BTS/ICS GUIDELINE FOR THE VENTILATORY MANAGEMENT OF ACUTE HYPERCAPNIC RESPIRATORY FAILURE IN ADULTS

Master draft document for consultation: 6/5/2015

Craig Davidson ¹
Steve Banham ¹
Mark Elliott ¹
Colin Gelder ²
Alastair Glossop ¹
Daniel Kennedy ¹
Milind Sovani ¹

¹ Guideline Group
² BTS Standards of Care Committee

Contributors:

Colin Church, Ben Creagh-Brown, James Dodd, Tim Felton, Bernard Foex, Leigh Mansfield, Lynn McDonnell, Robert Parker, Caroline Patterson, Lynn Thomas

This document is available for publication consultation from 7 May to 5 June 2015. Comments should be returned to:

British Thoracic Society, 17 Doughty St, London WC1N 2PL

louise.preston@brit-thoracic.org.uk

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft
Table of Contents

Summary of recommendations

1. Introduction
   1.1 Background introduction
   1.2 Definition of acute hypercapnic respiratory failure
   1.3 Importance of Acute Hypercapnic Respiratory Failure (AHRF)
   1.4 Intended use and target audience of the guideline
   1.5 Areas not covered by the guideline
   1.6 Units
   1.7 Guideline group members
   1.8 Methods and terminology
   1.9 Clinical questions and literature search
   1.10 Appraisal of the literature
   1.11 Considered judgement and grading of recommendations
   1.12 Drafting of the guideline
   1.13 Abbreviations/Glossary

2. Principles of mechanical ventilation
   2.1 Modes of mechanical ventilation
   2.2 Choice of interface for NIV
   2.3 Indications for and contra-indications to NIV in AHRF
   2.4 Monitoring during NIV
   2.5 Supplemental oxygen therapy with NIV

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft
2.6 Humidification with NIV
2.7 Bronchodilator therapy with NIV
2.8 Sedation with NIV
2.9 NIV Complications

2.10 Sputum retention
2.11 Modes of Invasive Mechanical Ventilation (IMV)
2.12 Ventilation strategies for IMV
2.13 Positive End Expiratory Pressure
2.14 Sedation in IMV

2.15 Patient-ventilator asynchrony
2.16 The use and timing of a tracheostomy

3: Management of acute hypercapnic respiratory failure

3.1 Obstructive lung diseases

3.1.1 Prevention of AHRF in AECOPD
3.1.2 Role of NIV in AECOPD
3.1.3 Starting NIV in COPD

3.1.4 Prognostic features relating to use of NIV in COPD
3.1.5 Duration of NIV in COPD
3.1.6 Optimising NIV delivery and troubleshooting
3.1.7 Indications for IMV in AECOPD
3.1.8 Outcome following NIV or IMV in AECOPD
3.1.9 Asthma
3.1.10 Non-CF Bronchiectasis
3.1.11 Cystic fibrosis

3.2 Restrictive lung diseases

3.2.1 Neuromuscular disease (NMD) and chest wall deformity (CWD)
3.2.2 NIV failure and discontinuing NIV following recovery in NMD and CWD
3.2.3 IMV in NMD/CWD
3.2.4 IMV Strategy in NMD and CWD
3.2.5 Obesity hypoventilation syndrome (OHS)
3.2.6 NIV settings and placement in OHS
3.2.7 NIV failure in OHS
3.2.8 Discontinuing NIV in OHS
3.2.9 IMV strategy in OHS

4: Weaning from invasive mechanical ventilation

4.1 Introduction
4.2 Weaning methods
4.3 Assessing readiness for discontinuation of mechanical ventilation
4.4 Outcome following extubation
4.5 Weaning Protocols
4.6 The use of NIV in the ICU
4.6.1 Planned NIV to speed weaning from IMV
4.6.2 NIV in high risk patients
4.6.3 NIV as ‘rescue’ therapy post extubation

5: Care planning and delivery of care

5.1 Appropriate care environments for the delivery of NIV
5.2 Palliative Care and Advanced Care Planning
5.3 End of Life Care

6: Novel therapies

6.1 Extra-corporeal CO₂ removal (ECCO₂R)
6.2 Helium/Oxygen ventilation

Appendix 1. Guideline Group Members and declarations of interest

Tables
Table 1. SIGN Levels of evidence
Table 2. SIGN Grades of recommendations
Table 3. Trouble shooting: a guide for when NIV is failing
Table 4. Indications for IMV in AECOPD
Table 5. Risk Factors for Extubation Failure following IMV
Table 6. Essential requirements for a NIV service
Table 7. Discharge checklist after an episode of AHRF

Figures
Figure 1 Summary for providing acute non-invasive ventilation (NIV)
Figure 2 Guide to initial settings and aims with IMV
Figure 3 Key elements of an integrated AHRF service
Summary of recommendations

2: Principles Of Mechanical Ventilation

2.1 Modes of mechanical ventilation

Recommendations

1. Pressure targeted ventilators are the devices of choice for acute NIV. (Grade B)

Good practice points

1. Both pressure support and pressure control modes can be used to deliver NIV.

2. Only ventilators designed specifically to deliver NIV should be used.

2.2 Choice of interface for NIV

Recommendation

1. A FFM should usually be the first type of interface used for acute NIV. (Grade D)

Good practice points

1. Availability of a range of mask types and sizes is required and staff involved in delivering NIV need experience of the different types available.
2. NIV circuits must allow adequate clearance of exhaled air through an exhalation valve or an integral exhalation port on the mask and this should be regularly checked to be functioning.

2.3 Indications for and contra-indications to NIV

Recommendation

1. The presence of adverse features increase the risk of NIV failure and should prompt consideration of placement in HDU/ICU if escalation to invasive ventilation would be appropriate. (Grade C)

Good practice points

1. Patients with adverse features should not be denied a trial of NIV.

2. The presence of relative contra-indications necessitates a higher level of supervision, consideration of placement in HDU/ICU and an early appraisal of whether to continue NIV or to convert to IMV.

2.4 Monitoring during NIV

Good practice points

1. Oxygen saturation should be monitored continuously.

2. Intermittent monitoring of pCO2 and pH is required.

3. ECG monitoring is advised if patient has pulse rate > 120 bpm or if there is dysrhythmias or possible cardiomyopathy.
2.5 Supplemental oxygen therapy with NIV

Recommendations

1. Oxygen enrichment should be at a rate to achieve SpO2 88-92%. (Grade A)

2. Oxygen is best entrained as close to the patient as possible. (Grade C)

Good practice point

1. As gas exchange will improve with increased alveolar ventilation, NIV settings should be optimised before increasing the FiO2.

2. High inspiratory pressure reduces the inspired oxygen concentration when supplemental oxygen is given.

3. Mask leak and delayed triggering may be caused by oxygen flow rates > 4L/min which risks promoting or exacerbating patient-ventilator asynchrony. The requirement for high flow rates should prompt a careful check for patient-ventilator asynchrony.

4. A ventilator with an integral oxygen blender is recommended if oxygen at 4L/min fails to maintain SpO2 > 88%.

2.6 Humidification with NIV

Recommendation

1. Humidification is not routinely required (Grade D)

Good practice point

1. Heated humidification should be considered if the patient complains of mucosal dryness or if respiratory secretions are thick and tenacious.
2.7 Bronchodilator therapy with NIV

*Good practice points*

1. Nebulised drugs should normally be administered during breaks from NIV.

2. If the patient is dependent on NIV, bronchodilator drugs can be given via a nebuliser inserted into the ventilator tubing.

2.8 Sedation with NIV

*Recommendations*

1. Sedation should only be used with close monitoring. (Grade D)

2. Infused sedative/anxiolytic drugs should only be used in an HDU or ICU setting. (Grade D)

3. If intubation is not intended should NIV fail, then sedation/anxiolysis is indicated for symptom control in the distressed or agitated patient (Grade D).

*Good practice point*

1. In the agitated/distressed and tachypneic individual *on NIV*, morphine 2.5-5mg may provide symptom relief and improve tolerance of NIV.

2.9 NIV Complications

*Good practice points*
1. Minor complications are common with NIV but serious complications are rare and patients should be frequently assessed to identify potential complications of NIV.

2. Care is needed to avoid overtightening of masks.

3. Previous episodes of pneumothorax warrant consideration of admission to HDU/ICU and initiation of NIV with low inspiratory pressures.

4. The development of a pneumothorax on NIV usually requires intercostal drainage and review of whether to continue with NIV.

2.10 Sputum retention

Recommendations

1. MI:E should be used, in addition to standard physiotherapy techniques, if sputum retention with an ineffective cough complicates AHRF in NM disease. (Grade B).

2. Mini-tracheostomy has a role in aiding clearance of secretions in cases of weak cough (NM/CWD) or excessive secretions (COPD, CF), especially in combination with NIV when IMV is not desired or indicated. (Grade D)

2.11 Modes of Invasive Mechanical Ventilation (IMV)

Recommendations

1. In NM disease, controlled IMV may need to be continued due to poor triggering and/or to correct chronic hypercapnia. (Grade C)
2. Early spontaneous breathing should be established in all causes of AHRF. (Grade C)

Good practice points

2. In the obstructive causes, controlled IMV should be continued until airway resistance falls.

2.12 Ventilator strategies for IMV in obstructive disease

Recommendations

1. During controlled ventilation, dynamic hyperinflation should be minimized by prolonging expiratory time (I:E ratio 1:3 or greater) and setting a low frequency (10-15 bpm). (Grade C)

2. During assisted ventilation, a higher level of pressure support minimises dynamic hyperinflation by shortening inspiratory time. (Grade C)

3. Permissive hypercapnia (aiming for pH 7.2-7.25) may be required to avoid high airway pressures when airflow obstruction is severe. (Grade D)

4. Carbonic anhydrase inhibitors should not be used routinely in AHRF (Grade C)

2.13 Positive End Expiratory Pressure

Recommendation

1. Applied (extrinsic) PEEP should not exceed intrinsic PEEP. (Grade C)
2.14 Sedation in IMV

*Recommendation*

1. Sedation should be titrated to a specific level of alertness. (Grade B)

2.15 Patient-ventilator asynchrony

*Recommendations*

1. Ventilator asynchrony should be considered in all agitated patients. (Grade C)

2. As patients recover from AHRF, ventilator requirements change and ventilator settings should be reviewed regularly. (Grade C)

2.16 The use and timing of a tracheostomy

*Recommendations*

1. Routine tracheostomy within 7 days of initiating IMV is not recommended.

   (Grade A)

2. The need for and timing of a tracheostomy should be individualized. (Grade D)

*Good practice points*

1. In AHRF due to COPD, and in many individuals with NM disease or OHS, NIV-supported extubation should be employed in preference to inserting a tracheostomy. (Grade D)
2. In AHRF due to NM disease, the decision to perform tracheostomy should be multi-disciplinary and, ideally, involve home ventilation specialists. (Grade D)

3: Management of hypercapnic respiratory failure

3.1 AECOPD

Recommendations

1. Controlled oxygen therapy should be used in AHRF due to AECOPD (Grade A)

Good practice point

1. Controlled oxygen therapy should be used in ALL causes of AHRF.

3.1.2 Role of NIV in AECOPD

Recommendations

1. For most patients with AECOPD, the initial management should be optimal medical therapy, targeting an oxygen saturation of 88 to 92%. (Grade A)

2. NIV should be started when pH < 7.35, pCO2 > 6.5 kPa and respiratory rate > 23 persist or develop despite optimal medical therapy. (Grade A)

3. Severe acidosis alone does not preclude a trial of NIV in an appropriate area with ready access to staff who can perform safe endotracheal intubation. (Grade B)
4. The use of NIV should not delay escalation to IMV when this is more appropriate. (Grade C)

5. The practice of NIV should be regularly audited to maintain standards (Grade C)

3.1.3 Starting NIV in COPD

Good practice points

1. Arterial Blood Gas measurement is needed prior to and following initiation of NIV.

2. Chest radiography is recommended but should not delay initiation of NIV in severe acidosis

3. Reversible causes for respiratory failure should be sought and treated appropriately.

4. At the start of treatment, an individual patient plan should document agreed measures to be taken in the event of NIV failure.

3.1.4 Prognostic features relating to use of NIV

Recommendations

1. Advanced age alone should not preclude a trial of NIV. (Grade A)

2. Worsening physiological parameters, particularly pH and respiratory rate, indicate the need to change the management strategy. This includes clinical review, change of interface, adjustment of ventilator settings and proceeding to endotracheal intubation. (Grade A)
Good practice point

1. If sleep-disordered breathing pre-dates AHRF, or evidence of it complicates an episode, the use of a controlled mode of NIV overnight is recommended.

3.1.5 Duration of NIV

Recommendation

1. NIV can be discontinued when there has been normalisation of pH and pCO2 and a general improvement in the patient’s condition. (Grade B)

Good practice points

1. The amount of time on NIV should be maximised in the first 24 hrs depending upon patient tolerance and/or complications.

2. NIV use during the day can be tapered in the following 2-3 days, depending on pCO2 self ventilating, before being discontinued overnight.

3.1.6 Optimising NIV delivery and troubleshooting

Good practice point

1. Before considering NIV to have failed, always check that potential troubleshooting issues have been addressed and that ventilator settings are optimal.

3.1.7 Indications for IMV

Recommendations
1. Invasive mechanical ventilation should be considered if there is persistent or deteriorating acidosis despite optimal delivery of NIV. (Grade A)

2. Intubation should be performed in respiratory arrest or peri-arrest unless there is rapid recovery from manual ventilation/provision of NIV. (Grade D)

3. Intubation is indicated in management of AHFRF when it is impossible to fit/use a non-invasive interface e.g. severe facial deformity, fixed upper airway obstruction, facial burns. (Grade D)

4. Intubation is indicated where risk/benefit analysis deems IMV more likely to produce a good outcome than NIV. (Grade D)

3.1.8 Outcome following NIV or IMV in AECOPD

Recommendations

1. Prognostic tools may be helpful in discussion regarding prognosis and in making decisions regarding appropriateness of IMV with the caveat that they are poorly predictive for individual patient use. (Grade B)

2. Clinicians should be aware of their own likely under-estimation of survival in AECOPD treated by IMV. (Grade B)

3. Clinicians should discuss management of possible future episodes of AHFRF with patients following an episode requiring ventilatory support because there is a high risk of recurrence (Grade B).

3.1.9 Asthma

Recommendations

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults 6/5/2015 Master consultation draft
1. NIV should not be used in asthma exacerbations with AHRF. (Grade C)

2. NIV cannot be recommended as an alternative to IMV in patients with AHRF due to asthma. (Grade D)

**3.1.10 Non-CF Bronchiectasis**

*Recommendations*

1. In patients with non-CF bronchiectasis and AHRF, controlled oxygen therapy should be used (Grade D).

2. In patients with non-CF bronchiectasis, NIV should be started in AHRF using the same criteria as in AECOPD. (Grade B)

3. In patients with non-CF bronchiectasis, NIV should usually be tried before resorting to IMV in those with less severe physiological disturbance (Grade C)

4. In patients with non-CF bronchiectasis, the patient’s clinical condition prior to the episode of AHRF, and the reason for the acute deterioration, should be evaluated and used to inform the decision about providing IMV (Grade C)

*Good practice points*

1. In patients with non-CF bronchiectasis and AHRF, the precipitating cause is important in determining short term prognosis.

2. Health status prior to the episode of AHRF is an important predictor of outcome.

**3.1.11 Cystic fibrosis**
Recommendations

1. In patients with CF, controlled oxygen therapy should be used in AHRF. (Grade D)

2. In patients with CF, NIV is the treatment of choice when ventilatory support is needed. (B)

3. In patients with CF, specialist and experienced physiotherapy is needed to aid sputum clearance. (D)

4. In patients with CF, a mini-tracheostomy combined with NIV may offer greater chance of survival than resorting to IMV. (D)

3.2 Restrictive lung diseases

3.2.1 Neuromuscular disease (NMD) and chest wall deformity (CWD)

Recommendations

1. In patients with NMD and CWD, controlled oxygen therapy should be used in AHRF (Grade D).

2. NIV should almost always be used in the acutely unwell NM/CWD patient with hypercapnia. Do Not Wait for acidosis to develop. (Grade D)

3. In patients with NMD and CWD, NIV should be considered in acute illness when VC known to be < 1L and RR > 20 even if normocapnic. (Grade D)

4. In patients with NMD and CWD, consider controlled ventilation as patient triggering may be ineffective (Grade D)
5. In patients with NMD and CWD, unless escalation to IMV has been agreed to be not desired by the patient or inappropriate, intubation should not be delayed if NIV is failing (Grade D)

**Good practice points**

1. NIV is the mode of choice in most cases of AHRF because many patients with NMD or CWD tolerate it well and because extubation from IMV may be difficult.

2. In patients with NMD and CWD, deterioration may be rapid or sudden making HDU/ICU placement more appropriate.

3. In patients with NMD and CWD, senior/experienced input is needed in care planning and is essential if differences in opinion exist or develop between medical staff and patient representatives.

4. In patients with NMD and CWD, it should be anticipated that bulbar dysfunction and communication difficulties will make NIV delivery difficult and may make it impossible.

5. Discussion about NIV and IMV, and patients’ wishes with respect to cardio-pulmonary resuscitation, should occur as part of routine care in NMD/CWD.

6. In patients with NMD and CWD, nocturnal NIV should usually be continued following an episode of AHRF pending discussion with a home ventilation service.

### 3.2.2 NIV failure and discontinuing NIV
Recommendation

1. In patients with NMD/CWD, the presence of bulbar dysfunction, more profound hypoxaemia or rapid desaturation during NIV breaks suggest placement in HDU/ICU is indicated unless it is agreed that escalation is inappropriate. (Grade B)

3.2.3 IMV in NM/CWD

Recommendations

1. In patients with NMD/CWD, senior staff should be involved in decision making, in conjunction with HMV specialists where experience is limited, and especially when the appropriateness of IMV is questioned. (Grade D)

2. In patients with NMD/CWD, advance care planning, particularly around the wish for IMV, is recommended in progressive NM & CWD which may best be supported by referral to a home ventilation service. (Grade D)

3.2.4 IMV Strategy

Good practice points

1. Patients with NMD usually require low levels of PS.

2. Patients with CWD usually require higher levels of PS.

3. PEEP in the range 5-10cm is commonly required to increase RV and reduce oxygen dependency.

3.2.5 Obesity hypoventilation syndrome (OHS)
Recommendations

1) Controlled oxygen therapy should be used in the morbidly obese OHS patient with AHRF (Grade D)

2) NIV should be started in AHRF using the same criteria as in AECOPD. (Grade B)

3) NIV is indicated in some hospitalised obese hypercapnic patients with day time somnolence, sleep disordered breathing and/or right heart failure in the absence of acidosis. (Grade D)

3.2.6 NIV settings and placement in OHS

Good practice points

1. High EPAP and IPAP settings are commonly required in OHS (e.g. IPAP >30, IPAP >8)

2. Volume control (or volume assured) modes of providing NIV may be more effective when high inflation pressures are required.

3.2.7 NIV failure in OHS

Good practice points

1. Fluid overload commonly contributes to ventilatory failure in patients with OHS and its degree is easily underestimated.

2. Forced diuresis may be useful.

3. As the risk of NIV failure is greater, and intubation may be more difficult, placement in HDU/ICU for NIV is encouraged.

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults 6/5/2015 Master consultation draft
3.2.8 Discontinuing NIV in OHS

Good practice points

1. NIV can be discontinued as in patients with COPD

2. Many patients with AHRF secondary to OHS will require long-term domiciliary support (CPAP or NIV).

3. Following an episode of AHRF referral to a home ventilation service is recommended.

3.2.9 IMV strategy in OHS

Good practice points

1. In patients with OHS, pressure controlled MV is recommended initially.

2. In patients with OHS, high PEEP settings may be needed to recruit collapsed lung units and correct hypoxaemia.

3. In patients with OHS, a forced diuresis is often indicated.

4: Weaning from invasive mechanical ventilation

4.1 Introduction

Recommendations

1. Treating the precipitant cause of AHRF, normalising pH, correcting chronic hypercapnia and addressing fluid overload should all occur before starting weaning. (Grade D)
2. A BNP-directed fluid management strategy should be considered in patients with known left ventricular dysfunction. (grade B)

4.2 **Weaning methods**

**Recommendations**

1. Assessment of patient’s readiness for weaning should be undertaken daily. (Grade C)
2. A switch from controlled to assisted IMV should be made as soon as patient recovery allows. (Grade C)
3. IMV patients should have a documented weaning plan. (Grade B)

4.3 **Assessing readiness for discontinuation of mechanical ventilation.**

**Recommendation**

1. A 30 minute SBT should be used to assess suitability for extubation. (Grade B)
2. Factors including upper airway patency, bulbar function, sputum load and cough strength should be considered prior to attempted extubation. (Grade D)

4.4 **Outcome following extubation**

**Recommendation**

1. Care is needed to identify factors that increase the risk of extubation failure so that additional support, such as NIV or cough assist, can be provided to reduce this risk. (Grade B)

4.5 **Weaning Protocols**

**Recommendations**

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft
1. Although an organised and systematic approach to weaning is desirable, protocols should be used with caution in patients with AHRF. (Grade B)

2. The use of computerised weaning cannot be recommended in AHRF. (Grade D)

4.6.1 The use of NIV in the ICU

4.6.2 Planned NIV to speed weaning from IMV

Recommendation

1. NIV is recommended to aid weaning from IMV in patients with AHRF secondary to COPD. (Grade B)

2. In other causes of AHRF, NIV may have a role in shortening the duration of IMV when local expertise in its use exist (and of cough assist when indicated) and other features indicate extubation is likely to be successful. (Grade D)

4.6.2 NIV in high risk patients

Recommendation

1. “Prophylactic” use of NIV should be considered to provide post extubation support in patients with identified risk factors for extubation failure. (Grade B)

4.6.3 NIV as ‘rescue’ therapy post extubation

Recommendations

1. NIV should not be used for unexpected post-extubation respiratory failure. (Grade B)
2. In COPD, a trial of NIV may be justified where local expertise exists. (Grade D)

5: Care planning and delivery of care

5.1 Appropriate care environments for the delivery of NIV

Recommendations

1. NIV services should operate under a single clinical lead with formal working links with the ICU. (Grade D)

2. Consideration of the severity of AHRF and evidence of other organ dysfunction should influence the choice of care environment. (Grade C)

3. NIV should take place in a clinical environment with enhanced nursing and monitoring facilities that are beyond that of a general medical ward. (Grade C)

4. Initial care environment decisions should include robust arrangements for escalation, anticipating that around 20% of AHRF cases should be managed in a level 2 or 3 environment. (Grade C)

Good Practice Points

1. A 2-4 bedded designated NIV unit covered by respiratory medicine (located within a medical high dependency area or within a respiratory ward with enhanced staffing levels) provides a robust basis for the provision of NIV in a DGH serving a population of 250,000 and with an average prevalence of COPD.
2. Areas providing NIV should have a process for audit and interdisciplinary communication.

5.2 Palliative Care and Advanced Care Planning

Recommendations

5 1. Clinicians delivering NIV or IMV should have ready access to palliative medicine. (Grade D)

2. Multidisciplinary advance care planning should be an integral part of the routine outpatient management of progressive or advanced disease, and care planning should be reviewed on presentation during an episode of AHRF (Grade D).

3. The use of NIV may allow time to establish patient preference with regard to escalation to IMV. (Grade D)

5.3 End of Life Care

Good Practice Points

1. Although removal of the NIV mask may be agreed as preferable, a dignified and comfortable death is possible with equipment in place.

2. Clinicians delivering NIV or IMV should have training in EOL care and the support of palliative care teams.

6 : Novel therapies

6.1 Extra-corporeal CO₂ removal (ECCO₂R)

Recommendations
1. ECCO$_2$R may be considered:

a. if, despite optimal invasive ventilation, severe hypercapnic acidosis (pH < 7.15) persists. (Grade D)

b. when 'lung protective IMV’ is indicated but hypercapnia would not be tolerated. (Grade D)

c. for IMV patients awaiting a lung transplant. (Grade D)

6.2 Helium/Oxygen ventilation

Recommendation

1. There is insufficient evidence to support the use of Heliox in the management of AHRF. (Grade A)
Figure 1. Summary for providing acute non invasive ventilation.

**Indications for NIV**
- **COPD**
  - pH < 7.35
  - pCO₂ > 6.5
  - RR > 23
  - If persisting after bronchodilators and controlled oxygen therapy

- **Neuromuscular disease**
  - Respiratory illness with RR > 20 if usual VC < 1l even if pCO₂ < 6.5
  - Or pH < 7.35 and pCO₂ > 6.5

- **Obesity**
  - pH < 7.35, pCO₂ > 6.5, RR > 23
  - Or Daytime pCO₂ > 6.0 and sleepiness

- **Absolute**
  - Severe facial deformity
  - Facial burns
  - Fixed upper airway obstruction

- **Relative**
  - pH < 7.15
  - (pH < 7.15 and additional adverse feature)
  - GCS < 8
  - Confusion/agitation
  - Cognitive impairment (warrants enhanced observation)

**Contraindications for NIV**
- **Asthma/Pneumonia**
  - Refer to ICU for consideration IMV if increasing respiratory rate/dyspnoea or pH < 7.35 and pCO₂ > 6.5

**NIV Setup**
- **Mask**
  - Full face mask (or even if home user of NIV)
  - **Initial Pressure settings**
    - EPAP: 5 (or higher if OSA known/expected)
    - IPAP in COPD/OHS/NS 15 (20 if pH < 7.25)
  - Up titrate IPAP over 10-30 mins to IPAP 20-30 to achieve adequate augmentation of chest/abdominal movement and slow RR
  - IPAP should not exceed 30 or EPAP > 8* without expert review

- **Backup rate**
  - Backup Rate of 16-20. Set appropriate inspiratory time

  - **I:E ratio**
    - COPD: 1:2 to 1:3
    - OHS, NM & CWD: 1:1

  - **Inspiratory time**
    - 0.8-1.2s COPD
    - 1.2-1.5s OHS, NM & CWD

  - Use NIV for as much time as possible in 1st 24 hours.
  - Taper depending on tolerance & ABGs over next 48-72 hours
  - SEEK AND TREAT REVERSIBLE CAUSES OF AHRF

**NIV Monitoring**
- **Oxygenation**
  - Aim: 88-92% in all patients
  - Note: Home style ventilators CANNOT provide > 50% inspired oxygen
  - If high oxygen need or rapid desaturation on disconnection from NIV consider IMV.

- **Red flags**
  - pH < 7.25 on optimal NIV
  - RR persisting > 25
  - New onset confusion or patient distress

- **Actions**
  - Check synchronisation, mask fit, exhalation port: give physiotherapy/bronchodilators, consider analgesics

  - CONSIDER IMV

---

BTS/ICS Guideline for the ventilator management of acute hypercapnic respiratory failure in adults

6/5/2015 Master Consultation draft
Fig 2. Guide to initial settings and aims with IMV

**Obstructive disease**

- **Oxygenation:**
  - SaO2 88-92% in obstructive causes AHF (except asthma aim >96%)
- **Acid base balance:**
  - pH 7.2-7.4 (permissive hypercapnia if PAWP > 30 cmH2O)
- **Tidal volumes:** 6-8mls/kg
- **Respiratory rate:** 10-15
- **I:E ratio:** 1:2-1:4

**Neuro muscular & CWD**

- **Oxygenation:** > 92%
- **Acid base balance:** as above
- **Tidal volumes:** Aim 6mls/kg
- **Respiratory rate:** 15-25
- **I:E ratio:** 1:1 – 1:2
**Figure 3: Key elements of an integrated AHRF service**

<table>
<thead>
<tr>
<th>Immediate Clinical Assessment</th>
<th>Assisted Ventilation Plan</th>
<th>Recovery and discharge phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygenation target 88-92%</td>
<td>Options:</td>
<td>Arrange pulmonary rehabilitation &amp; help with smoking cessation as indicated</td>
</tr>
<tr>
<td>Acid –Base Status</td>
<td>Intubation and transfer to ICU for IMV</td>
<td></td>
</tr>
<tr>
<td>Evidence of other organ dysfunction</td>
<td>NIV with transfer to ICU as risk of requiring IMV</td>
<td></td>
</tr>
<tr>
<td>Co-morbidities</td>
<td>NIV before/after transfer to NIV unit</td>
<td></td>
</tr>
<tr>
<td>Administer bronchodilator, antibiotics etc as indicated and get specialist therapy help for NM/OHS patients.</td>
<td>NIV before/after transfer to acute ward with specialist support</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non implementation or discontinuation of assisted ventilation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Review patient and family wishes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ensure NIV experienced clinical input and assistance of ICU if needed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use locally agreed protocols for AHRF management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Review reasons/route of admission and consider methods to improve if these were problematic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provide warning card/inform ambulance services re future need for controlled oxygen therapy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consider referral to home NIV service eg NM cases or suspected sleep disordered breathing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Arrange early specialist review</td>
<td></td>
</tr>
</tbody>
</table>

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults 6/5/2015 Master consultation draft
1. Introduction

1.1 Background

The British Thoracic Society (BTS) published the guideline “The use of non-invasive ventilation in acute respiratory failure” in 2002 [1]. This was in response to trials that had demonstrated that non-invasive ventilation (NIV) was an alternative to invasive mechanical ventilation (IMV) in life threatening respiratory acidosis due to acute exacerbations of chronic obstructive pulmonary disease (AECOPD). The guideline drew attention to evidence that, when NIV was used in the less severely unwell patient with AECOPD, it also limited progression to more severe respiratory failure [2]. This trial also demonstrated the feasibility of delivering NIV on a general medical or admission ward.

In subsequent years, NIV has been shown to deliver better rather than equivalent outcomes to invasive ventilation in AECOPD (see section 3). Although the 2002 guideline recognised that NIV is effective in other causes of acute hypercapnia, the evidence at the time was largely an extrapolation from its domiciliary use in neuromuscular and chest wall disease. Audits of UK practice have however raised concerns that expected patient benefit is not being delivered and of significant process deficiencies [3 4]. In addition, there is the risk, in the absence of justifying trial evidence, that the now preferred use of NIV in AECOPD is being extended to all hypercapnic patients, irrespective of circumstance or underlying disease process. That this is a real risk might be inferred from the results of national audits where the indication for NIV was not COPD in over 30% of cases[3 4].
In the UK, NIV development has largely been outside the organisational “umbrella” of critical care. This may have adversely affected resource allocation and contributed to a lack of integration in NIV and IMV patient pathways. Other unintended consequences might be restricting access to invasive ventilation and delaying the development of extended applications of NIV, such as accelerating extubation and its use in the management of post-extubation respiratory failure in the ICU [5]. The ‘closed unit’ approach now advocated in critical care may have also made care of the invasively ventilated respiratory patient the preserve of the intensivist. Such specialists may have little experience of the ability of domiciliary NIV to reverse chronic cardio-respiratory failure and this may lead to under-estimating survival, particularly in advanced neuromuscular (NM) or chest wall disease (CWD).

For these varied reasons, the need for up to date guidance was acknowledged by the British Thoracic Society (BTS) and the Intensive Care Society (ICS). The aim of the guideline is to provide an overview of the evidence for the use of both invasive and non-invasive ventilation and to encourage improvements in resourcing, training, outcomes and patient experience in adults who develop acute hypercapnic respiratory failure (AHRF).

1.2 Definition of acute hypercapnic respiratory failure

Acute hypercapnic respiratory failure results from an inability of the respiratory pump, in concert with the lungs, to provide sufficient alveolar ventilation to maintain a normal arterial PCO2. Co-existent hypoxaemia is usually mild and easily corrected. Conventionally, a pH < 7.35 and a PCO2 > 6.5kPa, persisting after initial medical therapy, define acute respiratory acidosis and have been used as threshold values for considering the use of non-invasive ventilation. More severe degrees of acidosis,
such as pH < 7.25, have been used as a threshold for considering provision of invasive mechanical ventilation.

1.3 Importance of AHRF

AHRF complicates around 20% of acute exacerbations of COPD [2,6]. It signals advanced disease, a high risk of future hospitalisations and limited long term prognosis. In one large case series the median survival following recovery from AHRF was one year [6]. Around 12% of hypercapnic COPD patients died during the index admission but this increased to 33% if the respiratory acidosis developed after hospitalisation [6]. In asthma, acute hypercapnia also signals an increased risk of death and an increased likelihood of future life-threatening attacks [7]. The same risks apply to AHRF complicating cystic fibrosis and bronchiectasis although this has not been formally reported. In the neuromuscular and chest wall diseases, including morbid obesity, respiratory pump failure is often insidious in onset but may be acute and unexpected. Acute on chronic ‘decompensated’ episodes of AHRF are more common in these conditions and normally indicate the future need for domiciliary NIV.

1.4 Intended use and target audience of the guideline

A central theme of the guideline is to promote integration in the planning and delivery of both NIV and IMV in acute hypercapnic respiratory failure. Despite trial evidence demonstrating the value of non invasive ventilation in the management of AHRF, its introduction into routine clinical practice has not delivered the expected patient benefit in the UK and may, inadvertently, have reduced access to invasive mechanical ventilation. It is recommended that the introduction of an integrated
AHRF patient pathway in all hospitals accepting medical emergencies will improve both clinical outcome and the patient experience.

The target audiences for the guideline are medical, nursing and physiotherapy staff working in emergency receiving rooms, medical assessment units, admission wards, respiratory wards and in high dependency and critical care units. The Guideline applies to adults. For information on NIV in children with neuromuscular weakness, see the BTS guideline Respiratory Management of Children with Neuromuscular Weakness [8].

1.5 Areas not covered by the guideline

The guideline does not cover the management of AHRF due to cardiac failure, trauma or acute brain injury. The guideline refers to domiciliary NIV but does not aim to provide guidance on this.

1.6 Units

Intra-thoracic pressure and pressures relating to mechanical ventilation are presented as cm H$_2$O. Arterial blood gas tensions are presented as kPa.

1.7 Guideline group members

A list of Guideline Group members and BTS Standards of Care Committee (SOCC) members who assisted with a production of the guideline is given in Appendix 1.

The Guideline Group members adhered to the BTS and ICS policies for the Declaration of Interests and, where appropriate, specific relevant interests are declared.
1.8 Methods and terminology

The methodology used to write the guideline adheres to the criteria as set by the AGREE collaboration in the document http://www.agreecollaboration.org/1/agreeguide/.

1.9 Clinical questions and literature search

Clinical questions were gathered in the PICOT (Patient, Intervention, Comparison, Outcome and Time) format to define the scope of the guideline and inform the literature search. Systematic electronic database searches were conducted in order to identify potentially relevant studies for inclusion in the guideline. For each clinical question the following databases were searched: Ovid MEDLINE (including MEDLINE In-Process), Ovid EMBASE, EMSCO CINAHL, Ovid PsycINFO and the Cochrane Library (including the Cochrane Database of Systematic Reviews, the Database of Abstracts of Reviews of Effects and the Cochrane Central Register of Controlled Trials).

An initial search was carried out in November 2010 using a combination of indexed and free text terms defining the clinical questions that had been agreed by the guideline group as important in formulating guidelines in AHRF. It was limited to studies after 1990, in adults, in journals published in English and where at least an abstract was available. The searches identified a total of 582 potential papers which were subsequently supplemented by publications known to members or resulting...
from additional searches undertaken by the writing groups after 2010. A second search for relevant publications between 2010 and 2013 was carried out in September 2013, yielding a further 308 potentially relevant references. Additional references were included from personal collections.

1.10 Appraisal of the literature

Appraisal was performed using the criteria stipulated by the AGREE collaboration. Each paper was appraised by at least two reviewers. The writing lead for each section read the title and abstract of papers identified and agreed with at least one member of each writing group whether such a paper was definitely, possibly relevant or not relevant to the section. The criteria used were whether the paper addressed a clinical question, whether the study method used was satisfactory and that it was available in English.

Full papers were obtained for all relevant or possibly relevant abstracts. Two members for each section independently appraised each paper using the SIGN critical appraisal checklists. An evidence level was assigned to each study using the SIGN methodology (Table 1). These evidence levels are shown in the evidence tables presented in the online supplement as Appendix 3.
Table 1: SIGN Levels of evidence

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1++</td>
<td>High quality meta-analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias</td>
</tr>
<tr>
<td>1+</td>
<td>Well-conducted meta-analyses, systematic reviews, or RCTs with a low risk of bias</td>
</tr>
<tr>
<td>1-</td>
<td>Meta-analyses, systematic reviews, or RCTs with a high risk of bias</td>
</tr>
<tr>
<td>2++</td>
<td>High quality systematic reviews of case control or cohort or studies</td>
</tr>
<tr>
<td>2+</td>
<td>Well-conducted case control or cohort studies with a low risk of confounding or bias and a moderate probability that the relationship is causal</td>
</tr>
<tr>
<td>2-</td>
<td>Case control or cohort studies with a high risk of confounding or bias and a significant risk that the relationship is not causal</td>
</tr>
<tr>
<td>3</td>
<td>Non-analytic studies, e.g. case reports, case series</td>
</tr>
<tr>
<td>4</td>
<td>Expert opinion</td>
</tr>
</tbody>
</table>

1.11 Considered judgement and grading of recommendations

The guideline group used the evidence tables to judge the body of evidence and develop recommendations for this guideline. Where evidence was lacking, expert opinions were obtained by consensus. The following were considered in the grading of the recommendations: the number of studies and number of patients providing evidence, the applicability of such evidence and whether generalizable to the patient groups in the guideline and to UK practice and the degree of strength as judged by the consistency of evidence obtained to support recommendations.

Recommendations were graded from A to D, using the SIGN Grading System (Table
2), as indicated by the strength of the evidence as listed in the tables. Important practical points that lack good research evidence were highlighted as ‘Good Practice Points’.

Table 2: SIGN Grades of recommendations

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>At least one meta-analysis, systematic review, or RCT rated as 1++, and directly applicable to the target population; or A body of evidence consisting principally of studies rated as 1+, directly applicable to the target population, and demonstrating overall consistency of results</td>
</tr>
<tr>
<td>B</td>
<td>A body of evidence including studies rated as 2++, directly applicable to the target population, and demonstrating overall consistency of results; or Extrapolated evidence from studies rated as 1++ or 1+</td>
</tr>
<tr>
<td>C</td>
<td>A body of evidence including studies rated as 2+, directly applicable to the target population and demonstrating overall consistency of results; or Extrapolated evidence from studies rated as 2++</td>
</tr>
<tr>
<td>D</td>
<td>Evidence level 3 or 4; or Extrapolated evidence from studies rated as 2+</td>
</tr>
</tbody>
</table>

Good practice points

- Recommended best practice based on the clinical experience of the guideline development group

1.12 Drafting of the guideline

The Guideline group corresponded regularly by email and telephone. The initial meeting of the writing group took place in Oct 2009 and subsequent meetings of the BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults 6/5/2015 Master consultation draft
full committee occurred in June and Nov 2010, Sept 2011 and March and Sept 2012. Draft documents were reviewed by the BTS Standards of Care Committee at meetings in 2013 and 2014 and a final draft was produced with the help and collaboration of members of SOCC in September 2014 – March 2015. The guideline was made available for public consultation in April/May 2015.

1.13 Abbreviations and Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABG</td>
<td>Arterial blood gases</td>
</tr>
<tr>
<td>AECOPD</td>
<td>Acute exacerbation of COPD</td>
</tr>
<tr>
<td>AHRF</td>
<td>Acute hypercapnic respiratory failure</td>
</tr>
<tr>
<td>ALI</td>
<td>Acute lung injury</td>
</tr>
<tr>
<td>APACHE II</td>
<td>Acute Physiology and Chronic Health Evaluation: a severity of illness score</td>
</tr>
<tr>
<td>ARDS</td>
<td>Acute Respiratory Distress Syndrome</td>
</tr>
<tr>
<td>Bi-level/Bi-PAP</td>
<td>Ventilation mode using 2 levels of pressure support</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
<tr>
<td>BODE</td>
<td>Body mass index, obstruction, dyspnoea and exercise tolerance score</td>
</tr>
<tr>
<td>Bpm</td>
<td>Heart rate (beats per minute)</td>
</tr>
<tr>
<td>BTS</td>
<td>British Thoracic Society</td>
</tr>
<tr>
<td>BUR</td>
<td>Back-up rate</td>
</tr>
<tr>
<td>CCM</td>
<td>Closed circuit method (of suctioning)</td>
</tr>
<tr>
<td>CF</td>
<td>Cystic fibrosis</td>
</tr>
<tr>
<td>COPD</td>
<td>Chronic obstructive pulmonary disease</td>
</tr>
<tr>
<td>CPAP</td>
<td>Continuous positive airways pressure</td>
</tr>
<tr>
<td>CWD</td>
<td>Chest Wall Disease</td>
</tr>
<tr>
<td>DH</td>
<td>Dynamic hyper-inflation</td>
</tr>
<tr>
<td>DMD</td>
<td>Duchenne muscular dystrophy</td>
</tr>
<tr>
<td>DNI</td>
<td>Do not intubate</td>
</tr>
<tr>
<td>DNR</td>
<td>Do not resuscitate</td>
</tr>
<tr>
<td>ECCO₂R</td>
<td>Extra corporeal carbon dioxide removal</td>
</tr>
<tr>
<td>ECG</td>
<td>Electrocardiogram</td>
</tr>
<tr>
<td>ED</td>
<td>Emergency department</td>
</tr>
<tr>
<td>EEV</td>
<td>End expiratory volume</td>
</tr>
<tr>
<td>EELV</td>
<td>End expiratory lung volume</td>
</tr>
<tr>
<td>EoL</td>
<td>End of Life</td>
</tr>
<tr>
<td>EPAP</td>
<td>Expiratory positive airway pressure</td>
</tr>
<tr>
<td>ePEEP</td>
<td>Extrinsic PEEP</td>
</tr>
<tr>
<td>ET</td>
<td>Endotracheal tube</td>
</tr>
<tr>
<td>ETS</td>
<td>Endotrachael suctioning</td>
</tr>
<tr>
<td>Expiratory trigger</td>
<td>Mechanism by which ventilator senses end of inspiration</td>
</tr>
<tr>
<td>FBC</td>
<td>Full blood count</td>
</tr>
<tr>
<td>FFM</td>
<td>Full face mask</td>
</tr>
</tbody>
</table>

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults 6/5/2015 Master consultation draft
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>FiO2</td>
<td>Fractional inspired concentration of oxygen</td>
</tr>
<tr>
<td>FRC</td>
<td>Functional residual capacity</td>
</tr>
<tr>
<td>HME</td>
<td>Heat and moisture exchanger</td>
</tr>
<tr>
<td>ICS</td>
<td>Intensive Care Society</td>
</tr>
<tr>
<td>ICU/HGU</td>
<td>Intensive care/High Dependency Unit</td>
</tr>
<tr>
<td>IE Ratio</td>
<td>Inspiratory/expiratory time ratio</td>
</tr>
<tr>
<td>IMV</td>
<td>Invasive mechanical ventilation</td>
</tr>
<tr>
<td>IPAP</td>
<td>Inspiratory positive airway pressure</td>
</tr>
<tr>
<td>iPEEP</td>
<td>Intrinsic PEEP</td>
</tr>
<tr>
<td>L/min</td>
<td>Litres per minute</td>
</tr>
<tr>
<td>LOS</td>
<td>Length of stay</td>
</tr>
<tr>
<td>NAVA</td>
<td>Neurally adjusted ventilatory assist</td>
</tr>
<tr>
<td>MI-E</td>
<td>Mechanical insufflation-expiration</td>
</tr>
<tr>
<td>MND</td>
<td>Motor neurone disease</td>
</tr>
<tr>
<td>MT</td>
<td>Mini tracheostomy</td>
</tr>
<tr>
<td>NCROP</td>
<td>National chronic obstructive pulmonary disease resources and outcomes project</td>
</tr>
<tr>
<td>NIV</td>
<td>Non-invasive (positive pressure) ventilation</td>
</tr>
<tr>
<td>NMD</td>
<td>Neuromuscular disease</td>
</tr>
<tr>
<td>NG</td>
<td>Nasogastric tube</td>
</tr>
<tr>
<td>OHS</td>
<td>Obesity hypoventilation syndrome</td>
</tr>
<tr>
<td>OSA</td>
<td>Obstructive sleep apnoea</td>
</tr>
<tr>
<td>PAV</td>
<td>Proportional assist ventilation</td>
</tr>
<tr>
<td>pCO2/pO2</td>
<td>Partial pressure of carbon dioxide/oxygen</td>
</tr>
<tr>
<td>PCV</td>
<td>Pressure controlled ventilation</td>
</tr>
<tr>
<td>PEEP</td>
<td>Positive end expiratory pressure</td>
</tr>
<tr>
<td>ePEEP</td>
<td>Extrinsic PEEP</td>
</tr>
<tr>
<td>iPEEP</td>
<td>Intrinsic PEEP</td>
</tr>
<tr>
<td>pH</td>
<td>Acid base balance</td>
</tr>
<tr>
<td>PSV</td>
<td>Pressure support ventilation</td>
</tr>
<tr>
<td>QoL</td>
<td>Quality of life</td>
</tr>
<tr>
<td>RCT</td>
<td>Randomised controlled trial</td>
</tr>
<tr>
<td>RICU</td>
<td>Respiratory intermediate care unit</td>
</tr>
<tr>
<td>RR</td>
<td>Respiratory rate</td>
</tr>
<tr>
<td>SBT</td>
<td>Spontaneous breathing trial</td>
</tr>
<tr>
<td>SpO2</td>
<td>Oxygen saturation</td>
</tr>
<tr>
<td>TcpCO2</td>
<td>Transcutaneous measurement of pCO2</td>
</tr>
<tr>
<td>Te</td>
<td>Expiratory duration (seconds)</td>
</tr>
<tr>
<td>Ti</td>
<td>Inspiratory duration (seconds)</td>
</tr>
<tr>
<td>U&amp;E</td>
<td>Blood urea and electrolyte values</td>
</tr>
<tr>
<td>VAP</td>
<td>Ventilator associated pneumonia</td>
</tr>
<tr>
<td>VC</td>
<td>Vital capacity</td>
</tr>
<tr>
<td>VCV</td>
<td>Volume controlled ventilation</td>
</tr>
<tr>
<td>VILI</td>
<td>Ventilator induced lung injury</td>
</tr>
<tr>
<td>Vt</td>
<td>Tidal volume</td>
</tr>
</tbody>
</table>
2. Principles of mechanical ventilation

2.1 Modes of mechanical ventilation

There are two basic modes of providing mechanical ventilation. In volume targeted ventilation, the operator sets the tidal volume to be delivered and the duration of inspiration (Ti). The ventilator generates whatever pressure is necessary to deliver this volume within this time.

In pressure targeted ventilation the operator sets the inspiratory pressure. The volume of air the patient receives is a function of the impedance to inflation of the lungs and chest wall and the inspiratory time. The Ti should be of sufficient length to achieve an adequate tidal volume and at a frequency that allows the patient enough time to fully exhale. (See Section 2 for details regarding Ti settings in different diseases).

The terminology used for pressure targeted ventilation can cause confusion. In bi-level ventilation, one pressure is set for inspiration (IPAP) and a second pressure for expiration (EPAP). The difference between the two is the level of ventilatory assistance or pressure support (PS). This mode, sometimes also termed BiPAP, is most commonly used for Non-Invasive Ventilation (NIV). The term “Continuous Positive Airway Pressure (CPAP) with Pressure Support” is used for Invasive Ventilation (IMV) and for the NIV mode on some ICU ventilators. In this mode, the operator sets an incremental inspiratory pressure above the CPAP setting rather than setting an absolute level of inspiratory pressure.

Pressure targeted ventilation has a number of advantages over setting a target volume. Firstly, the pressure delivered is constant and thus avoids the sudden and
uncomfortable pressure increase that occurs with volume control. Secondly, pressure targeted ventilation compensates for air leak\cite{9 10} which is an inevitable consequence of the mask interfaces used for NIV. Thirdly, positive pressure throughout expiration (EPAP) flushes exhaled CO$_2$ from the mask and distal ventilator tubing\cite{11 12}, aids triggering (see below) and counteracts the tendency for upper airway collapse during expiration. Pressure ventilators have been used in almost all of the RCTs in AHRF\cite{13}. In the UK, volume ventilators are rarely employed (outside of specialist centres) and will not be considered further in this guideline.

In the Spontaneous (S) mode (also known as Assist mode), the ventilator delivers assisted breaths in response to patient inspiratory effort. If the patient fails to make adequate inspiratory effort, no ventilator support is delivered. By contrast, in the Timed (T) mode (also known as Control mode), the ventilator delivers breathes at a rate set by the operator regardless of patient inspiratory effort. “Pressure Controlled Ventilation” (PCV) is the term used to describe ventilation where the operator sets the inspiratory pressure, the length of inspiration and the inspiratory rate. In the Spontaneous/Timed (S/T) mode (also known as Assist/Control) a backup rate is set by the operator. If the patient’s respiratory rate is slower than the backup rate, machine determined breaths will be delivered (i.e. controlled ventilation). If the patient breathes faster than the backup rate, no machine determined breaths will be delivered and all breaths will be triggered (or assisted). The proportion of controlled and assisted breaths will often vary depending on the patient’s state of alertness and respiratory drive.
Trigger sensitivity refers to the effort required by the patient to initiate, or trigger, inspiratory support by the ventilator. The lower the trigger sensitivity, the greater effort the patient needs to make to trigger a supported breath. Different trigger settings may be required for individual causes of AHRF (see section 3).

S/T is the NIV mode most commonly employed in treating AHRF. There have been no trials comparing Pressure Support Ventilation (PSV) and Pressure Controlled Ventilation (PCV) in the treatment of AHRF. Bench studies suggest that ventilators designed specifically for NIV have superior performance over standard ICU ventilators used to deliver NIV, particularly in the presence of significant leak [14-19]. The extent to which individual types of ICU ventilators (set in the NIV mode) can compensate for leak and the adequacy of patient triggering varies [20]. Generally ICU ventilators appear more prone to patient-ventilator asynchrony than home care ventilators [21].

**Evidence statement**

1. Most RCTs that demonstrate an advantage to NIV in AHRF have used pressure targeted ventilators. (Level 1+)

**Recommendation**

1. Pressure targeted ventilators are the devices of choice for acute NIV. (Grade B)

**Good practice points**

1. Both pressure support and pressure control modes can be used to deliver NIV.
2. Only ventilators designed specifically to deliver NIV should be used.

2.2 Choice of interface for NIV

The full face mask (FFM) is the most suitable interface in AHRF because mouth breathing predominates in the context of acute dyspnoea. To accommodate the natural diversity of the human face, a range of shapes and sizes of FFM is available. Taken together, the reported studies suggest that different types of interfaces do not affect outcome but the trials have been small and comparisons of masks have been inadequately powered to detect a difference [22-34]. The helmet interface, which covers the whole head, is an alternative interface [35-41] but triggering is less effective than with a mask. Patients may complain about noise caused by turbulence within the helmet [42] and it is not possible to provide humidified gases because of “rain out” in the helmet. A mask that covers the whole of the face (including the eyes, but not the ears) is useful when air leak remains excessive or when nasal bridge ulceration develops [43] and is sometimes better tolerated by the confused or agitated patient. In those who find the FFM claustrophobic or distressing, experienced practitioners may consider using a nasal mask or nasal pillows as an alternative. Mouth leak during sleep limits the effectiveness of nasal interfaces and nasal pillows are more easily dislodged than the FFM.

Ventilators designed for NIV usually employ a single lumen circuit whereas IMV ventilators use a dual lumen circuit (separate tubing for inhalation and exhalation). In the former a mask with an integral exhalation port is commonly used. If not, an exhalation port needs to be inserted into the ventilator circuit close to the mask. A minimum EPAP of 3cm is required to vent exhaled air [11 44].
following website for information on NIV interfaces that are currently available
http://ersbuyersguide.org/

Evidence Statement

1. A full face mask (FFM) is the interface of choice for general /non-specialist use. (Level 4)

Recommendation

1. A FFM should usually be the first type of interface used for acute NIV. (Grade D)

Good practice points

1. Availability of a range of mask types and sizes is required and staff involved in delivering NIV need experience of the different types available.

2. NIV circuits must allow adequate clearance of exhaled air through an exhalation valve or an integral exhalation port on the mask and this should be regularly checked to be functioning.

2.3 Indications for and contra-indications to NIV in AHRF

The indication for NIV in AHRF vary according to the underlying disease process. Broad criteria can be used and are summarised in Figure 1 and discussed further in Section 3. Severe facial deformity, fixed upper airway obstruction or facial burns will occasionally make NIV impossible. A number of other contra-indications have been suggested (see Figure 1) [45]. These have most often been employed as exclusion
criteria in clinical trials rather than being definitively shown to result in a worse outcome [13]. Some of the criteria have been challenged [46].

Coma, with associated loss of airway protection, has been regarded as a contra-indication but Diaz et al [46] report similar outcomes in those with a Glasgow coma score <8 as in more alert patients. Similarly, confusion, agitation and cognitive impairment render NIV more difficult but should not preclude its use.

In contrast to IMV, there is less haemodynamic compromise with NIV and hypotension per se should not preclude a trial of NIV. Significant arrhythmia, especially if causing hypotension, will tip the balance towards intubation as electro-conversion may be indicated.

An acute pneumothorax should be drained before applying NIV. If the pneumothorax is too small to allow the safe placement of a chest drain (or suspected to be chronic), NIV may proceed with careful monitoring. In this situation, using lower inflation pressures seems theoretically sensible but is without evidence. If the patient deteriorates, NIV should be discontinued in case it is contributing to the development of a tension pneumothorax and an urgent chest radiograph obtained.

Vomiting has been considered a contra-indication to NIV. The key issue is whether the NIV mask can be rapidly removed if necessary i.e. an assessment of whether the patient can signal the need to vomit. Marked abdominal distension may sometimes precipitate AHRF in individuals at risk e.g. in COPD or morbid obesity. Management should then address the underlying cause of distention.
The presence of copious secretions increases the risk of treatment failure [47] but NIV may improve the ability of the patient to cough and clear secretions and thus improve alveolar ventilation [48 49].

As NIV is intended to supplement spontaneous breathing, respiratory arrest or peri-arrest has been considered an absolute contra-indication. As bag and mask ventilation (itself a form of NIV) is used as a prelude to intubation, a short trial of NIV, by an experienced operator and with appropriate monitoring, can be justified in these circumstances paying special attention to the risk of glottic occlusion. Overall, the presence of adverse features is an indication for more intense monitoring and placement in HDU/ICU rather than as contra-indications per se.

**Evidence statement**

1. There are few absolute contra-indications to a trial of NIV but some adverse features, especially when combined, require more caution and more intense monitoring. (Level 4)

2. The presence of adverse features increases the risk of NIV failure. (Level 2++)

**Recommendation**

1. The presence of adverse features increase the risk of NIV failure and should prompt consideration of placement in HDU/ICU if escalation to invasive ventilation would be appropriate. (Grade C)

**Good practice points**

1. Patients with adverse features should not be denied a trial of NIV.
2. The presence of relative contra-indications necessitates a higher level of supervision, consideration of placement in HDU/ICU and an early appraisal of whether to continue NIV or to convert to IMV.

2.4 Monitoring during NIV

Continuous monitoring of oxygen saturation is essential. Repeated measurement of arterial blood gas (ABG) tensions will be required and can be assessed by capillary sampling or intermittent arterial puncture, noting that capillary sampling is less painful for the patient than intermittent arterial puncture [50 51]. One advantage of HDU/ICU placement may be to allow the safe use of an indwelling arterial line for repeated ABG sampling. Transcutaneous pCO\(_2\) (TcpCO\(_2\)) monitoring is a commonly employed investigation in home ventilation units e.g. during set up of nocturnal NIV and the devices are increasingly employed elsewhere within hospitals. Small studies have reported its use in acute respiratory acidosis [52-54]. A study by Van Oppen et al studied 10 patients with AHRF requiring acute NIV and demonstrated that TcpCO\(_2\) monitoring is reliable over 12 hours and provides an adequate estimation of pH [55]. Further studies are needed, particularly over a longer time period, to assess the role of transcutaneous CO\(_2\) monitoring.

ECG monitoring is advised for all patients with a tachycardia > 120 bpm, dysrhythmia or known cardiomyopathy. As in all severely ill patients, serial vital signs and National Early Warning Scores should be recorded.

Good practice points

1. Oxygen saturation should be monitored continuously.
2. Intermittent monitoring of pCO\(_2\) and pH is required.
3. ECG monitoring is advised if patient has pulse rate > 120 bpm or if there is dysrhythmias or possible cardiomyopathy.

5. **2.5 Supplemental oxygen therapy with NIV**

There are no trials to guide practice on when oxygen supplementation is required. It is well recognised that hyper-oxygenation is harmful in the management of AHRF [56-58]. In the absence of evidence of harm from modest hypoxaemia and to avoid confusion with different targets in different conditions, a saturation range of 88 to 92% is recommended for all patients with AHRF when spontaneously breathing or when receiving NIV [59]. This can usually be easily achieved in AECOPD with minimal oxygen supplementation but severe hypoxaemia may complicate AHRF in some of the other causative diseases such as asthma or CWD.

As for the best method of supplying supplementary oxygen, Padkin and Kinnear [60], in a study of patients who were not acutely unwell, reported no difference in inspired oxygen whether delivered directly into the NIV mask or into the ventilator tubing close to the mask. Introducing oxygen at the ventilator end of the tubing was less effective. The mean FiO2 achieved was 31% at 1L/min, 37% at 2L/min, 40% at 3L/min and 44% at 4 L/min. Higher flow rates provided minimal additional increase in FiO2. Kaul [61] found that the higher the inspiratory pressure employed, the less additional benefit resulted from increasing the oxygen flow rate because higher pressures increased leak. High flow rates also resulted in trigger delay. As this risks promoting or exacerbating patient ventilator asynchrony, NIV ventilators that allow
precise oxygen blending (and a higher FiO2 enrichment) is a safer and more appropriate alternative.

**Evidence statements**

1. In AHRF targetted oxygen therapy (SpO2 88-92%) reduces mortality. (Level 1+)

2. When providing NIV, oxygen enrichment is best given at or near to the mask. (Grade 3).

**Recommendations**

1. Oxygen enrichment should be at a rate to achieve SpO2 88-92%. (Grade A)

2. Oxygen is best entrained as close to the patient as possible. (Grade C)

**Good practice points**

1. As gas exchange will improve with increased alveolar ventilation, NIV settings should be optimised before increasing the FiO2.

2. High inspiratory pressure reduces the inspired oxygen concentration when supplemental oxygen is given.

3. Mask leak and delayed triggering may be caused by oxygen flow rates > 4L/min which risks promoting or exacerbating patient – ventilator asynchrony. The requirement for high flow rates should prompt a careful check for patient – ventilator asynchrony.

4. A ventilator with an integral oxygen blender is recommended if oxygen at 4 L/min fails to maintain SpO2 > 88%.
2.6 Humidification with NIV

There is no evidence to guide the use of humidification in acute NIV. It is rarely required in the first 24 hours and, as it may impair triggering, should only be used when upper airway drying impairs tolerance or secretions are thick and difficult to expectorate. There is some evidence that heated humidification reduces upper airway resistance and increases comfort when mask leak is high [62].

_Evidence statement_

1. No published evidence exists to guide clinical practice (Level 4)

_Recommendation_

1. Humidification is not routinely required (Grade D)

_Good practice point_

1. Heated humidification should be considered if the patient complains of mucosal dryness or if respiratory secretions are thick and tenacious.

2.7 Bronchodilator therapy with NIV

As part of a PhD thesis, Kaul found that nebulised bronchodilators given concomitantly with NIV in stable patients produced less benefit than when given whilst patients were breathing spontaneously [63]. Brief discontinuation of NIV for the administration of bronchodilators appears to be safe [64]. Accordingly, bronchodilator therapy is probably better given during breaks in NIV. This may also facilitate coughing and the clearing of respiratory secretions. If discontinuing NIV results in patient distress, NIV should be continued and a nebuliser should be sited proximally in the circuit [65].

_Good practice points_
1) Nebulised drugs should normally be administered during breaks from NIV.

2) If the patient is dependent on NIV, bronchodilator drugs can be given via a nebuliser inserted into the ventilator tubing.

2.8 Sedation with NIV

Patient agitation and distress are common in AHRF. These may be made worse by the application of NIV, especially in the initial period before there has been time for NIV to improve gas exchange and reduce the work of breathing. Despite the potential indications, sedatives/anxiolytics and/or opiates are infrequently used. When NIV is delivered in an environment that is unable to provide continuous monitoring, or the ready availability of medical staff to intubate safely, this concern is understandable. On the other hand, relieving distress might be expected to increase comfort, and hence success of NIV, and by slowing the respiratory rate will increase alveolar ventilation. In a 2007 survey of members of the critical care assemblies of the American College of Chest Physicians and the European Respiratory Society, respondents reported using sedatives or opiates in less than 25% of cases and 21% reported never using either [66]. The perceived risk of respiratory depression was given as the reason for none use. Individual practice was highly variable and, as the response rate was poor (42% European, 14% North American), many of the conclusions reported are more qualitative than quantative. When treatment was given it was mostly by bolus injection and very rarely according to a sedation
protocol. Greater experience in the use of NIV and being a critical care clinician increased reported use of opiates/sedation. This may reflect the usual place in which the respondent worked.

Case series in the ICU setting have reported that infusions of propofol [67], dexmedetomidine [68] and remifentany [69 70] are safe, improve comfort and reduce the failure rate of NIV. Senoglu et al compared infusions of dexmedetomidine and midazolam in 45 AECOPD cases with AHRF using a protocol aiming at a standard degree of sedation [71]. No differences were found in effectiveness between the two agents in causing the desired level of sedation nor in the speed or extent of correction pH or pCO2 with NIV. There were no significant adverse events and no patient failed to improve with NIV ie required intubation. In another report, the addition of infused dexmedetomidine to a standard protocol of “as needed” bolus IV midazolam and fentanyl, given according to a sedation protocol, failed to show additional benefit from the trial drug but sedation goals were readily achieved and NIV tolerance and success was already good with the standard protocol [72]. A review of sedation to facilitate NIV tolerance made the pharmacological case for preferring an opiate to a benzodiazepine (because the latter promote upper airway airway obstruction through inhibiting the pharangeal dilating muscles) but concluded that studies to date have been too small, have used different drugs and therapy regimes and employed a variety of outcome measures [73]. A prospective RCT study of IV Remifentanil in patients failing NIV is currently recruiting [74].

Evidence Statements
1. Patient distress is common in AHRF and often made initially worse by applying NIV. (Level 4)

2. There is inadequate evidence to guide the use of sedation/anxiolysis in acute NIV. Their use in a critical care setting is reported to improve outcome and reduce patient distress. (Level 2)

**Recommendations**

1. Sedation should only be used with close monitoring. (Grade D)

2. Infused sedative/anxiolytic drugs should only be used in an HDU or ICU setting. (Grade D)

3. If intubation is not intended should NIV fail, then sedation/anxiolysis is indicated for symptom control in the distressed or agitated patient (Grade D).

**Good practice point**

1. In the agitated/distressed and tachypneic individual on NIV, morphine 2.5-5mg may provide symptom relief and improve tolerance of NIV

**2.9 NIV Complications**

The reported rate of complications varies widely. One review gives an incidence of between 30 and 50% [75], the range partly depending on how a complication is defined. Extended duration of NIV, patient agitation and the frequent need to adjust mask fit are all associated with an increase in rate/severity of mask related complications.
Nasal bridge ulceration is the most common (5-10%) and may be severe enough to result in NIV failure [76]. Over-tightening is a common cause. Modern masks are designed to mould to the face when pressurized and over-tightening will impair this. Should signs of skin trauma become apparent, a barrier dressing such as Granuflex can be effective whilst a strategy of regular breaks and alternating between two interface types also reduces the risk. Latex allergy occasionally results in florid skin reactions. Some patients seem especially prone to mask related rash even in the absence of allergy. Topical steroids may be indicated and/or antibiotics if the wound becomes infected.

NIV may cause severe gastric distension. It usually indicates poor coordination between patient and ventilator and it may be necessary to insert a nasogastric (NG) tube. Sinus or ear discomfort and nasal mucosal congestion or drying/ulceration can all occur. The value of humidification in preventing these side effects is uncertain but water-based nasal gels and topical corticosteroids or decongestants have been used. Petroleum based emollients should not be used with supplemental oxygen.

An acute pneumothorax may be life threatening but difficult to detect. The development of unexplained agitation/distress or chest pain requires this complication to be excluded by CXR [77]. Co-existent interstitial lung disease, pleural adhesions or previous episodes of spontaneous or ventilator induced pneumothorax all increase the risk. Using a lower IPAP to avoid large tidal volumes and EPAP to avoid significantly increasing EEV are logical but not evidence based. If a pneumothorax develops, intercostal drainage is usually required.

**Good practice points**
1. Minor complications are common with NIV but serious complications are rare and patients should be frequently assessed to identify potential complications of NIV.

2. Care is needed to avoid overtightening of masks.

3. Previous episodes of pneumothorax warrant consideration of admission to HDU/ICU and initiation of NIV with low inspiratory pressures.

4. The development of a pneumothorax on NIV usually requires intercostal drainage and review of whether to continue with NIV.

2.10 Sputum retention

Sputum retention can be the precipitant for AHRF, cause NIV to fail and be a common reason for respiratory distress post extubation in patients managed by IMV. Excessive sputum production characterises bronchiectasis and cystic fibrosis and complicates some patients with AECOPD. Promoting sputum clearance can be particularly challenging in those with neuromuscular disease and the morbidly obese. Techniques, such as manually assisted cough and mechanical insufflation-exsufflation (MI-E) aid sputum clearance in patients with neuromuscular disease [78 79]. In a study of patients with scoliosis or COPD, MI-E was reported to have no benefit [80]. In a more recent RCT, the use of MI-E reduced post extubation respiratory failure in a mixed group of patients including some with AHRF [81]. This study also provided NIV to those with respiratory distress. The reader is referred to the BTS Physiotherapy Guidelines [82] for more detailed information on aiding sputum clearance.
Mini-tracheostomy (MT) facilitates secretion clearance in the spontaneously breathing patient [83] and may have a role when sputum retention or ineffective cough is thought to be a major determinant of AHFR. In an attempt to avoid intubation in a patient with a high secretion load, a combination of respiratory support by NIV and suctioning via a MT has been described. This probably only applies if IMV is not desired or is considered inappropriate as, in most such cases, IMV offers more chance of a successful outcome. In the patient initially managed by IMV, a MT may be inserted at the time of ET tube decannulation in high-risk patients, for example those with a high secretion load and/or a poor cough.

**Evidence Statements**

1. Manual assisted cough and MI:E are safe methods for aiding secretion clearance. (Level 1+)

2. MI:E is more effective than manual assisted cough in stable NM patients. (Level 2+)

3. Mini-tracheostomy is a safe bedside procedure that can facilitate secretion clearance. (Level 4)

**Recommendations**

1. MI:E should be used, in addition to standard physiotherapy techniques, if sputum retention with an ineffective cough complicates AHFR in NM disease. (Grade B).
2. Mini-tracheostomy has a role in aiding clearance of secretions in cases of weak cough (NM/CWD) or excessive secretions (COPD, CF), especially in combination with NIV when IMV is not desired or indicated. (Grade D)

### 2.11 Modes of Invasive Mechanical Ventilation (IMV)

Critical care ventilators are complex devices capable of delivering multiple modes [84 85]. The traditional divide between pressure and volume has become blurred and hybrid modes combine aspects of both. Most AHRF patients do not require sophisticated modes of providing IMV.

Initially, when airway resistance is high and/or compliance is low (e.g. in asthma, cystic fibrosis or bronchiectasis) a period of PCV allows time for bronchodilators, steroids and antibiotics to treat airway inflammation, overcome infection and for 'bronchial toilet' to be provided. These considerations also variably apply to the restrictive causes of AHRF. A failure to adequately trigger is more likely in NM disease and prolonging the period of controlled MV may be necessary. In all AHRF patients, allowing restorative sleep is important [86-88].

Management should shift towards supporting rather than mandating the pattern of ventilation as recovery begins. If there is adequate spontaneous effort, and the respiratory rate is not excessive, a switch to PSV is recommended as the risk of respiratory (and general) muscle wasting may be reduced by establishing early spontaneous breathing [89]. In a study in ARDS, those allowed to breathe spontaneously had less need for sedation than patients treated with controlled IMV, a reduced requirement for vasopressors, fewer days of ventilatory support, earlier
extubation and a shorter length of ICU stay [90]. The relevance of this study to AHRF has not been tested.

Evidence statements

1. Prolonged mechanical ventilation is associated with disuse atrophy of the respiratory muscles. (Level 2+)

2. Extrapolation of the evidence in ARDS suggests early spontaneous breathing reduces the need for sedation, improves cardiac function and reduces the duration of IMV. (Level 1-)

Recommendation

1. In NM disease, controlled IMV may need to be continued due to poor triggering and/or to correct chronic hypercapnia. (Grade D)

2. Early spontaneous breathing should be established in all causes of AHRF. (Grade C)

Good practice points

1. In the obstructive causes, controlled IMV should be continued until airway resistance falls.

2.12 Ventilation strategies for IMV

In obstructive causes of AHRF, tidal volume is often limited by airflow obstruction compounded by the mechanical disadvantage of hyperinflation. The use of high inflation pressures, to achieve a “normal” Vt, risks increasing end expiratory lung
volume (dynamic hyperinflation (DH)) [91]. DH most dramatically occurs at intubation but may re-appear on switching from Controlled to Assisted Ventilation [92].

Adverse consequences of DH include barotrauma, impaired gas exchange and patient discomfort. Increased intra-thoracic pressure impedes venous return and increases right ventricular afterload with a resulting fall in cardiac output and hypotension [93].

Prolonging expiratory time limits gas trapping which may be achieved by shortening the inspiratory time and reducing the minute volume, an approach recommended in airflow obstruction [94 95]. When this approach still results in significant gas trapping, the recommendation is to use a lower than normal tidal volume (Vt) in combination with a low respiratory rate and a prolonged expiratory phase [94 95]. This can often only be achieved using a Controlled Ventilation mode combined with deeper levels of sedation. On switching to pressure support (assist) during early recovery and increased level of inspiratory pressure will minimise dynamic hyperinflation by shortening inspiratory time and so prolonging expiration.

In ARDS, over-distention and repetitive recruitment/de-recruitment of lung units causes alveolar damage (so called ventilator induced lung injury, VILI) and even systemic inflammation [96]. One explanation for improved outcome with low Vt ventilation (<6 ml/kg), compared to conventional practice, may be avoidance of VILI [97]. The ARDS literature provides evidence for permissive hypercapnia, demonstrating a pH above 7.2 is well tolerated [98]. This is the consensus target when pH control is difficult [84 85]. Allowing permissive hypercapnia will result in cerebral vasodilation and a rise in intracranial pressure and may compromise myocardial contractility. Attempts to raise pH to > 7.2 may however compound...
hyperinflation and barotrauma in obstructive AHRF. In ARDS, a peak airway pressure of 30 cm is the usual trigger for employing permissive hypercapnia. By avoiding VILI, a ventilator strategy limiting Vt reduces mortality in ARDS despite the consequent hypercapnic acidosis [99].

In AECOPD, attempts to rapidly restore pO2 and pCO2 to normal are unnecessary. Although there is little published evidence to provide guidance, it is suggested that the higher the pre-morbid pCO2 (which may be inferred by a high admission bicarbonate (eg HCO3 >30), the higher the target pCO2 should be. In asthma, recovery from extreme levels of hypercapnia is recognized [100]. Any metabolic causes of acidosis e.g. from insulin insensitivity or excessive B2 stimulated glycogenolysis should be treated separately.

In NM causes of AHRF, adequate Vt is often achieved with relatively low inflation pressures (eg 10-15) but higher pressures are needed in CWD & OHS because of reduced chest wall compliance. Lung recruitment strategies (i.e. increasing PEEP) should be considered when there is persisting hypoxia or evidence of dependent lung collapse. PCV may need to be continued when triggering is likely to be inadequate or tiring.

In all causes of AHRF and evidence of chronic hypercapnia at presentation, reducing the bicarbonate buffering capacity will require a period of relative hyperventilation.

Resulting urinary bicarbonate loss resets central respiratory drive. Carbonic anhydrase inhibitors can be used but caution is needed as high doses produce unpredictable effects through central stimulation of breathing [101 102]. See Figure 2 for a guide to initial settings and aims with IMV.
Evidence statements

1. In ARDS a low Vt strategy improves survival. (Level 1+)

2. In airflow obstruction, prolonging the expiratory time reduces dynamic hyperinflation (gas-trapping). (Level 2+)

Recommendations for IMV in obstructive disease

1. During controlled ventilation, dynamic hyperinflation should be minimized by prolonging expiratory time (I:E ratio 1:3 or greater) and setting a low frequency (10-15 bpm). (Grade C)

2. During assisted ventilation, a higher level of pressure support minimises dynamic hyperinflation by shortening inspiratory time. (Grade C)

3. Permissive hypercapnia (aiming for pH 7.2-7.25) may be required to avoid high airway pressures when airflow obstruction is severe. (Grade D)

4. Carbonic anhydrase inhibitors should not be used routinely in AHRF (Grade C)

2.13 Positive End Expiratory Pressure

Positive end expiratory pressure (PEEP) increases residual lung volume and has the potential to shift the lungs to a more compliant portion of the pressure-volume curve. In restrictive causes of AHRF, lung volume is often reduced and there may be dependent lung that is either poorly ventilated or in which there is no effective alveolar ventilation. In these circumstances, increasing the ePEEP may correct improve hypoxaemia and increase Vt for a given inspiratory pressure. In obstructive disease, PEEP improves expiratory airflow and, in doing so, reduces expiratory
resistance, limits DH and improves alveolar ventilation [103 104]. DH is indicated by the presence of intrinsic PEEP (iPEEP) [105], by a progressive fall in tidal volume with constant ventilator pressure settings (or, with volume control, an increase in inflation pressure) and by signs of patient distress such as tachycardia and hypotension. In restrictive causes of AHRF, PEEP

End-expiratory lung volume (EELV) and/or iPEEP can be estimated clinically or measured invasively [106 107]. Active expiratory muscle contraction, common in airflow obstruction, will artificially increase apparent iPEEP. Levels of iPEEP in obstructive airways disease have been reported to range from 4.6-13.6 cmH2O [108].

Setting the PEEP level in excess of iPEEP will increase EELV with the potential to be deleterious. This has led to the recommendation that PEEP be set at 50-80% of iPEEP [109 110]. However, as the severity of airway obstruction in the small airways will vary throughout the lung, a variable response to increasing the PEEP might be anticipated. If the balance of an increase in extrinsic PEEP (ePEEP) were to reduce overall airway resistance then EELV will fall even though ePEEP apparently exceeds iPEEP [111 112].

In support modes of ventilation, iPEEP must be overcome by patient effort before a breath can be triggered. It therefore acts as an inspiratory threshold load. A high iPEEP may lead to ineffective triggering and patient discomfort. Off setting iPEEP by increasing the ventilator PEEP setting will therefore reduce the effort of triggering and improve patient-ventilator asynchrony [113-115]. The same pathophysiological process occurs during treatment with NIV when an appropriate setting of EPAP improves triggering and patient comfort.

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft
63
Evidence Statement

1. In obstructive causes of AHRF, PEEP may increase tidal volume, improve compliance and reduce airflow obstruction. (Level 2+)

2. Setting PEEP greater than iPEEP can be harmful. (Level 2+)

3. In restrictive causes of AHRF, PEEP may assist in lung recruitment, improve compliance and correct hypoxaemia (Level 3)

Recommendation

1. Applied (extrinsic) PEEP should not exceed intrinsic PEEP. (Grade C)

2.14 Sedation in IMV

Patients receiving IMV require sedation, especially before stability is achieved [84]. Most ICUs use Propofol or a Benzodiazepine, either alone or in combination with an opioid. Benzodiazepines with inactive metabolites and/or short acting synthetic opioids have been recommended to avoid over-sedation [116 117]. Although sedation increases IMV tolerance, and may be useful for promoting restorative sleep, over-use is associated with adverse outcomes such as prolonged duration of IMV, increased ICU length of stay and delirium [118].

To avoid over-sedation, intermittent withholding of drug therapy until an objective degree of wakefulness develops has been recommended [119]. In two trials this has been shown to reduce duration of IMV and ICU length of stay [119 120]. Studies of sedation protocols targeting specific (higher) levels of alertness have also reported a reduction in duration of IMV, ICU and hospital LOS [121-124]. However a meta-analysis of RCTs on sedation breaks demonstrated safety but failed to confirm the
earlier reported benefits [125] and a more contemporary RCT, combining protocolised sedation with daily breaks, found no benefit [126]. No study has shown harm from sedation breaks but the effect of stopping or reducing sedation on patient experience has not been reported.

Evidence statements

1. Daily interruption of sedation is safe and may reduce the duration of IMV and ICU LOS. (Level 1+)

2. Sedation protocols, that target specific levels of alertness, reduce duration of IMV and ICU LOS. (Level 1+)

Recommendation

1. Sedation should be titrated to a specific level of alertness. (Grade B)

2.15 Patient-ventilator asynchrony

Patient-ventilator asynchrony is common and increases patient discomfort, the work of breathing, the need for sedation, confusion, the need for tracheostomy and mortality [127 128]. The commonest cause is ineffective triggering due to either respiratory muscle weakness and/or excessive effort required to overcome iPEEP and trigger a breath [129]. Trigger failure is more common during sleep and more likely if hypercapnia persists by day. A hybrid mode, such as PSV with an adequate
mandatory backup rate to avoid pCO2 increasing during sleep, is recommended in these circumstances.

Auto triggering refers to inappropriately delivered breaths being provided by the ventilator. It can be provoked by patient movement, suctioning, coughing and swallowing and is more likely when the trigger sensitivity is set to high. Both a delay in the onset of a triggered breath or an inadequate amount of pressure support to adequately augment inspiratory flow can lead to an unpleasant sensation best described as ‘air hunger’. This can be difficult to detect or for the patient to report. Experienced NIV practitioners may trial increasing trigger sensitivity and/or pressure support and monitor the effect on patient comfort and respiratory rate. If inadequate support was being given, breathing rate will fall. The detection of the more subtle forms of patient-ventilator asynchrony requires examination of the pressure/flow waveforms [130]. The most sensitive current measure of patient-ventilator asynchrony is by simultaneous recordings of diaphragm electrical activity and pressure changes in the oesophagus [129]. Flow rather than pressure triggers have reduced the incidence of asynchrony [131 132] as has the move away from volume controlled ventilation [133 134].

Proportional Assist Ventilation (PAV) and Neurally Adjusted Ventilatory Assist (NAVA) are modes that are being assessed as a way to reduce patient-ventilator asynchrony. With PAV, the degree of pressure support is determined breath by breath by the patients inspiratory effort [135-137]. Compared to PSV, PAV has been reported to reduce the probability of returning to a controlled mode and the incidence of patient-ventilator asynchrony [138]. In NAVA, the ventilator attempts to match neural drive by adjusting the degree of pressure support (within safe limits) using the
electrical activity of the diaphragm to 'drive' the ventilator. Studies comparing patient-ventilator interaction show a reduction in triggering delay with NAVA, reduced cycling delay and a reduction in asynchrony events [139 140]. Uncertainties persist on how to adjust the NAVA level and this technical issue is currently frustrating efforts to demonstrate clinical benefit.

It is important to emphasize that patient ventilator asynchrony is even more common with NIV. Whilst the same principles apply as with IMV, it has been less frequently recognised or investigated in acute NIV but also critically affects the success of NIV and the patient experience (see below).

Evidence Statements

1. Patient-ventilator asynchrony is common, deleterious and can be minimised through informed adjustment of ventilator settings. (Level 2+)

2. Proportional and Neurally Adjusted Ventilatory Assist have been shown experimentally to reduce ventilator asynchrony but have yet to improve patient outcome. (Level 2+)

Recommendations

1. Ventilator asynchrony should be considered in all agitated patients. (Grade C)

2. As patients recover from AHRF, ventilator requirements change and ventilator settings should be reviewed regularly. (Grade C)

2.16 The use and timing of a tracheostomy
It is accepted that translaryngeal intubation beyond 10 days can be detrimental [141 142]. Historically, it was believed that early tracheostomy reduced ventilator time and ICU length of stay [143] and a survey of ICU physicians in 2005 found that 61% of respondents would perform a tracheostomy without first performing a trial of extubation and 50% favoured tracheostomy insertion within the first week [144]. Two large multi-centre studies have failed to show benefit from tracheostomy performed within 7 days of admission [145 146]. A subsequent meta analysis of trials also reported no effect upon the incidence of VAP or mortality [147] although less sedation was required after a tracheostomy was inserted. Tracheostomy carries a morbidity and mortality risk at the time of insertion [148] and subsequently [149]. A UK national report has highlighted the risk of critical airway incidents in patients with tracheostomies [150]. Accordingly, consideration of the risk and benefit should be undertaken before proceeding to insert a tracheostomy and due consideration should be given to extubation onto NIV to avoid a tracheostomy. This is particularly the case in progressive NM/CWD when tracheostomy insertion carries the risk of permanence. These aspects, and the evidence summarised below, are considered further in section 3.

**Evidence statement**

1. Early insertion of a tracheostomy does not reduce mortality, duration of IMV or incidence of VAP. (Level 1++)

**Recommendations**
1. Routine tracheostomy within 7 days of initiating IMV is not recommended. (Grade A)

2. The need for and timing of a tracheostomy should be individualized. (Grade D)

Good practice points

1. In AHRF due to COPD, and in many individuals with NM disease or OHS, NIV-supported extubation should be employed in preference to inserting a tracheostomy.

2. In AHRF due to NM disease, the decision to perform tracheostomy should be multi-disciplinary and, ideally, involve home ventilation specialists.
3 : Management of acute hypercapnic respiratory failure

3.1 Obstructive lung diseases

Acute exacerbations of chronic obstructive pulmonary disease account for 100,000 admissions annually in England. Of these, around 20% will present with or develop hypercapnia [2 6], an indicator of increased risk of death [2 56]. The development of AHRF is often multifactorial. These include infection, mucosal oedema, bronchospasm, sputum retention, excessive O2 therapy, sedation, pneumothorax, pulmonary embolism and left ventricular failure. Since the publication of the BTS guideline in 2002 [1] and subsequent NICE recommendations [45], the use of NIV in AECOPD has increased and most hospitals admitting unselected medical patients are now able to provide a NIV service [57].

3.1.1 Prevention of AHRF in AECOPD

There is compelling evidence that uncontrolled oxygen therapy increases the degree of acidosis and subsequent mortality in AECOPD [2 151]. In a trial comparing the use of high flow oxygen with titrated oxygen in 405 individuals with presumed AECOPD in the pre-hospital (ambulance/paramedic) setting, Austin and co-workers [58] reported that titrated oxygen reduced mortality by 58% for all patients (relative risk 0.4) and by 78% for patients with confirmed COPD (RR 0.22). Patients with COPD who had received titrated oxygen according to the protocol (targetted at a saturation of 88-92%) were less likely to have respiratory acidosis (mean difference in pH 0.12) than those who received high flow oxygen. This data provides further evidence to recommend the routine use of titrated oxygen treatment in patients with breathlessness and a history or clinical likelihood of COPD in the pre-hospital...
setting. Importantly, the mechanism(s) of oxygen induced hypercapnia are the same in the other causes of AHRF and accordingly the same general advice is applicable to ALL causes of AHRF.

Evidence Statement

1. The use of controlled oxygen therapy in individuals with suspected AECOPD reduces mortality and the frequency and severity of AHRF. (Level 1++)

Recommendation

1. Controlled oxygen therapy should be used in AHRF due to AECOPD (Grade A)

Good practice point

1. Controlled oxygen therapy should be used in ALL causes of AHRF

3.1.2 Role of NIV in AECOPD

There are three clinical situations in which NIV is recommended in AECOPD [152]. Firstly, the patient with a modest respiratory acidosis with the aim of preventing deterioration to a point when IMV would conventionally be considered. Secondly, as an alternative to IMV when conventional criteria for IMV are met (lower pH, more distress) with the intention to proceed to IMV if NIV fails. Thirdly, as the ‘ceiling’ of treatment for patients who, for whatever valid reason, are not candidates for IMV. The evidence base for NIV has not always defined the particular patient case mix in this way.
There have been many trials of NIV in acidotic AECOPD, including 21 where NIV was compared to standard non-ventilatory treatment, one trial of NIV versus sham NIV and two trials of NIV versus IMV. Five of the studies were conducted in an ICU setting, one in the pre-hospital setting, two in emergency departments, two in High Dependency Units and the remainder in general wards. In general, patients in studies conducted in the ICU had lower pH and therefore more severe exacerbations [153].

In a meta-analysis of NIV use versus usual care, NIV was associated with a lower mortality (relative risk 0.41), a lower need for intubation (relative risk 0.42), lower likelihood of treatment failure (relative risk 0.51) greater improvements at one hour in pH (weighted mean difference 0.03), PaCO2 (weighted mean difference -0.40 kPa) and respiratory rate (weighted mean difference -3.08 breaths per minute). NIV also resulted in fewer treatment associated complications (relative risk 0.32) and a shorter duration of stay in hospital (weighted mean difference -3.24 days)[13].

In one trial, NIV was compared to IMV for AECOPD after a failure of standard medical treatment. There was no difference in survival. However, in those patients in whom NIV was successful, duration of hospital stay was shorter, there were fewer complications, fewer patients required de novo oxygen supplementation and there were fewer readmissions to hospital in the following year [153].

No trial has demonstrated a worse outcome with NIV compared to non-ventilatory management although, in one study, NIV use may have caused a delay in escalation to IMV [154]. The danger that the use of NIV in some patients may inadvertently lead to a worse outcome is suggested however by a large American retrospective study. Chandra and colleagues [155] reported on an estimated 7.5 million
admissions for AECOPD in the USA between 1998 and 2008. During this period there was a 460% increase in the use of NIV and a 42% decline in IMV use. Worryingly, given the increasing familiarity of staff with the using NIV over time, the number of patients failing NIV and requiring IMV increased over time and hospital mortality also increased. By 2008, NIV failures had a 29% risk of death, a 60% greater risk than patients managed by immediate intubation and provision of IMV. NIV failures, who were then managed by IMV, had a seven-fold greater risk of death than patients successfully treated by NIV. Possible explanations include that further physiological deterioration may have resulted from the delay in the institution of IMV in NIV failures and/or that patients who fail NIV are more severely ill [156].

The outcomes in AECOPD reported in the UK NCROP audit [6] are also of concern as NIV outcome was less favourable than reported in the RCTs discussed above. The low level of ICU involvement and/or use of IMV reported has led to the suggestions that the clinical environment in which NIV was delivered in the UK was inadequate for the level of patient complexity/acid-base disturbance, that there was an over-reliance on the effectiveness of NIV and an under recognition of NIV failure [6]. See section 5 for further consideration of the possible unintended consequences of the introduction of NIV in managing AHRF in AECOPD.

In around 20% of AHRF cases secondary to AECOPD, optimised medical therapy, that includes targeting an oxygen saturation to 88-92%, will result in normalisation of arterial pH [2 59]. Established guidance is therefore to await improvement and initiate NIV if, after 60 minutes, the following are present: pH < 7.35, pCO2 > 6.5 kPa and respiratory rate >23 breaths per minute [1 45].
There is some evidence that NIV may also be beneficial in patients with hypercapnia in the absence of acidosis. A study from China [157] showed a reduction in the need for endotracheal intubation in a sub-group analysis of patients with hypercapnia but a pH > 7.35 (9/80 v 2/71, p=0.04). However, length of stay and duration of NIV was longer than a similar UK study [158] and there was a high incidence of side effects, particularly gastric distension (23%) despite low inflation pressure being used (IPAP 12± 4). It is thus unclear if this study is applicable to UK practice.

There is insufficient evidence to support the use of absolute values of pH or pCO2 as an indication for IMV rather than NIV [159]. Nevertheless, a pH of 7.25 has been suggested as a threshold level below which IMV should be considered. NIV may still be effective at reversing such severe acidosis but the failure rate is higher [153].

Evidence statements

1. Optimal medical therapy, including controlled oxygen therapy, leads to a resolution of respiratory acidosis in 20% of individuals with AECOPD. (Level 1+)

2. Compared to standard medical therapy, NIV improves survival, reduces the need for endotracheal intubation, reduces complications and reduces length of stay. (Level 1+)

3. There is no lower limit of pH below which a trial of NIV has been shown to be harmful. (Level 2++)

4. Continued use of NIV when the patient is deteriorating, rather than escalating to IMV, increases mortality. (Level 2+)
5. Audit data show that “real world” outcomes do not reproduce those demonstrated in the RCTs. (Level 2+)

6. One risk of an expansion of ward-based rather than HDU/ICU provision of NIV may be greater delay in expert review and/or escalation to IMV. (Level 4)

**Recommendations**

1. For most patients with AECOPD, the initial management should be optimal medical therapy, targeting an oxygen saturation of 88 to 92%. (Grade A)

2. NIV should be started when pH < 7.35, pCO2 > 6.5 kPa and respiratory rate > 23 persist or develop despite optimal medical therapy. (Grade A)

3. Severe acidosis alone does not preclude a trial of NIV in an appropriate area with ready access to staff who can perform safe endotracheal intubation. (Grade B)

4. The use of NIV should not delay escalation to IMV when this is more appropriate. (Grade C)

5. The practice of NIV should be audited regularly to maintain standards (Grade C)

**3.1.3 Starting NIV in COPD**

Recommendations regarding investigations before starting NIV are based on expert opinion. Arterial blood gas measurement is required to diagnose and quantify the severity of AHRF and a chest radiograph to seek evidence of causation or complications. To avoid any delay in giving ventilatory support, NIV should be
initiated in extreme acidosis (e.g. pH<7.25) without waiting for a CXR. Other investigations (e.g. FBC, U+E, ECG) should be performed to identify and treat reversible causes of AHRF. In some cases echocardiography may be indicated to differentiate between acute pulmonary oedema causing respiratory acidosis and AECOPD. As is further discussed in Section 5, it is recommended that an action plan be agreed in the event of NIV failure and that this is documented at the start of treatment.

Good practice points

1. Arterial Blood Gas measurement is needed prior to and following initiation of NIV.

2. Chest radiography is recommended but should not delay initiation of NIV in severe acidosis.

3. Reversible causes for respiratory failure should be sought and treated appropriately.

4. At the start of treatment, an individual patient plan should document agreed measures to be taken in the event of NIV failure.

Figure 1 provides a summary for providing acute non invasive ventilation.

3.1.4 Prognostic features relating to use of NIV in COPD

The 2003 UK National COPD audit [160] demonstrated a higher hospital mortality in patients with a lower admission pH and oxygen saturation, higher urea, lower albumin and older age (see below for further discussion) irrespective of treatment modality. Increased base excess (indicating chronicity of hypercapnia), MRC
dyspnoea index and respiratory rate are additional prognostic variables [160 161]. The presence of pulmonary infiltrates on X-ray and impaired consciousness level [GCS<8] increase NIV failure rate [162] although successful outcome in the presence of impaired consciousness have been reported [46 163].

In contrast to the UK National COPD audit, Nava et al reported a good outcome for patients aged greater than 75 years in terms of intubation avoidance and reduced mortality with NIV [164]. Others have also achieved satisfactory results in the elderly [165]. However, in a retrospective analysis of 240 ward-based cases from a single centre, age >75 years was associated with poorer outcomes with NIV [166].

The UK NCROP audit, which collected data on 9,716 AECOPD admissions, reported mortality at 12% when the presentation pH was the lowest value reached, 24% when acidosis increased after presentation and 33% when acidosis only developed after admission [6]. These findings reflect a combination of increasing severity of illness and a lack of response to standard medical treatment. In addition, delay in providing therapeutic NIV and/or IMV contributed. The audit also highlighted that a coincident metabolic acidosis was an adverse finding.

Once NIV has been initiated, a reduction in respiratory rate and improvement in pH within 4 hours predicts NIV success [167]. Associated features are a reduction in signs of respiratory distress, reduced anxiety or agitation and a decrease in heart rate. In one large study, Confalonieri et al showed that if pH< 7.25 and respiratory rate > 35 persist, NIV failure is likely [168]. Worsening acidosis, after initial improvement with NIV, is also associated with a worse prognosis [169-171]. In a case series published by Moretti et al, 20% of patients deteriorated after initially
improving with NIV. In these circumstances prognosis was poor, whether patients were subsequently intubated or continued with NIV [172].

Roche Campo and co-workers [88] found that polysomnographic evidence of severe sleep disturbance in COPD patients with AHRF correlated with a poor outcome and Gursel [86], reporting on a retrospective analysis of COPD and OHS patients treated in an ICU setting, found better outcome in patients receiving pressure control rather than pressure support NIV overnight. Clinical research in stable sleep hypoventilation also suggests that limiting an increase in hypercapnia during sleep is important and that a controlled ventilation mode may be more advantageous than the assist mode [173].

Evidence statements

1. Advanced age is not an important determinant of outcome with NIV treatment of AHRF. (Level 1+)

2. An improvement in physiological parameters, particularly pH and respiratory rate, predict a successful outcome from NIV treatment. (Level 1+)

3. Worsening in physiological parameters, particularly pH and respiratory rate, is predictive of an increased risk of death and/or requirement for intubation. (Level 1+)

Recommendations

1. Advanced age alone should not preclude a trial of NIV. (Grade A)

2. Worsening physiological parameters, particularly pH and respiratory rate, indicate the need for clinical review and a change of management strategy.
This includes change of interface, adjustment of ventilator settings and proceeding to endotracheal intubation. (Grade A)

Good practice point

1. If sleep-disordered breathing pre-dates AHRF, or evidence of it complicates an episode, the use of a controlled mode of NIV overnight is recommended.

3.1.5 Duration of NIV in COPD

Normalisation of pH and a pCO2 < 6.5 are commonly used as a guide to the discontinuation of NIV therapy. Restoring respiratory drive will require a more prolonged period of NIV to reduce the pCO2 than to correct the acidosis.

The optimal amount of NIV in the initial period, and the most effective way to withdraw it as the patient’s condition improves, have not been examined in published trials. As the work of breathing falls and acute hyper-inflation reverses, as a result of treatment with steroids, antibiotics and intense bronchodilator therapy, unsupported alveolar ventilation will return towards normal. The more florid the evidence for infection precipitating AHRF, the more likely there is to be full reversal. Normalisation of pCO2 may not be possible in some patients, particularly in those who show evidence of chronic hypercapnia on admission.

In most RCTs, the intention has been that patients should receive semi-continuous NIV for the first 24 hours. The amount of NIV actually delivered, when this has been reported, has been less than planned from a median of 20 hours in one study [174] to 7 hours in another [158]. Conventional practice is to gradually reduce the amount of time on NIV, with increasingly prolonged periods of self ventilation during the day,
whilst continuing with NIV overnight. Monitoring of pCO2 on and off NIV is a useful guide to how quickly the withdrawal of NIV can proceed. Transcutaneous pCO2 measurement may facilitate this better than continued arterial or capillary sampling. A gradual reduction of ventilator pressures, and a switch to pressure support or a reduction in back up rate, should mirror patient recovery. Attempts to adjust ventilator settings to achieve patient comfort remain important. Those with a less clear infective cause for AHRF, and/or evidence of chronicity of hypercapnia, should be assessed for alternative or additional causative factors such as marked fluid retention, OSA or OHS. One study suggested there may be an advantage to employing NIV for longer than the conventional 3 days [157]. More trial data is needed to guide optimal withdrawal of NIV.

Evidence statement

1. In clinical trials, NIV has been discontinued when there has been normalisation of pH and pCO2 and a general improvement in the patient's condition. (Level 1+)

Recommendation

1. NIV can be discontinued when pH has normalised and the patients general condition has improved (Grade B)

Good practice points

2. The amount of time on NIV should be maximised in the first 24 hrs depending upon patient tolerance and/or complications.
3. NIV use during the day can be tapered in the following 2-3 days, depending on pCO2 self ventilating, before being discontinued overnight.

3.1.6 Optimising NIV delivery and troubleshooting

The commonest reasons for failure of NIV are excessive mask leak, insufficient pressure support and ventilator patient asynchrony. If the pressure support is inadequate, alveolar ventilation will not be significantly increased. This may be detected by a lack of augmentation of chest and abdominal wall movement. National NIV audits have revealed that inadequate IPAP is often used in AECOPD [3 4]. In general, while a patient might be started on NIV with an IPAP of 15, this should be progressively increased to reach a IPAP of 20-30 within 10-30 minutes of starting NIV, the higher pressure and more rapid escalation being indicated by patient size and more severe acidosis respectively (see Fig 1).

In the presence of persisting hypoxaemia, that is thought unrelated to sputum retention, the EPAP may need to be increased up to 8 cm in an attempt to recruit areas of poorly ventilated lung. (It may also be appropriate if there is a degree of upper airway obstruction). If ineffective, or this results in distress, senior review is indicated whilst the FiO2 is temporarily increased.

Leak should always be minimized by mask adjustment and/or by changing the mask type. Ventilator-patient asynchrony may be caused by mask leak, insufficient or excessive IPAP, inappropriate setting of Ti or Te, high levels of iPEEP or excessively sensitive triggers. If the cause is unclear, advice should be sought from an experienced NIV practitioner.
Although there is no published and agreed definition of NIV failure, it is suggested by either persisting or worsening of acidosis despite attempts to optimize NIV delivery. In these circumstances, advice from an experienced NIV practitioner should be sought 

*as soon as possible*. NIV failure is associated with low/falling pH [167] and a high APACHE II score [175]. Persisting with ineffective NIV adds to patient discomfort and, if IMV is indicated, risks further patient deterioration and cardio-respiratory arrest. Evidence that this risk is real comes from the use of NIV in post-extubation respiratory failure where delay in re-intubation, caused by persisting with NIV when not effective, increased mortality [176]. If NIV is adding to patient distress, and intubation has been agreed to be inappropriate (see below), NIV should be discontinued and palliative care measures adopted.

A guide for trouble shooting when NIV is failing is presented as Table 3.

*Good practice point*

1. Before considering NIV to have failed, always check that potential troubleshooting issues have been addressed and ventilator settings are optimal.
Table 3: Trouble shooting : A guide for when NIV is failing

<table>
<thead>
<tr>
<th>Problem</th>
<th>Cause(s)</th>
<th>Solution(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator cycling independently of patient effort</td>
<td>Inspiratory trigger is too sensitive</td>
<td>Adjust trigger</td>
</tr>
<tr>
<td></td>
<td>Excessive mask leak</td>
<td>Reduce mask leak</td>
</tr>
<tr>
<td>Ventilator is not triggering despite visible patient effort</td>
<td>Excessive mask leak</td>
<td>Reduce mask leak</td>
</tr>
<tr>
<td></td>
<td>Inspiratory trigger sensitivity is too high</td>
<td>Adjust trigger</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For NM patients consider switch to PCV</td>
</tr>
<tr>
<td>Inadequate chest expansion despite apparent triggering</td>
<td>Inadequate Tidal volume</td>
<td>Increase IPAP. In NM or chest wall disease consider longer Ti</td>
</tr>
<tr>
<td>Chest/abdominal paradox</td>
<td>Upper airway obstruction</td>
<td>Avoid neck flexion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase EPAP</td>
</tr>
<tr>
<td>Premature expiratory effort by patient</td>
<td>Excessive Ti or IPAP</td>
<td>Adjust as necessary</td>
</tr>
</tbody>
</table>
3.1.7 Indications for IMV in AECOPD

Intubation should be immediately considered for AECOPD patients presenting with or developing respiratory arrest, gasping respiration, a pH <7.15 or showing signs of a low cardiac output. Intubation may also be appropriate if NIV is contra-indicated, technically impossible or when NIV has been tried but has failed.

There is insufficient evidence to support the use of absolute values of pH or pCO2 as intubation criteria and it is unlikely that any absolute value of pH or pCO2 would be applicable to all patients in all situations [159]. Nevertheless, pH<7.25 has been suggested as a level below which IMV should be considered and <7.15 that IMV is indicated (following initial resuscitation and use of controlled oxygen).

In the UK, only a small proportion of patients receiving NIV treatment escalate to IMV despite data suggesting a higher proportion should do so [3 4 6]. A degree of unjustified ‘therapeutic nihilism’ is recognised to have shaped UK IMV practice. Duration of ICU stay and survival in AECOPD is better than most other medical causes for which invasive ventilation is employed [5]. In a prospective cohort study, clinician’s estimated prognosis for patients with AECOPD or chronic asthma was much lower than indicated by predictive modelling [177].

Specialist support to NIV delivery may reduce mortality. In one study employing critical care outreach nurses, the mortality was reduced from 57% to 35%. This was in part due to a greater number of patients receiving IMV [178]. Validated prognostic scoring tools (see next section) may aid discussion regarding intubation.

Table 4 summarises the indications of IMV in AECOPD.
Evidence statements

1. Intubation is indicated if NIV is failing (unless it is agreed that this is not desired by the patient or it is deemed not in the patient’s “best interest”). (Level 1+)

2. Neither patient characteristics nor patho-physiological parameters are sufficiently robust to predict the success of either NIV or IMV but, in general, the more adverse features that are present and the greater the physiological disturbance the higher the chance of treatment failure or death. (Level 2++)

Recommendations

1. Invasive mechanical ventilation should be considered if there is persistent or deteriorating acidosis despite optimal delivery of NIV. (Grade A)

2. Intubation should be performed in respiratory arrest or peri-arrest unless there is rapid recovery from manual ventilation/provision of NIV. (Grade D)

3. Intubation is indicated in management of AHRF when it is impossible to fit/use a non-invasive interface e.g. severe facial deformity, fixed upper airway obstruction, facial burns. (Grade D)

4. Intubation is indicated where risk/benefit analysis deems IMV more likely to produce a good outcome than NIV. (Grade D)
Table 4: Indications for IMV in AECOPD

- Imminent respiratory arrest
- Severe respiratory distress
- Failure or contra-indications to NIV
- Persisting pH < 7.15 or deterioration in pH despite NIV
- Depressed consciousness (GCS < 8)

3.1.8 Outcome following NIV or IMV in AECOPD

There are a number of tools which may inform discussion regarding prognosis in COPD. These include the BODE index [179] and DECAF score [180]. Although developed for the ICU setting and for IMV, APACHE II is also a predictor of mortality [175 181 182]. Confalonieri et al suggested that prognosis following successful use of NIV in AHRF was better than if IMV were employed [183]. The number and length of further hospitalizations were significantly higher and the survival rate at 12 months significantly lower (50% vs 71%) than in patients who received NIV. Follow up of patients in the RCT of Plant et al [167] showed a median survival of 16.8 months in those treated with NIV and 13.4 months in those receiving standard treatment (p=0.12). The trend in improved survival was attributable to prevention of death during the index admission.
An inception cohort of 73,106 COPD patients followed up after their first AHRF treated by NIV reported a 2 year survival of 70% and a median survival of 3.6 years [184]. After a second hospitalization, patients typically entered a deteriorating pattern with more frequent and severe episodes until death. A retrospective analysis of 100 COPD patients, followed for up to 5 years after their first episode of NIV [185], found that 52% survived 2 years. When the BMI was less than 22, age greater than 75 years or there was prior home oxygen use survival was only 26%. In a prospective cohort of COPD patients surviving AHRF treated by NIV [186] 80% were re-admitted within a year of whom 50% died. APACHE II score at admission, home oxygen prescription and a BMI below 25 predicted early recurrent AHRF or death.

In summary, an admission with AHRF is a critical point in the natural history of COPD and indicates a high risk of recurrence and poor long term prognosis. It should prompt a discussion about the patients wishes for management of future episodes and discussions about end of life care generally.

There is evidence of prognostic pessimism amongst clinicians caring for patients with AECOPD. In an outcome study of 517 patients, 62% survived to 180 days yet overall predicted survival at the time of admission was 49% [177]. For those considered to be in the worst prognostic group (a survival rate of 10%), 40% recovered. Accordingly, as survival from AECOPD becomes less likely, clinicians become less good at prediction and err on the side of under-estimating survival. By implication, it is likely that patients who might otherwise survive are currently being denied admission to ICU because their survival potential is under-estimated. Importantly, from a patient perspective, Wildman et al reported in a subsequent study that the majority of patients surviving IMV for AHRF had stable and acceptable
QoL despite poor health status and 96% stated they would opt for IMV again under similar circumstances [187].

Evidence Statement

1. There are validated tools for the assessment of prognosis in stable and exacerbating COPD populations but these are unreliable for individual prognostication (Level 2++)

2. Physicians underestimate survival potential in AECOPD treated by IMV. (Level 2+)

3. The majority of patients with COPD or chronic asthma who receive IMV would elect to receive it again (2+).

4. An episode requiring ventilatory support generally indicates advanced disease with a high risk for future episodes of AHRF and poor future prognosis (level 2++)

Recommendations

1. Prognostic tools may be helpful in discussion regarding prognosis and in making decisions regarding appropriateness of IMV but with the caveat that they are poorly predictive for individual patient use. (Grade B)

2. Clinicians should be aware of their own likely under-estimation of survival in AECOPD treated by IMV. (Grade B)
3. Clinicians should discuss management of possible future episodes of AHRF with patients following an episode requiring ventilatory support because there is a high risk of recurrence (Grade B).

3.1.9 Asthma

Five small RCTs [188-192] of NIV in asthma have been published. Four were conducted in the emergency department and one in a respiratory ICU. Importantly, none of the RCTs included patients with hypercapnia and intubation rates were low [193]. Most showed treatment with NIV led to a faster improvement in FEV1 and a shorter ICU/hospital stay. They all had important design weaknesses. The trial by Soma et al [191] lacked a second control arm (conventional inhaled bronchodilators) and the trial by Brandao et al [188] did not give systemic steroids. No information was provided about acceptability of NIV to patients. The only study reporting use in AHRF asthma was a retrospective cohort study by Meduri et al [194] of 17 patients with a mean pH of 7.25. NIV was reported to be successful in avoiding intubation in 15.

The use of NIV in asthma, and particularly AHRF, needs to be set in the context of a very low mortality with invasive mechanical ventilation [195]. There is also the potential for patients with acute asthma to deteriorate rapidly, to require high inflation pressures and a high inspired oxygen concentration. Using NIV therefore carries significant risk. A trial of NIV might be considered appropriate but only when intubation can be rapidly performed (i.e. provided within ICU or resus) and with continuous medical supervision. In all other circumstances when ventilatory support is indicated it should be by intubation and provision of IMV. The overall IMV management of severe asthma is similar to that in AECOPD but, whereas a target
saturation of 88-92% is recommended in the other obstructive cases, a higher target of 96% is advised in asthma. For more specialist consideration the reader is referred to standard textbooks or recent reviews.

Evidence statements

1. There is insufficient evidence to support the use of NIV in AHRF in asthma. (Level 3)

2. IMV in asthma carries a very low mortality. Most asthma deaths relate to presentation in extremis or a failure to immediately implement IMV when indicated rather than a failure of IMV per se. (Level 2+)

Recommendations

1. NIV should not be used in asthma exacerbations with AHRF. (Grade C)

2. NIV cannot be recommended as an alternative to IMV in patients with AHRF due to asthma. (Grade D)

3.1.10 Non-CF Bronchiectasis

Recurrent episodes of hypercapnic respiratory failure may characterise bronchiectasis with periods of good or acceptable quality of life/health status in the intervening months or years. In some, domiciliary ventilation will be indicated for symptoms of sleep disordered breathing. There are no RCTs of NIV v IMV in acute exacerbations of bronchiectasis. The recommendations regarding NIV for AECOPD are appropriate although there is the additional challenge of excessive and often difficult to clear sputum. Intermittent NIV may relieve breathlessness and help
patients to participate more effectively with physiotherapy. A mini-tracheostomy, or other techniques to aid sputum clearance, may be indicated [196].

There is little data on outcomes for AHRF in non-CF bronchiectasis. In a retrospective review [197] of patients managed by NIV (n = 31) or IMV (n = 26) for AHRF, the NIV group had less severe physiological disturbance. There was no difference in hospital mortality between the two groups (26% and 27%). The NIV failure rate (need for intubation or death in the ICU) was 33%. Using logistic regression, the APACHE II score was the only predictor of hospital mortality (OR 1.19 per point) and the severity of hypoxia (PaO2/FiO2 ratio) the only predictor of NIV failure (OR 1.02 per mmHg decrease). Accordingly, hospital mortality of patients with bronchiectasis and AHRF approximates 25% with management by NIV or IMV. When selectively applied, NIV fails in one-third of the patients and this is predicted by the degree of hypoxemia. Similar criteria should therefore be used as in AECOPD when deciding appropriateness of intubation: health status, co-morbidities, previous episodes of IMV and patient preferences. Evidence of an acute precipitating factor (infection) should favour intubation as reversibility is more likely than in progressive chronic hypercapnia.

_Evidence statements_

1. In patients with non-CF bronchiectasis and AHRF, NIV is indicated if there is a respiratory acidosis using the same criteria as in AECOPD. (Level 3)

2. Outcome with NIV is no worse than with IMV in selected patients (level 2+)

_Recommendations_

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft
1. In patients with non-CF bronchiectasis and AHRF, controlled oxygen therapy should be used (Grade B).

2. In patients with non-CF bronchiectasis, NIV should be started in AHRF using the same criteria as in AECOPD. (Grade B)

3. In patients with non-CF bronchiectasis, NIV should usually be tried before resorting to IMV particularly in those with less severe physiological disturbance (Grade C)

4. In patients with non-CF bronchiectasis, the patient’s clinical condition prior to the episode of AHRF, and the reason for the acute deterioration, should be evaluated and used to inform the decision about providing IMV (Grade C)

Good practice points

1. In patients with non-CF bronchiectasis and AHRF, the precipitating cause is important in determining short term prognosis.

2. Health status prior to the episode of AHRF is an important predictor of outcome

3.1.11 Cystic fibrosis

Recurrent episodes of acute on chronic hypercapnic respiratory failure characterise advanced CF, such episodes usually being precipitated by infection. There may be intervening months of acceptable quality of life/health status. There are no RCTs of NIV versus IMV in AHRF complicating but the recommendations regarding NIV for AECOPD remain appropriate. Hypoxaemia is often more severe than in AECOPD, in some relating to co-existent pulmonary hypertension. Secretion clearance is also a
major issue and may render NIV ineffective or poorly tolerated [198-201]. Case series of patients with cystic fibrosis receiving NIV as a bridge to transplantation have been reported [202 203].

As the outcome of invasive ventilation in CF is generally poor, it has been recommended that NIV be used preferentially [196]. In a retrospective multi-centre study of 60 ICU hospitalizations for 42 adult CF patients admitted between 2000 and 2003, NIV was used in 57% and was successful in 67% [204]. Endotracheal intubation was implemented on 19 occasions and ICU mortality was 14%. Among recognized markers of CF disease severity, only the annual FEV₁ loss significantly related to outcome (HR = 1.47, p = 0.001). Admission SAPS II, a pathophysiological score, weakly predicted outcome (HR = 1.08, p < 0.001) but the perceived need for endotracheal intubation strongly predicted mortality (HR = 16.60, p < 0.001). In a study from a single centre 30 patients were managed by IMV on 34 occasions [205]. Eleven patients died in the ICU and a further 7 before hospital discharge. 60% intubated for pneumothorax and/or haemoptysis survived contrasting with only 30% when intubated for infection. Mean survival post discharge was 447 days. There were no significant differences in survivors for colonizing organism, frequency of infective exacerbations or acute severity of illness. A greater fall in body mass index over the preceding 24 months was more frequent in non-survivors. The authors concluded that CF patients developing AHRF due to haemoptysis and/or pneumothorax should be considered for management by IMV.

Evidence statements
1. Chronic disease markers are more relevant than rates of hospitalization or FEV1 decline in assessing outcome in AHRF complicating CF. (2+)

2. When ventilatory support is needed, outcome following IMV is worse than with NIV, especially when infection is the precipitant. (2+)

3. Secretion clearance is a major issue and may render NIV ineffective or poorly tolerated. (2-)

**Recommendations**

1. In patients with CF, controlled oxygen therapy should be used in AHRF. (Grade B)

2. NIV is the treatment of choice when ventilatory support is needed. (grade C)

3. In patients with CF, specialist and experienced physiotherapy is needed to aid sputum clearance. (Grade D)

4. A mini-tracheostomy combined with NIV may offer greater chance of survival than resorting to IMV. (Grade D)

### 3.2 Restrictive lung disease

The causes of AHRF include severe chest wall deformity, neuromuscular conditions that affect the respiratory muscles and the obesity/hypoventilation syndrome. Presentation is often with advanced chronic hypercapnia. An insidious decline in the patients condition may not have been medically recognised as due to the development of respiratory failure. Acute presentations, often with infection precipitating acute illness, are likely when the VC is less than 1L. Recurrent episodes of acute ill health do not preclude a good quality of life, acceptable health
status and prolonged survival when supported by domiciliary ventilation. There are no RCTs to guide practice in AHRF and the recommendations presented are extrapolated from the AECOPD literature, from reports of the value of domiciliary NIV (most evidence coming from trials in the more progressive NM diseases) and expert opinion.

3.2.1 Neuromuscular disease (NMD) and chest wall deformity (CWD)

Respiratory impairment generally parallels disease progression in the NM conditions. In some, diaphragm involvement precedes locomotor disability and presentation with acute on chronic hypercapnia is typical. This is characteristic of acid maltase deficiency and the ALS variety of motor neurone disease. In some of the muscular dystrophies, bulbar muscle involvement is common. As a result, sleep disordered breathing may arise from a combination of respiratory muscle weakness and upper airway obstruction with the resulting nocturnal hypoventilation gradually spilling over into daytime hypercapnia. Bulbar dysfunction will also make voluntary cough less effective. NICE has published guidance on the use of NIV in motor neurone disease [206] but did not consider management of acute illness nor the value of intubation if NIV fails. Whilst respiratory failure is predictable in the majority, some MND patients present before a formal diagnosis has been made [207 208] and this is may also occur in less progressive conditions such as Limb girdle MD or Myotonic Dystrophy. The natural history of severe restrictive disease is of progressive chronic hypercapnia that eventually leads to death. Long term survival is, however, possible
with domiciliary NIV in a variety of chronic NM and CWD, even if presenting in severe respiratory failure. Accordingly, access to NIV or IMV should not be restricted. The success of domiciliary NIV has made the management of any associated cardiomyopathy more relevant.

In CWD, evidence of pre-existing sleep disordered breathing is also common at AHRF presentation. In some individuals, very marked chronic hypercapnia is an unexpected finding when ABGs are performed. Such patients may have established pulmonary hypertension (PHT), chronic hypoxaemia and polycythaemia.

In contrast to AECOPD, where the degree of acidosis is more important than the degree of hypercapnia, any elevation of pCO2 in NMD/CWD may herald an impending crisis [207]. Patients have a reduced respiratory reserve but may initially sustain sufficient alveolar ventilation to maintain a normal carbon dioxide tension. Minor infection, such as coryza, may be provocative and over the next 24-72 hours progressive hypercapnia develops which then risks sudden deterioration and respiratory arrest. Interestingly, tolerance of acute and chronic hypercapnia varies considerably. Some patients are excessively sleepy with minimal elevation of pCO2 whilst others remain alert despite much more severe hypercapnia. NIV should be considered in any breathless/acuteely unwell NM/CWD patient before a respiratory acidosis develops and is indicated with any elevation in pCO2.

In the absence of bulbar dysfunction, NIV is usually better tolerated in the restrictive causes of AHRF than the obstructive conditions. In the absence of significant skeletal deformity, only a low degree of pressure support (for example, a pressure difference of 8 to 12) is needed in NMD. In contrast, in severe kyphoscoliosis, an IPAP >20 and up to 30 may be required because of high impedance to inflation.
Expiratory flow is not normally limited in either restrictive category and the IE ratio for the backup rate (or more suitably PCV) should initially be set at 1:1 to allow an adequate time for inspiration. Bulbar dysfunction renders effective NIV more difficult to achieve, requires a higher EPAP to overcome upper airway obstruction and special attention to aid cough and the clearing of both upper and lower airways. Clinical experience of providing NIV is needed to best titrate the EPAP usually between 5 and 10cm. A modest increase in the normal ventilator settings is advised in the case of HMV users being admitted with AHRF.

Whilst triggering is usually normal in CWD, it is commonly inadequate in the other restrictive conditions. Many NMD patients find pressure-controlled ventilation more comfortable and it may more effectively control nocturnal hypoventilation.

Evidence statement

1. There are no trials comparing NIV v IMV in AHRF in NMD/CWD but there is evidence of the effectiveness of domiciliary NIV in treating chronic hypercapnia, improving long term survival and preserving a good or acceptable quality of life (Level 4)

Recommendations

1. In patients with NMD and CWD, controlled oxygen therapy should be used in AHRF (Grade D).

2. NIV should almost always be used in the acutely unwell NM/CWD patient with hypercapnia. Do Not Wait for acidosis to develop. (Grade D)
3. In patients with NMD and CWD, NIV should be considered in acute illness when VC known to be < 1L and RR > 20 even if normocapnic. (Grade D)

4. In patients with NMD and CWD, consider controlled ventilation as patient triggering may be ineffective (Grade D)

5. In patients with NMD and CWD, unless escalation to IMV has been agreed to be not desired or appropriate, intubation should not be delayed if NIV is failing (Grade D)

Good practice points

1. NIV is the mode of choice in most cases of AHRF because many patients with NMD or CWD tolerate it well and because extubation from IMV may be difficult.

2. In patients with NMD and CWD, deterioration may be rapid or sudden making HDU/ICU placement more appropriate

3. In patients with NMD and CWD, senior/experienced input is needed in care planning and is essential if differences in opinion exist or develop between medical staff and patient representatives.

4. In patients with NMD and CWD, it should be anticipated that bulbar dysfunction and communication difficulties will make NIV delivery difficult and may make it impossible.

5. Discussion about NIV and IMV and patient wishes with respect to cardio-pulmonary resuscitation should occur as part of routine care in NMD/CWD.
6. In patients with NMD and CWD, nocturnal NIV should usually be continued following an episode of AHRF pending discussion with a home ventilation service.

3.2.2 NIV failure and discontinuing NIV following recovery in NMD and CW

In NMD/CWD and AHRF, deterioration to the point of cardio-respiratory arrest may occur rapidly and with little warning. Decisions regarding resuscitation and intubation can be particularly challenging as little or no evidence exists for most of the causative conditions, communication with the patient may be difficult and/or cognition be impaired and there may be unreasonable expectation on the part of families and carers. A resuscitation plan is important but may be difficult to negotiate. Inability to clear secretions is a common cause of NIV failure. This may result from an excessive volume of secretions but commonly is because of impaired clearance due to a combination of limited inspiratory capacity, expiratory muscle weakness and bulbar dysfunction interfering with glottic control. Specialist advice and experience is required to manage NIV in the presence of bulbar dysfunction and also in providing effective cough assistance [209]. As with all patients, good communication is important. As this may be a challenge, it is another reason for seeking specialist help and advice. Enlisting the help of normal carers is commonly useful because they may engender more reassurance to patients and so be better at aiding sputum clearance.

Recovery from AHRF usually takes longer than in AECOPD so that stepping down from semi-continuous NIV should proceed more slowly and be continued overnight. The higher the presentation HCO3, the longer the period of relative hyperventilation will be required to reduce buffering capacity. A target of pCO2 around 6.5 kPa self
ventilating is generally recommended. Following recovery, the majority of individuals with NMD or CWD will require NIV at home. Ideally it should be continued overnight until discussion with or transfer to a Home Ventilation Service.

**Good practice points**

1. In NMD/CWD, intolerance of the mask and severe dyspnoea are less likely to cause NIV failure whilst bulbar dysfunction makes NIV failure more likely.

2. Deterioration in NMD/CWD may be very sudden. Difficulty achieved adequate oxygenation or rapid desaturation on disconnection for a break from NIV are important warning signs.

3. In patients with NMD/CWD, the presence of bulbar dysfunction, more profound hypoxaemia or rapid desaturation during NIV breaks suggest placement in HDU/ICU is indicated.

### 3.2.3 IMV in NM/CWD

Many clinicians have limited experience of managing NMD and CWD and there is the danger of under-estimating survival potential in the face of severe general disability. Patient choice, seeking the views of advocates when communication with the patient is difficult, is paramount and the views of a specialist centre on both the delivery of IMV and weaning are recommended.

The risk of sudden deterioration is greater due to reduced respiratory reserve, impaired cough, cardiomyopathy (possibly undiagnosed) and, in some, communication challenges. Intubation practice, elective or in AHRF, varies between centres and between countries. For instance, in motor neurone disease,
elective intubation is reported to occur in 0.8% (Ireland), 6% (USA) and 10.6% (Italy) of cases [208].

Outcome data following IMV is limited to case series in MND and OHS but these reports usefully illustrate shared issues in progressive NM disease and many patients with advanced CWD. An early report of outcome in MND following intubation for AHRF highlighted that 50% of patients were undiagnosed at the time of intubation, only 17% weaned and few left hospital [210]. More recently Sancho et al [211] reported a median survival of one-year in patients intubated after failing acute NIV [212]. Chio reported on 1260 motor neurone disease cases over an eight year period from a single Italian neurology centre; 134 patients received IMV, which was initiated as an emergency in 40% [208]. Median survival was 250 days. Death occurred in hospital in 20%, at home in 48% and in a nursing home in 32%. Neither patient experience nor economic analysis was reported.

The outcome of patients with MND referred to a specialist weaning service in the UK was examined by Chadwick and co-workers [212]. 30 patients had been transferred over a 15 year period. Diagnosis followed intubation in 17. In 14 patients, extubation to long-term NIV was possible of whom 9 were non-bulbar cases and 10 returned home. 13 remained tracheostomy ventilated, of whom 9 were bulbar and 7 returned home. Median survival from tracheal intubation was 13.7 months (95% CI 0 to 30.8) for those known to have MND and 7.2 months (95% CI 5.1 to 9.4) for those not previously diagnosed. There has been a call for the value of IMV in MND to be re-evaluated both as an elective policy and at the time of crisis [213]. In many of the other NM diseases, for example acid maltase deficiency and DMD, a more prolonged survival with a good quality of life is to be expected following recovery.
from AHRF and an aggressive approach to managing AHRF in NM & CWD is, in the opinion of the guideline group, more justified than historically has been the case in the UK. It is also what most patients and their families want. Expert experience is that the majority of patients will survive a period of IMV. Co-morbidity is important, especially associated cardiomyopathy. The weaning process may be prolonged but, in the absence of severe bulbar dysfunction, many can be safely extubated onto NIV and avoid a tracheostomy. Should this fail, and a tracheostomy be required, specialist centres report high success in subsequent decannulation using NIV. Whilst long term survival may be limited, QoL may be acceptable and health status may improve with the institution of domiciliary NIV. This is particularly the case in the more slowly progressive NM conditions and in stable CWD. In the latter group even advanced pulmonary hypertension may resolve.

**Evidence statements**

1. There are national (and centre) differences in use of IMV in AHRF complicating motor neurone disease. (Level 3)

2. The diagnosis of motor neurone disease and other NM conditions may only be made following intubation. (Level 3)

3. De-cannulation of a tracheostomy is more difficult when there is bulbar disease. (Level 3)

4. Planned elective domiciliary NIV is preferable to crisis management in NM and CWD as this reduces the risk of acute presentation and provides a proven alternative to IMV which risks prolonged or permanent tracheostomy ventilation (Level 3)
Recommendations

1. In patients with NMD and CWD, senior staff should be involved in decision making, in conjunction with HMV specialists where experience is limited, and especially when the appropriateness of IMV is questioned. (Grade D)

2. In patients with NMD and CWD, advance care planning, particularly around the wish for IMV, is recommended in progressive NMD & CWD which may best be supported by referral to a home ventilation service. (Grade D)

3.2.4 IMV Strategy in NMD and CWD

In NM patients the impedance to inflation is often low and it is rarely necessary to increase IPAP above 20. IPAP should be initially set at 10 and increased according to the resulting tidal volume. In contrast, patients with kyphoscoliosis often require high inflation pressures. Expiratory airflow is generally not limited but impedance is typically high so that an I:E ratio of 1 to 1 is recommended.

When lung volume is reduced, there is radiological evidence of lobar collapse or unexplained hypoxia the ePEEP may need to be increased up to 10 [11 12]. Adjustments should be individualised according to ventilatory parameters (respiratory rate, dynamic compliance, plateau pressure) and patient comfort.

Good practice points

1. Patients with NMD usually require low levels of PS.

2. Patients with CWD usually require higher levels of PS.
3. PEEP in the range 5-10 is commonly required to increase RV and reduce oxygen dependency.

3.2.5 Obesity hypoventilation syndrome (OHS)

In obese patients, hospitalised for any reason, the presence of hypercapnia increases morbidity and mortality [214]. Despite this there is currently a lack of specific evidence to guide treatment of either chronic hypercapnia or AHRF when it complicates obesity. One non-randomised trial showed long term survival was better in those who accepted treatment for sleep disordered breathing (SDB) compared with those who did not [215]. Severe obstructive sleep apnoea is the principal cause of hypercapnia but hypoventilation also results from the mechanical effect of obesity [216].

Presentation with acute on chronic failure is more common than de novo AHRF, but the precipitant cause for destabilization may be unclear. Not uncommonly, chronic hypercapnia is unexpectedly revealed peri-operatively following routine or emergency surgery in an obese patient not known to have OHS. The possibility of OSA/OHS in the morbidly obese (BMI> 35) needs to be borne in mind by surgical and anaesthetic teams.

In the absence of evidence, we recommend that the indications for NIV in the breathless obese patient should be the same as in AECOPD ie pCO2 > 6.5 and pH < 7.35. Additionally NIV should be considered in any patient admitted to hospital with a raised pCO2 who is excessively somnolent or when there is marked fluid retention. Following recovery patients will need to be referred to a HMV centre. OHS patients treated with NIV for AHRF can sometimes be switched to CPAP at a later date.
Evidence statements

1. NIV is indicated if there is a respiratory acidosis using the same criteria as in
   AECOPD. (Level 1-)

2. In the absence of acidosis, NIV may be indicated in some hypercapnic and/or
   somnolent obese patients. (Level 2+)

Recommendations

1. Controlled oxygen therapy should be used in the morbidly obese OHS patient
   with AHF (Grade D)

2. NIV should be started in AHF using the same criteria as in AECOPD. (Grade B)

3. NIV should be considered in some hospitalised obese hypercapnic patients
   with daytime somnolence, sleep disordered breathing and/or right heart
   failure in the absence of acidosis. (Grade D)

3.2.6 NIV settings and placement in OHS

Obese patients with severe AHF have a significant risk of sudden deterioration
despite NIV and are likely to be difficult to intubate (see below). Upper airway
obstruction is common and will be more apparent during sleep. It may persist despite
increasing the EPAP > 5 as indicated by intermittent abdomino-thoracic paradox
during NIV “assisted” breaths. Another indication of this is intermittent mask leak
that accompanies obstructed inspiration. A more upright position may help but an
EPAP in the 10-15 range is often required. Expert assessment is recommended to
best titrate the EPAP. The degree of tidal volume augmentation may be
compromised by high level EPAP. Occasionally different EPAP settings may be appropriate depending on sleep/awake state. In some, the impedance to inflation is very high and an IPAP of >30 may be required. Prolonging Ti will increase the resulting VT delivered so that a I:E ratio of 1:1 is advised. If the resulting VT is still inadequate, consideration should be given to using volume controlled ventilation or a volume assured mode [87] although the benefits of both are currently unproven.

Good practice points

1. High EPAP and IPAP settings are commonly required in OHS (e.g. IPAP >30, IPAP >8).

2. Volume control (or volume assured) modes of providing NIV may be more effective when high inflation pressures are required.

3.2.7 NIV failure in OHS

The same indications that apply to AECOPD suggest the patient who is failing with NIV and the same troubleshooting solutions apply (see Table 3). Fluid retention is common in AHRF due to OHS. The extent of fluid retention can be underestimated and be in excess of 20L. High inspiratory pressures are often required to achieve adequate augmentation of VT [217]. Achieving a SaO2 88-92% may be difficult relating to collapse of dependent lung and/or reflecting underlying pulmonary vascular disease. Sudden and precipitous falls in oxygenation may follow temporary removal of NIV. If high EPAP settings fail to improve the A-a gradient, a ventilator offering oxygen blending may be required. A difficulty in clearing secretions because of markedly restricted lung volumes may contribute to poor gas exchange.

Good practice points
1. Fluid overload commonly contributes to ventilatory failure in patients with OHS and its degree is easily underestimated.

2. Forced diuresis may be useful.

3. As the risk of NIV failure is greater, and intubation may be more difficult, placement in HDU/ICU for NIV is encouraged.

### 3.2.8 Discontinuing NIV in OHS

During wakefulness weaning should proceed as in AECOPD. NIV overnight should be continued pending discussion with the local Home Ventilation Service. Other aspects, such as consideration of bariatric surgery and optimal EPAP settings when returning home, are important.

*Good practice points*

1. NIV can be discontinued as in patients with COPD

2. Many patients with AHRF secondary to OHS will require long-term domiciliary support (CPAP or NIV).

3. Following an episode of AHRF referral to a home ventilation service is recommended.

### 3.2.9 IMV Strategy in OHS

Intubation can be challenging and patient deterioration may be rapid. There is also a higher risk of aspiration. Pressure control is recommended until stability has been achieved and should be initially set at 20 and increased according to the resulting tidal volume. Inspiratory pressure in excess of 30 may be required. To recruit
collapsed lung, PEEP may need to be 10-15 cm [11 12]. It should be adjusted according to ventilatory parameters (respiratory rate, dynamic compliance, plateau pressure) and patient comfort. Relative hyperventilation will often be required to reset acid-base balance and a forced diuresis may also be needed.

5 Good practice points

1. In patients with OHS, pressure controlled MV is recommended initially.

2. In patients with OHS, high PEEP settings may be needed to recruit collapsed lung units and correct hypoxaemia.

3. In patients with OHS, a forced diuresis is often indicated.
Section 4: Weaning from invasive mechanical ventilation

4.1 Introduction

Weaning is defined as the progressive reduction of ventilatory support leading up to extubation. Delayed weaning complicates 6% of patients managed by IMV but consumes 37% of ICU resources [218]. In one study, up to 50% of patients who self-extubated did not require re-intubation [219] implying that many patients are treated with IMV for longer than necessary. Clinical criteria to be met before starting weaning are detailed below [220 221]:

- adequate oxygenation (PaO$_2$ / FiO$_2$ ratio > 27kPa ( 200mmHg)
- FiO$_2$ < 0.5
- PEEP < 10 cmH2O
- adequate alveolar ventilation (pH > 7.3, pCO$_2$ < 6.5kPa)

Fluid balance should also be optimised. The detrimental effect of excess hydration is now recognised in sepsis [222] and in acute lung [223] and kidney injury [224]. A positive fluid balance adversely affects alveolar ventilation, oxygenation, weaning progress and extubation outcome [219 225]. Brain natriuretic peptide (BNP) has been reported to predict failure to wean and correlates with weaning duration; a BNP-directed fluid management strategy has been reported to shorten time to extubation, particularly in patients with left ventricular dysfunction [226].

Evidence statements

1. Easily measured clinical parameters indicate when weaning can commence.
   (Level 2+)
2. Excess fluid administration may delay starting weaning or contribute to its failure. (Level 2++)

3. In left ventricular dysfunction, a BNP-directed fluid management strategy has been shown to shorten the duration of invasive mechanical ventilation. (Level 2)

Recommendations

1. Treating the precipitant cause of AHRF, normalising pH, correcting chronic hypercapnia and addressing fluid overload should all occur before starting weaning. (Grade D)

2. A BNP-directed fluid management strategy should be considered in patients with known left ventricular dysfunction. (Grade B)

4.2 Weaning methods

Despite several multi-national studies there is no consensus as to the optimal weaning method. Brochard and colleagues [227] reported that weaning by reducing PS was better than other weaning protocols. Subsequent trials have reported that daily (or multiple) T piece trials (TPT) are as effective as PS weaning [228 229]. It is likely that patient specific characteristics are more important than the weaning protocol in determining how long weaning will take. There is agreement that the Synchronised Intermittent Mandatory Ventilation (SIMV) method is inferior to PS or T piece weaning. It is also accepted that a formalised weaning plan, and staff familiarity with the approach adopted on the ICU, are important factors to improve successful weaning [230].
Evidence statement

1. Progressive reduction of pressure support and daily spontaneous breathing trials are satisfactory methods of weaning. (Level 1+)

Recommendations

1. Assessment of patient’s readiness for weaning should be undertaken daily. (Grade B)

2. A switch from controlled to assisted IMV should be made as soon as patient recovery allows. (Grade B)

3. IMV patients should have a documented weaning plan. (Grade B)

4.3 Assessing readiness for discontinuation of mechanical ventilation.

Spontaneous breathing trials (SBT) are used to assess readiness to resume normal breathing. During the SBT a patient breathes with minimal or no pressure support (defined as <8). A successful trial requires the absence of respiratory distress. Failure of an SBT may be defined by subjective (comfort) or objective criteria (deterioration in gas exchange or measured ventilator parameters) [227 228]. Studies have shown that the majority of SBT failures occur within 30 minutes [231 232]. Repeated failure of SBT should lead to consideration of other methods of weaning [233 234].

It is important to note that the criteria that define success of an SBT do not necessarily reflect the likelihood of successful extubation and 10% of patients who successfully manage an SBT will fail to maintain adequate gas exchange and/or...
develop signs of distress [235]. A SBT assesses the balance of respiratory load to capacity of the respiratory muscles but does not take into account other factors that affect success of extubation such as upper airway patency, bulbar function, sputum load or strength of cough [235].

Evidence statement

1. A spontaneous breathing trial is useful in assessing load/capacity but does not predict the success of extubation. (Level 1+)

Recommendation

1. A 30 minute SBT should be used to confirm adequate respiratory muscle strength prior to extubation. (Grade B)

2. Factors including upper airway patency, bulbar function, sputum load and cough strength should be considered prior to attempted extubation. (Grade D)

4.4 Outcome following extubation

Successful extubation is defined as the absence of the need for ventilatory support for 48 hours. Patients receiving post-extubation NIV (see below) are classified as ‘weaning in progress’ [236].

Much of the evidence regarding the prediction of an increased risk of post-extubation failure have come from trials of relatively short duration IMV and with a mixture of underlying pathologies [230 237 238]. Several risk factors have been identified. The more adverse factors present, the greater the risk of extubation failure. Risk factors for extubation failure are shown in Table 5 [230 237 238].
Table 5 Risk Factors for Extubation Failure following IMV

- Positive fluid balance
- Raised rapid shallow breathing index (RSBI) during SBT
- Pneumonia or pulmonary disease as the cause requiring IMV
- Increased age
- Prolonged duration of IMV
- Anaemia
- Increased severity of illness
- Low albumin
- Previous failed extubation
- Bulbar dysfunction

Respiratory distress may occur early or develop later on after extubation. Early failure commonly results from loss of airway patency eg from upper airway oedema that becomes evident following removal of the ETT [239]. Patients with neuromuscular disease are at risk of early extubation failure due to bulbar dysfunction and/or ineffective cough despite a successful SBT. The planned use of NIV and a mechanical insufflator-exsufflator (e.g. Cough Assist) following extubation reduces the risk of early failure. Late extubation failure is more complex in aetiology and more than one cause may be present. The causes are summarised below [239]:

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft
• Capacity – load imbalance: patients with severe airflow obstruction or neuromuscular weakness

• Impaired bulbar function: aspiration of upper airway secretions, impaired gas exchange and/or obstructed breathing

• Ineffective cough: typically in NM/CWD but also other patients with AHRF

• Non respiratory issues - myocardial ischaemia/ left ventricular dysfunction, encephalopathy/delirium or severe abdominal distension

Evidence statement

1. Patient, clinical and ventilatory factors aid the identification of patients at increased risk of extubation failure. (Level 2+)

Recommendation

1. Care is needed to identify factors that increase the risk of extubation failure so that additional support, such as NIV or cough assist, can be provided to reduce this risk. (Grade B)

4.5 Weaning Protocols

Weaning protocols that specify the steps to follow during weaning have been claimed to reduce the duration of IMV, increase the success of extubation, reduce unplanned or accidental extubation and reduce the tracheostomy rate, ventilator associated complications and costs compared to usual care [240]. The studies involved were, however, not specific to AHRF. Most were performed in the USA, where differences in supervision of patient management exist compared with the UK.

There is also marked variation in the weaning methods and protocols between the
studies reported. The one European weaning protocol study that has reported did not find a reduction in ventilation time [241]. Computer-automated weaning, in which adjustment in pressure settings occur in response to changes in patient parameters, has been compared to professional-led weaning. One multi-centre RCT found that duration of weaning was reduced [242]. A second study reported no difference in weaning duration between automated weaning and weaning by an experienced nurse [243]. There is currently insufficient evidence to support the use of automated weaning over clinical/nurse-led protocols.

Evidence statements

1. Weaning protocols may reduce the duration of IMV and ventilator associated pneumonia. (Level 1+)

2. There is conflicting evidence regarding the value of computer-automated weaning. (Level 1-)

Recommendations

1. Although an organised and systematic approach to weaning is desirable, protocols should be used with caution in patients with AHRF. (Grade B)

2. The use of computerised weaning cannot be recommended in AHRF. (Grade C)

4.6 The use of NIV in the ICU

4.6.1 Planned NIV to speed weaning from IMV
In an uncontrolled study in lung transplantation, NIV was found to speed extubation and reduce the time spent invasively ventilated and the attendant complications [244]. Subsequent studies have compared the use of NIV to conventional weaning in patients who have failed a SBT. Benefit was demonstrated in patients with underlying COPD [47 245]. These studies utilised NIV at high levels of pressure support and used for longer than 24 hrs. NIV weaning was reported to confer no benefit in a subsequent study [246], however a subsequent Cochrane review concluded that NIV for weaning patients with COPD from IMV reduced mortality and the incidence of pneumonia without unacceptably increasing the need for reintubation [247].

Evidence statements

1. NIV has been shown to accelerate weaning from IMV in the COPD patient failing a SBT. (Level 1+)

Recommendation

1. NIV is recommended to aid weaning from IMV in patients with AHRF secondary to COPD. (Grade B)

2. In other causes of AHRF, NIV may have a role in shortening the duration of IMV when local expertise in its use exists (and of cough assist when indicated) and other features indicate extubation is likely to be successful. (Grade D)

4.6.2 NIV in high risk patients
NIV has been assessed in patients who have passed a SBT but who have risk factors for extubation failure such as age > 65 years, poor cough, cardiac and respiratory co-morbidity and hypercapnia (whilst ventilated and/or pre-existing). NIV use was reported to reduced the re-intubation rate and mortality in one study [248] and has also been reported to be effective where obesity (BMI >35) is an additional adverse feature [249].

Evidence statements

1. NIV may be effective in reducing respiratory failure, re-intubation and mortality in COPD (Level 1+) and patients with increased BMI (Level 2+)

2. Planned post extubation NIV reduces mortality, ICU and hospital LOS and the incidence of VAP. (Level 1-)

Recommendation

1. “Prophylactic” use of NIV should be considered to provide post extubation support in patients with identified risk factors for extubation failure. (Grade B)

4.6.3 NIV as ‘rescue’ therapy post extubation

A number of RCTs have examined the use of NIV as an unplanned “rescue” treatment for post-extubation respiratory distress. One multi-centre RCT reported that patients who passed a SBT but who then developed post-extubation respiratory failure had an increased ICU mortality if treated with NIV as opposed to re-intubation [176]. This study has been criticised as few patients were treated in the participating centres despite a long recruitment period raising the suspicion that lack of familiarity
with NIV may have resulted in it being poorly applied. The patients who failed NIV and went on to require intubation had received long periods of ineffective NIV before re-intubation, 9 hours longer than the control group, which may also have contributed to the worse outcome. *Post hoc* analysis suggested a benefit from being treated with NIV post extubation in patients with COPD.

**Evidence statement**

1. The use of NIV as rescue therapy for unexpected post-extubation respiratory failure does not improve outcome and may be detrimental. (Level 1+)

**Recommendations**

1. NIV should not be used for unexpected post-extubation respiratory failure. (Grade B)

2. In COPD, a trial of NIV may be justified where local expertise exists. (Grade D)
5: Care planning and delivery of care

5.1 Appropriate care environments for the delivery of NIV

A study by Roessler and colleagues from Germany randomised 51 patients to either out-of-hospital (OOH-NIV) or standard medical treatment. OOH-NIV was reported to be feasible, safe and effective [250]. A survey of French mobile intensive care units also suggests that NIV and CPAP can be safely employed pre-hospital in acute cardiogenic pulmonary oedema but not other causes of respiratory failure [251]. Further evaluation of out-of-hospital NIV in AHRF is required.

NIV is commonly initiated in the emergency department (ED). A prospective observational study of 245 patients attending 24 hospital EDs in Australia identified the staff responsible for NIV set up [252]. This was equally distributed between nursing and medical personnel. Hess and colleagues conducted a survey of 132 academic EDs in the US and concluded that, although NIV was widely available, physician confidence/competence was a barrier to optimal application [253]. A survey of NIV use in UK EDs found a wide variety of practice and suggested the need for a specific ED guide for NIV [254]. A pro–forma based COPD management tool, supported by targeted education, was reported to improve ED care including the use of NIV [255].

Previous guidelines have recommended limiting the number of areas providing NIV to ensure that staff perform it sufficiently regularly [45]. Suitable sites need to be able to provide a NIV service 24/7. If NIV is provided in more than one area within a hospital, protocols and guidelines should be shared [256]. The essential requirements for a NIV service are summarised in Table 6.
Table 6: Essential requirements for an NIV service

- Specifically identified area for NIV treatment
- Staffing levels above minimum for a general medical ward
- Locally developed NIV protocols [based on published best practice guides] uniformly applied across all areas
- A designated lead with a ‘core’ multidisciplinary group [physicians, nurses, physiotherapists and intensivists] co-ordinating hospital wide NIV service provision and performance
- Access to expert support for NIV technical advice both in and out of hours
- Mechanism for regular audit
- Regular staff educational updates and training module for new staff

For all but the mildest cases, Nava and Hill recommend that NIV is delivered in a level 2 facility with enhanced staffing levels [257]. A survey carried out in 1999 found that NIV was provided in level 2/3 facilities in most western European countries [258]. In contrast, NIV has traditionally been delivered in admission or respiratory ward settings in the UK. This may partially account for only a small proportion of UK patients failing NIV treatment being escalated to IMV [6].

A number of strategies have been explored to support the effective use of NIV outside the HDU/ICU. Sala et al [259] described the practicalities of creating a respiratory intermediate care unit (RICU). Paus-Jenssen, in a Canadian prospective study [260], used an expert respiratory therapist team to implement NIV across a number of clinical environments. In a similar study, critical care outreach nurses supported NIV delivery elsewhere in the hospital and, as a result, mortality was reduced from 57% to 35% [178]. A greater number of patients were also identified as suitable for IMV when failing NIV. Cabrini reported an Italian prospective study of
NIV administered in a non-ICU setting but managed by an anaesthetist-led medical team [261]. In 129 consecutive treatments, 10% required intubation and there was a low mortality rate of 12.4%. These reports together suggest that collaboration between admitting teams and the ICU can improve the delivery of care in AHRF.

Hospitalisation with AHRF involves 3 phases — immediate clinical assessment, an assisted ventilation plan when indicated and the formulation of a future care plan (short term in the event of NIV failure and longer term on recovery & discharge or, depending on outcome, the provision of end of life care). Figure 3 details key elements of an AHRF service and Table 7 provides a discharge checklist.
Table 7: Discharge checklist after episode of AHRF

- Ensure plans are developed to highlight and support ‘lifestyle’ choices – nutrition, smoking cessation, vaccination policy, disability/mobility issues
- Ensure discussion of wishes regarding future care in event of AHRF
- Ensure pre-discharge discussion of home NIV for CWD, OHS, and NMD patients and referral to home ventilation team
- Ensure COPD patient referral to pulmonary rehabilitation, ideally prior to discharge
- Ensure follow up to appraise clinical progress and need for additional measures [oxygen, home NIV], review pharmacotherapy and reinforce lifestyle/rehabilitation aspects
- Consider early home visit eg outreach COPD team/community nurses
- Ensure timely communication with community health care team

It has been estimated that an average sized District General Hospital, serving a population of 250,000, should anticipate, depending on local COPD prevalence, up to 100 AECOPD cases requiring ventilatory support per annum. Given the additional causes of AHRF, this probably equates to 150 NIV/IMV cases in most hospitals, and considerably more in areas with high COPD and/or OHS prevalence or those hospitals serving larger populations. NIV facilities should be able to cope with seasonal variation and the increased demand that may occur during influenza epidemics [262].

As discussed in section 3, patient outcome reported in UK national audits are notably worse than would be expected from trial data and facilities for provision of NIV, and evidence of consultation with the ICU, are frequently limited or inadequate [3, 4, 6].
Important deficiencies that have been identified include delays in commencing ventilatory support, under recognition of more complex acid-base disturbances, use of inadequate ventilatory pressures, rare use of a different mask when NIV is failing and lack of progression from NIV to IMV and lack of consultation in decision making. The preponderance for application of NIV in lower level facilities than elsewhere in the world (outlined above) along with evidence of a lack of integration with the ICU [3 4] indicates that attention directed at organisational factors are needed and are highly likely to improve patient outcome and experience in AHRF.

NIV facilities need to encompass adequate capacity and the expertise, and associated staffing levels, to deal with complex critically ill patients who have a significant risk of death. To be effective, the NIV service needs to have good operational links to ICU in the expectation that 10 and 20% of NIV treated patients should be managed in HDU/ICU and that many will be potential candidates for IMV. The case for a specifically identified and appropriately staffed and equipped area for providing NIV is strongly supported by the evidence. In some European countries, NIV services are provided in a Respiratory Intermediate Care Unit [258].

Evidence statements

1. A care environment with either level 2 or 3 staffing favours a successful outcome from NIV therapy (Level 2+).

2. Coordination between the ICU and ward areas improves outcome in AHRF (Level 3)

3. Organizational aspects are pivotal in achieving best outcomes. (Level 4)
Recommendations

1. NIV services should operate under a single clinical lead with formal working links with the ICU. (Grade D)

2. Consideration of the severity of AHRF and evidence of other organ dysfunction should influence the choice of care environment [Grade C]

3. NIV should be provided with enhanced nursing and monitoring facilities beyond that of a general medical ward (Grade C)

4. Initial care decisions should include robust arrangements for escalation, anticipating that up to 20% of AHRF cases should be managed in a level 2 or 3 environment. (Grade C)

Good Practice Points

1. A 2-4 bedded designated NIV unit covered by respiratory medicine (located within a medical high dependency area or within a respiratory ward with enhanced staffing levels) provides a robust basis for the provision of NIV in a DGH serving a population of 250,000 and with an average prevalence of COPD.

2. Areas providing NIV should have a process for audit and inter-disciplinary communication.

5.2 Palliative Care and Advanced Care Planning
It is recognised that palliative interventions may be appropriate and yet be provided at the same time as other therapies intended to prolong life [263]. Accordingly, employing NIV as part of care that aims to relieve distress and has escalation limits may be entirely justified.

Effort is needed to establish patient preferences with respect to intubation or resuscitation status. Momen and co-workers, in a systematic review of end of life conversations in COPD, found considerable variation among patients in the desire to discuss end-of-life [264]. Almost 50% of patients did not wish such a conversation and there was a preference to wait until disease was 'advanced', with patient perception that this implied the last few days of life. Advance directives/ living wills assist healthcare providers in tailoring clinical response and support [265]. Chakrabarti reported interviews with 50 stable COPD patients and found that discussion, with demonstration of NIV equipment, altered future treatment perceptions and willingness to consider an advance directive [266].

Sinuff and co-workers reported clinician attitudes to NIV in patients with acute respiratory failure and do not intubate/do not resuscitate instructions [267]. While about 60% of physicians considered that NIV should be discussed in this context, 85% of respiratory therapists (those actually administering NIV) felt NIV should be actively promoted. This may reflect a lack of confidence and understanding amongst physicians of the potential for NIV to relieve distress and be effective even in advanced disease. In Denmark, 15% of patients with do not intubate instructions who received NIV survived at least a year, with COPD and CHF the most favourable underlying diagnoses [268].

Evidence statements
BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft
1. In advanced disease, care planning should ideally predate acute presentation or commence as early as possible on presentation with AHRF. (Level 4)

2. Clinicians have a more negative view of both NIV benefits and patient perception of treatment wishes than health professionals experienced in NIV delivery. (Level 4)

Recommendations

1. Clinicians delivering NIV or IMV should have ready access to palliative medicine. (Grade D)

2. Multidisciplinary advance care planning should be an integral part of the routine outpatient management of progressive or advanced disease, and care planning should be reviewed on presentation during an episode of AHRF (Grade D).

3. The use of NIV may allow time to establish patient preference with regard to escalation to IMV. (Grade D)

5.3 End of Life Care

A questionnaire study of 118 COPD patients, carried out in Canadian teaching hospitals [269], reported that patients were less interested in prognosis, CPR, IMV or referral to palliative care than were patients with metastatic cancer. In another study, comparing QOL between advanced COPD patients and cancer patients, COPD patients reported higher levels of physical discomfort with uncontrolled shortness of breath in 78% [270]. A recent review of the 4 RCTs that have explored whether NIV relieves dyspnoea in AECOPD concluded that benefit was likely but that study
limitations constrained a confident conclusion [271]. With regard to physical symptoms, breathlessness and fatigue are dominant in AECOPD whilst attention to secretion clearance is an additional major concern in bronchiectasis and CF and for many with NM disease. Ability to communicate, to feel safe, to be individually respected and enabled to retain control are common psychological needs.

Patients receiving NIV as “ceiling care” who fail to improve will need appropriate end-of-life attention, including, when indicated, appropriate sedation/relief of distress including dyspnoea. It is important that if withdrawal of NIV is decided upon that this is achieved with minimum distress to the patient and their relatives. The BMA guidance on EoL care in 2007 did not address withdrawal of assisted ventilation [272]. Although withholding and withdrawing are considered ethically equivalent [273], for many individuals, including clinicians, discontinuing mechanical ventilation is felt be emotionally different to, for instance, stopping haemodialysis. This may be because of the immediacy of the consequence [274]. A Japanese study reported interviews with 35 critical care physicians and found withdrawing ventilation was regarded differently to stopping other life sustaining measures because of concern over an abrupt and distressing demise [275]. There was a desire for a ‘soft landing’ with a slow and gradual death perceived as ‘natural’. The ATS Clinical Policy Statement of 2007 provides comprehensive guidance on withdrawal of mechanical ventilation including symptom management of the dying patient. It emphasizes that decision making is a process requiring frequent discussion with patient, family, health professionals and others [276]. Pro-active family centred conferences allow time for families to adjust and provision of literature on bereavement reduces the risk of subsequent emotional morbidity [277].
In practical terms, both progressive reduction of pressure/back-up rate to achieve CO2 narcosis/coma or, alternatively, extubation when intubated or removal of NIV have been described. In the former scenario, Cox and co-workers suggest initial weaning of oxygen over 10 minutes with appropriate adjustment to opiate or anxiolytic medication [278]. Once patient comfort is assured, it is suggested that mandatory ventilation is withdrawn and pressure support reduced to zero over 5-10 minutes. Kuhnlein and co-workers conducted structured interviews with 29 families regarding the circumstances of dying in MND patients receiving NIV [279]. Seventeen caregivers described the final stages and eventual death as ‘peaceful’.

Eleven of the patients died peacefully while using NIV. Choking sensation was evident in some bulbar patients. The authors indicated that the use of sedatives, anxiolytics and opiates could have been improved, emphasizing that palliative care training or support is needed to achieve best practice.

In conclusion, the role of NIV in achieving a ‘good death’ may currently be under-utilised and there may be a lack of appreciation that a peaceful death can occur whilst receiving supportive ventilation.

Evidence statements

1. The concerns of patients with COPD towards their end of life centre on high levels of physical symptoms, especially breathlessness. (Level 3)

2. Clinicians often consider withdrawal of assisted ventilation [NIV/IMV] as more challenging than removal of other life support techniques. (Level 4)

Good Practice Points

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults 6/5/2015 Master consultation draft
1. Although removal of the NIV mask may be agreed as preferable, a dignified and comfortable death is possible with the equipment in place.

2. Clinicians delivering NIV or IMV should have training in EOL care and support of palliative care teams.

5 6: Novel therapies

6.1 Extra-corporeal CO₂ removal (ECCO₂R)

The use of extra-corporeal membrane oxygenation (ECMO) and extra-corporeal CO₂ removal (ECCO₂R) have primarily been investigated in the management of ALI. By lowering pCO₂ and correcting acidosis, they may have a role in AHRF. The most commonly used device is the iLA (interventional lung assist) membrane ventilator (Novalung®, Novalung GmbH, Talheim, Germany) [280] that receives arterial blood and returns it to a large vein (A-V). There is a risk of vascular injury, haemorrhage and of distal limb ischaemia. Case reports and series document efficacy in AHRF complicating asthma and thoracic kyphosis [281 282] and allow lung protective ventilation in situations where hypercapnia would not be tolerated [283]. The iLA has been used successfully in bronchopleural fistulae [284] and as a bridge to lung transplantation [285]. NICE has issued guidance on the use of ECCO₂R devices [286]. Technical development of veno-venous systems that incorporate a pump and can provide oxygenation as well as CO₂ removal (Hemolung and iLA Active™) have similarities to ECMO yet with fewer complications than A-V systems.

Evidence Statement
1. Extra-corporeal CO₂ removal devices reduce pCO₂ but, as yet, there is no evidence of outcome benefit. (Level 3)

Recommendations

1. ECCO₂R may be considered:
   a. if, despite optimal invasive ventilation, severe hypercapnic acidosis (pH < 7.15) persists. (Grade D)
   b. when ‘lung protective IMV’ is indicated but hypercapnia would not be tolerated. (Grade D)
   c. for IMV patients awaiting a lung transplant. (Grade D)

6.2 Helium/Oxygen ventilation

When mixed with oxygen (Heliox), the lower density of helium reduces resistance to airflow in large airways where flow is predominantly turbulent. It has a theoretical advantage in obstructive causes of AHRF [287]. Heliox has been studied in combination with both NIV and IMV. It increases the delivered dose of bronchodilators and has been reported to improve symptoms and physiologic variables in spontaneously breathing asthmatics [288 289]. At oxygen concentrations > 40%, Heliox has no benefit compared to oxygen-air mixtures [290]. A large RCT in AECOPD found that Heliox in combination with NIV did not reduce rates of intubation, duration of ventilatory support or mortality [291]. Heliox has been reported to reduce pCO₂ and airway pressures in intubated patients with severe asthma [292] but a subsequent meta-analysis concluded it does not affect outcome.
[293]. An uncontrolled study reported that Heliox improves patient comfort in the presence of post-extubation respiratory distress when stridor is present [294].

Evidence statement

1. The use of Heliox does not reduce rates of intubation, length of IMV or reduce mortality in patients in AECOPD or asthma. (Level 1+)

Recommendation

1. There is insufficient evidence to support the use of Heliox in the management of AHRF. (Grade B)
APPENDIX 1 Guideline group members

Chair: Craig Davidson

Section Leads: Steve Banham, Mark Elliott and Daniel Kennedy

Contributors

**Non invasive ventilation**: Mark Elliott, Sara Bolton, Colin Church, Tim Felton, Leigh Mansfield, Milind Sovani, Lynn McDonnell.

**Invasive ventilation**: Daniel Kennedy, Craig Davidson, Ben Creagh-Brown, Alastair Glossop, Leigh Mansfield.

**Weaning from Invasive Mechanical Ventilation**: Craig Davidson, Robert Parker.

**Care Planning**: Steve Banham, Ben Creagh-Brown, Craig Davidson, Lynn Thomas, Bernard Foex, Rob Parker

The chair and section leads gratefully acknowledge the considerable assistance provided by members of the BTS Standards of Care Committee. Colin Gelder, James Dodd and Caroline Patterson deserve special mention for their contribution in advising on structure and editing the final form of the guideline. David Smith and Sally Welham provided support and assistance throughout the guideline process and Martin Wildman, Robert Winter & Simon Baudouin commented on the aims and format of the guidance.

**Representation**

Dr Robert Winter and Sara Bolton represented the Intensive Care Society, Dr Bernard Foex represented the College of Emergency Medicine, Dr Daniel Kennedy represented the Royal College of Anaesthetists and Surgeon Captain Lynn Thomas represented the Royal College of Physicians.

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults 6/5/2015 Master consultation draft
Declarations of interest

Craig Davidson declares being paid as a consultant to Smith Medical between 2008 and 2013.

Mark Elliott declares he has received a honorarium, travel and subsistence expenses for speaking at a meeting in Australia organised by Resmed, a Respiratory Sleep and Ventilation company. He has received an honorarium and travel expenses for speaking at a meeting in London organised by Phillips Respironics, a Respiratory Sleep and Ventilation company. He has received travel and subsistence expenses for speaking at a meeting in China organised by Curative Medical Inc - a Respiratory Sleep and Ventilation company. No honorarium. He has received travel expenses for speaking at meetings in India organised by Phillips Respironics, a Respiratory Sleep and Ventilation company.

Alastair Glossop has been a paid consultant and received honoraria and travel expenses for speaking at meetings organised by Armstrong Medical Ltd in the UK between 2014 and 2015.
References


5. Davidson AC. Towards a comprehensive ventilatory strategy for acute exacerbations of COPD. JICS 2008;9(1):5 - 7


10.1378/chest.08-3018 [published Online First: Epub Date]]


10.1378/chest.11-2279 [published Online First: Epub Date]]


BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft

136


55. van Oppen JD, Daniel PS, Sovani MP. What Is the Potential Role of Transcutaneous Carbon Dioxide in Guiding Acute Noninvasive Ventilation? Respiratory care 2014 doi: 10.4187/respcare.03335[published Online First: Epub Date]].


BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft


84. Core Topics in Mechanical Ventilation: Cambridge University Press, 2008.


89. Heunks LM, Dekhuijzen RP. Mechanical ventilation and diuse atrophy of the diaphragm. The
ventilatory support in patients with acute lung injury. American journal of respiratory and
critical care medicine 2001;164(1):43-9
91. Ward NS, Dushay KM. Clinical concise review: Mechanical ventilation of patients with chronic
obstructive pulmonary disease. Critical care medicine 2008;36(5):1614-9 doi:
10.1097/CCM.0b013e318170f0f3[published Online First: Epub Date] .
92. Gladwin MT, Pierson DJ. Mechanical ventilation of the patient with severe chronic obstructive
93. Fougeres E, Teboul JL, Richard C, et al. Hemodynamic impact of a positive end-expiratory
pressure setting in acute respiratory distress syndrome: importance of the volume status.
Critical care medicine 2010;38(3):802-7 doi: 10.1097/CCM.0b013e3181c587fd[published
Online First: Epub Date] .
94. Tuxen DV, Lane S. The effects of ventilatory pattern on hyperinflation, airway pressures,
and circulation in mechanical ventilation of patients with severe air-flow obstruction. The
American review of respiratory disease 1987;136(4):872-9
95. Leatherman JW, McArthur C, Shapiro RS. Effect of prolongation of expiratory time on dynamic
hyperinflation in mechanically ventilated patients with severe asthma. Critical care
medicine 2004;32(7):1542-5 doi: 00003246-200407000-00012 [pii][published Online First:
Epub Date] .
96. Ranieri VM, Suter PM, Tortorella C, et al. Effect of mechanical ventilation on inflammatory
mediators in patients with acute respiratory distress syndrome: a randomized controlled
trial. JAMA 1999;282(1):54-61
97. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung
injury and the acute respiratory distress syndrome. The Acute Respiratory Distress
10.1056/NEJM200005043421801[published Online First: Epub Date] .
mortality in the acute respiratory distress syndrome. The New England journal of medicine
Date] .
asthma in a 35-year-old woman. Intensive care medicine 1998;24(12):1335-8
101. Swenson ER. Carbonic anhydrase inhibitors and ventilation: a complex interplay of
stimulation and suppression. The European respiratory journal 1998;12(6):1242-7
102. Jones PW, Greenstone M. Carbonic anhydrase inhibitors for hypercapnic ventilatory failure in
chronic obstructive pulmonary disease. The Cochrane database of systematic reviews
103. Aerts JG, van den Berg B, Boggaard JM. Controlled expiration in mechanically-ventilated
patients with chronic obstructive pulmonary disease (COPD). The European respiratory
journal 1997;10(3):550-6
resistance in mechanically ventilated patients with chronic obstructive pulmonary
medicine 2004;30(7):1311-18

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft
113. MacIntyre NR, Cheng KC, McConnell R. Applied PEEP during pressure support reduces the inspiratory threshold load of intrinsic PEEP. Chest 1997;111(1):188-93

BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults 6/5/2015 Master consultation draft


00003246-201002000-00023 [pii][published Online First: Epub Date].


156. Elliott MW, Nava S. Noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease: "Don't think twice, it's alright!". American Journal of Respiratory & Critical Care Medicine 2012;185(2):121-23


177. Wildman MJ, Sanderson C, Groves J, et al. Implications of prognostic pessimism in patients with chronic obstructive pulmonary disease (COPD) or asthma admitted to intensive care in the UK within the COPD and asthma outcome study (CAOS): multicentre observational cohort study.[see comment]. British Medical Journal 2007;335(7630):1132


BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft


189. Holley MT, Morrissey TK, Seaberg DC, et al. Ethical dilemmas in a randomized trial of asthma treatment: can Bayesian statistical analysis explain the results? Acad Emerg Med 2001;8(12):1128-35


10.1056/NEJMoa062200[published Online First: Epub Date]].


10.1186/cc6916[published Online First: Epub Date]].


10.1164/rccm.201205-0939OC[published Online First: Epub Date]].


than 15 days. American journal of respiratory and critical care medicine 2001;164(2):225-30


BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft


263. WHO definition of palliative care. Available at: www.who.int/cancer/palliative/definition/en.


BTS/ICS Guideline for the ventilatory management of acute hypercapnic respiratory failure in adults
6/5/2015 Master consultation draft
10.1016/S0140-6736(00)02485-5 [published Online First: Epub Date]
10.1183/09031936.00021008 [published Online First: Epub Date]
00002480-200801000-00002 [pii] [published Online First: Epub Date]
287. Hurford WE, Cheifetz IM. Respiratory controversies in the critical care setting. Should heliox be used for mechanically ventilated patients? Respiratory care 2007;52(5):582-91; discussion 91-4

