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Reduction of lung atelectasis in bariatric surgery with focus on alveolar recruitment maneuvers by using lung ultrasound score

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Abstract
Bariatric surgery has been shown to be the most efficient and long-lasting method for treating severe obesity, surpassing existing treatments according to extensive meta-analyses. Recruitment maneuver (RM) stands for an intentional temporal increase in transpulmonary pressure (airway pressure _ pleural pressure) above the value used during mechanical ventilation, aiming to re-open the non-aerated or poorly aerated alveolar unit to improve oxygenation, ventilation, and lung mechanics. RM increases the lung mass aeration, thus reducing lung heterogeneity while increasing the baby's lung size. It also minimizes the repetitive terminal respiratory units opening and closing. RMs also increase pulmonary compliance and improve arterial oxygenation intraoperatively and postoperatively. Moreover, RM with positive end-expiratory pressure has shortened hospitalization. It has also been established as an effective preventive measure for post-laparoscopic shoulder pain.

Keywords: Bariatric surgery, severe obesity, meta-analyses, recruitment maneuver (RM)

Introduction
Extensive meta-analyses have shown that bariatric surgery stands as the most efficient and long-lasting method for treating severe obesity, surpassing existing conventional treatments [1]. Lung recruitment maneuvers have been suggested and employed for opening up collapsed lungs along with reversing atelectasis [2]. Lung atelectasis refers to the incomplete expansion, or reversible collapse, of the small airways, representing a substantial issue, particularly in cases who have received general anaesthesia, with the occurrence reaching as high as 90% [3, 4].

Recruitment maneuver (RM)
The goal is to reopen alveolar unit that are not properly aerated, while enhancing oxygenation, ventilation, as well as overall lung function. To ensure the lungs remain open, a sufficient positive end-expiratory pressure (PEEP) is maintained above the lower inflection point of an inspiratory maneuver [5]. RMs have proposed that the lung structure homogenization along with mechanical stress distribution over the lungs. This may be achieved through applying a suitable amount of pressure to the airways for a sufficient duration, while also ensuring that appropriate positive end-expiratory pressure (PEEP) levels are maintained. When RMs successfully open up collapsed lung tissue, it decreases shear stress, respiratory effort, pulmonary right-to-left shunt, as well as postoperative pulmonary adverse events. At the same time, it increases oxygenation, ventilation, lung mechanics, functional residual capacity (FRC), along with end-expiratory lung volume [5].

Techniques of recruitment maneuvers
Various methods have been suggested for conducting RMss, each with varying magnitudes of transpulmonary pressure increase, rise time, the maneuver duration, as well as implementation timing. The results of the latest investigations are contradictory. The majority of reaeration takes place during the first seconds after the rise in airway pressure. Thus, several authors have reached the conclusion that longer RMs are unlikely to provide more benefits but instead increase the risk of hemodynamic deterioration [6].

The researchers attempted to identify substitutes for prolonged inflation RM that might potentially achieve similar effectiveness while posing lower hazards as regards hemodynamic deterioration as well as barotrauma. The research suggests gradually increasing the plateau pressure by making stepwise adjustments to the airway pressure as well as PEEP. This approach is intended for use in ICU cases and during GA for surgery [7].

Titrating PEEP Recruitment (stepwise recruitment):
Titrating PEEP maneuver was conducted as follows:
Switching the ventilation mode to pressure-controlled ventilation (PCV) along with maintaining a driving pressure (plateau pressure - PEEP) of no more than 15 CmH2o. Gradually increasing PEEP by two cmH2O every two breaths until the peak inspiratory pressure stays below 40 cmH2O. Then, gradually decreasing PEEP by two cmH2O every two breaths to determine the optimal PEEP level [8].
Stepwise maneuvers may provide superior regulation of airway pressure elevation compared to continuous inflation, leading to a reduced likelihood of hyperinflation as well as hypotension. Several experimental investigations have shown that stepwise RMs exhibit a longer-lasting positive effect in comparison to traditional RMs. Stepwise RMs are also linked to lower levels of inflammatory markers and decreased damage to epithelial cells in cases of mild acute respiratory distress syndrome (ARDS). However, it is necessary to conduct extensive studies in order to evaluate the RMs safety and effectiveness, as well as the benefits of certain approaches [9].

Evaluation of the effect of lung recruitment
There is no widely agreed-upon approach to reliably assess the RMs efficiency. The most effective method for assessing the RMs efficacy remains a subject of controversy. The assessment should be based on data obtained from various monitoring systems, and it should involve both anatomical as well as functional evaluation. The primary physiological measures that are often evaluated are the PaO2/FiO2 ratio stress index, pulmonary compliance, along with the pressure-volume (P-V) curve. Imaging modalities, involving computed tomography (CT), lung ultrasonography (LUS), as well as electric impedance tomography (EIT) might provide valuable assistance [10].

Rational and advantages of recruitment maneuvers
The purpose of RM includes opening up the collapsed alveoli, raising the amount of air in the lungs at the end of expiration, improving the gases' exchange, and boosting oxygenation, while reducing ventilator-induced lung injury (VILI) [11].

This benefit could be induced through two mechanisms [12]:
The first mechanism involves increasing the amount of air-filled lung tissue, thus reducing lung heterogenicity while increasing the baby's lung size.
The second mechanism involves reducing the repetitive opening and closing of the terminal respiratory units.
Furthermore, RMs enhance pulmonary compliance while enhancing arterial oxygenation both during and after surgical procedure. Additionally, utilizing RM with PEEP has been authorized to reduce the duration of hospital stays [13]. RM has been shown to be a beneficial preventative treatment for post-laparoscopic shoulder pain [14].

Ultrasound findings in pulmonary diseases
Lung consolidation occurs when there is a significant loss of aeration, as seen in conditions involving lobar bronchopneumonia, pulmonary contusion, as well as lobar atelectasis. The visual appearance resembles a tissue-like echo texture, sometimes referred to as "hepatization". Alveolar consolidation may be identified by three distinct sonographic patterns [15].

Atelectasis
Distinguishing between atelectasis and consolidation with lung ultrasound is challenging. Bronchograms are suggestive as above, yet they exhibit a reducted specificity. If a significant amount of fluid accumulates in the pleural space (referred to as pleural effusion), the occurrence of compression atelectasis is more probable. A little accumulation of fluid increases the probability of consolidation. If there is a substantial collapse, then accompanying indications such as an elevated hemidiaphragm will be seen. Almost all pleural effusions among critically-ill cases are accompanied with underlying consolidated or atelectatic lung tissue. The definitive method to differentiate compression atelectasis from consolidation is to do effusion drainage and observe whether the lung undergoes re-aeration [16].

Lung US patterns corresponding to various aeration degrees
Lung reaeration could be evaluated through monitoring lung ultrasound variations. There are four LUS patterns that could be utilized while monitoring lung aeration in a semi-quantitative manner. These patterns correlate to increasing loss of aeration [17]:

a) The existence of horizontal artefacts known as A-lines extending beyond the pleural line indicates proper pulmonary aeration.
b) The existence of many and well defined vertical B-lines indicates a moderate reduction in lung aeration caused by the interstitial syndrome.
c) The presence of coalescent B-lines indicates a significant reduction in lung aeration due to the partial filling of alveolar spaces by pulmonary edema or confluent bronchopneumonia.
d) The lung consolidation indicates complete aeration loss while air in distal bronchioles remains. (Figure 1).

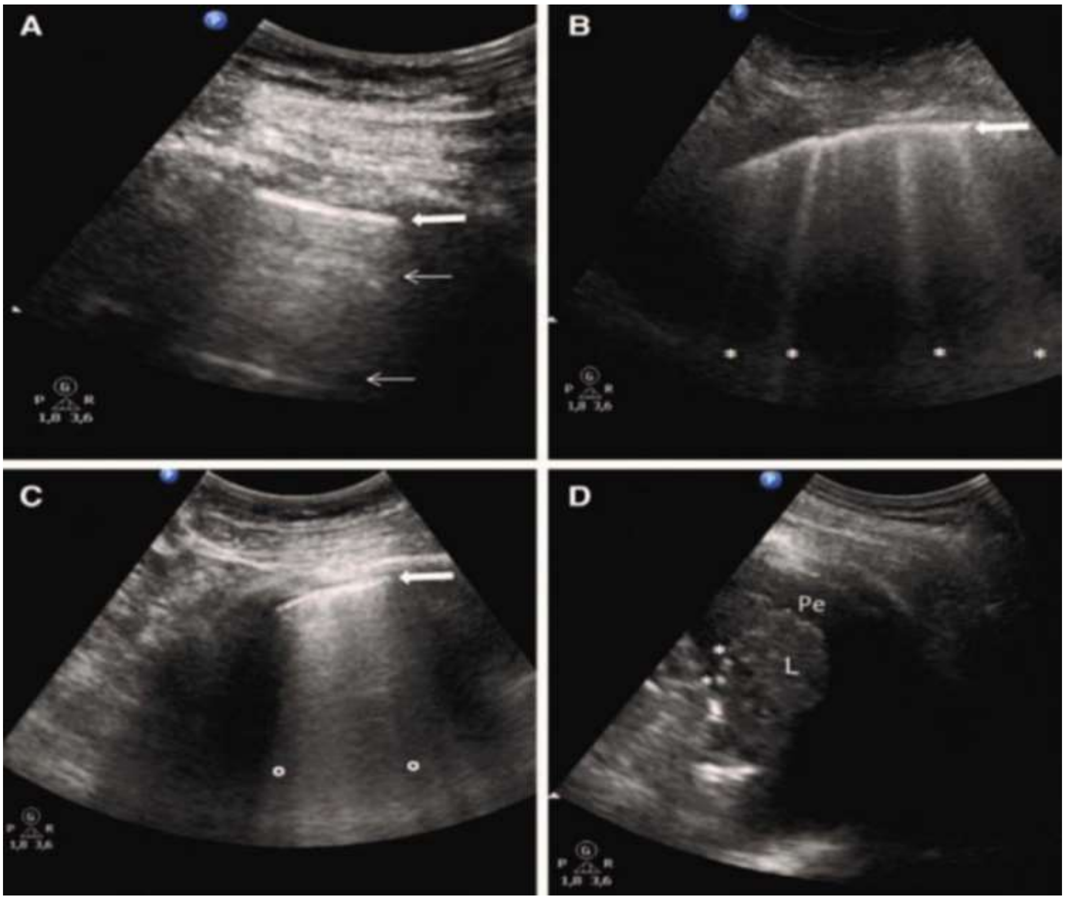

Fig 1: LUS corresponding to progressive loss of aeration [18]

LUS scores for aeration monitoring

The atelectasis severity was assessed by determining the modified LUS score on a scale of 0 to 3. A score of 0 indicated the presence of 2 or fewer B lines, a score of 1 indicated the presence of 3 or more B lines or multiple areas of subpleural consolidation separated by a normal pleural line, a score of 2 indicated the presence of multiple coalescent B lines or multiple areas of subpleural consolidation separated by a thickened pleura, and a score of 3 indicated the presence of consolidation or small areas of subpleural consolidation with a diameter over 1×2 cm [19].

The LUS score is determined by adding up the scores collected in all six designated lung areas. The score falls between 0 and 18 for the whole thorax, or between 0 and 36 depending on the number of regions. The score is inversely related to the level of lung aeration. Higher values indicate chronic atelectasis. We consider pulmonary atelectasis to be substantial when the LUS score is equal to or more than 2 at any area [19].

Limitations of lung ultrasound

It is important to acknowledge the limits of lung ultrasonography while assessing its overall usefulness. The quality of LUS is contingent upon the skill and expertise of the operator, resulting in variability in its performance. Enhanced technical proficiency along with extensive clinical expertise of the operator enhance the diagnosis effectiveness. Nevertheless, research has shown that even basic skills in such a modality could be acquired very easily [20].

One drawback of LUS in comparison to chest radiography is the required examination time. The duration of a comprehensive LUS couldt vary, lasting for 20 minutes to complete. In contrast, a chest radiography can be done in only a few minutes [20].

Another limitation as regards LUS is that observations such as A-lines as well as B-lines could be obseerved in many conditions. For instance, research has shown that in children developing bronchiolitis, there is a significant overlap in the lung ultrasound findings of atelectasis and pneumonia. Nevertheless, this issue is not exclusive to the United States, since comparable problems with specificity are present in both chest radiography and, to a lesser degree, in CT scans [20].

Lung ultrasonography is primarily an imaging technique that relies on artefacts, and it usually only shows abnormalities abutting the pleural line. To thoroughly examine the deeper structures of the chest, it is recommended to utilize chest radiography and/or CT imaging. Similarly, in the Intensive Care Unit (ICU), lung ultrasonography (US) has greater limitations in assessing the placement of lines and tubes compared to chest radiography. Therefore, instead of being competing methods, chest radiography and lung ultrasound serve as supplementary methods that may be used together to enhance patient care [20].

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