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Algorithm-based monitoring of intensive care ventilation using electrical impedance tomography

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Preface

The causes of acute respiratory failure are complex and often lead to structural lung impairments that make the use of ventilation therapy a life-saving necessity. Due to gravitational effects, regional surfactant defects, and the uneven distribution of atelectases, this results in the inhomogeneous distribution of regional ventilation.

Adjusting the ventilation to a patient's individual regional lung function is a highly complex task that must be regularly evaluated. Nevertheless, such an evaluation is essential because "lung-protective" ventilation reduces the mortality of patients with acute lung injury (ALI).

The individual adjustment of the positive end-expiratory pressure (PEEP) is key to optimised ventilation. It is quite a challenge to find the best PEEP level for patients with acute respiratory failure to avoid atelectases and alveolar over-distension. Furthermore, the optimally adjusted PEEP changes continuously with the lung function that is affected by disease and therapeutic measures. The PEEP level, therefore, has to be re-evaluated on a regular basis.

An optimally adjusted PEEP is a fundamental prerequisite for lung-protective ventilation. It reduces cyclic, tidal recruitment of lung regions and leads to a more homogeneous distribution of ventilation and perfusion in the lung. When PEEP values are too low, lung areas may be damaged by the formation of atelectasis, while excessive PEEP values can cause over-distension.

Various bedside methods can be used for optimising the PEEP setting. The most commonly used approaches include low-flow pressure volume curves, stress index, PEEP trial and the PEEP/FIO_2 table. They all

share the limitation that they cannot display the regionally inhomogeneous ventilation distribution. Radiological technologies such as chest X-rays, computed tomography, pulmonary ultrasound and less commonly, magnetic resonance tomography are also employed, but can only depict the pulmonary status at a specific point in time.

Chest X-rays performed bedside have the least significance among these methods. In some cases, they only show large pulmonary lesions. The effort associated with performing a CT or MRI examination of ventilated intensive-care patients is enormous and also represents a major risk for patients with unstable respiration. Furthermore, CT examinations create significant radiation exposure levels for patients. Despite all these limitations for use with ventilated intensive-care patients, CT is currently the only method that allows for optimising ventilation settings in relation to the regional lung function, which means that patients with severe respiratory failure must be subjected to CT examinations to optimise their ventilation settings.

Electrical impedance tomography (EIT) for the first time offers a bedside method for reliable non-invasive, continuous determination of the regional lung function without radiation exposure. In contrast to other medical imaging methods, EIT displays body functions instead of body structures. It provides real-time images, e.g. for monitoring ventilation, perfusion or gas exchange.