NSW Ambulance **Clinical Practice Standard**

CLINICAL PRACTICE STANDARD — Aeromedical Operations AO.CLI.12 – Difficult Oxygenation

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Directorate	Aeromedical Operations (AO)	
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Summary	To describe the processes and procedures for a lung protective strategy in the mechanical ventilation of patients that are difficult to oxygenate prior to and during retrieval, especially those with acute respiratory distress syndrome	
Applies to	NSW Ambulance aeromedical doctors and paramedics.	
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Related Legislation	Nil	
Related Documents	Nil	

Compliance with this operating procedure is **mandatory**

CLINICAL PRACTICE STANDARD — Aeromedical Operations
AO.CLI.12 – Difficult Oxygenation

1. Introduction

NSW Ambulance Aeromedical Operations are frequently tasked with retrieving patients with Acute Respiratory Distress Syndrome (ARDS) as well as other patients who are difficult to oxygenate. ARDS is a clinical syndrome consisting of acute hypoxaemia, reduced lung compliance and pulmonary infiltrates usually occurring within 7 days. In such patients the use of a protective ventilation strategy is recommended.[1, 2] This strategy focuses on reduced tidal volumes (VT), avoidance of high alveolar pressures (plateau pressure (P_{plat}) and the acceptance of elevated P_{CO2} (permissive hypercapnoea). This protocol does not apply to obstructive pathologies such as asthma where high airway resistance is the main issue.

2. Purpose

The purpose of this procedure is to describe the processes and procedures for a lung protective strategy in the mechanical ventilation of patients that are difficult to oxygenate prior to and during retrieval, especially those with ARDS. ARDS associated with COVID-19 should be treated similarly as a there is currently no direct evidence that it is a separate phenotype.

This practice standard is not for the management of acute unexplained hypoxia, which is covered in the Hypoxia Emergency Action Card. This practice standard may be then used if the patient remains hypoxic once conditions such as bronchospasm, pneumothorax and mucous plugging have been ruled out as the cause.

3. Procedure

3.1 Pre-Retrieval

When oxygenation/ventilation issues are identified in a patient planned for retrieval it is important to gather information during the phone handover to assist with mission planning. There is rarely any urgency to rapidly transfer the patient.

Ensure that the most senior doctor at the referring hospital is involved in the patient’s care. Assess whether current ventilation at the referring hospital is consistent with best practice and diplomatically suggest alternatives if not.

Ask for a period of test ventilation (one hour) at the referring hospital using a Hamilton T1 (or other appropriate transport ventilator), with documentation of ventilation parameters and blood gases if available.

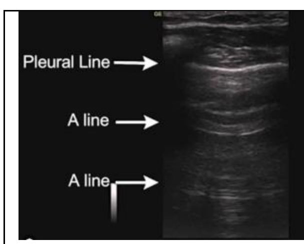
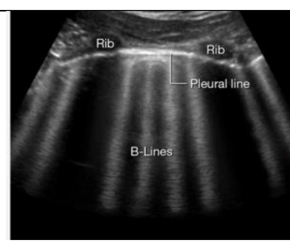
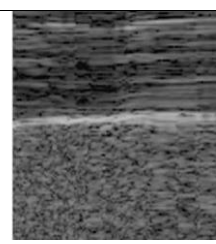
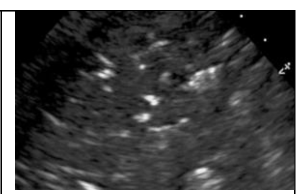
Request a recent chest X-ray (within six hours) if not already available, and if contemplating helicopter (non-pressurised) transfer, assess how expected altitude will further compromise oxygenation. (Consider fixed wing (sea level cabin) or road alternatives).
Involve the Duty Retrieval Consultant (DRC) in all cases where difficult ventilation is anticipated.

If adequate oxygenation during transfer is considered unlikely, the Aeromedical Control Centre (ACC) and referring/receiving critical care consultants must be involved as it may be more prudent to arrange an early ECMO response.

Lung ultrasound
Lung ultrasound offers a rapid, repeatable and non-ionising method to assess the lung. Most of the methods are qualitative. Quantitative methods such a global aeration scores do exist however they require some training and time to score appropriately. The “blue” protocol is commonly referred to, however it should be noted that it was originally established on spontaneously ventilating patients.

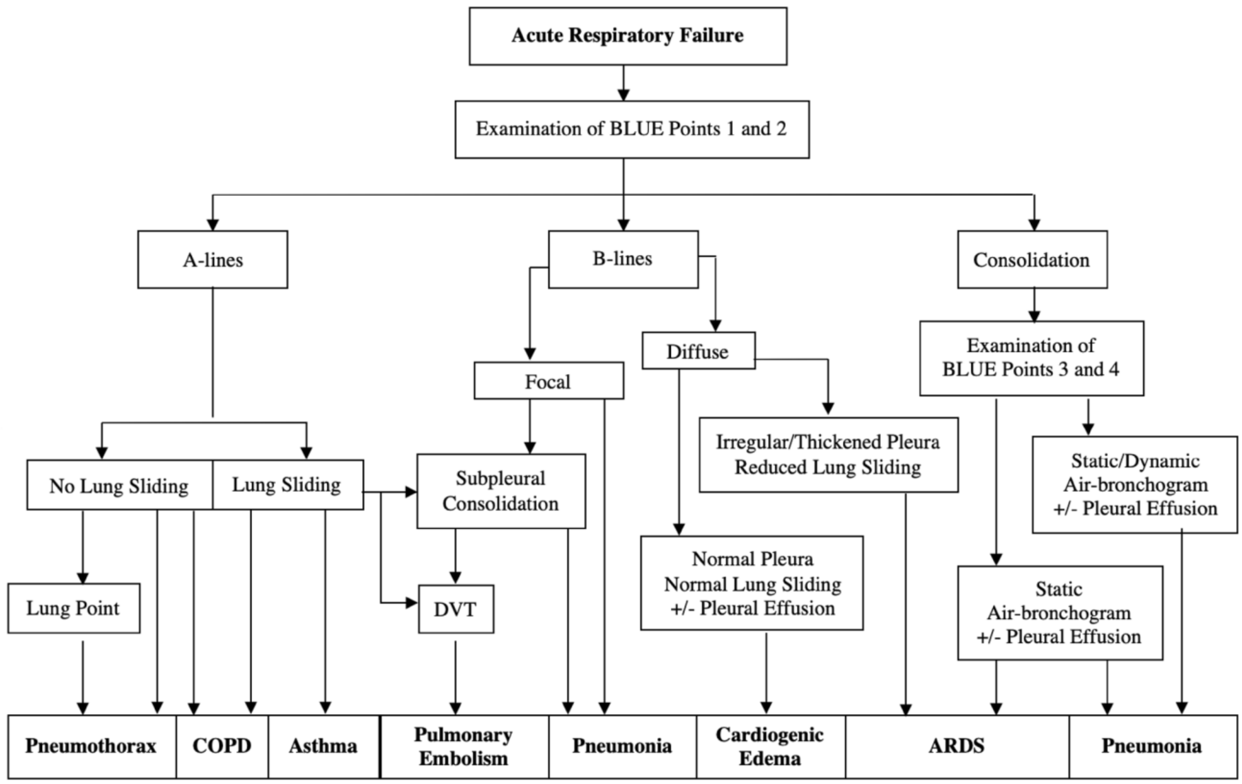
There are 4 locations on the chest to examine for a complete assessment:
1. Anteriorly on the midclavicular line, approx. at the 1st to 2nd IC space
2. Anteriorly on the anterior axillary line, approx. at the 4rd to 5th IC space
3. Laterally on the mid axillary line, also at approx the 4th to 5th IC space
4. Posteriorly on the PLAPS point which lies posteriorly at the 4th to 5th IC space, aiming the probe anteriorly.

There are 4 signs to observe for + pleural effusion

			
A-line **Horizontal** hyperechoic lines Represent high gas-to-volume ratio Normal lung, hyperinflation or pneumothorax	**B line** **Vertical** Hyperechoic, well defined ‘comet tails’ Widening of interlobular septa by fluid pressure or capiliary fibrosis. Two per view may be normal. >3 likely abnormal	**Sliding of pleural line** Represents absence of air. Movement with pulse rather than	**Consolidation** Represents alveolar collapse that traps fluid or air

		respiration may represent pneumonia	

These can be put together using the diagram below to guide diagnosis and therapy.



From : Islam M, Levitus M, Eisen L, Shiloh AL, Fein D. Lung Ultrasound for the Diagnosis and Management of Acute Respiratory Failure. Lung. 2020 Feb;198(1):1-11. doi: 10.1007/s00408-019-00309-1.

3.2 Management of the Difficult to Oxygenate Patient

3.2.1 Emergency Action:

In the event of unexplained acute hypoxia use the Hypoxia Emergency Action Card to diagnose and troubleshoot immediate life threats.

Any patient who is difficult to ventilate/oxygenate is at risk of co-existing conditions effecting oxygenation such as mucous plugging, bronchospasm and/or barotrauma. They may also have gastric or small bowel distension and gastric drainage is recommended. If obstructive ETCO2 trace – rule out ETT obstruction and consider treating bronchospasm regardless of audible wheeze.

3.2.2 Patient Positioning:

Patients should be positioned as upright as their haemodynamic status and stretcher limitations will allow. This aims to improve functional residual capacity (FRC), reduce V/Q mismatch, and improve alveolar recruitment.[1 2]

There is increasing evidence for the use of prone positioning (for a minimum of 12-16 hours per day) in moderate and severe ARDS[1]. Transporting patients in prone positioning brings its own significant risks and challenges. These patients should trigger complex mission planning with the SRC and DRC around consideration of transporting these patients outside of their prone period of the day.

3.2.3 Sedation and Neuromuscular Junction Blockade:

Lung protective strategies require that the patient be well sedated. The abnormal breathing patterns potentially utilised in the early phases of treatment are often poorly tolerated by awake patients and result in dys-synchrony.

Neuromuscular blockade agents (NMBA) are safe to use in ARDS and should be used if there is patient-ventilator dys-synchrony or if high airway pressure persist despite adequate sedation.[2, 3] In practice, if patient is on high FiO2 then consider keeping the patient deeply sedated and paralysed to avoid possible dys-synchrony or coughing that may exacerbate hypoxia.

There is consensus that in early (<48hrs) moderate-severe ARDS there is a mortality benefit from administration of NMBA[1,2,3]. The recommended NMBA is a cisatracurium infusion for no greater than 48hrs[2,3]. Other paralytic agents, such as rocuronium and vecuronium, can also be used as a continuous infusion. If using bolus doses of paralysis during transport, dose on a regular schedule and consider dosing more frequently or higher doses than normal to ensure continuous and complete paralysis.

3.2.4 Ventilator Choice:

The Hamilton T1 is the preferred transport ventilator for difficult to ventilate/oxygenate patients and should be used on ALL missions where handover information suggests difficulty in ventilating a patient.

3.2.5 Ventilator Mode:

A variety of ventilator strategies may be helpful in difficult to oxygenate patients.

Either volume-controlled (VCV) or pressure-controlled (PCV) modes can be utilised so long as parameters such as plateau pressures and tidal volumes are regularly checked and kept within recommended safe limits. Currently there is insufficient evidence to determine superiority of either PCV or VCV [4].

PCV modes have higher mean airway pressure compared to traditional volume-controlled modes, which may be of benefit for recruitment and thus oxygenation. Volume-targeted pressure-regulated modes such as SIMV+ on the Hamilton T1 delivers a breath in a similar pattern to PCV and will also have this benefit.

PCV strategies are commonly utilised by intensive care units for hypoxic patients. In addition to traditional PCV modes, ICUs may use a BiLevel mode which cycles between higher and lower pressure settings and allows spontaneous respiration at any point in the cycle. Alternatively, PCV with a long inspiratory time causing an inspiratory breath hold may be utilised. The purpose of these strategies is to increase the mean airway pressure and encourage re-recruitment of atelectic lung. If using this strategy, first adjust respiratory rate to achieve sufficient pH targets and then adjust time inspired to maximise inspiratory hold time whilst ensuring that the expiratory flow returns to zero to prevent iatrogenic gas trapping

ASV

The Hamilton T1 ventilator offers a closed-loop ventilation mode called Adaptive Support Ventilation (ASV). It automatically adjusts all ventilator settings to achieve a minute-volume set by the clinician. The operator sets the MV, PEEP and FiO_2. ASV mode starts with default setting based on the gender and predicted body weight, and the ventilator will continuously adjust the ventilation according to several measured parameters breath by breath. A recent systematic review suggests that ASV is better than clinician adjusted ventilation at maintaining ventilation within lung protective limits, it is as safe as conventional ventilation and is as effective as conventional ventilation at avoiding dysoxaemia (Botta et al). There are no long-term studies of its effectiveness.

It should be used with caution however as:

1. The maximum delta-p inspiratory pressure is 10cmH20 below the set upper limit pressure and this needs to be considered by the clinician
2. It should not be used with infants and neonates, large leak on NIV and irregular respiratory patterns.
3. At the start of ventilation, it takes time to perform its initial adjustments from the default settings and this may result in a period of hypoventilation – the clinician needs to be especially vigilant when it first starts ventilating and adjust the manual settings as needed.

3.2.6 Transferring ventilators:

Careful clamping of endotracheal tubes should be performed when transferring between ventilators to avoid loss of PEEP, and resultant atelectasis. It also limits exposure to staff of potentially infectious secretions. This should only be done in patients who are not spontaneously breathing. Clamping ETT in spontaneously breathing patients increasing risk of barotrauma or negative pressure pulmonary oedema.

3.2.7 Goals of Ventilation:

When normal parameters of ventilation and oxygenation are unachievable, ventilation goals shift to achieving the closest to normal parameters as possible without causing additional injury to the lungs.

The parameters below are useful as a guide to the extremes of acceptable parameters. If unable to achieve then the case should be discussed with the DRC/accepting intensivist.

- $SpO_2 \geq 88$ %:
- pH$\geq$ 7.15
- $P_{plat} \leq 30$ cmH_20

Tidal volumes should be kept low targeting V_T 6mL/kg of **Predicted body weight (PBW)**, and not exceeding 8mls/kg.[1 2]

Estimation

PBW(kg)=Height(cm)-100 if male, -105 if female
This is accurate to within 7% for height 125-190cm

The P_{plat} should be kept below 30 cmH_20 to avoid Ventilator Induced Lung Injury (VILI). In volume control ventilation (VCV) P_{Plat} is obtained through initiating an Inspiratory hold manoeuvre through the ventilator.[1,2] In paediatric patients a lower P_{plat} of <28 cmH_20 should be targeted.[5]

If the P_{plat} is >30 cmH_20 then:

1) Troubleshoot patient, endotracheal tube and ventilator for reversible cause of high airway pressure using High Airway Pressure Emergency Action Cards.
2) TV should be incrementally reduced down to a minimum of 4mL/kg as long as the pH$\geq$ 7.15 (permissive hypercapnia), increased respiratory rate or time inspired may be required. [6]

A P_{plat} >30cm$H_2$0 may be tolerated if TV at 4mL/kg or pH<7.15.[6]

Hypoxaemia, in the absence of confounding factors, should be managed by concurrent incremental increases in Fi02 and PEEP. PEEP improves oxygenation by increasing the mean airway pressure (P_{mean}), and provided it is hemodynamically tolerated, can go up to a maximum of 20 cm$H_2$0 on the Oxylog and higher on the Hamilton.

In patients with moderate and severe ARDS avoid a high driving pressure (P_{plat}-PEEP), which has been linked to increased mortality.[7] This can be achieved through trialing a 'high PEEP' (average of 12-15 cm$H_2$0) while maintaining plateau pressure <30 cm$H_2$0. Monitoring of these patients to identify who responds (improvement in Pa02/Fi02) to higher PEEP and stopping these interventions in non-responders is recommended.[7,8]

If hypotension is limiting ability to increase PEEP then a fluid bolus or inotropes may be considered.

It is reasonable to have the patient on FiO2 1.0 during initial management and transfers between ventilators but avoid maintaining hyperoxia. Down titrate FiO2 as soon as practical and continue to down titrate as the patient improves to avoid reabsorption atelectasis that occurs with high FiO2.

Permissive hypercapnia is often required and typical respiratory rates for adult patients with ARDS range between 15 and 25 breaths per min. If setting high respiratory rates check for expiratory flow reaching zero prior to inhalation to avoid iatrogenic gas trapping. If in PCV mode and tidal volumes are <6ml/kg check the flow curve – if the inspiratory flow has not reached zero before cycling into expiration then can increase inspiratory time to increase tidal volumes.

Regular reassessment of tidal volumes, Pplat, oxygenation and ETCO2 will be required as the patient improves or deteriorates to ensure that safe parameters are being maintained and that chosen ventilation strategy is sufficient. Improvements may be slow but may allow adjustment of targets or ventilation settings to safer options. Shortly prior to departure take another ABG to calibrate ETCO2 to PaCO2 and pH.

3.2.8 Use of Bag-Valve-Mask (BVM) Ventilation:

Use of BVM ventilation for extended periods should be avoided due to the inability to accurately monitor the delivered tidal volumes and pressures generated. In addition a BVM with PEEP valve does not effectively maintain PEEP during the periods in between breaths.

BVM pressure release “pop off” valves vary from 35-70 cmH20 and in some models this can be capped off to allow significantly higher pressures to be generated. Adult BVM’s can generate approximately 60 cmH20/6 kPa and paediatric/neonatal BVMs generate approximately 40 cmH20/4 kPa. If utilising BVM ventilation ensure the pressure release valve is not capped off to limit inadvertent barotrauma unless required to achieve effective ventilation and aim to transition the patient on to the ventilator as soon as practical.

Prolonged use is unnecessary as any patient that can be ventilated with BVM ventilation can also be ventilated on the Hamilton T1 ventilators. PEEP and FiO2 delivery will be superior with a ventilator and TV and pressure can be accurately monitored and adjusted.

For comparison:

- Retrieval BVM with the pressure release valve open and PEEP valve attached can generate maximum PEEP 20 cmH20 and peak inspiratory pressure up to 60 cmH20. FiO2 can be ≤98% depending on minute ventilation and fresh gas flow setting.
- Oxylog 3000+ has a maximum PEEP/CPAP 20cmH20 and peak inspiratory pressure 55mmHg. FiO2 40-100%.
- Hamilton T1 has a maximum PEEP/CPAP 35 and peak inspiratory pressure 60cm. FiO2 21-100%.

3.2.9 Special circumstances:

Pulmonary hypertension

May poorly tolerate hypoxia and hypercapnia and as such require higher O2 targets and lower pCO2 targets. High PEEP will increase pulmonary vascular resistance but so can hypoxia and hypercapnia. Consider inodilators (such as milrinone) or pulmonary vasodilators (such as nebulized GTN or epoprostinol) in discussion with Intensivist and DRC.

Worsening Oxygenation with high PEEP

First confirm appropriate ETT position above carina and suction to ensure mucous plugging isn’t contributing to unequal distribution of ventilation. Focal lung disease may result in overdistension of normal lung tissue with high PEEP and worsening V-Q mismatching. A right to left shunt will also increase due to an increase in pulmonary pressures as PEEP increases. Try decreasing PEEP and/or providing additional venous return via a fluid bolus.

3.3 Recruitment Manoeuvres

Recruitment manoeuvres, through application of transiently high airway pressures, are intended to expand collapsed lung so as to increase (recruit) the number of alveolar units participating in gas exchange. They are carried out either as a short period of high PEEP (30-40cmH20) or in a staircase recruitment manoeuvre.[1,2]

Recruitment manoeuvres are **not recommended to be used routinely** in ARDS patients.[1, 2] There has been high quality evidence in a large RCT that the use recruitment manoeuvres in ARDS carry an increased relative risk of death, pneumothorax requiring drainage and barotrauma.[9] Most patients will be adequately recruited given sufficient time using appropriate ventilator settings.

In cases of clear recent de-recruitment (intubation, endotracheal aspiration or accidental disconnection) or severe ARDS with refractory hypoxaemia ($Pa0_2$/$Fi0_2$ ratio <100 mmHg), despite optimisation of therapy, a recruitment manoeuvre may be considered in the absence of any contraindication.[2]

As yet, there is also no clear guidance for those that may benefit from recruitment in ARDS making bedside assessment difficult. Given the significant risks associated with recruitment maneouvres and variability in clinical cases it is appropriate to discuss the potential risk and benefits to the patient being transferred with the receiving Intensivist and/or DRC prior to use.

There is no one recommended recruitment manoeuvre, but if used it should: [2]

- Not last longer than 20-30 seconds
- Airway pressure should not exceed 30-40 cmH20
- Be ceased if there any signs of haemodynamic compromise (hypotension)

3.4 Unable to Ventilate

If after proceeding through the checklist, the goals of ventilation cannot be met with a transport ventilator, the case should be discussed with the DRC and referring/receiving ICU consultant.

Depending on the clinical condition of the patient, consideration should be given to:

- Delaying transfer until patient condition improves
- ECMO

3.5 Prior recommendations no longer advised

High Frequency Oscillatory Ventilation

The use of high frequency oscillatory ventilation has been demonstrated to have no benefit in ARDS, and in some cases harm through barotrauma, hypotension and oxygenation failure and is not recommended.[1,2]

3.6 Additional Management for ARDS

Restrictive Fluid strategy

A restrictive fluid strategy should be employed in all patients with ARDS; the main effect being the shortening of the duration of mechanical ventilation required.[1,10]

4. Definitions

ARDS: Acute Respiratory Distress Syndrome

Berlin classification of ARDS:

- Mild $Pa0_2/Fi0_2$ ratio >200 mmHg
- Moderate $Pa0_2/Fi0_2$ ratio 100-200 mmHg
- Severe $Pa0_2/Fi0_2$ ratio <100 mmHg

VCV: Volume Control Ventilation

PCV: Pressure Control Ventilation

P_{peak}: Peak Inspiratory Airway Pressure

P_{mean}: Mean Airway Pressure

P_{plat} : Plateau Pressure

PEEP: Positive End Expiratory Pressure

5. References

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APPENDICES

1. N/A

REVISION HISTORY

Version (Document #)	Amendment notes
Version 4.0 Issued 05 June 2024 WI2024-046	Added section on use of Lung US Updated Hamilton T1 references in including ASV mode De-emphasized Recruitment Maneuvers
Version 3.0 Issued 13 April 2021 WI2021-061	Extensive update for Hamilton T1 Ventilator Update of literature review Revised description of physiology and targets Updated Body Weight calculations Updated advice regarding use of recruitment Added references to Emergency Action Cards Approved by Executive Director, Aeromedical Operations
Version 2.0 Issued 16 September 2016	Minor amendments and transition to new format Approved by Executive Director, Health Emergency & Aeromedical Services.
Version 1.0 Issued May 2013	Original Approved by Executive Director, Health Emergency & Aeromedical Services.