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COVID-19 disease: Non-Invasive Ventilation and high frequency nasal oxygenation

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Abstract

Severe COVID-19 causes significant numbers of patients to develop respiratory symptoms that require increasing interventions. Initially, the treatment for severe respiratory failure included early intubation and invasive ventilation, as this was deemed preferable to be more effective than Non-Invasive Ventilation (NIV). However, emerging evidence has shown that NIV may have a more significant and positive role than initially thought. NIV includes Continuous Positive Airway Pressure (CPAP) and Bi-Level Positive Airway Pressure (BiPAP). CPAP is the method of choice with the use of BiPAP for those with complex respiratory conditions who contract COVID-19. The use of High Flow Nasal Oxygen (HFNO) remains contentious with different perspectives in how this modality can be used to treat respiratory failure in COVID-19.

Current thinking suggests that NIV and HFNO may be an appropriate bridging adjunct in the early part of the disease progress and may prevent the need for intubation or invasive ventilation. Patients requiring NIV or HFNO may be nursed in locations outside of the critical care unit. Therefore, this article reviews the different types of NIV and HFNO, indications and the nursing care.

Keywords 2019-nCoV; COVID-19; critical care; high flow nasal oxygen; non-invasive ventilation; SARS-CoV2

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Key points

- The disease trajectory of COVID-19 is not yet fully understood, which has resulted in a rapidly changing and understanding of treatment options.
- Recent evidence has shown Non-Invasive Ventilation to have a more significant and positive role than initially thought.
- The evidence for the use of High Flow Nasal Oxygen in COVID-19 disease is unclear, with differing views on its use.

COVID-19 is a new to human virus, and as a result, its virulence and disease trajectory are still not fully understood, and treatment has had to be developed as the pandemic progressed. In all countries, since the disease was first identified, it has been accepted that a high number of patients with severe COVID-19 disease develop acute respiratory distress syndrome (ARDS) and require respiratory support.¹ Defined as Type 1 respiratory failure (T1RF), there is hypoxia (PaO₂ <8kPa), without hypercapnia (carbon dioxide retention or PaCO₂),² with patients commonly presenting with hypoxia worsening, and additional signs such as tachypnoea, increased use of accessory muscles, tachycardia, pale and cold peripheries, sweating, confusion, agitation or reduced level of consciousness and cyanosis.

Early reports from China, during their initial outbreak, suggested that early intubation and invasive ventilation were preferable to delaying care with the use of Non-Invasive Ventilation (NIV).³ The problems arising from this were that firstly, there were limited numbers of ventilators available for the unprecedented numbers of patients. Secondly, weaning patients off ventilation proved to be extremely challenging and not always successful. Searching for ways to address the problems, the improved understanding of severe COVID-19 disease has led to changes in the management of patients. Tried in Italy, as they desperately tried to cope with the pandemic, Continuous Positive Airway Pressure (CPAP), a form of NIV, appeared to have a more significant and positive role than initially thought.⁴ With improved and enhanced CPAP equipment, there is now growing evidence that it may be of benefit to patients early in the disease process, may prevent deterioration and reduce the need for invasive ventilation at all.⁴ NIV assists breathing by supplying a mixture of air and oxygen using positive pressure to help the patient to take deeper breaths, so improving oxygenation without an airway adjunct, via a tight mask or a hood. The patient must be conscious, able to initiate their own breaths and to maintain their own airway.^{5,6}

This is still an early phase in understanding disease progression, and as a result, the use of High Flow Nasal Oxygen (HFNO) remains controversial in suspected and confirmed severe cases of COVID-19 disease.³ Nevertheless, with high numbers of patients requiring invasive ventilation, limited availability of intensive care beds and overstretched resources, 'bridging' or holding measures such as NIV or HFNO may need to be used to improve oxygenation prior to intubation.⁶ It is also becoming evident that for some, remaining conscious, able to see healthcare professionals and try to cooperate with them is very reassuring, and key to their continuing the ongoing struggle for breath.

There are two types of NIV: CPAP and BiPAP (Bi-Level Positive Airway Pressure). It is generally accepted that NIV is often used in short-term life-threatening respiratory conditions, such as pulmonary oedema or when intubation carries a greater risk than other benefits, for example, patients with chronic T2RF from Chronic Obstructive Pulmonary Disease (COPD).⁷ HFNO differs in that it involves the use of nasal cannulae to provide positive pressure to the airways, similar to CPAP. Advantages of using HFNO over other methods include the humidification of oxygen to prevent dehydration of the airway passages, the high flow rates can be used to provide carbon dioxide 'washout', there is a reduction in the anatomical dead space and oxygen levels close to 100% can be delivered.⁸

The emerging evidence from Italy has shown NIV is not sufficient to manage T1RF in all patients presenting with severe COVID-19.^{9–11} For some patients, while NIV may temporarily improve oxygenation and work of breathing, it does not change natural disease progression and is not a replacement for intubation and invasive ventilation.^{6,12,13} However, there is emerging evidence that there is a place for NIV in the care of patients post extubation. Review of early data suggests more than 50% of patients have required re-intubation and it is now thought that NIV support may bridge support for this group of patients where fatigue remains a significant symptom, and help in breathing is needed to aid recovery.¹⁴

Continuous positive airway pressure (CPAP)

CPAP delivers a constant flow of oxygen at a prescribed pressure, measured in cmH₂O, which remains constant during inspiration and expiration. Intrinsic positive end expiratory pressure is the residual volume preventing collapse of the alveoli normally measuring around 2.5–3 cmH₂O.⁵ CPAP is usually commenced at a higher level than normal intrinsic pressure around 5cmH₂O. For most patients with T1RF, it is secondary to conditions which either collapse the alveolar or widen the gap between the alveolar and the blood vessels that surround them thereby reducing gaseous exchange. The application of Positive End Expiratory Pressure (PEEP) assists in maintaining the patient's airway pressure prevents alveolar collapse, in turn increasing lung volumes and distends them to reduce the distance between the alveolar and the blood vessels to improve gaseous exchange.^{5,7,14} In severe COVID-19, initial CPAP settings have been suggested 10 cmH₂O and 60% oxygen.¹⁵

For CPAP to be effective, a sealed system is required, through application of a tight-fitting mask or a hood.^{5,6} Both methods for establishing a sealed system have benefits and disadvantages. With a face mask, the tight fit means patients may experience pressure damage to the nasal bridge. Newer types of facemask are available with high-volume low-pressure seals which reduce the pressure needed to create the seal when applied correctly, but with rapidly increasing numbers of patients needing CPAP, these may be difficult to acquire. An ill-fitting mask leads to significant leaks, resulting in poor inflation of the lungs, with dry oxygen/air leaking round a mask likely to lead to irritation, abrasions, and oedema of the cornea and conjunctiva. The second method, a CPAP hood, requires the patient's head to be fully enclosed with a secure seal around the neck and the hood can be supported by straps under the armpits.¹⁶ While such hoods reduce the risk of facial pressure sores, when straps are used, they can cause

discomfort, pain and potentially with prolonged use, pressure sores. It also has to be noted that for many patients the noise generated from the high flow required impedes communication with Healthcare staff and for some, causes claustrophobia which is counterproductive in terms of recovery.^{5,6} A potential complication is that gasping breathing, and reduced compliance of the lungs can lead to air being swallowed, which if not addressed will lead to gastric distention and vomiting, with a risk of aspiration of gastric contents. As with COVID-19 type diseases, patients' lungs are less compliant, the risk of developing barotrauma and pneumothorax must be recognised and observations regularly taken and in the light of the rapid deterioration that occurs with COVID-19 urgent, early intervention is essential.¹⁷ If positive pressure ventilation is continued where there is an undrained pneumothorax, it can lead to a tension pneumothorax and potentially cause cardiac arrest.¹⁷

As cited above, due to the need for a tight-fitting mask, regular assessment of the patient's pressure areas on the face must be taken, and protective dressings applied if necessary. Note where there is a naso-gastric tube in place, dressing is more likely to be needed.⁵ For both CPAP and BiPAP to be effective, the patient is required to wear the mask for extended periods of time, to recruit and maintain alveolar distension with the pressure settings. It has to be noted that it is less likely to be effective in patients who have poor tolerance to the pressures and have a productive cough as secretions will require frequent removal of the mask for suctioning of oral or nasopharyngeal secretions.

Bilevel positive airway pressure (BiPAP)

NIV BiPAP is commonly used in the care of patients with chronic respiratory disease, such as COPD, so it may be useful in COVID-19 for patients who have co-morbidities such as COPD plus COVID-19.¹⁸ In COVID-19, BiPAP may have a clinical use to improve the work of breathing. However, it carries a risk that inappropriate settings may allow the patient to take an excessively large tidal volume causing baro and volutrauma. BiPAP allows for a high driving pressure coupled with a low driving pressure. This resembles CPAP but provides some additional support. Prior to commencing BiPAP, the patient must be assessed for a pneumothorax, ideally by a chest X-Ray or ultrasound. Due to the need for PPE chest auscultation for COVID-19 patients, is not recommended as it increases the risk of transmission to the Healthcare professional.^{19,20}

Inspiratory Positive Airway Pressure (IPAP) settings can be varied to achieve adequate tidal volumes, by allowing patients to breath to a pre-set inspiratory pressure. To achieve adequate tidal volumes, the IPAP can range from 12 to 35cmH₂O. Expiratory Positive Airway Pressure (EPAP) works on the same principles as PEEP in CPAP devices, preventing alveolar collapse on expiration which is maintained above atmospheric pressure. To overcome the difficulty of breathing on a ventilator (including valves) and increase of dead space from the ventilator tubing is achieved by pressure support. Pressure support is calculated by minus IPAP from EPAP, and it is recommended that there should be a difference of at least 8cmH₂O,⁵ with supplementary oxygen provided, if needed, to achieve oxygenation. Some BiPAP ventilators offer a 'ramp' setting, also termed 'rise time', which allows the pressure to be slowly increased over the first few minutes of ventilation until the required pressure is reached. This

prevents barotrauma and is considered less distressing for the patient when treatment is commenced. Using this approach, a 25% rise time will take up 25% of the total inspiratory time before the peak pressure is reached.²¹

Given BiPAP may be used where there are multiple comorbidities, decisions regarding escalation in treatment must be agreed prior to the treatment. BiPAP may be used as a trial, with a view to intubation if this fails. The treatment escalation plan should have been discussed with the patient and relatives prior to commencing treatment (if it is not life threatening). Patients and families need to be aware of when BiPAP is the ceiling of treatment and should have discussed palliation and end of life care.^{6,7}

HFNO

CPAP is the preferred form of non-invasive ventilatory support in the management of the hypoxaemic COVID-19 patient,¹⁷ with the evidence supporting the use of HFNO is still being debated, with conflicting guidance emerging.¹⁴ As a result, currently in the UK, the national guidance does not recommend HFNO in COVID-19 because for the lack of evidence of efficacy, the high oxygen usage, and risk of infection spread.^{18,22–24} Nevertheless, Slesarev et al. (2020)²³ argue that the use of HFNO may meet patient oxygen demands while allowing them to manage their own body positions. This includes self-proning, with chest physiotherapy and intensive nursing care as adjuncts, preventing the need for invasive ventilation. The World Health Organisation (WHO)²⁵ have supported the use of HFNO in some patients, but they recommend close monitoring for clinical deterioration which could result in emergency intubations, which in turn increases the risk of infection for healthcare workers.

HFNO is sometimes used for patients with increased respiratory effort e.g. tachypnoea, shortness of breath, increased work of breathing in the presence of hypoxia, evidence of T1RF ($\text{PaO}_2 < 10\text{kPa}$) and desaturation despite increasing oxygen requirements.⁸ However, contra-indications include severe respiratory distress, severe cardiovascular instability, unconscious patients, upper airway obstruction, basal skull fractures, epistaxis and an impaired ability to cough or clear secretions. It must be noted that HFNO dries the lining of the respiratory system. Therefore, a humidification water chamber and fluid bag is used and must be checked regularly to maintain water levels and the humidification circuit temperature of 37°C.

HFNO tends to be initially commenced at a flow rate of 60 litres/min and oxygen to achieve the target saturations (SpO_2). Patients must be continuously monitored and vital signs recorded to determine if there is any improvement, when the therapy can then be titrated. If there is no initial improvement, oxygen levels should be increased until target saturations are achieved. However, if the oxygen is $> 50\%$ the patient should be urgently re-assessed as intubation may be appropriate. It must be noted that in COVID-19, the intubation team will require enhanced personal protective equipment (PPE), which may extend the time before intervention is possible.^{5,8} When clinically indicated, oxygen should be weaned first before the flow. When weaning the

flow, this should be decreased at 5 litres at time, or as tolerated by the patient.

Nursing considerations for patients requiring NIV and HFNO

Patients requiring NIV or HFNO must be nursed in specialist settings, with higher nurse to patient ratios to support continual observation. As demand for ventilators increases, the ability to procure equipment for use in clinical settings may be difficult,^{18,26} resulting in staff working with varying types of ventilators and consumables (e.g. ventilator tubing, masks and filters) which raises a patient safety risk. Nurses re-deployed or working outside of intensive care units must be given adequate training to care for patients requiring respiratory support using different sets of equipment used.^{27,28} In addition, as HFNO and CPAP require significant demands of oxygen, hospital oxygen supplies may become depleted leading to critical failures in availability not just locally but regionally and nationally.¹⁹

Both NIV and HFNO are classed as an aerosol generating procedure (AGP) and increase the risk of viral transmission. When disconnecting patients from NIV or HFNO, all equipment should be placed into the standby mode to minimize the spread of the virus in the atmosphere. To reduce the risk of aerosolization, when using HFNO, the patient should wear a surgical mask to reduce particle dispersion, and care must be used with viral filters and all secure connections. Healthcare professional must use enhanced PPE for all procedures, with, where possible, patients cohorted within a negative pressure environment.²³

Patient assessment and observations must include continuous pulse oximetry, hourly vital and neurological signs, together with an early warning scoring (if used). Added observations include checking for respiratory deterioration, such as increased work of breathing or worsening breathing pattern, use of accessory muscles and mouth breathing, tachypnoea and bradypnoea. Decreasing saturations and/or increasing oxygen requirements to maintain oxygen saturations must be recorded and reported. Arterial blood gases (ABG) should be recorded as clinically indicated, but at the least, within 1 hour of starting treatment and repeated within four and 12 hours. Patients at risk of further deterioration may benefit from an arterial line which allows for continuous blood pressure monitoring and for ABGs to be taken as clinically indicated.⁵

NIV causes raised intrathoracic pressure, which for patients who are haemodynamically unstable, may compromise cardiovascular stability through reducing venous return. There may also be challenges with maintaining an appropriate fluid balance. As patients with severe COVID-19 usually present with history of fever and increased shortness of breath, they may be intravascularly dehydrated. Insensible losses, accrued over the preceding days prior to admission to hospital, associated with fever and high respiratory rates will, therefore, need to be considered and factored in when planning fluid balance. This is crucial because there is a 25% incidence of COVID-19 patients admitted to critical care units develop acute kidney injuries (AKI).¹⁴

Periods off NIV should be of short duration, to prevent desaturation, but as patients are conscious, they need time

limited breaks to eat and drink, with regular mouth care to prevent problems from dry and sore mouth. Nutritional supplements may be required if there is poor oral dietary intake and nasogastric (NG) feeding may need to be considered. However as conscious proning is being increasingly used, NG feeds need to be stopped prior to position changes and gastric aspirates monitored. In addition, care must be taken to avoid patients lying supine with continuous enteral feeds running, as this increases the risk of pulmonary aspiration.²⁹

Conclusion

The use of NIV and HFNO in severe COVID-19 disease remains contentious, with evidence for and against still being gathered, analysed and disseminated. In any pandemic where there is an incomplete knowledge of the disease trajectory and patient complications, all available respiratory support options have to be considered and trialed. For instance, CPAP was only considered in Italy to address the lack of ventilators but has been shown to play a positive role for some patients. It cannot, and does not, replace invasive ventilation but it may, if used early, reduce deterioration to the point that invasive ventilation is not required. ◆

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