency hydrophobic filter inserted between the face mask and the respiratory circuit or between the face mask and the Ambu must be used (Figure 8).

iii. Preoxygenation with 100% oxygen for 3 to 5 minutes and rapid sequence induction must be considered to avoid manual ventilation of the patient, which is a procedure at risk of aerosolizing the virus through the respiratory tract. If manual ventilation is needed, small tidal volumes must be applied.

iv. The rapid sequence can be modified if the patient has a very high alveolar arterial oxygen gradient, is unable of tolerating 30 s. of apnea or is succinylcholine contraindicated.

v. Awake fiberoptic intubation must be avoided, unless otherwise indicated, but the local anesthetic and/or a coughing episode during the anesthetic of the respiratory tract can aerosolize the virus. Consider using a videolaryngoscope so that the operator can keep their face away.

vi. Tracheal intubation must be preferred over the use of a laryngeal mask.

vii. For the management of patients suffering respiratory distress due to a coronavirus infection outside the operating room, non-invasive ventilation

must be avoided, if possible, to avoid generating virus aerosols in the room, and early intubation must be considered in the event of rapid deterioration.

viii. While a patient is being resuscitated, heart massages must be stopped during intubation to avoid exposing the clinician to aerosols during intubation, and the use of curares must be considered prior to intubation, if possible, to avoid coughing during or after intubation.[95]

Ventilator settings

If an intensive care patient is being managed for COVID-19 and requires an operation, the ventilator settings should be maintained.

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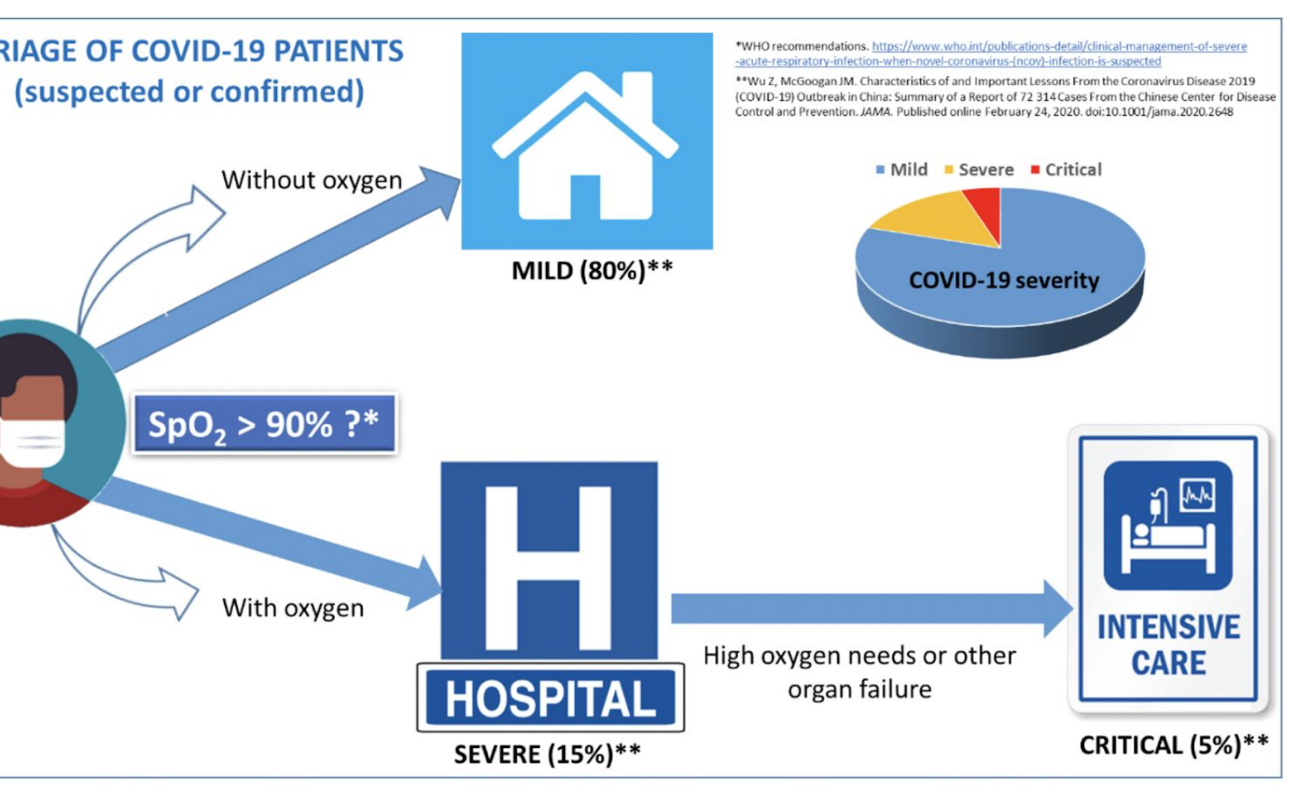


Figure 1 : Triage of patients suspected or confirmed of having COVID-19

• NIV/Optiflow • Intubation • Extubation • Tracheostomy/tracheotomy • Broncoscopy	• Expectoration induction • Aspiration of secretions in an open circuit • Manual ventilation prior to intubation • CPR • Autopsy

Figure 2: Procedures at risk of generating aerosols[5, 6]

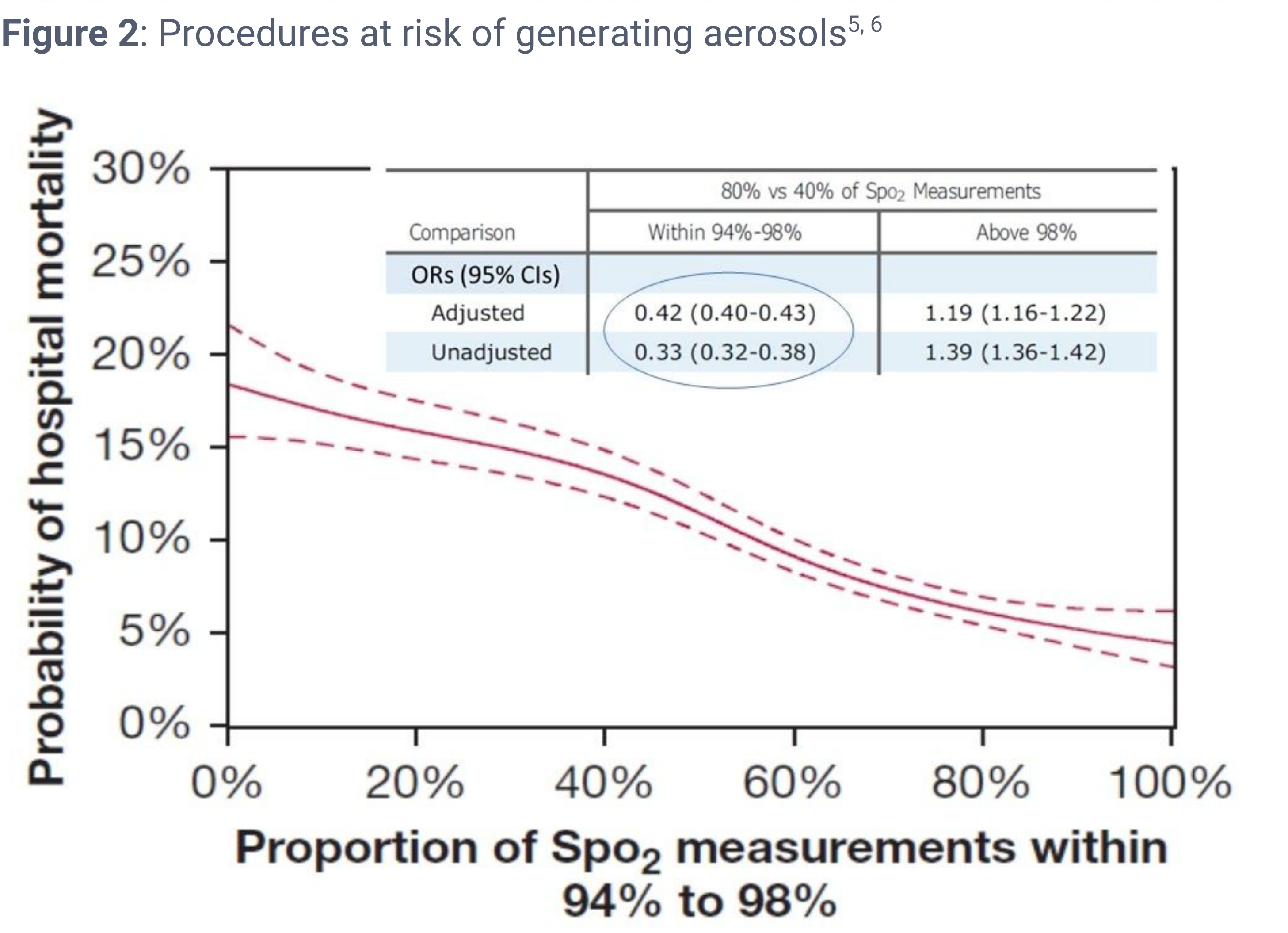


Figure 3 : impact of time within the oxygenation target (without hypoxemia and without hyperoxemia) on mortality[15].

Figure 4: The utilization of High Flow Nasal Therapy during COVID-19 remains controversial[27] and requires caution (red panel). In addition to limit the use of HFNT to negative pressure rooms, the utilization of mask above the HFNT cannulas has been recommended (yellow panel)[24, 25]. Other protections may be used such as the visor (blue panel) or utilization of non rebreathing mask (green panel).

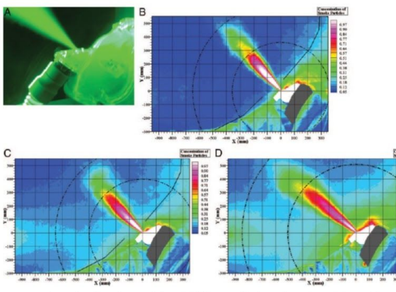


FIGURE 3. *A*: the ComfortFull 2 mask was attached to a high-fidelity HPS. The photograph was taken with the room light switched off and revealed exhaled smoke dispersion through the exhalation diffuser of the mask attached to the HPS. *B*: *B* to *D* refer to data related to the ComfortFull 2 mask. The x-axis represents the distance from the center of the mask along the median sagittal plane, whereas the y-axis represents the vertical distance from the center of the mask. Normalized concentration in the plume was estimated by computer analysis from the light scattered by smoke particles. Shown at IPAP of 10 cm H_2O and EPAP of 4 cm H_2O. The white color code and the red color code represented regions consisting of 100% and 70%, respectively, of exhaled air, whereas the background of the isolation room (deep blue code) was essentially free of exhaled air. *C*: at IPAP of 14 cm H_2O. *D*: at IPAP of increased to 18 cm H_2O.

Figure 5 : NIV masks with expiratory leaks are to be avoided[37]

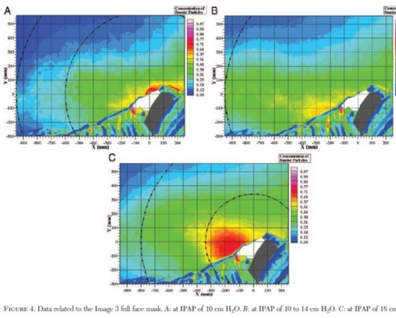


FIGURE 4. Data related to the Image 3 full face mask. *A*: at IPAP of 10 cm H_2O. *B*: at IPAP of 10 to 14 cm H_2O. *C*: at IPAP of 15 cm H_2O.

Figure 6 : In cases where NIV is used, naso-buccal masks should be used and total inspiratory pressure levels should be limited and remain under 15 cmH_2O (PEEP + Inspiratory assistance).

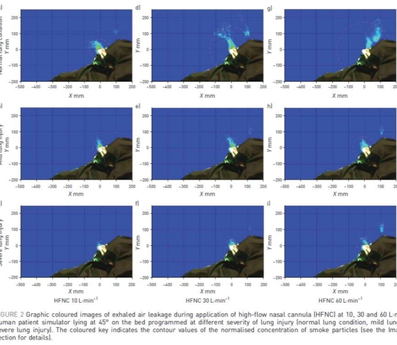


FIGURE 2 Graphic coloured images of exhaled air leakage during application of high-flow nasal cannula (HFNC) at 10, 30 and 60 $L{\cdot}min^{-1}$ on the human patient simulator lying at 45° on the bed programmed at different severity of lung injury (normal lung condition, mild lung injury and severe lung injury). The coloured key indicates the contour values of the normalised concentration of smoke particles (see the Image analysis section for details).

Figure 7 : Aerosol generation during HFNT seems to be low in this model for patients with respiratory conditions (middle and lower photos) for low flows (10 and 40L/min).

In the room			Outside (on the cart)	
	REA checklist		Copy of MERS COV procedure	
	Closed windows			
	Negative pressure operation	2 packs	Chemo coated gowns	
	Lock sliding door	1 box	3M FFP2 masks	
	Intercom operation	1 box	Duckbill FFP mask	
1	"vital signs" kit	1 box	Hairnets	
3	ECG consumables	1	Hydro-alcoholic solution	
1	Paper, pen kit	1	Hydro-alcoholic solution	
2	Antibacterial respirator filters	1	Box of T6-T7 impervious gloves	
2	Respi drawer antibacterial filters	1	Box of T7-T8 impervious gloves	
1	Closed aspiration system	1	Box of T8-T9 impervious gloves	
5	NaCl pipettes for a closed system	4	Pairs of protective goggles	
1	Hydro-alcoholic solution	1 roll	DASRI (infectious waste disposal) bag	
1	Box of T6-T7 impervious gloves	4	Cardboard foldable infections waste disposal barrel	
1	Box of T7-T8 impervious gloves	50	Light green biotox tubes	
1	Box of T8-T9 impervious gloves	10	Biotox request sheets	
2	Disposable bedsheets	4	Biotox (double packaging)	
2	Disposable pillow cases	2	Tracheal aspiration traps	
2	Disposable fitted sheets			
1 box	Basin bag			
1	Basin		**In the airlock**	
1	Disposable urinal (if man)	1	Hydro-alcohonic solution	
1 box	Vomit bag	1	Seal	
1	Gelling agent	1	Surfanios premium	
1 roll	110 L infectious waste disposal bags	1 pack	Wipes	
1	Broom	1	Cardboard foldable infectious waste disposal container	
1 pack	Floor and environment cloths	1	metal waste container	
1	Javel water pipette + empty bottle for dilution	1	Box of nitrile gloves, small (S)	
5	Bean-shaped basins	1	Box of nitrile gloves, medium (M)	
3	Disposable trays	1	Box of nitrile gloves, large (L)	

Figure 8: An example of a checklist for a COVID room (USI Pitié-Salpétrière, Paris, Centre de référence COVID-19)[4]

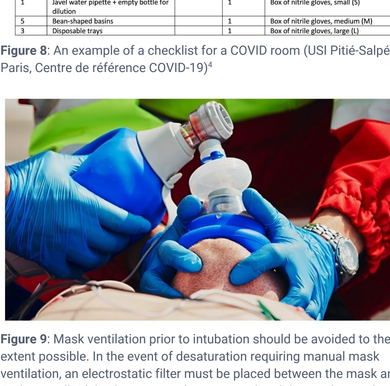
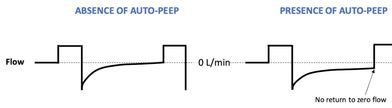


Figure 9: Mask ventilation prior to intubation should be avoided to the greatest extent possible. In the event of desaturation requiring manual mask ventilation, an electrostatic filter must be placed between the mask and the Ambu, small tidal volumes must be generated and the mask must be maintained so that it is as hermetic as it can possibly be to limit leaks.

Notes for mechanical ventilation settings:

* Identifying autoPEEP (i.e. intrinsic-PEEP) on the flow curve



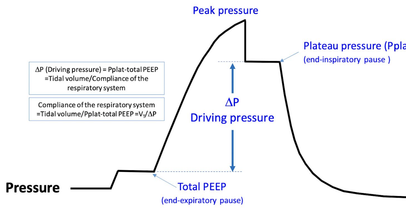
In case of suspected auto-PEEP or in case of doubt, it should be measured by a tele-expiratory pause. The measurement of auto-PEEP is one of the parameters to be systematically and regularly monitored [70].

** Plateau pressure and driving pressure (DP)
Plateau pressure: The most important item to be monitored and the best validated is the limitation of plateau pressure below 30 cmH_2O.

Driving pressure: DP = $Plat_p$-TotPEP = Teleinspiratory pause pressure – Teleexpiratory pause pressure = Tv/C_{stat}

DP = P_{plat} - $PEEP_{tot}$ = end-inspiratory pause pressure - end-expiratory pause pressure = V_T/C_{stat}

Where $PEEP_{tot}$ is total PEEP and C_{stat} is lung compliance when stationary.



*** PEEP/ FiO_2 scale [63, 92]
High PEEP/FiO_2 scale

PEP, cmH_2O	5	8	10	10	12	14	16	18	18	20	20	20	20	22	22	22	24
FiO_2, %	30	30	30	40	40	40	40	40	50	50	60	70	80	80	90	100	100

To be used in moderate to severe cases of ARDS with recruitment potential. This high PEP strategy is to be continued in the event of positive effects on oxygenation, in the absence of hemodynamic disruption and if plateau pressure remains at < 30 cmH_2O[49].

During COVID-19, the use of elevated PEEPs should not be systematic and should depend on the recruitment potential[66].

**** Ratio Recruitment-to-inflation (R/I ratio)
Recently, a new mechanics-based index to directly quantify the potential for lung recruitment has been developed by Brochard group, called the Recruitment-to-Inflation ratio (R/I ratio)[67].
The R/I ratio can be calculated automatically from a webpage (https://crec.coemv.ca). Due to the limited access to computers or internet while under airborne precautions, one author (LC) provided a compact form for calculating the R/I ratio manually. In patients without airway closure:

$$R/I\ ratio = \frac{V_{Te,H\rightarrow L} - V_{Te,H}}{V_{Ti}} \times \frac{P_{plat,L} - PEEP_L}{PEEP_H - PEEP_L} - 1$$

VTe,H is the exhaled tidal volume at high PEEP,
VTi is the preset inspiratory tidal volume, $Pplat,L$ is the plateau pressure at low PEEP, $PEEPH$ and $PEEPL$ denotes high and low PEEP, respectively.
In patients with airway closure, the low PEEP is replaced with the measured airway opening pressure when airways are reopened above airway closure (6). A threshold of 0.5 was used as for defining high recruitability (R/I ratio ≥ 0.5) and low recruitability (R/I ratio <0.5)[66].