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# COVID-19 disease: invasive ventilation

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## Abstract

This article focuses on the critical care nurse's role in the management of patients with COVID-19 who require invasive ventilation in order to improve outcomes and prevent complications. The nature of COVID-19 is such that many patients deteriorate rapidly and for members of this group requiring intubation and invasive ventilation, different approaches to airway management and ventilatory support are required. In order to reduce the risk of complications and an overview of invasive ventilation, including commonly used modes, potential complications, nursing care, weaning and extubation are all described. COVID-19 presents several challenges as the disease progresses, hypoxemia may worsen, and the patient can develop Acute Respiratory Distress Syndrome. Therefore, additional treatment strategies including the use of the prone position and the use of nitric oxide and prostacyclin nebulisers have been included. The strategies presented in this article are relevant to both critical care nurses and those re-deployed to intensive care units where nurses will inevitably be involved in the management of patients requiring invasive ventilation. Weaning these patients off invasive ventilation is multi-factorial and may be short or long term. A multi-disciplinary weaning plan, the principles,

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## Key points

- Severe COVID-19 causes respiratory failure and severe hypoxaemia and patients may require invasive ventilation and strategies such as prone position to improve oxygenation.
- Nurses need to understand the different modes of ventilation, including the strengths and limitations of each.
- Invasive ventilation is a complex subject and nurses need to understand their role in nursing a patient with severe COVID-19 disease who requires ventilation.

stages/phases, and speed of weaning with expected parameters prior extubation are explained. Planned and unplanned extubation with the serious complications of the latter as the patient may not be ready and may require emergency re-intubation resulting in setbacks should be avoided.

**Keywords** 2019-nCoV; ARDS; COVID-19; critical care; prone position; SARS-CoV2; ventilation

## Introduction

Hypoxia and the need for invasive ventilation are frequently the main reasons critically ill patients requiring transfer to the critical care unit. Competence in this area is crucial, with research into the nurse's role in the management of patients on invasive ventilation showing that high quality nursing care can positively affect outcomes and prevent complications.<sup>1–3</sup> However, invasive ventilation has been identified as an area of practice where nurses feel least competent.<sup>4</sup> Therefore, in this article, topics including optimizing oxygenation and prevention of complications of invasive ventilation in relation to severe COVID-19 infection have been fully explored.

## Intubation

Where respiratory failure requires emergency tracheal intubation (passing of an endotracheal tube (ETT) into the trachea) for patients with COVID-19, it is a high-risk procedure, increasing viral load to healthcare workers and other patients. Prior to COVID-19, intubation was normally performed in controlled environments such as the anaesthetic room, resuscitation room and critical care units.<sup>5</sup> Due to the rapid increase in numbers of patients, and the acute deterioration associated with severe COVID-19 infection, it is now frequently performed outside of the critical care unit by specially formed intubation teams.<sup>6</sup> It must be noted that this is a high-risk procedure for complications such as oesophageal intubation or difficult airway ('can't intubate, can't ventilate').<sup>5</sup> In consequence, staff in emergency departments and ward areas may now be required to manage deteriorating patients that require advanced airway management, until the intubation team is assembled or available. As COVID-19 patients deteriorate rapidly, they may be judged as

being at increased risk of gastric aspiration and for this group, Rapid Sequence Induction (RSI) is used. RSI also has the advantage that it can minimise the apnoea time during which significant aerosolization through use of facemask ventilation occurs.

During RSI, there should be minimal staff in the vicinity to reduce risks from exposure, with the team including the intubator, an assistant and someone to administer the drugs. In case of an emergency, a runner outside the room should also be available. In addition, all staff need to be wearing appropriate personal protective equipment (PPE) for an aerosol generating procedure (AGP).<sup>7</sup> The procedure involves inducing loss of consciousness (by use of drugs), application of cricoid pressure, insertion of an ETT and confirmation of tube position. ETTs come in varying sizes and are either cuffed or un-cuffed. Adult tubes are cuffed, whereas un-cuffed tubes are used in children under 8 years old to prevent excessive pressure on tracheal tissue.

Regarding the decision to intubate a suspected or confirmed COVID-19 patient, there are procedural and medical issues to be taken into consideration. Any airway intervention should be managed electively rather than as an emergency.<sup>8</sup> In consequence, protocols, and cognitive aids such as checklists, cross-checking and pre-planning for all eventualities including difficult airway scenarios should be discussed and agreed prior to the procedure.<sup>8</sup> Prior to intubation, the patient should be pre-oxygenated with 100% using a bag, valve mask (ambu bag) or anaesthetic circuit. A two-person technique should be used, to achieve a better seal, and to reduce the risk of aerosolization.

Potential complications include right main bronchus intubation, lacerated lips, tongue, pharynx and trachea, vocal cord injury, chipped teeth, aspiration, introduction of infection, tube dislodgement, airway obstruction, pneumothorax, equipment failure, hypoxia, hypotension, and arrhythmias. Emergency equipment including that used for difficult airway management must be available. In addition, post intubation auscultation is not advisable due to the challenges with PPE and the risk of cross contamination. Confirmation of tracheal tube placement should be assessed by the intubator viewing the ETT passing through the vocal cords, an appropriate capnography trace displayed on the monitor, chest movement visualised and a chest radiograph (CXR) performed to confirm appropriate position.<sup>3</sup>

Once intubated any 'necessary' disconnection (e.g. when connecting the patient to the critical care ventilator from a transport ventilator) in the ventilation circuit should be preceded by clamping the ETT until they are reconnected and ventilation established. This should take no longer than 5 seconds. ETT connections must be secure to prevent disconnection; in COVID-19 patients, this may involve using tape to prevent accidental disconnection. In addition, a closed suction catheter should be used to prevent disconnection of the ventilator circuit for suctioning. This prevents hypoxia, loss, or Positive End Expiratory Pressure (PEEP) and reduces the risk of aerosolization. Manual ventilation (also termed 'hand bagging') should be avoided due to concerns regarding aerosolization and increased risk of infection.<sup>6</sup>

The grade of intubation is used to describe the laryngeal view during laryngoscopy and used to determine how difficult it is to intubate a patient. The Cormack-Lehane or Mallampati

classification is the most commonly used,<sup>9</sup> it is routinely documented and reported during hand over in case re-intubation is required.<sup>10</sup> Ongoing care of an ETT includes noting the ETT position at the teeth or lips and checking ties are secured using ETT tape ties or commercially available tube ties such as Anchor Fast or Thomas Tube Holders. ETT cuff pressure using a manometer should be recorded every 2–4 hours, with the aim of 25–30 mmHg. Specific information handed over at each shift may include date of ETT insertion, grade (difficulty) of intubation, size of ETT, position at teeth, any signs of pressure damage from the tie, last time suctioned performed, quantity and description of secretions removed either by suctioning or aspiration of the ETT subglottic port.

### Invasive ventilation

Invasive ventilation has evolved significantly since the early positive pressure ventilators developed in the 1940's and the iron lung negative pressure ventilators used in the polio outbreak.<sup>11</sup> Invasive ventilators today are now in the fourth generation of technology and allow for a range of modes.<sup>12</sup> Invasive ventilation assists with the movement of gases (air) into and out of the patient's lungs, while minimizing the effort of breathing. Positive pressure ventilation is delivered via an endotracheal or tracheostomy tube. Ventilatory support includes controlled or mandatory modes, spontaneous modes or a combination of the two.<sup>13</sup>

As invasive modes of ventilation vary between manufacturer, each critical care unit will have their own preferences for combinations of ventilation strategies. Due to the increased demands for ventilators during the COVID-19, hospitals may procure ventilators at short notice, that are not normally used within their critical care units, these in extremis may also include anaesthetic machines.<sup>14</sup> This is a cause for concern, as nurses may not have had the appropriate training, supervision, and experience of using these ventilators, which can adversely impact on patient safety.<sup>15</sup>

Commonly used modes include Synchronized Intermittent Mandatory Ventilation (SIMV), Pressure Support (PS), Positive end expiratory pressure (PEEP) and Continuous positive airway pressure (CPAP). High Frequency Jet Ventilation (HFJV), High Frequency Oscillatory Ventilation (HFOV) and Extra Corporeal Membrane Oxygenation (ECMO) are advanced methods of invasive ventilation and oxygenation, detailed descriptions of which are beyond the scope of this article. ECMO is a highly specialized procedure undertaken in tertiary referral centres. It involves completely resting the lungs and is used where standard ventilation methods have failed.<sup>3</sup> It must be noted that while ECMO can have a role specifically for severe COVID-19 patients who meet a specific requirement, the availability of ECMO beds is likely to exceed capacity and therefore, it will only be available for a small proportion of patients.

SIMV delivers a pre-determined respiratory rate, and either a pre-set tidal volume (volume controlled) or pressure (pressure controlled). The patient is still able to take additional breaths, and these may be supported by Pressure Support. Pressure support, (PS) also termed Assisted Spontaneous Breathing (ASB), is a spontaneous mode in which the patient triggers a breath and it is supported by a pre-set pressure. This mode of ventilation can be used as a weaning method, as the level of support can be

reduced as the patient becomes more alert, and able to breathe effectively.<sup>13</sup> Invasive ventilation can cause weakened lung muscles and the underlying illness and sedation can affect weaning from ventilation. In addition, a ventilator has series of valves, ventilator tubing and the ETT, which is a fraction of the patient's normal airway size. Therefore, breathing on a ventilator is often referred to as breathing through a straw, and PS allows for spontaneous breathing and compensation of the ventilator circuit resistance.<sup>3,13</sup>

PEEP maintains airway pressure above atmospheric pressure during the expiratory phase. Arterial blood oxygenation is improved by preventing alveolar collapse during expiration and re-recruiting collapsed alveoli. This technique maintains or increases Functional Residual Capacity (FRC) and improves diffusion throughout the lungs.<sup>13</sup> Usually PEEP will be at least 5cmH<sub>2</sub>O. This may need to be increased to recruit collapsed alveoli, from reduced surfactant, atelectasis, sputum retention and tracheal suctioning.<sup>3</sup> Continuous Positive Airway Pressure (CPAP) is similar to PEEP but used when the patient is self-ventilating.<sup>13</sup>

### Volume control and pressure control

The oxygen/air (gas) mixture can be delivered to a patient either by a pre-determined volume or pressure. Volume Control (VC) delivers a pre-set tidal volume, however, the pressure the machine delivers is not controlled. This can result in high-airway pressures causing barotrauma, pneumothorax, and other complications. Pressure control (PC) delivers a pre-determined inflation pressure resulting in varying tidal volumes, a reduction in the risk of complications and is the preferred mode for most COVID-19 patients, especially those with Acute Lung Injury (ALI) or Acute Respiratory Distress Syndrome (ARDS). A disadvantage of using PC involves a patient not receiving an adequate tidal volume and may lead to hypercarbia and under-ventilation.<sup>3,4,13</sup>

To trigger or initiate a breath in a patient breathing spontaneously, the ventilator needs to sense the correct time for inspiration. Three methods are used: pressure sensing, volume/flow sensing or neutrally adjusted ventilator assist (NAVA). **Pressure sensing** involves the ventilator sensing a drop in the ventilator circuit as the patient tries to breathe. However, the length of ventilator tubing and effort required to trigger a breath may be too difficult and uncomfortable for many patients, which may result in the patient failing to synchronise with the ventilator. **Volume/flow sensing** provides constant gas throughout the ventilator circuit and allows for gas returning to the ventilator to be compared to the amount flowing out. When a change is detected, a breath is triggered. **NAVA** is a specialist mode of ventilation not commonly used, which involves sensing the electrical activity of the diaphragm via an oesophageal electrode in order to trigger inspiration.<sup>3,13</sup>

Cycling refers to how the ventilator switches from inspiration to expiration and there are four types. Firstly, **time cycling** involves the inspiratory phase lasting for a fixed period of time; the ventilator then automatically switches to expiration. Secondly, **volume cycling** is where once the present tidal volume has been reached the ventilator switches to expiration. Thirdly, **pressure cycling** is when the pre-set inspiratory level is reached and the

ventilator switches to expiration. Finally, **flow cycling** allows for the inspiratory phase to switch when the flow falls below a certain level, for example, once the breath is completed.

### Assembly of the ventilator

Prior to commencing invasive ventilation, the critical care team needs to be aware of the patient's normal lung function whenever possible so that parameters can be set to deliver appropriate and realistic targets for oxygenation.<sup>3</sup> Ventilators need to be assembled as per the manufacturer guidance, require both oxygen and gas sources and a continuous power supply, ideally with generator back-up. In addition, for COVID-19, ventilator filters must be validated against the passage of a variety of viral and bacterial species.<sup>6</sup>

Nurses working at the bedside must be able to detect complications due to invasive ventilation. These may include airway complications such as upper airway damage, laryngotracheal stenosis, fistula formation, intubation of the right main bronchus and ETT blockage or displacement e.g. during coughing or self-extubation. Breathing complications include ventilator disconnection, ventilator associated pneumonia (VAP), barotrauma due to excessive airway pressures, volutrauma damage due to excessive lung volumes, atelectasis, and oxygen toxicity due to persistent high oxygen concentrations. Pressure on the ventilator tubing includes biting on the ETT, sputum plugs blocking the ETT or TT, bronchospasm, and pneumothorax (simple or life threatening). Circulatory complications include increased intrathoracic pressure. This causes reduced venous return, leads to reduced blood pressure, and increased right ventricular workload. Sedation and analgesic drugs can cause hypotension, while fluid retention can cause gastrointestinal disturbances and gastric distension. Neurological problems include discomfort due to coughing, gagging or biting on ETT. Complications of over, or under, sedating patients, and/or prolonged use of sedation can cause delirium and polyneuropathy. Long-term effects of delirium include post-traumatic stress disorder (PTSD), delayed discharge and prolonged recovery. Other difficulties associated with invasive ventilation include pressure damage to the mouth, lips, and neck due to ETT ties. In addition, for patients requiring prolonged ventilation, complex weaning impacts on mobility, resulting in muscle wastage that compounds delayed recovery.<sup>3,4,6,13</sup> In consequence, nurses must be acutely aware of, recognise and respond to the wider issues associated with patients requiring invasive ventilation.

The increasing numbers of severe COVID-19 patients requiring invasive ventilation is likely to place a critical demand on oxygen supplies which may lead to supply failure.<sup>6</sup> In addition, increasing demand for ventilators and different types of ventilators being used in practice may lead to a critical lack of consumables, compromising patient safety.

### Care of a patient requiring invasive ventilation

Patients requiring invasive ventilation need to be closely observed and continuously monitored. Although ventilators have alarms, they do not replace close observation of the patient and immediate access to a registered nurse, experienced and competent in caring for a ventilated patient.<sup>16</sup> The monitoring of ventilated patients must include ECG, pulse oximetry and End



Tidal Carbon Dioxide (EtCO<sub>2</sub>). Ventilator observations include mode of ventilation, respiratory rate (set/actual), fraction of inspired oxygen (FiO<sub>2</sub>), airway pressures, tidal volumes, minute volume and inspiratory:expiratory (I:E) ratio. Vital signs and ventilator observations must be recorded frequently. The standard practice is to perform this hourly or if there is a change in patient condition or ventilator settings. During COVID-19, with a diluted skill mix and less availability of critical care trained staff, the frequency of ventilator observations may be decreased; a cause for concern as it may lead to failure to recognise deterioration and complication early, delaying response and reducing opportunity for patient improvement.

Arterial blood gases (ABG) are used to assess oxygenation and to guide clinical decision making. These should not be performed routinely, but in response to the patient's condition or changes in treatment or ventilator settings. Sedation and pain should be assessed hourly using validated tools such as the Richmond Agitation and Sedation Scale (RASS) and the Critical Care Pain Observation Tool (CCPOT). In consequence, nurses must be able to monitor, analyse, interpret, and respond to a range of information, taking appropriate action when abnormal parameters have been identified.<sup>13,16</sup>

### Ventilator associated pneumonia

Ventilator Associated Pneumonia (VAP) has no universal, internationally agreed definition.<sup>17</sup> However, it is a type of pneumonia that occurs 48–72 hours after intubation in invasively ventilated patients. VAP can be broadly categorised as possible or probable VAP. **Possible VAP** is indicated if there are purulent secretions or positive microbiology cultures from the respiratory tract. Conversely, **probable VAP** is evidenced by purulent secretions and positive microbiology cultures from the respiratory tract and/or pleural fluid, lung histopathology or other specific diagnostic tests. Possible causes of VAP include aspiration during intubation, vomiting a feed, multiple intubations, the patient is immune compromised, has COPD, ARDS, chronic disease or has been recently hospitalised.<sup>17</sup> Hellyer et al.,<sup>18</sup> (2016) argue that VAP is a major source of increased prolonged illness and death, increased length of ICU, hospital stay and costs.

Signs of VAP may be identified when performing a respiratory assessment and include signs of sepsis and/or high or low leukocytes and other inflammatory markers e.g. C-Reactive Protein. Patients frequently present with increased amounts of sputum, changes in consistency (thick or purulent) and colour (yellow, green). Percussion of the chest may reveal dullness over the infected area requiring increasing ventilatory support and oxygen requirements.<sup>3</sup> Preventative strategies include the use of the Ventilator Care Bundle (VCB). This includes maintaining a bed elevation of >30°, administering deep vein thrombosis (DVT) prophylaxis, peptic ulcer prophylaxis, managing sedation effectively, providing oral care with chlorhexidine and regular subglottic aspiration of the ET tube. Each intervention needs to have a proven-evidence base and the VCB changes as the evidence evolves.<sup>19–21</sup>

### Humidification

Patients with an ETT or TT bypass the normal processes of cleaning, humidifying and warming that take place in the upper

respiratory tract.<sup>3</sup> Therefore, gases delivered by invasive or non-invasive ventilation need to be clean, humidified and warm. To prevent pathogens and foreign bodies entering the patient's body, invasive ventilators have humidification and warming systems in the circuit.

Humidification can either be active or passive. Active humidification may be used in long term ventilation, and is achieved by passing gas through an external, heated water bath chamber (wet circuit). The technique includes a heated source, water chamber or humidification chamber, temperature control unit and gas/liquid interface.<sup>22</sup> The heat source warms distilled water producing water vapour. Gas collects the water vapour as it passes through the chamber, before reaching the patient. Heated humidification circuits can be used with or without a heated wire breathing circuit, which reduces the condensation in the ventilator circuit and reduces the risk of complications for example, pooling of water in the inlet limb of the ventilator circuit tubing, and thermal injury to the patient.<sup>22</sup>

Passive humidification may be appropriate in short term ventilation (usually less than three days) for example for post-operative patients, using a heat and moisture exchange (HME) filter, fitted into the ventilator circuit.<sup>3,22</sup> An HME requires the moisture and heat from the patients expired breath to be recycled through a filter system. This type of humidification is termed a 'dry circuit'. The HME should be placed as close to the patient as possible, often placed between catheter mount and the patients ETT. The frequency of changing HMEs is determined by local infection prevention and control guidelines, but any manipulation of the ventilator circuit may result in contamination.<sup>22</sup>

Severe COVID-19 patients requiring invasive ventilation are at risk of the build-up of secretions and obstruction of ETT (plugging), particularly when using dry humidification. When using a wet circuit, the filters can represent an airflow obstruction when saturated, therefore regular assessment and replacement is required. However, when using both a dry and wet humidification system simultaneously, the 'wet' humidification increases the risk of breaking of the ventilator circuit, due the build-up of fluid in the ventilator tubing and regular changing of HMEs.<sup>7</sup> In consequence, all filters including HMEs should be checked regularly for water saturation, a maximum of 12 hourly, and routinely changed as indicated, but left no longer than 24 hours or as per manufacturers guidelines.

### Improving oxygenation in COVID-19 patients

Patients with severe COVID-19 infection commonly develop ARDS, this is defined<sup>23</sup> as:

'an acute diffuse, inflammatory lung injury, leading to increased pulmonary vascular permeability, increased lung weight, and loss of aerated lung tissue ... [with] hypoxemia and bilateral radiographic opacities, associated with increased venous admixture, increased physiological dead space and decreased lung compliance.'

Other risk factors associated with developing ARDS include sepsis, ventilator induced lung injury, aspiration, pneumonia, toxic inhalation, near drowning, trauma, hypothermia, massive transfusion and pancreatitis.<sup>17</sup> Presentation is acute (<1 week). The chest radiograph or CT shows bilateral opacities consistent with pulmonary oedema, PF ratio <300 mmHg with a minimum

of 5 cmH<sub>2</sub>O PEEP (or CPAP), respiratory failure not due to cardiac failure or pulmonary overload.<sup>24</sup> The Berlin definition for ARDS categorises severity as (box xxx):

- Mild (PaO<sub>2</sub>/FiO<sub>2</sub> 200–300) on a PEEP >5.
- Moderate (PaO<sub>2</sub>/FiO<sub>2</sub> 100–200) on a PEEP >5.
- Severe (PaO<sub>2</sub>/FiO<sub>2</sub> <100) on a PEEP >5.

For severe COVID-19 patients who develop ARDS, management includes using lung protection strategies: (low volume, low pressure ventilation), tidal volume 6ml/kg and plateau airway pressure <30cmH<sub>2</sub>O. Early evidence suggests pressures may need to be lower than previously recommended.<sup>25</sup> There needs to be pre-oxygenation of patients prior to any intervention e.g. suctioning to prevent prolonged periods of desaturation.

The use of nitric oxide or nebulised prostacyclin if using a wet circuit has been noted to improve vasodilation and thus improve oxygenation and reducing airway pressures.<sup>25</sup> PEEP may be used to recruit collapsed alveoli; however, high PEEP should be avoided. Recruitment manoeuvres are used to improve oxygenation by providing brief inspiratory flow cycles to maximum plateau pressure and inflating collapsed alveoli. Recruitment manoeuvres tend to be used as a rescue therapy in severe refractory hypoxia or following accidental disconnection from the ventilator. The procedure remains controversial in routine care, as it provides a temporary increase in oxygenation which is not sustained, and therefore must only be performed by an experienced practitioner.<sup>26,27</sup>

To improve oxygenation, prone positioning should be considered early and if necessary, repeated several times until oxygenation improves. Prone positioning involves placing an invasively ventilated patient face down to improve oxygenation-ventilation-perfusion. Recently, intensive care experience has shown a beneficial response to prone position by COVID-19 patients not yet requiring invasive ventilation.<sup>27</sup> Early recommendations are that proning patient on admission to ICU during the early phase of their disease may be beneficial and avoid more aggressive ventilation strategies. It can be used irrespective of the PF ratio.<sup>25</sup>

Prone positioning recruits alveoli in outer dorsal regions of the lung, allowing improved distribution of tidal volumes and drainage of secretions. Patients may remain prone for at least 18 hours a day, as this length of time has been shown to have the greatest benefit.<sup>26</sup> Nevertheless, turning a patient into the prone position is high-risk for complications including airway obstruction from a kinked or displaced ETT. Once in the prone position, frequent oral suctioning and mouth care is required as secretions may reduce the integrity of ETT securing devices. In addition, prone positioning can lead to facial swelling causing retinal nerve compression, ETT ties becoming too tight and pressure ulcers. Electrodes for cardiac monitoring need to be applied posteriorly on the patients back and in the event of cardiac arrest the anterior/posterior placement of defibrillator pads/paddles should be used.<sup>26</sup> Enteral feeding can continue in the prone position; however, the procedure is high risk for vomiting and/or increased gastric residual vomiting.<sup>28–30</sup> Absolute contra-indications for prone position include spinal instability, unstable fractures, burns, open wounds, pregnancy, recent tracheal surgery and raised intracranial pressure. Relative contra-indications include haemodynamic instability (including the use of vasopressors), cardiac pacemakers and abdominal surgery.<sup>31</sup>

Neuromuscular blocking agents may be required to maintain gaseous exchange, this reduces extrapulmonary resistance and ventilatory desynchrony which in turn results in improved oxygenation. Paralysis of the diaphragm allows for metabolic rest, reduced oxygen consumption and invasive control of breathing mechanics.<sup>26</sup> Neuromuscular blockage may be required in patients with ARDS as this allows for less PEEP to maintain oxygenation, and reduced mortality.

A patient's haemodynamic status may impact on ventilation, for example, invasive ventilation increases the intrathoracic pressure and may result in reduced cardiac preload with venous return reduced. Intra-thoracic pressure may increase during suctioning, positioning and when using PEEP.<sup>26</sup> A patient's pre-existing cardiac history may impact on ventilation, for example in a patient with an impaired cardiac ejection fraction, it may impact on weaning. In consequence, perfusion as well as oxygenation needs to be considered as they are interlinked and interdependent. Adequate perfusion and blood flow to the tissues is required to promote oxygenation.<sup>26</sup>

### Weaning from invasive ventilation

Weaning off invasive ventilation is the process used to assist an individual to breathe unaided. The process is complex and may take days, weeks or months. The weaning plan should be individualised and commenced once the patient is placed on an invasive ventilator. It includes correcting the cause of the respiratory failure, maintaining muscle strength, maintaining adequate nutritional support and psychological preparation.<sup>13</sup>

The speed at which a patient may be weaned will be determined by the factors outlined above and may be short or long term. Principles of weaning includes a pre-weaning assessment and the development of a multi-disciplinary weaning plan.<sup>13</sup> Patients ventilated for less than 3 days may be able to be weaned faster (short term) than those who have been ventilated for a longer period. Long-term weaning is more complex and follows the same principles as short-term weaning, however, the process is more gradual and involves a multi-disciplinary approach. In addition, a tracheostomy may be performed to assist with weaning. Prolonged weaning can have a negative psychological effect on the patient and their families. It is therefore important to explain the stages in the weaning plan and each stage.<sup>13,3</sup>

The pre-weaning assessment should be undertaken each day by the critical care team and appropriate parameters set relating to oxygenation and weaning. Individualised parameters should be set by the team to facilitate weaning. Patients can quickly become dependent on invasive ventilation, and the weaning plan allows a gradual re-introduction to normal breathing. The longer the patient has been ventilated, the more complex a weaning plan may be required. Weaning whilst on high concentrations of oxygen is not recommended.

The weaning phase and plan varies between patients and is determined by the pre-weaning assessment. Weaning plans should be started in the morning or early afternoon. Patients should not be weaned overnight, but allowed to rest. Weaning involves stopping all or most sedation and assessing the patient, explaining the procedure to the patient, suctioning the airway as indicated, continuing monitoring and assessment, sitting the

patient upright to maximise chest expansion, a Glasgow Coma Scale >8, and a cough reflex. The patient must be on a spontaneous mode of ventilation with a low PEEP and PS, be able to protect their own airway, and a rescue plan must be agreed in case the procedure fails. An ABG may be taken after 20–30 minutes of spontaneous breathing. If within normal parameters, and following review from the intensivist, it may be appropriate to consider extubation. It must be noted that weaning may take several days or weeks, using an individualised assessment and plan.

Extubation involves the removal of an ETT when the patient is stable and no longer requires an artificial airway. Planned extubations should take place during the daytime when additional staff, and suitably trained or skilled staff who can intubate, are available. The patient should be extubated early so that their progress can be monitored and, if any additional input is needed, it can be identified early. Following intubation, the patient should be monitored and re-assessed as indicated. Indications for re-intubation include uncoordinated respiratory function, exhaustion, agitation and poor oxygenation.<sup>13</sup> The individual rescue plan for a patient must be agreed by the critical care team and should include identifying if it would be appropriate to re-intubate. If necessary, Non-Invasive Ventilation (NIV) may be used to prevent re-intubation. However, it must be noted that in COVID-19, evidence suggests re-intubation rates within 24–48 hours are higher than expected (up to 60%). These patients can have severe upper airway swelling and the use of dexamethasone and nebulised adrenaline can be used. In consequence, delaying initial extubation for longer may prevent re-intubation when the need for access to specialist staff is immediately required.<sup>25</sup>

Unplanned extubation is a serious complication as the patient may not be ready with the result that emergency re-intubation may be required. There is evidence to suggest that in patients who require re-intubation, it may result in setbacks in their recovery and should be avoided. Reasons for unplanned extubation include patient being awake and pulling at the ETT tube or the tube becoming dislodged during patient care for example during repositioning. There is a possibility of increased self-extubation due to limited staff and patients could be over sedated. In the event of an unplanned extubation, it should be regarded as an emergency, the nurse must immediately assess the patient (ABCDE approach) and call for help. If necessary, initiating airway management procedures and oxygenating the patient. If they are self-ventilating, high flow oxygen should be started. If the patient is apnoeic then an appropriately sized oropharyngeal airway should be inserted and ventilation commenced using a bag, valve mask and a two-person technique.

## Conclusion

The rapid deterioration that occurs from the nature of COVID-19 leading to tracheal intubation and the nurse's role in the management of patients with COVID-19 on invasive ventilation has been explored. The impact of COVID-19 is such that critical care nurses and their re-deployed colleagues have had to face a radical change in the ways in which they care for and support ventilated patients. Additional approaches were not designed for the rapid changes in patient status or the scale of patients

needing critical care. It is important that during this time of crisis, the long effects and impact of invasive ventilation are not overlooked. The aim of the article has been to enable nurses to adapt their practice to meet the current situation, while making every effort to maintain patient safety, and to protect themselves, their colleagues and peers. ◆

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