Management of Respiratory Failure: Maintaining Safe Ventilation with Prone Positioning.

Clinical Problem:

This expanded case summary details the management of a 39-year-old female who was admitted to ICU with respiratory failure. This case was selected, as respiratory failure is the most common reason for admission to ICU. This therefore provides an opportunity to assess the strategies that are employed to ensure safe ventilation.

This patient with a background of alcohol excess presented to the emergency department with a 3-day history of dyspnoea. In the emergency department she had clear evidence of respiratory distress and severe sepsis as she was hypoxic, tachypnoeic and tachycardic with an elevated lactate and inflammatory markers. She had radiological evidence consistent with pneumonia, demonstrating right mid and lower zone consolidation. She received fluid resuscitation and intravenous antibiotics (co-amoxiclav and clarithromycin) targeting community-acquired pneumonia. She maintained adequate oxygenation on facemask oxygen and was therefore transferred to the medical high dependency unit.

142 words

Management:

Unfortunately shortly after admission to Medical HDU her oxygen requirements escalated. Her oxygen delivery was switched to high flow nasal humidified oxygen (NHFHO2). Despite the delivery of 70L of 100% oxygen via NHFHO2 her condition continued to deteriorate with inadequate gas exchange demonstrated by a PaO2 7.3 kPa. It was clear that invasive ventilation would be required given the poor gas exchange, on going work of breathing and progressive tiring of respiratory effort. She was therefore transferred to ICU.

The decision was made to invasively ventilate upon admission to ICU. Intubation was uneventful however her gas exchange remains poor despite ventilation. The initial ventilation plan was pressure-controlled ventilation using P-SIMV, ensuring safe tidal volumes (6 ml/kg ideal body weight) to minimise barotrauma and volutrauma, whilst implementing an appropriate level of PEEP to ensure optimal compliance and alveolar splinting. Diuresis was implemented in an attempt to minimise pulmonary oedema and enhance gas exchange.

Despite various strategies such implementing bi-level ventilation, adjusted pressure release ventilation (APRV) and neuro-muscular blockade her oxygenation did not improve to a safe level.

Domains: 3.8, 3.9, 4.6.

The decision was made to implement prone positioning ventilation (PPV). There was an immediate improvement in her oxygen saturations, gas exchange, peak airway pressures and transpulmonary pressures. PPV was maintained for 16 hours before being turned supine. This is in line with recent guidelines on prone ventilation and to avoid pressure related necrosis. Shortly after returning the supine position her gas exchange deteriorated again which prompted a return to PPV for a further 16 hours. Upon returning to a supine position on this occasion her gas exchange was maintained whilst spontaneously breathing with pressure support of 4 cmH20 and PEEP of 8 cmH2O.

She had a subsequent protracted course in ICU complicated by a left pleural effusion, large peri-pancreatic pseudocyst, pancreatitis and delirium. However she did make a stepwise improvement with sedation, antibiotic therapy, percutaneous drainage of pancreatic cyst, intercostal chest drain and physiotherapy. Two weeks later she was successfully weaned from ventilatory support and discharged to the surgical team.

336 words

Discussion:

ARDS is a life threatening condition in which there is failure of the lungs to provide adequate gas exchange. It is one of the most common reasons for admission to ICU and is associated with considerably mortality. The Berlin Criteria below helps define ARDS[1].

Table 1. ARDS Berlin definition.

The Berlin definition of acute respiratory distress syndrome	
Timing	Within 1 week of a known clinical insult or new or worsening respiratory symptoms
Chest imaging[a]	Bilateral opacities — not fully explained by effusions, lobar/lung collapse, or nodules
Origin of edema	Respiratory failure not fully explained by cardiac failure or fluid overload. Need objective assessment (e.g., echocardiography) to exclude hydrostatic edema if no risk factor present
Oxygenation[b]	
Mild	200 mmHg $< PaO_2/FIO_2 \leq$ 300 mmHg with PEEP or CPAP $\geq$ 5 cmH_2O[c]
Moderate	100 mmHg $< PaO_2/FIO_2 \leq$ 200 mmHg with PEEP $\geq$ 5 cmH_2O
Severe	$PaO_2/FIO_2 \leq$ 100 mmHg with PEEP $\geq$ 5 cmH_2O

Abbreviations: CPAP, continuous positive airway pressure; F_IO_2, fraction of inspired oxygen; PaO_2, partial pressure of arterial oxygen; PEEP, positive end-expiratory pressure; [a]Chest radiograph or computed tomography scan; [b]If altitude is higher than 1,000 m, the correction factor should be calculated as follows: [PaO_2/FIO_2_(barometric pressure/760)]; [c]This may be delivered noninvasively in the mild acute respiratory distress syndrome group.

Improving mortality in ARDS has been the subject of research for a number of years. The only convincing evidence thus far has been delivered by the ARDSnet trial[2] which suggests low tidal volume (6 ml/kg ideal body weight) in order to avoid barotrauma and volutrauma. This trial has formed the fundamentals of our current ventilator practice in ICU. We no longer aim for perfect gas exchange but instead aim for acceptable gas exchange to ensure safe ventilation, avoiding the long term complications of high airway pressures.

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Additional ARDS treatment strategies include neuro-muscular blockade (ARURASYS trial[3]), extra-corporeal membranous oxygenation (CESAR[4]), high frequency oscillation (OSCAR[5]/OSCILLATE[6]) and prone positioning.

Prone ventilation in ARDS has been a contentious issue for a number of years. Prone positioning is thought to be associated with:

- improvement in regional ventilation
- redistribution of perfusion to optimise V/Q matching
- recruitment of dorsal and basal lung segments

In spite of the physiological basis and anecdotal support for PPV, the evidence base demonstrating a survival benefit has been lacking.
Until recently most studies confirmed that PPV does improve oxygenation however this does not correlate with improved survival[7]. One of these studies by Gattonini et al was criticised by prone ventilation enthusiasts as having poor design such as the enrolment of a hetrogenous group of ARDS patient with no severe ARDS, poorly defined protocols, late implementation of prone ventilation in established ARDS and shorter prone duration[8].

In 2013 the PROSEVA group[9] demonstrated both improved oxygenation and survival using PPV and is summarised below:

- Design
    - Multi-centre RCT
    - n = 466
    - Prone n = 237, control n = 229
    - Intention to treat analysis
    - Primary outcome – all cause mortality
- Inclusion criteria
    - Severe ARDS
        - P/F ratio < 150 mmHg
        - FiO2 > 0.6
        - PEEP > 5 cmH20
        - Vt 6 mlkg IBW
    - Mechanical ventilation < 36 hours
- Intervention
    - Stabilisation period 12 – 24 hours prior to enrollment
    - Randomised to supine or control
    - Supine group – semi-recumbent
    - Prone group – prone for 16 hours
    - Mechanical ventilation modelled on ARDSnet protocol
        - Peak airway pressures < 30 cmH20
        - Goal pH 7.2 to 7.45
- Outcomes
    - 32% mortality in supine vs 16% in prone

The strength of this study includes the well-defined protocols, homogenous recruitment of those with severe ARDS, use of protective lung ventilation in both groups, early initiation of intervention and longer duration of prone ventilation. There is however an imbalance of SOFA scores with the control

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group having higher SOFA scores and vasopressor requirements. The increased mortality in the control group may therefore be explained by cardiovascular collapse as opposed to hypoxaemia[8]. The prone group received more neuromuscular blockade, which may be a confounding factor as paralysis itself may have enhanced the mortality benefit in this group as seen in the ACURASYS trial. A final point to note regarding this trial is that it only included centres which are experienced in PPV. However I see this as a strength and not a criticism as any intervention should be completed by an experienced team in order derive the most benefit, particularly when being used for the purposes of trial data. This should encourage the use of more prone ventilation in order to build upon our experience of this strategy.

Our patient quickly met the criteria of this study, having refractory oxygenation failure and ARDS as defined by the above consensus. Her oxygenation quickly improved immediately after PPV and facilitated an effective protective ventilation strategy. We were compliant with the PROSEVA protocol, utilising neuromuscular blockade when required and applying ARDSnet protective lung ventilation. One thing I am unclear on is the optimal timing of PPV. The PROSEVA study had a stabilisation period of 12-24 hours prior to prone ventilation. We applied the prone position before 12 hours of stabilisation, mainly because we could not stabilise any further and our patient's gas exchange was unsafe. Any intervention was therefore time-critical. Other options included referral for ECMO, nitric oxide, adopting non protective lung strategies or continuing with our current management. Of these strategies PPV seems to be the most sensible despite the time-scale, in terms of physiology, evidence base and logistics, allowing the continued provision of safe ventilation.

750 words

Lessons learnt:

It has been educationally valuable to be involved in this case as this was the first time that I witnessed PPV. It was particularly satisfying as it demonstrated a profound improvement in gas exchange whilst maintaining safe ventilation.

PPV is often quoted and thought of as a rescue therapy. However given the results of the PROSEVA study and what we have learned from protective lung strategies it seems sensible to implement prone ventilation early in ARDS rather waiting until a rescue therapy is required.

In my own practice I will have a low threshold for providing PPV to patients with ARDS and ensure that this is performed early in keeping with the PROSEVA study. This will ensure enhanced alveolar recruitment[3], enhanced oxygenation, minimal lung injury and potentially improved survival. Additionally I would ensure that staff in our unit were familiar with the care and potential pitfalls of PPV to ensure optimal chance of improving mortality with this intervention.

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The cornerstone of modern ICU management is the recognition of the harm that we may cause and providing a framework to reduce this. One of the most powerful aspects of prone ventilation is its ability to optimise gas exchange whilst providing safe ventilation which is why I am satisfied to include PPV in my respiratory failure management.

215 words

References:

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