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EDITORIAL

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Unveiling alveolar recruitment: the fascinating trail between theory and practice

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Alveolar recruitment as well as avoidance of de-recruitment are well-accepted fundamental goals of the ventilatory management of ALI/ARDS patients, albeit even in the recent past the search for a definite strategy of recruitment and of positive end-expiratory pressure (PEEP) setting was the source of partially heated debates [1, 2, 3]. Compared with such fundamental controversies, the question of how to quantify alveolar recruitment may appear as a marginal sub-topic, especially because techniques based on CT scans, which is considered the gold standard [4], or others relying on respiratory mechanics [5, 6], have been fairly well established as research tools for decades. Nevertheless, even these techniques are limited mainly due to the lacking possibility of continuous measurements, in the case of CT to the need of transporting patients to the imaging facilities, and to the fairly complicated methods. In contrast, arterial oxygenation did not always prove to be strongly related to alveolar recruitment as detected by means of CT [7], the variability of the results being possibly dependent on the CT technique used [8].

In the current issue of *Intensive Care Medicine*, two new approaches for assessing alveolar recruitment are proposed by Tusman et al. [9] and Richard et al. [10], based on experimental studies in pigs. The first method relies on a continuous CO_2-expirogram-based analysis of respiratory dead space, and the second one on positron emission tomography (PET). Of course, these techniques also have important limitations per se and, at least presently, they cannot be considered as upcoming *clinical* standards; nevertheless, when compared with the above-mentioned techniques, they permit to obtain particular and specific insights into the process of lung recruitment, and are therefore worth deeper consideration.

The investigation by Tusman and colleagues [9] adopted simultaneous analyses of respiratory dead space and CT-based lung morphology in order to determine the PEEP level necessary to keep the lung open after a recruitment manoeuvre. Indeed, alveolar dead space, the ratio of alveolar dead space to alveolar tidal volume, as well as the difference between arterial and end-tidal PCO_2, were proven to efficiently detect de-recruitment. A particular strength of this study is given by its clinically relevant design. In fact, both PEEP levels and tidal volumes were applied in a range compatible to current clinical practice. The most important property of the technique proposed by Tusman et al. [9], however, is that it may allow a fairly simple and continuous monitoring of de-recruitment, even at bedside. Nevertheless, the technique used for continuous arterial PCO_2 measurement, which is a pre-requisite for continuously measuring alveolar dead space, is currently not commercially available. This is a major drawback since in the actual study airway dead space alone, which may be measured by Fowler's method [11] independently from

arterial PCO_2, was revealed to be far less useful for detecting de-recruitment.

Even from a theoretical point of view, the approach of Tusman et al. [9] to put the focus on the analysis of dead space and CO_2 elimination, instead of oxygenation or shunt alone, is particularly intriguing, albeit not completely new but rather following the rationale proposed by Suter et al. in their seminal work [12]. The importance of this strategy may be emphasized by the post-hoc analysis presented by Gattinoni et al., which showed that in a group of ALI/ARDS patients an improved CO_2-elimination during prone position compared with supine was an indicator of a favourable outcome [13]. Nevertheless, we should remain aware of the fact that *alveolar* dead space is a theoretical construct, and that CO_2-elimination as well as the shape of the CO_2-expirogram depends mainly on the V_A/Q-distribution, as do variables related to oxygenation [14, 15]. As just mentioned, however, oxygenation-related variables have not always been revealed to be strong indicators of recruitment in previous studies [7, 8].

The study by Richard et al. [10] suggests PET as a potentially interesting research tool for studying alveolar recruitment. The study design was less clinically oriented in that lung injury induced by oleic acid instillation was only mild, and that only two PEEP settings (0 and 10 cm H_2O) were studied in the supine and prone position, respectively, without any recruitment manoeuvre. These limitations, however, do not diminish the importance of the key message. In fact, although PET has some drawbacks which are similar to CT, it uniquely offers the possibility to study not only the degree of aeration, as shown in the actual study, but also the physiopathology of ALI/ARDS, e. g. the process of inflammation [16, 17, 18]. Putting together these discoveries may indeed improve our understanding of the impact of strategies of mechanical ventilation on injured lungs.

Finally, with regard to the design of both studies some caution should be recommended. In fact, both techniques proposed for assessing recruitment have been evaluated in pig models of lung injury. In particular, lung injury induced by saline lavage as in Tusman et al.'s [9], study behaves differently than human ALI/ARDS, as stated by the authors themselves in their discussion. Furthermore, when studying lung function in pigs, one should always be aware of the fact that pig lungs are fairly different from human lungs in the following ways: (a) collateral ventilation is lacking in pigs, hence functional units are larger than in other species [19]; and (b) due to a thicker smooth muscle layer in the pulmonary vasculature, pigs are far more susceptible to hypoxia than humans [20]. Although the physiological meaning of these differences cannot be quantified, it seems reasonable that they may somehow influence the efficiency of gas exchange in both species. In particular, the strong effects of hypoxia on pulmonary vascular reactivity observed in pigs is even consistent with a more efficient Euler-Lilienstrand reflex [21] and, consequently, possibly with a more homogeneous distribution of the V_A/Q ratio in this species, at least under pathological conditions and/or during hypoxia. Although it is speculative, the possible role of such interactions should be considered whenever lung function is studied in pigs.

In conclusion, Tusman et al. [9] and Richard et al. [10] present two techniques which fit well into the methodologies actually available to assess alveolar recruitment and de-recruitment. In spite of their limitations, we should not overlook their strengths as research tools, but also their potential for future clinical use, in particular when considering that even standard techniques are still far from being ideal ones for both research *and* clinical practice.

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