Review article

Year in Review 2015: Recruitment manoeuvres in ARDS

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Abstract

Refractory hypoxaemia is a problem in patients with acute respiratory distress syndrome (ARDS). Although mechanical ventilation is the mainstay of management of ARDS, this therapy itself can cause damage to the lungs due to high tidal volume and high airway pressures. Lung protective strategies are used to reduce damage to the lungs due to mechanical ventilation. Use of small tidal volumes can cause alveolar derecruitment and arterial hypoxaemia. Lung recruitment manoeuvre (RM) opens up collapsed segments of the ARDS lung but the collapse may reappear once the RM is complete. Although RM has been shown to improve oxygenation there is still no clear data showing improvement in clinical outcome. This review summarises the different techniques used for RM, physiological effects of RM on lung mechanics along with monitoring RM at the bedside.

Keywords: ARDS, hypoxaemia, recruitment manoeuvres, lung protective ventilation.

Introduction

Refractory hypoxaemia is a problem in patients with acute respiratory distress syndrome (ARDS). Although mechanical ventilation is the mainstay of management of ARDS, this therapy itself can cause damage to the lungs due to high tidal volume and high airway pressures.[1,2] There is strong evidence that low tidal volume ventilatory strategies improve survival.[3] Lung protective strategies are used to reduce damage to the lungs due to mechanical ventilation. However, the use of small tidal volumes can cause alveolar derecruitment and arterial hypoxaemia. In the ARDSNet trial, patients randomised to the low tidal volume group had lower PO_2 levels, possibly due to alveolar derecruitment.[3] The lung in ARDS have regions of collapse which can possibly be recruited. It is known that damage to ARDS lungs can occur not only due to volutrauma or barotrauma but also due to atelectrauma. Recruitment and prevention of derecruitment of the collapsed areas can be expected to reduce atelectrauma, improve gas exchange as well as reduce ventilator-induced lung injury. Lung recruitment manoeuvre (RM) is one of the many lung-protective strategies that can be used to open up these collapsed areas in the lung.[4]

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Physiological effects of recruitment manoeuvre

Historically, RM was found to safely improve arterial oxygenation in patients who develop atelectasis due to general anaesthesia,[5] and in neonates undergoing high-frequency oscillation for respiratory distress syndrome.[6] Literature review shows that RM inflation pressure range of 30–60 cm H_2O for a duration 3 s to 3 min, have reported various improvements in gas exchange.[7-14] Recruiting the lung may benefit by two mechanisms: The first is the increase in the aerated lung mass, minimising the lung heterogeneity and increasing the size of the baby lung. The second is the prevention of repeated opening and closure of the terminal respiratory units reducing shear stress. Pelosi *et al* showed that recruiting manoeuvres improved lung mechanics and oxygenation only in patients with extrapulmonary ARDS. RM did not improve lung mechanics in pulmonary ARDS and also did not influence the amount of improvement in arterial oxygenation after application of the recruitment manoeuvre.[15] Mahto *et al* found that only

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50 % of patients responded to initial recruitment manoeuvre suggesting the heterogeneity of disease presentation. They concluded that not all patients respond to recruitment manoeuvre and show an increase in oxygenation.[16]

The use of high tidal volumes produce higher peak pressures in these lungs with very low compliance leading to higher incidence of barotrauma.[17] Such ventilation can also lead to release of inflammatory mediators such as interleukins 1 and 6, tumour necrosis factor alpha causing biotrauma.[18] Ventilation with low tidal volumes also result in progression of lung injury.[19] Thus, careful attention needs to be given to tidal volumes and at least intermittent application of distending pressures much higher than that recommended for the ventilation of patients with ARDS. Chen YM *et al* in animal experiments showed that RM and lung protective ventilation in rabbits with ARDS improved oxygenation and reduced extravascular lung water.[20,21]

Techniques of recruitment manoeuvre

There are many techniques of providing RM in the clinical setting as well as in experimental model (*Table 1*). Lapinsky *et al* showed increase in oxygen saturation in all 14 patients while using sustained inflation manoeuvre of 45 cm of H_2O for a period of 20 seconds.[22] There were no adverse effects observed in his study. Lim *et al* used volume controlled mode, V_T (tidal volume) reduced by 2 ml/kg and positive end expiratory pressure (PEEP) increased by 5 cm of H_2O every 30 seconds.[23] At V_T 2 ml/kg and PEEP 25, continuous positive airway pressure (CPAP) 30 cm H_2O was applied for 30 seconds. He found that there was increase in PaO_2 and static compliance, sustained for the duration of the study. Grasso *et al* applied CPAP of 40 cm H_2O for 40 seconds found that there was improvement in oxygenation only in early ARDS group and in patients with low lung elastance.[24] Oczenski *el al* applied sustained inflation (CPAP 50 cm H_2O for 30 s) found that significant increase in P/F ratio at 3 min post-RM, no significant differences in P/F ratio between RM and control group at baseline and after 30 min.[25] Constantin *et al* did comparative study between CPAP of 40 cm H_2O for 40 sec and sigh by PEEP of 10 cm H_2O above lower inflection point on pressure-volume (P–V) curve for 15 minutes; found that both manoeuvres improved oxygenation at 5 and 60 minutes.[26] Drop in systolic pressure <70 mm Hg on two occasions in the CPAP group was observed. No significant drop in systolic blood pressure (SBP) was observed in sigh group. Some level of sedation is usually required to carry out an RM but neuromuscular blockade is not absolutely necessary. Monitor the patient carefully for hypotension and desaturation during the RM. The RM should be followed up with an appropriate PEEP level to prevent derecruitment.[16]

Monitoring recruitment manoeuvre at the bedside

Computed tomography (CT) scan provides a wealth of information such as presence and distribution of inflated and collapsed areas of the lung, change in these areas with ventilation and whether recruiting the collapsed areas is a possibility. However, CT cannot still be used for everyday management, especially at the patient bedside, and is limited for use during clinical research.

The physiological effects of recruitment manoeuvre have been evaluated based on changes in respiratory mechanics, improvement in the ventilation–perfusion ratio and oxygenation. However, measurement of oxygenation alone is insufficient as several factors can influence oxygenation.[33, 34] The multiple pressure–volume curves method has been proposed as an acceptable bedside assessment of recruitment.[35] However, performing multiple pressure–volume curves is difficult in clinical practice, and alveolar recruitment can be underestimated.[36]

Direct measurement and monitoring of end expiratory lung volume (EELV) could be used to assess both alveolar recruitment and derecruitment at the bedside. Chiumello *et al*[37] demonstrated that, although CT remains the gold standard for gas lung volume, EELV measurement using an automated system based on the nitrogen washout technique that is incorporated into a ventilator (Engstro¨m Carestation; GE Medical System, Helsinki, Finland) is an acceptable alternative. Several studies opine an improvement in lung aeration can be assessed and detected by lung ultrasound (LUS).[38,39] Although LUS is an easily repeatable technique, it remains time-consuming, unsuitable for continuous

***Table 1*: Randomised controlled trials of recruitment manoeuvres**

Trails	Year of Publication	Type of RM Used	Findings
Pelosi *et al.*[15]	1999	Three consecutive sighs of plateau pressure 45 cm of H_2O every minute for an hour	Increase in the end expiratory lung volume, reduction in the intrapulmonary shunt and improvement in oxygenation
Lapinsky *et al.*[22]	1999	Sustained inflation manoeuvre of 45 cm of H_2O for a period of 20 seconds	Improvement in oxygen saturation in all 14 Patients, sustained up to four hours in 10 patients. No significant adverse effects noted
Rothen *et al.*[27]	1999	Sustained inflation of 40 cm of H_2O for 26 seconds in anesthetized patients	May re-expand all previously collapsed lung tissue, as detected by lung computed tomography, and improve oxygenation
Lim *et al.*[23]	2001	On volume controlled mode, V_T reduced by 2 ml/kg and PEEP increased by 5 cm of H_2O every 30 seconds. At Vt 2 ml/kg and PEEP 25, CPAP 30 cm of H_2O was applied for 30 seconds.	Increase in PO_2 and static compliance, sustained for the duration of the study. No major respiratory or haemodynamic complications
Bein *et al.*[28]	2002	Progressive increase in peak airway pressure (within 30 sec) up to 60 cm H_2O and sustained for the next 30 seconds	Marginal improvement in oxygenation Deterioration of cerebral haemodynamics
Patroniti *et al.*[29]	2002	CPAP of 20% higher than peak airway pressure for 3–5 seconds every minute on pressure support ventilation	Improvement in oxygenation Improved lung compliance
Grasso *et al.*[24]	2002	CPAP of 40 cm H_2O for 40 seconds	Improved oxygenation noted only in early ARDS and in patients with low lung elastance
Meade *et al.*[30]	2002	Sustained inflation (CPAP 35–40 cm H_2O for 20–40 s)	No net effect on oxygenation or pulmonary mechanics after first or subsequent RMs
Oczenski *et al.*[25]	2004	Sustained inflation (CPAP 50 cm H_2O for 30 s)	Significant increase in PaO_2/FiO_2 (P/F) ratio at 3 min post-RM, no significant differences in P/F ratio between RM and control group at baseline and after 30 min
ARDSNet[31]	2003	CPAP of 35–45 cm H_2O for 30 seconds	Effects of RM were inconsistent and transient
Stewart *et al.*[32]	2007	Sustained inflation (CPAP 40 cm H_2O for 40 s)	None reported
Constantin *et al.*[26]	2008	Comparative study between CPAP of 40 cm H_2O for 40 sec and sigh by PEEP of 10 cm H_2O above lower inflexion point on P -V curve for 15 minutes	Both manoeuvres improved oxygenation at 5 and 60 minutes Drop in systolic pressure <70 mm Hg on two occasions in the CPAP group No significant drop in BP during sigh
Mahto *et al.*[16]	2013	During the RM, PEEP was increased from baseline to 15, 20 and 25 cm H_2O sequentially (every 30 s from the baseline PEEP until 25 cm H_2O). The VT was decreased by 25%, 50% and 75% respectively from the baseline VT during the incremental PEEP trial phase.	Significant increase in P/F ratio post recruitment manoeuvre after 30 minutes

monitoring and obviously inappropriate to detect lung hyperinflation.

Electrical impedance tomography (EIT), allows real-time rather than intermittent monitoring, measures relative impedance changes in lung tissue during tidal breathing and provides images of the lungs divided into regions of interest.[40]

Recruitment manoeuvre and prone position

Prone position has become an established method for pulmonary recruitment and increase in oxygenation in many ARDS patients. Kacmarek suggested that the recruitment manoeuvre in prone position is more effective for PaO_2 increase, and that the PEEP level required to sustained PaO_2 increase is lower in prone than in the supine position.[41]

-Lim *et al* performed an experimental trial with seven acute lung injury dog models.[42] They showed that lower PEEP levels are needed for preserving the recruitment manoeuvre in prone position. Another study by Cakar *et al* showed that the alveolar recruitment more effectively improves oxygenation with lower PEEP levels in prone position as compared to supine position.[43]

Complications

Studies done by Lim *et al* and Kloot TE *et al* have shown increased intrathoracic pressure resulting from recruitment manoeuvre transiently compromises haemodynamic function by impeding venous return with an increase in right atrial pressure, decreasing cardiac output and arterial pressure. RM should be used with caution in patients with haemodynamic instability.[44-47] Substantial reductions (20–30%) in cardiac output and mean arterial blood pressure have been reported during sustained inflations of 40 cm H_2O.[24] Bein T *et al* found 17% decrease in cerebral perfusion pressure, along with a marked, sustained decrease in jugular venous oxygen saturation, from 69 to 59%, due to recruitment manoeuvre in head-injured patients with ARDS.[48] Eddy *et al* after a systematic review of 31 studies involving 985 patients concluded that the majority of adverse events occurred during RM, with hypotension (12%) and desaturation (8%) being the most common complications.[49] Serious adverse events, such as barotrauma (1%) and arrhythmias (1%), were uncommon. Only 10 (1%) patients were reported to have had RM terminated prematurely due to adverse events. Seventeen studies (287 patients) reported no adverse events from RM. Translocation of bacteria from the lung due to increased stretch during RMs is more a theoretical concern.[50-52] Study done by Cakar *et al* in a rat model, showed that a sustained inflation RM of 45 cm of H_2O for 30 seconds at fifteen minute intervals did not result in bacterial translocation as evident on blood cultures.[53]

Summary

Recruitment manoeuvre may improve oxygenation and further prevent derecruitment of alveoli if antiderecruitment strategy of RM is used. It also prevents repetitive opening and closing of alveoli thus reducing the chances of VILI. Extrapulmonary ARDS is more likely to respond to RMs compared to pulmonary ARDS; consolidated lungs may not be recruitable. RM is more likely to be beneficial during the early stages of ARDS, compared to later stages when fibroproliferative changes set in. Patients who are already on optimal PEEP are unlikely to benefit from RM. Overdistention due to recruitment manoeuvre can lead to decrease in venous return and cardiac output causing significant haemodynamic compromise. Thus haemodynamic effects of RM should be considered among patients who are on inotropes and blood pressures should be continuously monitored during RM. Monitoring the effects of recruitment manoeuvre at the bedside have become an integral part of the strategy. The optimal technique of recruitment is unclear and may vary depending on individual clinical circumstances. Prone position has become an established method for pulmonary recruitment and increase in oxygenation in many ARDS patients. RM have been clearly shown to improve gas exchange, there is no evidence that suggests improved morbidity or mortality. Routine use of RM should be avoided as it may not be associated with benefit. RM may be used as rescue therapy in refractory hypoxaemia and in patients with severe ARDS.

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