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

Akademisk avhandling

som för avläggande av medicine doktorsexamen vid Sahlgrenska Akademin
vid Göteborgs Universitet kommer att offentligen försvaras i Hjärtats aula, Sahlgrenska Universitetssjukhuset, Göteborg, fredagen den 28 maj, 2010, kl.09.00

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Avhandlingen baseras på följande delarbeten:

I. Stenqvist O, Olegård C, Söndergaard S, Odenstedt H, Karason K, Lundin S.
Monitoring functional residual capacity (FRC) by quantifying oxygen/carbon dioxide fluxes during a short apnea.
Acta Anaesthesiol Scand 2002; 46:732-739

II. Olegård C, Söndergaard S, Houltz E, Lundin S, Stenqvist O.
Estimation of functional residual capacity at the bedside using standard monitoring equipment: A modified nitrogen wash-out/wash-in technique requiring a small change of the inspired oxygen fraction.
Anesth Analg 2005; 101:206-12

III. Olegård C, Söndergaard S, Pålsson J, Lundin S, Stenqvist O.
Validation and clinical feasibility of nitrogen wash-in/wash-out functional residual capacity measurements in children.
Acta Anaesthesiol Scand 2009; Oct 15 [Epub ahead of print]

IV. Olegård C, Söndergaard S, Odenstedt H, Lindgren S, Lundin S, Stenqvist O.
Volume-dependent compliance and resistance during three different recruitment maneuvers.
In manuscript 2010.

Göteborg 2010

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_{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_{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_{flux} and the FRC_{N2} method. End-tidal (~alveolar) O_2 and CO_2 concentrations were obtained before and after a few seconds of apnoea, and FRC_{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_{N2} was calculated using changes in inspiratory and end-tidal gas concentrations breath-by-breath after a small step-change for inspiratory oxygen (F_IO_2). These methods were validated both in mechanically ventilated patients and in lung models. The FRC_{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_{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_{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 manouvre, PEEP

ISBN 978-91-628-8122-1 http://hdl.handle.net/2077/22292