Lung volume recruitment in acute respiratory failure in patients admitted to intensive care facilities

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Rectification on the paper "Lung volume recruitment in acute respiratory failure in patients admitted to intensive care facilities by L.H. Hassing, S.J.C. Verbrugge and I. Kesecioglu, Neth J Crit Care 2007;11 (3): 134-140, a part of the discussion have been accidentally omitted. The editors apologize for the inconvenience caused; the discussion which was missing is printed below.

Cutting of recruitment manoeuvres and adverse effects
The issue of when to break off a recruitment manoeuvre also involves the question when not to start with a recruitment manoeuvre at all. The criteria used to stop or not start a lung recruitment manoeuvre as defined in the studies are listed in Table 3.

As well as these criteria, we believe that the following should be identified as contraindications to starting a recruitment manoeuvre: significant right ventricular failure; patients with a low circulating volume or cardiac compromised patients; severe airway obstruction (COPD); focal lung problems (e.g. large pulmonary infiltrate/abscess); lung transplant patients or patients with newly placed bronchial sutures; patients with a pneumothorax and patients with a subarachnoidan bleeding or signs of increased intracranial pressure.

The two main adverse effects of recruitment manoeuvres reported in literature are haemodynamic impairment and barotrauma. Reis Miranda et al. studied right ventricular afterload during recruitment manoeuvres in patients after cardiac surgery with an open pericardium and could find no significant effect on cardiac index, right ventricular preload, contractility and afterload [21]. Findings from other authors confirm that recruitment manoeuvres do not have to result in major haemodynamic disturbances [18,22,43]. However caution should continue to be exercised in patients with severe cardiac compromise or with a depleted circulatory volume. Similarly, several studies performing recruitment manoeuvres reported no barotrauma during or after recruitment [29,41,44,65] as opposed to other studies which did [16,19,23,30,49].

Moreover, the individual effect of PEEP and peak pressure on the incidence of barotrauma during recruitment manoeuvres is unknown and warrants further investigation. Some studies at least, oppose the traditional view that recruitment obviously leads to haemodynamic impairment and barotrauma.

When and how to repeat recruitment manoeuvres
No solid advice regarding when and how to repeat recruitment manoeuvres can be found in the studies reviewed. From the foregoing discussion and based on theory, it is clear that the goal of the initial high inspiratory pressure is to recruit collapsed alveoli and to determine the critical opening pressure. Thereafter, a PEEP level that prevents the lung from collapse should be set. Should renewed collapse of alveoli occur, a fall in P/F-ratio indicates that a re-opening manoeuvre has to be performed.

Muscle paralysis
From a practical point of view we think muscle relaxants should not be given if the patient is adequately sedated as they may induce several side effects (e.g. an increased incidence of critical illness polyneuropathy). Only in exceptional cases is temporary paralysis necessary to execute the recruitment manoeuvres.

Monitoring recruitment and defining its success
The definition of a successful recruitment manoeuvre was not easy to deduce from the articles we reviewed. A P/F-ratio greater than 250-400 and/or a decrease in FIO2 < 0,60 with SpO2 >88-93% are reasonable markers for success. SpO2 and Pao2 were most frequently used as a study parameter (Table 4). Improved oxygenation with a reduction in PCO2 may also indicate lung recruitment [3]. A correlation between SpO2, alveolar recruitment and End-Expiratory Lung Volume (EELV), although weak was found in a study conducted by Maggiore et al [26]. A correlation between SpO2 and EELV was also found by Pelosi et al [39]. An increase in P/F-ratio correlated with an increase in compliance and a decreased intrapulmonary shunt in a study performed by Villagra [33].

A number of direct and indirect methods to determine the state of the openness of the lung are available. Computer tomography (CT) or magnetic resonance imaging (MRI) allow optimal visualization of individual lung areas but are impractical [66]. Newer, simpler techniques of visualization which can be used at the bedside still have to be further validated and introduced into the clinic setting [67,88].

When a pressure-volume curve is obtained during ventilation, a period of active recruitment of collapsed alveoli will lead to an increase in volume as can be observed by an increased slope of the inflation limb. Finally, the slope of the inflation limb will flatten which can be interpreted as maximal recruitment, and subsequent deflation will lead to the characteristic deflation curve. However, it is possible that not all recruitable lung tissue has been recruited at the pressure used, and that a further increment of the pressure will result in an additional recruitment of alveoli that are still collapsed. Thus, although P-V curves can give additional information on the
state of the lung, they may not be the ideal indicators for the degree of openness of the lung.

The determination of the Functional Residual Capacity (FRC) can help establish how “open” a lung is. However, an increase of FRC will not always be due to an increase of recruitable lung area; it can also be due to overinflation at a still reduced FRC.

Using 100% oxygen, an arterial oxygen tension above 450 mmHg (P/F-ratio > 450) characterizes an “open” lung. When maximal recruitment has been reached, a further increase of inspiratory pressures will not lead to a further rise in arterial oxygenation, indicating that the lung is open. Increasing inspiratory pressures even further will lead to a decrease in $p_aO_2$ because of V/Q mismatching. When searching for the minimum pressure needed to maintain an open lung, a decrease in pressure below the critical closing level will result in the immediate decrease in arterial oxygenation. Considering the above, we believe that at present, the use of the P/F-ratio is the superior method to define the state of openness of the lung in the clinical setting.

**Functional outcome.**
The lack of strong evidence in favour of recruitment manoeuvres does not mean they should not be used. Most studies (23/34) did see positive effects of recruiting the lung although the follow-up period was short.

**Conclusion**
This review shows us that the way a recruitment manoeuvre should be carried out is still a matter of debate and that future studies with more standardized ways of employing such manoeuvres are necessary.

The most frequently studied categories of patients and those who profit most are ALI/ARDS patients, post-cardiac surgery patients and patients with lung collapse after endotracheal suctioning. We believe that at present, the use of the P/F-ratio is the method that best combines practicality with sensitivity in defining the state of openness of a lung. When performing a recruitment manoeuvre, a critical opening pressure has to be reached before a previously collapsed alveolus can open. A lot of studies restrict the peak pressures used due to possible harmful effects but limiting peak inspiratory pressures (mean 48 ± 8.7 in this review) may even prevent recruitment of the most severely affected alveoli. Opening pressures should be applied for about 10-15 seconds mean (49 ± 32 seconds for 26/34 studies). Use of pressure-controlled time-cycled modes of mechanical ventilation in which the alveolar pressure can never exceed the peak inspiratory pressure set on the ventilator are preferable to volume-cycled modes of mechanical ventilation. PEEP can prevent the collapse of open and perfused alveoli but PEEP itself does not recruit collapsed alveoli because recruitment is an inspiratory phenomenon. If PEEP is set too low, recollapse of alveoli will occur and defining the right PEEP level by finding the closing pressure of the alveolar system should always be part of a recruitment protocol. If during ventilation renewed alveolar collapse of alveoli occurs, a fall in P/F-ratio indicates that a re-opening manoeuvre has to be performed. The two main logical adverse effects of recruitment manoeuvres traditionally reported in literature are haemodynamic impairment and barotraumas, but studies are appearing which oppose this view.

We think that, if one general method of recruitment incorporating the directives mentioned above is accepted by a majority of intensivists, this could be a starting point for further evaluating the value of recruitment manoeuvres.