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REVIEW

Acute hypercapnic respiratory failure and its management on the acute medical take

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Abstract

Acute hypercapnic respiratory failure accounts for 50 000 hospital admissions each year in the UK. This article discusses the pathophysiology and common causes of acute hypercapnic respiratory failure, and provides practical considerations for patient management in acute medical settings. Non-invasive ventilation for persistent acute hypercapnic respiratory failure is widely recognised to improve patient outcomes and reduce mortality. National audits highlight a need to improve patients' overall care and outcomes through appropriate patient selection and treatment initiation. Multidisciplinary involvement is essential, as this underpins inpatient care and follow up after hospital discharge. New non-invasive ventilation modalities may offer better patient comfort and compensate better for sleep-related changes in respiratory mechanics. Emerging therapies, such as nasal high flow, may offer an alternative treatment approach in those who cannot tolerate non-invasive ventilation, but more research is required to completely understand its effectiveness in treating acute hypercapnic respiratory failure.

Key words: Acute hypercapnic respiratory failure; Average volume assured pressure support; Chronic obstructive airways disease; Non-invasive ventilation; Obesity hypoventilation syndrome

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Introduction

A wide range of diseases can cause acute hypercapnic respiratory failure, so recognising and treating the underlying disease is vital. Appropriate non-invasive ventilation improves outcomes in the right patient, disease, and the right setting with appropriate multidisciplinary input.

What is the scale of the problem and how can we address it?

Acute hypercapnic respiratory failure is defined biochemically as a pH of <7.35 and an arterial $PaCO_2$ >6 kPa. It results from the respiratory pump and lung failure, leading to decreased alveolar ventilation that is insufficient to maintain a normal arterial $PaCO_2$. Acute hypercapnic respiratory failure arises acutely or insidiously. Common causative diseases are identified in Table 1.

A study examining the outcomes of 222 patients with acute hypercapnic respiratory failure (not just in those requiring non-invasive ventilation) revealed high inpatient mortality (7%), 30-day readmission rate (23%) and overall mortality (16%) during follow up (19–31 months) (Meservey et al, 2020). When appropriately indicated, non-invasive ventilation reduces inpatient mortality by 50% and is therefore embedded into international guidelines for the management of acute hypercapnic respiratory failure (Davidson et al, 2016; Rochwerg et al, 2017).

UK national audit data comparing the overall outcomes of non-invasive ventilation highlighted a lower inpatient mortality rate in 2019 (26% from 34% in 2013) (Mahase, 2020). This is higher than reported in randomised controlled trials (9.9% observed across 12 trials in a Cochrane review) (Osadnik et al, 2017). Published data demonstrate higher mortality rates in patients receiving non-invasive ventilation later in their stay – Jayadev et al (2019) found this to be 18.4% in those receiving non-invasive ventilation 3–23 hours after admission vs 15.9% within 3 hours (P=0.425) across 2008–14 UK audit data. Currently only 51% of patients are initiated on non-invasive ventilation within 60 minutes of the blood

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Table 1. Medical diseases resulting in acute hypercapnic respiratory failure and requiring inpatient non-invasive ventilation

Organ	Disease	Disease commonly requiring inpatient non-invasive ventilation
Pulmonary	Disorders of airways: acute exacerbation chronic obstructive pulmonary disease, cystic fibrosis, bronchiectasis Disorders of lung parenchyma: pulmonary fibrosis and sarcoidosis Cardiogenic pulmonary oedema Pleural effusion Chest trauma Disorders of thoracic cage with increased chest wall stiffness: kyphoscoliosis, flail chest, obesity hypoventilation syndrome	Acute exacerbation chronic obstructive pulmonary disease, obesity hypoventilation syndrome Chest wall disease
CNS causes with diminished respiratory drive	Primary CNS injury: brainstem stroke or trauma, overdose of sedative or opioid Basal ganglia: Parkinson's disease Brainstem: multiple sclerosis Spinal cord: motor neuron disease, multiple sclerosis, injury of the spinal cord, tetanus, neoplasm, amyotrophic lateral sclerosis, spinal muscular atrophy Anterior horn cell: post-polio syndrome	Neuromuscular disease: motor neuron disease
Peripheral nervous system	Peripheral nerve: Guillain–Barré syndrome Neuromuscular junction: myasthenia gravis, toxins (botulism), drugs: corticosteroids, anticholinesterase inhibitors	
Muscular disorders	Myopathies: Duchenne muscular dystrophy, muscular dystrophy (congenital, limb girdle muscular dystrophy) myotonic dystrophies, mitochondrial disease	Neuromuscular disease: myotonic dystrophy, muscular dystrophy

gas result that is associated with a clinical decision to provide non-invasive ventilation, demonstrating that improvements in clinical practice are required.

Repeated national audits, the National Confidential Enquiry into Patient Outcome and Death and the British Thoracic Society quality standards exemplify the areas that require addressing in order to improve care (Davies and Juniper, 2018; Davies et al, 2018). Historically, clinicians underestimate survival in respiratory disease (Wildman et al, 2007). This, combined with limited bed availability, may contribute to poor outcomes; thus, multidisciplinary teams are vital to ensure appropriate treatment escalation plans and address complex ethical decisions.

This article summarises the key causes and pathophysiology of acute hypercapnic respiratory failure, including the evidence for the role of non-invasive ventilation in acute hypercapnic respiratory failure. It also provides practical tips for managing acute hypercapnic respiratory failure on the medical take, including the use of newer modalities of non-invasive ventilation and outlines emerging research into nasal high flow and its possible role in the management of acute hypercapnic respiratory failure.

Which diseases commonly result in acute hypercapnic respiratory failure and require non-invasive ventilation?

Treating the causative pathology in acute hypercapnic respiratory failure is essential. In a few conditions, despite optimal treatment of the underlying condition, acute non-invasive ventilation may be required. These include chronic obstructive pulmonary disease, obesity hypoventilation syndrome, chest wall disease and neuromuscular disease, as summarised in Table 1.

NHS England reports acute exacerbations of chronic obstructive pulmonary disease to account for 115 000 hospital admissions annually in England (NHS England, 2014). Acute hypercapnic respiratory failure complicates a quarter of these, signalling advanced disease and repeated hospital admissions, and highlighting the need for advanced care planning (NHS England, 2014).

The estimated prevalence of obesity hypoventilation syndrome is 0.4% in adults but this remains under-recognised (often as a result of misdiagnosis), with one third of cases being diagnosed during hospitalisation with acute hypercapnic respiratory failure (Sequeira et al, 2017). Obesity hypoventilation syndrome is defined as a body mass index >30 kg/m^2 combined with chronic alveolar hypoventilation (in the absence of other causes of hypoventilation) leading to daytime hypercapnia ($PaCO_2$ >6 kPa). An 18% inpatient mortality rate has been demonstrated among those admitted to an intensive care unit and characterised as obesity hypoventilation syndrome, based on the exclusion of other pathology (Marik and Desai, 2013).

In extrapulmonary lung disease resulting from either deformity of the thoracic rib cage, or neuromuscular disease causing restricted lung expansion, the risk of developing chronic hypercapnic respiratory failure increases when the vital capacity falls below 1–1.5 litres.

How does it develop?

Acute hypercapnic respiratory failure results from an imbalance between the load imposed upon respiratory muscles, respiratory muscle capacity and neural drive (Figure 1). Decompensation results from functional decline and there are many triggers, including infection, mucosal oedema, sputum retention, bronchospasm, sedation, excessive oxygen therapy, pneumothorax, pulmonary embolism and left ventricular failure.

Chronic obstructive pulmonary disease

These patients have increased respiratory muscle load as a result of small airway narrowing and increased airway resistance. The small calibre airways and increased collapsibility limit expiratory flow (an inability to augment expiratory flow despite increasing expiratory muscle effort). This increases intrinsic positive end expiratory pressure and poses an 'inspiratory threshold load'. Hyperinflation is also accompanied by respiratory muscle shortening, reducing efficacy and muscle capacity. Furthermore, to preserve muscle fatigue and limit breathlessness, patients breathe rapidly, leading to poorer tidal volumes, increased air-trapping, dead space and ventilation–perfusion mismatching. This all contributes to acute hypercapnic respiratory failure.

Obesity-related respiratory failure

Obesity alters pulmonary mechanics, but not all patients develop ventilatory failure. Increased resistive, elastic and threshold loads result in increased respiratory muscle load. The resistive load secondary to lower lung volumes, premature airway closure, and

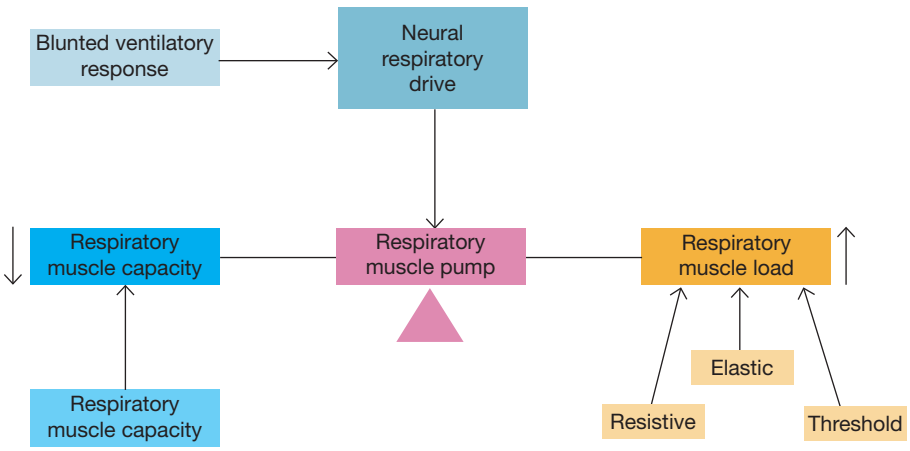

Figure 1. Pathophysiology contributing to acute hypercapnic respiratory failure.

peripheral airway calibre reduction leads to increased airway resistance. The increased elastic load occurs as a result of a reduction in chest wall and lung compliance, leading to increased work of breathing. The threshold load occurs as a result of the presence of intrinsic positive end expiratory pressure, particularly when supine, requiring patients to generate higher negative intrathoracic pressures to initiate a breath. Patients with obesity hypoventilation syndrome appear to lack the compensatory increased ventilatory drive that eucapnic obese patients have in response to the pulmonary mechanics described above (Bahammam et al, 2005). Coupled with reduced respiratory muscle capacity and reduced neural drive patients, acute hypercapnic respiratory failure ensues.

Neuromuscular disease

Respiratory failure is triggered by progression or exacerbation of the underlying disease process, leading to reduced respiratory muscle capacity, especially when inspiratory muscle strength is under 30% of that predicted.

How do you establish the diagnosis and treat acute hypercapnic respiratory failure?

Clinicians identify aetiology through careful history taking and examination. Table 2 summarises pertinent symptoms, signs and investigations to establish the underlying cause of acute hypercapnic respiratory failure. Where a cause is not identified, head injury and drug overdose should be excluded. Liaising with family is valuable when discussing treatment escalation plans, if unable to discuss this with the patient first hand. Quality of life, performance status, the patient's wishes and advanced directives should be ascertained with an open discussion regarding the complications of an intensive care stay.

Oxygen saturation on pulse oximetry of <92% should prompt further investigation with an arterial blood gas in the first instance. Acidosis warrants urgent assessment, a review of oxygen prescription and administration of non-invasive ventilation. Achieving an arterial pH >7.35 and PaO_2 of >6.5 kPa in acute hypercapnic respiratory failure allows adequate tissue oxygenation if cardiac output and haemoglobin are also adequate.

Table 2. Clinical patterns of the common causes of acute hypercapnic respiratory failure

Condition	Typical symptoms	Typical signs	Investigations to determine diagnosis (previous +/- current)
Acute exacerbation chronic obstructive pulmonary disease	Dyspnoea, cough, chest pain	Pursed lip breathing, wheeze	Spirometry (previous) Chest X-ray, white cell count, C-reactive protein
Obesity hypoventilation syndrome	Orthopnoea, early morning headache, excessive daytime somnolence, ankle swelling	High body mass index, increased neck circumference, pitting oedema	Sleep studies Chest X-ray, brain natriuretic peptide, echo
Kyphoscoliosis or chest wall abnormalities	Dyspnoea, daytime somnolence, sleep disruption, early morning headaches	Kyphoscoliosis, pectus carinatum or pectus excavatam	Sleep studies Chest X-ray Brain natriuretic peptide
Neuromuscular disease	Muscle weakness, dysphagia, dysarthria, daytime somnolence, sleep disruption	Muscle wasting, fasciculations, bulbar palsy, paradoxical breathing	Lung function tests Sniff nasal inspiratory pressure testing Chest X-ray Nerve conduction studies
Cardiogenic pulmonary oedema	Dyspnoea, orthopnoea, paroxysmal nocturnal dyspnoea, chest pain	Tripod position, elevated jugular venous pressure, pitting oedema, crackles	Brain natriuretic peptide Echo Chest X-ray

Patients with chronic obstructive pulmonary disease are frequently treated with high oxygen concentrations, with toxicity contributing to acute hypercapnic respiratory failure in 17% of cases, as described in UK national audit data. Excess oxygen worsens hypercapnia leading to respiratory depression. A randomised controlled trial comparing high flow oxygen (n=226) vs titrated oxygen (n=179) in the pre-hospital setting demonstrated that titrated oxygen reduced mortality by 58% for all patients (relative risk 0.42, 95% confidence interval 0.20–0.89; P=0.02) (Austin et al, 2010). The British Thoracic Society guidelines highlight that correct oxygen prescriptions include documentation of concentration, mode of delivery and target saturations (O'Driscoll et al, 2008).

Optimal medical treatment can correct respiratory acidosis alone, particularly for patients with chronic obstructive pulmonary disease. Prompt treatment with nebulised bronchodilator drugs and corticosteroids reverses acute hypercapnic respiratory failure in 20% of exacerbations (Plant et al, 2000). Antibiotics for lower respiratory tract infection or pneumonia, diuretics to manage pulmonary oedema and naloxone to reverse excessive hypoventilation from opioid overdose are key treatments. However, persistence of respiratory acidosis (pH <7.35 and pCO_2 >6.5), despite optimal medical management, requires alternative support such as non-invasive ventilation.

What is the evidence for non-invasive ventilation and when is it indicated?

Gas exchange is supported by non-invasive or invasive mechanical ventilation. Invasive mechanical ventilation bypasses the upper airway with tracheal tubes, laryngeal masks or tracheostomy. Non-invasive ventilation delivers an inspiratory and expiratory pressure, with the difference representing the ventilatory assistance or 'pressure support'. This augments tidal volume and minute ventilation, reducing the work of breathing and $PaCO_2$. Expiratory positive airway pressure reduces upper airway collapse and maintains end-expiratory lung volume. Non-invasive ventilation is indicated as outlined in Table 3 and has further benefits such as:

- Earlier consideration of use than endotracheal intubation
- Alternative or ceiling of treatment for individuals not willing to receive invasive mechanical ventilation or deemed too high risk
- Less risk as with invasive mechanical ventilation (upper airway trauma, sedation, ventilator-associated pneumonia).

Non-invasive ventilation in patients with acute exacerbation of chronic obstructive pulmonary disease

The landmark YONIV trial, a prospective multicentre randomised controlled trial (n=236; 14 UK hospitals), paved the way for use of non-invasive ventilation outside the intensive care unit. Non-invasive ventilation compared with standard therapy in patients with mild

Table 3. Indications for the use of non-invasive ventilation

Obstructive airways disease: acute exacerbation of chronic obstructive airways disease (pH <7.35 and $PaCO_2$ >6.5 kPa) and respiratory rate >23 breaths per minute if persisting after bronchodilators and controlled oxygen therapy
Obesity-related respiratory failure: obesity hypoventilation syndrome (pH <7.35 and $PaCO_2$ >6.5 kPa) and respiratory rate >23 or daytime $PaCO_2$ >6.5 kPa and somnolent
Neuromuscular disease, for example motor neurone disease
Respiratory illness with respiratory rate >20 if usual vital capacity <1 litre even if $PaCO_2$ <6.5 kPa or pH <7.35 and $PaCO_2$ >6.5 kPa
Chest wall deformities, eg kyphoscoliosis, thoracoplasty, flail chest, ankylosing spondylitis
Cardiogenic pulmonary oedema*

**Non-invasive ventilation is considered in patients with cardiogenic pulmonary oedema if acute hypercapnic respiratory failure is persistent following medical management*

to moderate acidosis during acute exacerbations of chronic obstructive pulmonary disease had a lower failure rate (15% vs 27%, *P*=0.02) and reduced mortality (12/118 vs 24/118, *P*=0.05). Outcomes were worse if pH<7.30 (Mukherjee et al, 2018).

A Cochrane review of 17 randomised controlled trials (*n*=1264 participants) reinforced that non-invasive ventilation, plus usual care, decreases mortality by 46% (relative risk 0.54, 95% confidence interval 0.38–0.76; *n* = 12), endotracheal intubation by 65% (relative risk 0.36, 95% confidence interval 0.28–0.46; *n* = 17) and hospital length of stay in both the ward and intensive care unit, compared to usual care alone (Osadnik et al, 2017).

Despite these outcomes, guidelines recommend individuals with a pH <7.25 should be looked after in an intensive care unit, as 25% of cases (including those failing non-invasive ventilation) will require invasive mechanical ventilation (Davidson et al, 2016).

Non-invasive ventilation in patients with asthma

A meta-analysis of five randomised controlled trials showed no benefit in mortality or in intubation rates in those who received non-invasive ventilation vs routine care in acute asthmatics, hence there is no evidence for the use of non-invasive ventilation in these patients (Lim et al, 2012). Accurately phenotyping patients with obstructive airways disease distinguishes patients with fixed airflow obstruction (chronic obstructive pulmonary disease), for whom non-invasive ventilation has a role.

Non-invasive ventilation in patients with obesity hypoventilation syndrome

Carrillo et al (2012) prospectively assessed 716 patients (173 with obesity hypoventilation syndrome and 543 with chronic obstructive pulmonary disease) with acute hypercapnic respiratory failure. Patients with obesity hypoventilation syndrome exhibited improved outcomes; less late non-invasive ventilation failure (7% vs 13%, *P*=0.037), less readmission to the intensive care unit and lower mortality (6% vs 18%, *P*<0.001). Obese patients in the chronic obstructive pulmonary disease group were less likely to fail non-invasive ventilation.

Non-invasive ventilation in patients with neuromuscular or chest wall disease

In patients with extrapulmonary restrictive lung disease, the beneficial effect of non-invasive ventilation in the domiciliary setting has resulted in a paucity of randomised controlled trials evaluating non-invasive ventilation acutely. Elevation in daytime pCO_2, nocturnal hypoxaemia, a forced vital capacity of <50% predicted, or a fall in forced vital capacity >15% over 3 months, prompts initiation of non-invasive ventilation (Davidson et al, 2016). Challenges include patients with bulbar weakness who cannot maintain head posture and are at risk of upper airway obstruction during sleep, aspiration, poor cough and sputum retention. A multidisciplinary treatment approach, including physiotherapy, suction, mechanical insufflation-exsufflation or cough assist devices and non-invasive ventilation, is effective. Senior staff and those from specialist home mechanical ventilation units should aim to discuss treatment escalation plans and advanced care planning with patients.

Non-invasive ventilation in patients with cardiogenic pulmonary oedema

Before non-invasive ventilation, all patients must receive standard medical therapy including diuretics and nitrates. Vital et al (2013) (*n* = 32, 2916 participants) showed positive airway pressure (continuous positive airways pressure or bilevel ventilation) reduced inpatient mortality (relative risk 0.66, 95% confidence interval 0.48–0.89) and reduced intubation rates (relative risk 0.52, 95% confidence interval 0.36–0.75) in a meta-analysis. Continuous positive airways pressure should be considered first, given the ease of application.

When should we think twice about using non-invasive ventilation?

Severe acidosis, greater baseline physiological and neurological impairment, significant comorbidity, and lower body weight confer a higher risk of treatment failure with non-

invasive ventilation (Davidson et al, 2016). Higher mortality rates are seen in patients with coexisting pneumonia; the National Confidential Enquiry into Patient Outcome and Death group reported that 76/171 (44.4%) died compared with 41/165 (24.8%) without pneumonia (Davies and Juniper, 2018). Ghosh and Elliott (2019) make a case for distinguishing whether pneumonia itself results in acute respiratory distress, or if it is a complication of the underlying disease, as the latter would warrant treatment with non-invasive ventilation because of the nature of the underlying disease. Prognostication is needed to help with decision making when contemplating non-invasive ventilation to ensure the proper treatment approach is selected.

Contraindications and complications

Severe acidosis requires extra vigilance. Absolute contraindications are described in Table 4. Poor interface tolerance, inefficient secretion clearance, discomfort from patient-ventilator synchrony, agitation and/or delirium can contribute to poor usage. Five per cent develop pressure ulcers, so regular breaks, barriers and alternating interfaces can help.

Which non-invasive ventilation modalities to use

Traditional bilevel non-invasive ventilation delivers fixed pressures and relies on the user to adjust the settings to ensure adequate volume delivery and cycle synchrony. The fixed pressure support may be insufficient to control $PaCO_2$ levels in patients whose respiratory effort varies during sleep, or in patients at risk of hypoventilation in REM (rapid eye movement sleep), or it may provide too much pressure in non-REM sleep and lead to intolerance or complex sleep apnoea. Newer hybrid modes such as volume-targeted pressure support can ensure a more consistent tidal volume, while also delivering the advantages of pressure support ventilation.

Average volume-assured pressure support ventilation targets a tidal volume over several breaths (based on 6–10 ml/kg of ideal body weight). If there is variance in respiratory mechanics, for example reduced compliance or increased physiological dead space altering the tidal volume and alveolar ventilation, average volume-assured pressure support can automatically adjust inspiratory positive airway pressure to account for this variance. It does this by detecting the average pressure support provided to the patient over the previous 2 minutes and uses an internal algorithm to ensure appropriate changes in pressure support to target the set tidal volume. The backup rate is set at 2 breaths per minute lower than the rate

Table 4. Contraindications to the use of non-invasive ventilation

Absolute	Fixed upper airway obstruction
	Acute pneumothorax (not drained)
	Severe facial deformity or facial burns
	Inability to protect airway
	Haemodynamic compromise (hypotension and arrhythmia) necessitating invasive mechanical ventilation
Relative	Glasgow Coma Score <8
	pH <7.15 or pH <7.25 and additional adverse feature
	Confusion or agitation
	Asthma
	Pneumonia
	Vomiting
	Abdominal distension or bowel obstruction
	Copious respiratory secretions

of the last six spontaneous breaths. The device estimates the anatomical dead space using height, so overestimates of height may be required in patients with emphysema to provide a calculated dead space closer to their physiological dead space, to provide the alveolar ventilation required. A benefit of average volume-assured pressure support ventilation is the reduced number of manual interventions, with less pressure support while patients are awake, increasing patient comfort.

Few studies explore average volume-assured pressure support in acute hypercapnic respiratory failure, but evidence points towards a more rapid improvement in physiological parameters, useful in the context of decreased consciousness. A randomised controlled trial (n=60) showed that average volume-assured pressure support results in earlier improvements in Glasgow Coma Scale, respiratory rate and pH at 12 hours and $PaCO_2$ at 48 hours compared to fixed bilevel pressure support. The duration of non-invasive ventilation was also shorter with average volume-assured pressure support (1 (1–1.25) vs 2 (1–3) days, P=0.049) but length of stay overall was unaltered (El-Abdin et al, 2017).

Non-invasive ventilation guide: set up and troubleshooting

The most common mode of bi-level ventilation is spontaneous-timed (ST). This ensures that assisted breaths are delivered in response to patient's inspiratory effort (S) while control/timed (T) breaths are delivered independent of patient effort if the patient's respiratory rate is slower than the back-up rate. The mixed ST mode with a backup rate is useful in acute hypercapnic respiratory failure caused by fluctuating states of alertness and respiratory drive, and also avoids further $PaCO_2$ rises during sleep.

Figure 2 gives a guide to non-invasive ventilation setup and up-titration of pressures is needed according to treatment response to maintain oxygen saturations between 88% and 92%. Figure 3 gives a guide to solving problems that may occur with non-invasive ventilation. There are a few nuances that should be taken into consideration:

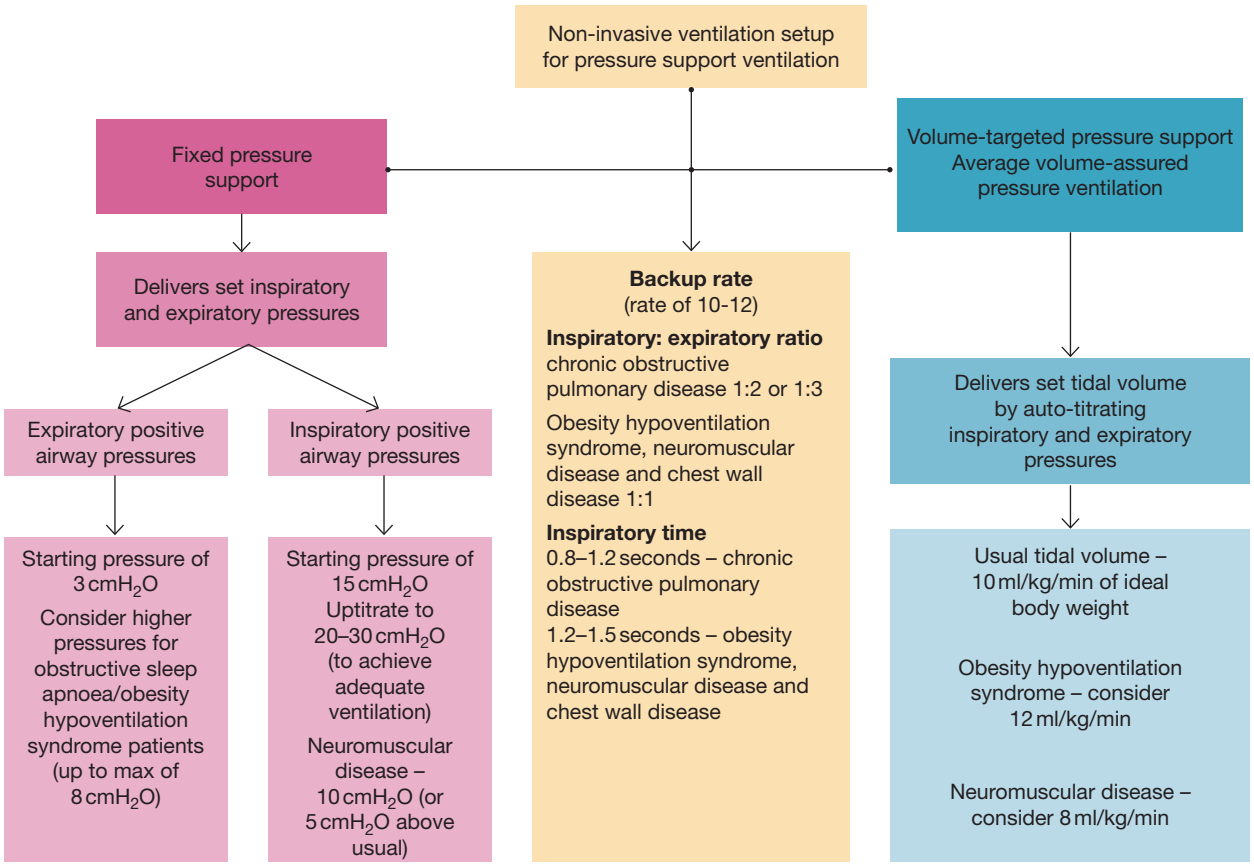

Figure 2. A simple guide for non-invasive ventilation setup for pressure support ventilation.

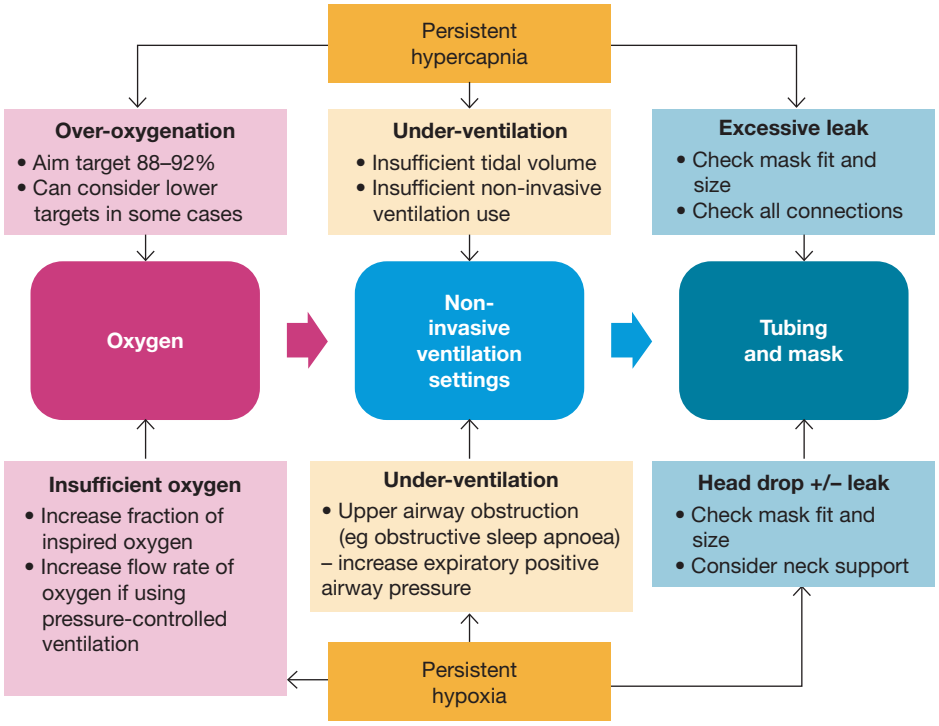

Figure 3. A guide to non-invasive ventilation troubleshooting.

- In patients with obesity hypoventilation syndrome or obstructive sleep apnoea, a higher expiratory positive airway pressure is often required to overcome any upper airway resistance and high thoracic impedance
- Patients with chronic obstructive pulmonary disease who have significant hyperinflation may also need a higher expiratory positive airway pressure to counter an already increased intrinsic positive end-expiratory pressure
- Patients with motor neuron disease may require a lower set tidal volume as this helps improve tolerability.
- In patients with motor neuron disease, adequate tidal volumes may be achieved with lower inflation pressures (as the impedance to inflation is low) in contrast to those with chest wall disease, where higher pressures may be required as a result of reduced chest wall compliance.

As a note of caution, the British Thoracic Society guidelines (Davidson et al, 2016) suggest that inspiratory positive airway pressure should not exceed 30 cmH_2O or expiratory positive airway pressure 8 cmH_2O without expert review.

Adjustable non-invasive ventilation settings depend on the mode of ventilation being used. With average volume-assured pressure support, the usual initial tidal volume is 10 ml/kg of ideal body weight. Tidal volume should always be calculated based on ideal body weight because the size of the lungs does not change with increased weight. This can be increased to 12 ml/kg if the patient is felt to be under-ventilating.

If using a fixed pressure mode of non-invasive ventilation, then increasing the inspiratory positive airway pressure will increase the pressure support and increase the tidal volume. It is always useful to think about patient-ventilator asynchrony in under-ventilated patients. This means checking that the ventilator's back-up rate is not too high (as this can lead to a large number of machine-triggered breaths when the patient is not ready) and considering prolonging the ramp time (only for average volume-assured pressure support) to help patient comfort.

Excessive leaking prompts the need for a change in mask interface. Mouth leak limits the effectiveness of nasal interfaces during sleep and nasal pillows are more easily dislodged.

Non-invasive ventilation: monitoring and follow-up

British Thoracic Society quality standards (Davies et al, 2018) provide detailed recommendations about how to appropriately select patients that need non-invasive

ventilation, as well as how to deliver this effectively. Non-invasive ventilation should be made available within 1 hour of presentation of acutely decompensated hypercapnic respiratory failure. Improvement in pH or respiratory rate, or both, is a predictor of success, often seen in the first 1–4 hours in those who respond (Davies and Juniper, 2018). Non-invasive ventilation settings should be optimised before increasing the fraction of inspired oxygen, as gas exchange will improve.

A nurse:patient ratio of 1:2 is the minimum recommended staffing ratio in all areas providing acute non-invasive ventilation and all staff who prescribe, initiate or make changes to acute non-invasive ventilation must have training and be assessed and deemed competent. No randomised controlled trial has compared weaning approaches and use is recommended for as long as tolerated on day 1. Once acidosis has improved, use is reduced according to clinical need. Discontinuing nocturnal non-invasive ventilation depends on restoring respiratory drive and the overall pCO_2 when self-ventilating.

Murphy et al (2018) provided evidence that in acute hypercapnic respiratory failure related to acute exacerbations of chronic obstructive pulmonary disease, domiciliary non-invasive ventilation could be considered if patients remain hypercapnic at 2 weeks post- exacerbation. Patients with obesity hypoventilation syndrome should be reassessed after hospital discharge, with consideration of a baseline domiciliary sleep study for positive airway pressure therapy. Patients with neuromuscular disease or chest wall disease often require long-term domiciliary ventilation after a single episode of acute hypercapnic respiratory failure.

Is there a role for nasal high flow oxygen?

Nasal high flow oxygen is primarily established in acute and critical care settings for treating patients with mild-to-moderate hypoxaemic respiratory failure and for weaning off a ventilator, offering benefit through delivery of high flow rates (up to 70 litres/min humidified and heated) independently to oxygen delivery. Physiological effects include reducing anatomical dead space, generation of positive end-expiratory pressure improving alveolar ventilation, decreasing $PaCO_2$ and workload of breathing.

Huang et al (2020) conducted a systematic review (six randomised controlled trials and two cohort studies) evaluating nasal high flow cannulae alone compared to non-invasive ventilation in acute hypercapnic respiratory failure. They concluded that nasal high flow cannulae was non-inferior to non-invasive ventilation with regard to intubation rate in both randomised controlled trials (odds ratio = 0.92, 95% confidence interval 0.45–1.88) and cohort studies (odds ratio = 0.94, 95% confidence interval 0.55–1.62). Non-invasive ventilation appeared more effective in reducing mortality in randomised controlled trials (odds ratio = 1.33, 95% confidence interval 0.68–2.60) but the intertreatment difference was not statistically significant. Three studies reported on patient comfort and indicated a significant effect in support of nasal high flow cannulae, and four studies reported on complications with lower nasal facial breakdown noted in the nasal high flow cannulae group. Thus, nasal high flow cannulae offer promise in the setting of acute hypercapnic respiratory failure and further trials with superiority design are needed to evaluate the effect on patient-related outcomes.

Conclusions

This article presents an overview of the management of acute hypercapnic respiratory failure and practical tips for improving diagnosis and management of the underlying causes presenting on the acute medical take. It also discusses the evidence for acute non-invasive ventilation and highlights the importance of choosing the right treatment approach, with adequate treatment escalation plans to improve patient outcomes. For the purposes of resource planning, it highlights the need to consider new modalities such as average volume-assured pressure support. Future research must focus on emerging treatments, such as nasal high flow, that may prevent the need for a ventilator altogether.

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Key points

- Clinical history and examination is key to determining the underlying diagnosis in acute hypercapnic respiratory failure.
- A multidisciplinary approach, focusing on optimal oxygen delivery and appropriate medical treatment of the underlying cause, improves outcomes in acute hypercapnic respiratory failure.
- Challenges exist in choosing the right patient population for non-invasive ventilation or invasive mechanical ventilation and ensuring adequate monitoring in the correct setting.
- It is vital to discuss treatment escalation plans, involving community teams and home mechanical ventilation services when appropriate.
- Volume-targeted average pressure support automated devices may result in faster improvement of acute hypercapnic respiratory failure.
- Newer treatments such as nasal high flow cannulae need further evaluation of outcomes in the treatment of acute hypercapnic respiratory failure.

Conflicts of interest
Dr Anita Saigal and Dr Amar Shah declare that they have no conflicts of interest; Dr Swapna Mandal has received research grants from Fisher Paykel.

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