Functional residual capacity
Development of new monitoring techniques for critically ill patients

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Functional Residual Capacity
Development of new monitoring techniques for critically ill patients

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Abstract

Functional residual capacity (FRC) and end-expiratory lung volume (EELV) are important parameters for respiratory monitoring in critically ill adult and paediatric patients. Until now we have lacked clinically useful methods to measure these lung volumes. In this thesis two methods for bedside measurements of FRC in mechanically ventilated patients have been developed and evaluated. The first method (FRC$_{\text{flux}}$) is based on quantification of metabolic gas fluxes of O$_2$ and CO$_2$ during a short apnoea. The second method is a modified nitrogen wash-out/wash-in technique (FRC$_{\text{N2}}$) based on standard monitoring equipment. The possibility to combine measurements of EELV with a tool to assess lung mechanics by measuring volume dependent compliance (VDC) was also assessed.

Methods: Baseline exchange of oxygen and carbon dioxide was measured using indirect calorimetry for both the FRC$_{\text{flux}}$ and the FRC$_{\text{N2}}$ method. End-tidal (alveolar) O$_2$ and CO$_2$ concentrations were obtained before and after a few seconds of apnoea, and FRC$_{\text{flux}}$ was calculated according to standard wash-out/wash-in formulae taking into account the increased solubility of CO$_2$ in blood when tension is increased during apnea. The FRC$_{\text{N2}}$ was calculated using changes in inspiratory and end-tidal gas concentrations breath-by-breath after a small step-change for inspiratory oxygen (F$_I$O$_2$). These methods were validated both in mechanically ventilated patients and in lung models. The FRC$_{\text{N2}}$ technique was also tested in small children and infants both perioperatively, using a Mapleson -D system, and in the ICU. A lung injury animal model was used to investigate the effects on FRC$_{\text{N2}}$ and VDC by lung lavage and after three different lung recruitment manoeuvres (RMs).

Results: The FRC measurement methods showed good precision and reproducibility. Experimental acute lung injury caused by lung lavage resulted in large decreases in EELV and VDC. There were differences in the response to RMs in individual animals demonstrated by combined measurements of changes in EELV and volume-dependent compliance.

Conclusions: New methods have been developed for measurements of lung volumes using standard monitoring equipment only. The FRC$_{\text{N2}}$ method makes it possible to measure lung volumes in realtime at the bedside in combination with volume-dependent compliance. Combined measurements of changes in lung volume and compliance could be helpful to define responders and non-responders to lung recruitment manoeuvres, and to increases in positive end-expiratory pressure (PEEP). These new monitoring tools may help clinicians to tailor ventilation to the individual patient and hopefully attenuate the risk for ventilator induced lung injury.

Keywords: FRC, functional residual capacity, EELV, end expiratory lung volume, volume dependent compliance, VDC, acute respiratory failure, recruitment manoeuvre, PEEP