



Protective Ventilation in the OR

Spontaneous breathing - another aspect of intraoperative protective ventilation?

General anaesthesia with neuromuscular blockade and subsequent controlled ventilation is suspected to be a major cause of respiratory impairment. Apart from parameters for controlled ventilation, intraoperative spontaneous breathing might as well be one of the options for further improvement. This article provides interesting insights into literature based backgrounds.

Various aspects of lung protection during general anaesthesia ventilation have been discussed in the past years. We have gathered evidence insights and recommendations from literature for you [\(link\)](#). This discussion mainly concentrated on controlled mechanical ventilation, which is quite clear as many surgical procedures require neuromuscular relaxation and consequently call for protective methods of mechanical ventilation.

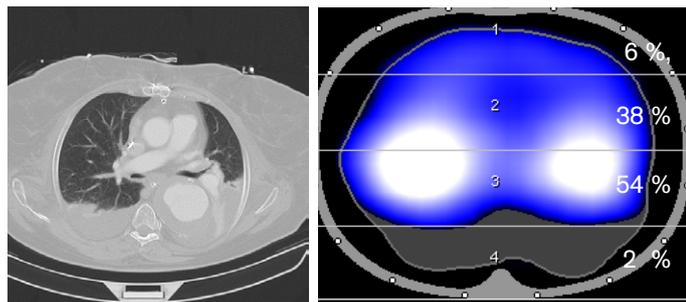
But it should be considered that neuromuscular relaxation and subsequent (mandatory) positive pressure ventilation appears to be a significant factor itself leading to respiratory impairment and potentially to the above cited postoperative pulmonary complications that protective ventilation intends to counteract. Therefore, it seem not too far-fetched to ask, whether spontaneous breathing either as early as possible towards the end of general anaesthesia or even soon after securing the airway may be more beneficial. The following shall briefly highlight what the literature says and what the opinion of clinicians is who have worked on this topic for the past years.

Tip: For further technical background information, see our "technology insights" [e-book](#).

Uneven distribution...

Imaging studies in animals have demonstrated that ventilation is not physiologically distributed during continuous mandatory ventilation (CMV). During CMV, ventilation is being shifted to the anterior, nondependent and less perfused lung regions leading to the well described ventilation/perfusion (V/Q) mismatch¹.

Fig. 1: CT image (A) from a patient with dorsal lung collapse, representing the regional distribution of air content. EIT image (B) from a patient with a comparable lung condition, representing the regional distribution of ventilation.



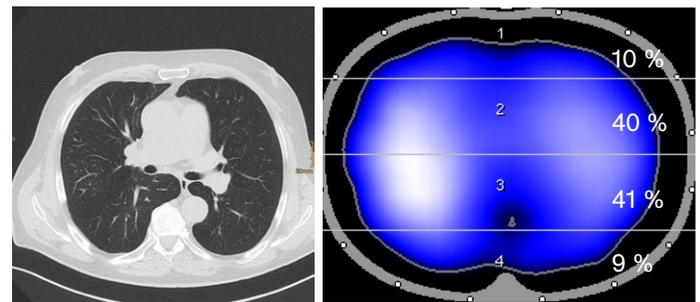
A. Lung collapse as displayed by CT B. Lung collapse as displayed by EIT

This also applies to both, anaesthetised patients with healthy lungs and patients with substantial pulmonary dysfunction. The reason for this supposedly lies in the role of the diaphragm. When pharmacologically relaxed, the intra-abdominal hydrostatic pressure will push against the diaphragm and move it more cranially – with increasing the pressure from anterior to posterior. This counters or even prevents diaphragm movement in the dependent lung regions resulting into ventilation being shifted to the nondependent lung regions and leaving dorsal lung regions close to the diaphragm being less ventilated or atelectatic. In due course mechanically administered tidal volume goes primarily into the anterior, nondependent and less perfused parts of the lung leading to the aforementioned V/Q mismatch⁵.

... getting even

While breathing spontaneously, the posterior parts of the diaphragm move more than the anterior tendon plate resulting in better ventilation of the dependent lung regions even when supine. This results in a better V/Q matching as the diaphragm is able to oppose alveolar compression^{1,5}. The improved aeration of the juxtadiaphragmatic lung regions is the reason for the improved functional residual capacity (FRC) associated with spontaneous breathing¹.

Fig. 2 CT image (C) from a patient with normally aerated lungs, representing the regional distribution of air content; EIT image (D) representing a homogeneous distribution of ventilation.:



C. Normally aerated lung as displayed by CT D. Normally aerated lung as displayed by EIT

Diaphragmatic Excursion

The above was also confirmed in a research studying diaphragmatic excursion by diaphragmatic fluoroscopy during spontaneous breathing and during positive pressure ventilation. The diaphragm was divided into three segments: top (ventral, nondependent), middle and bottom (dorsal, dependent) in order to analyse differences. During normal spontaneous breathing, total diaphragmatic excursion was significantly greater compared to positive pressure breaths. The data from this study clearly show, that when breathing spontaneously, most diaphragmatic excursion is being observed in the bottom, dependent region, no matter if it was a normal breath or a deep breath.

During positive pressure ventilation, excursion of the diaphragm was less in the bottom, dependent part but rather at the top, non-dependent part when lower tidal volumes were applied. Only when having applied larger tidal volumes, diaphragmatic excursion was more or less equal in top and the bottom part of the diaphragm². This may be remarkable having the discussion on lung protective ventilation in mind which demands for low tidal volumes.

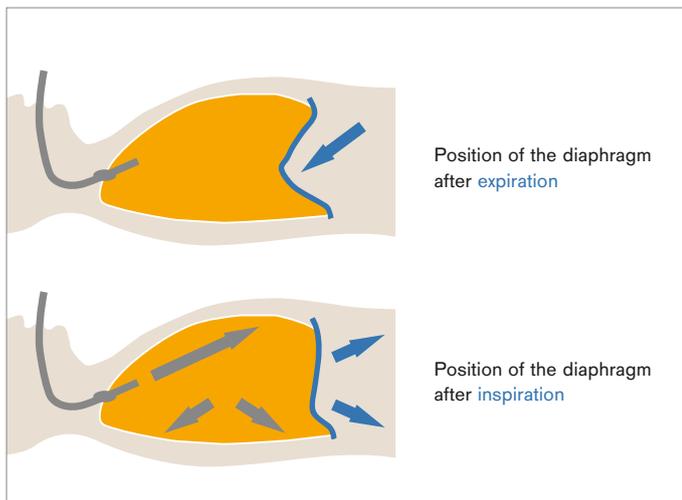


Fig. 3: Diaphragmatic activity during spontaneous breathing favours redistribution of gas to dependent, well perfused areas

Support needed

It appears that spontaneous breathing potentially leads to better ventilator conditions compared to CMV. But during surgery, anaesthetic drugs – especially opioids – impair spontaneous breathing by causing respiratory depression⁷. When comparing general anaesthesia using Isoflurane or Sevoflurane with either positive pressure ventilation (PPV) or spontaneous breathing, it was found that PPV produced better respiratory results compared to spontaneous breathing, specifically with respect to oxygenation and etCO_2 . No differences were observed with regards to haemodynamic parameters. However, in this study, spontaneous breathing attempts were not actively supported by any means⁸.

Brimacombe et al tested if pressure support ventilation (PSV) with PEEP would achieve better results compared to the application of CPAP only, without any tidal support. The results clearly show that PSV results in higher oxygenation saturation, lower etCO_2 values and higher expired tidal volumes compared to CPAP without tidal support thus providing more effective gas exchange³. In another trial, Bosek et al found that a PSV with a pressure titrated to produce a near normal (physiological) V_t improves the efficiency of spontaneous breathing during inhalational anaesthesia by lowering respiratory rate (RR) and PaCO_2 while preserving haemodynamic homeostasis⁴.

But there is another aspect to intraoperative spontaneous breathing that extends into the postoperative period. The above mentioned trial by Keller et al also found that time to emerge from general anaesthesia using Sevoflurane shortened from 12 minutes down to 6 minutes when patients were breathing spontaneously during general anaesthesia⁵. This finding was just recently confirmed by an RCT by Capdevilla et al suggesting that intra-operative PSV in patients with laryngeal mask (LMA) reduces anaesthesia emergence time and Propofol consumption compared to continuous mandatory ventilation. In addition they found, that PSV improved respiratory function and did not cause adverse effects⁶.

CONCLUSION

The above intends to raise spontaneous breathing as a potentially interesting component of lung protective ventilation in the OR resulting in a better ventilation distribution. However, although there is also good reason and absolute necessity for mechanical ventilation for various patients and surgical procedures, spontaneous breathing might be a good option in the future for even more indications as anticipated today. Further research is required to determine these indications and provide evidence for the effectiveness of spontaneous breathing in intraoperative ventilation.

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