Influence of xenon on pulmonary mechanics and tidal volume distribution

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Background

The anaesthetic xenon has organ protective properties [1] and might attenuate ventilator-induced lung injury. Due to its high viscosity, xenon administration increases maximum airway pressure (P_{max}) in mechanically ventilated patients [2]. Since potential barotrauma is rather determined by transpulmonary pressure (P_{tp}), which is influenced by thoracic compliance, we investigated the influence of xenon application on P_{tp} in patients with normal and obesity-associated reduced thoracic compliance. Furthermore, we tested the hypothesis that xenon influences tidal volume distribution, and thus formation of atelectasis during anaesthesia.

Methods

Following study registration (NCT02682758), ethical approval (#5161R, 29/09/15) and written informed consent, 10 patients of normal weight (body mass index, BMI<25 kg m^{-2}) and 10 adipose patients (BMI>30 kg m^{-2}) with healthy lungs undergoing peripheral surgery with xenon-based general anaesthesia were included in this prospective observational study (age 53±18 years). During volume-controlled ventilation (8ml/kg predicted body weight, PEEP 5mbar), P_{tp} was calculated from plateau pressure and esophageal pressure, which was measured using intraesophageal balloon catheters. Secondary outcomes included airway resistance (R_{AW}), static (C_{stat}) and dynamic (C_{dyn}) lung compliance. Further, by means of electrical impedance tomography (EIT, PulmoVista 500, Draeger), dorsoventral distribution of tidal volume was quantified (centre of ventilation index, CVI), and homogeneity of lung aeration was measured (inhomogeneity index, HI [3]). Measurements were taken 1. during awake spontaneous breathing (EIT-derived parameters), 2. after induction of general anaesthesia, as well as 3. during subsequent inhalation of xenon (Fi_{Xe} 0.6, figure 1). *Statistics:* Paired t-test/Repeated measures ANOVA (Sidak post-hoc test), p<0.05.

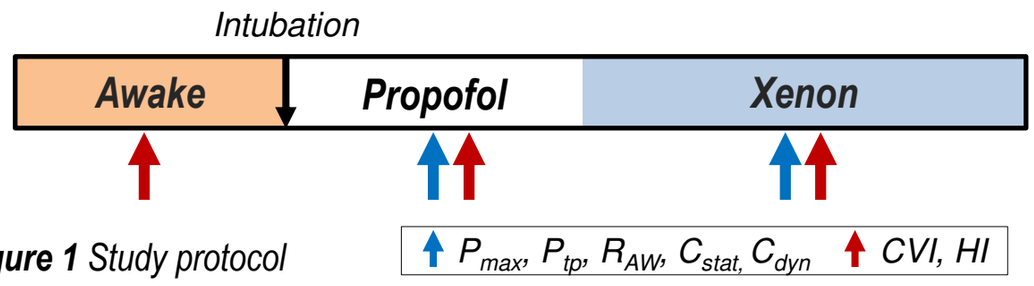

Figure 1 *Study protocol*

Results

Xenon application significantly increased P_{max} by 9%, while P_{tp} remained unaffected (figure 2). Also, xenon increased R_{AW} and consequently reduced C_{dyn} (figure 3), but had no influence on C_{stat} (43.2±9 vs 43.1±10ml*$mbar^{-1}$, p=0.98). After induction of anaesthesia, we observed a significant shift of tidal volume distribution towards ventral lung areas, which was not altered during xenon-based anaesthesia (figure 4). Also, induction of anaesthesia was associated with an increased inhomogeneity of lung aeration (HI 0.35±0,02 vs 0.38±0.03, p<0.05), which remained unaffected by xenon (HI 0.37±0.03, p=0.99). Finally, there were no relevant differences of any primary or secondary outcome depending on patients' BMI.

Conclusion

Xenon application increases P_{max}, but has no influence on transpulmonary pressure, independent of patient's thoracic compliance. Since xenon increases airway resistance and dynamic, but not static compliance, we conclude that the observed effects are due to xenon's relatively high viscosity. Further, xenon does not influence anaesthesia-induced formation of atelectasis. Taken together, we could not identify any potential mechanisms of lung damage due to xenon administration.

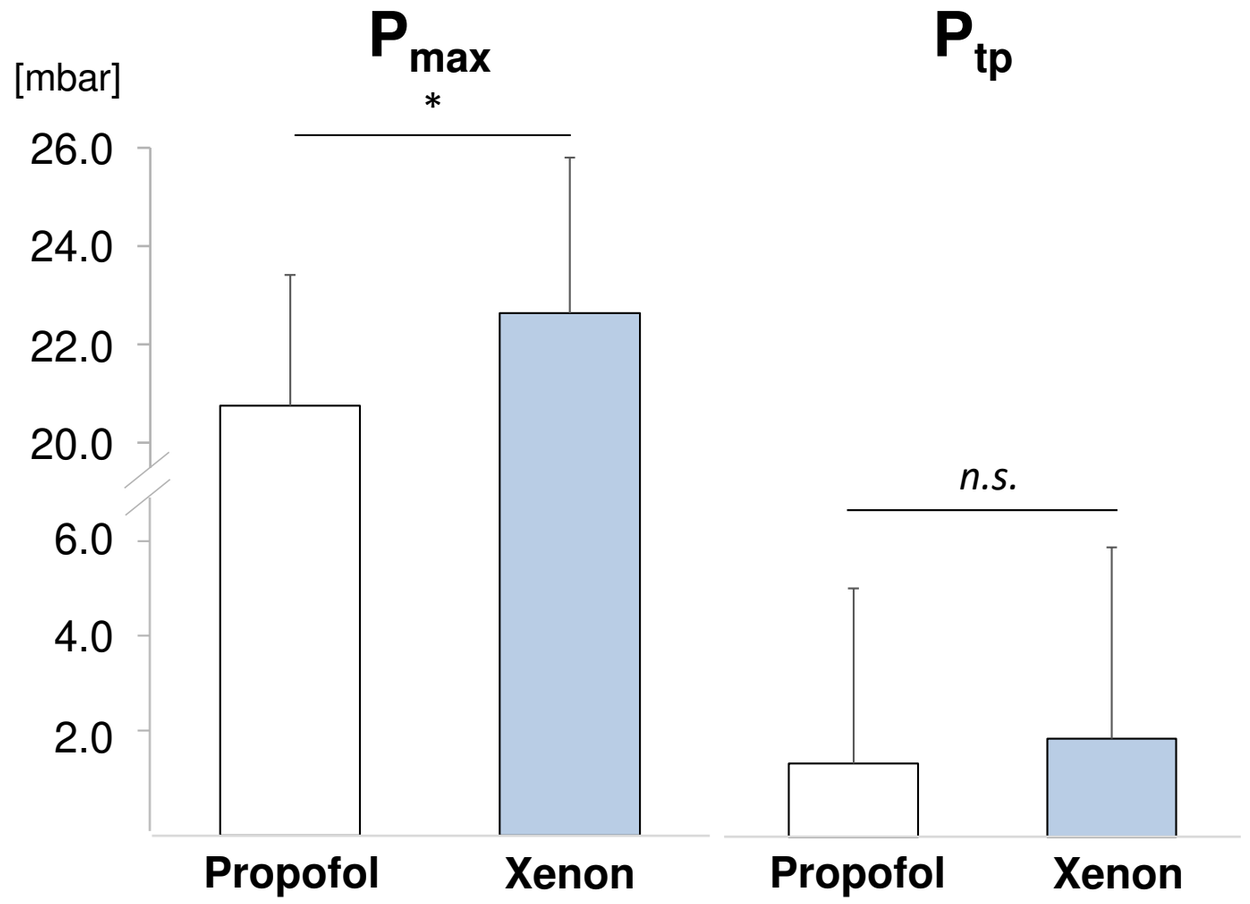

Figure 2 *Maximum inspiratory pressure (P_{max}) and transpulmonary pressure (P_{tp}) during propofol and consecutive xenon-based anaesthesia; mean ±SD; *p<0.05*

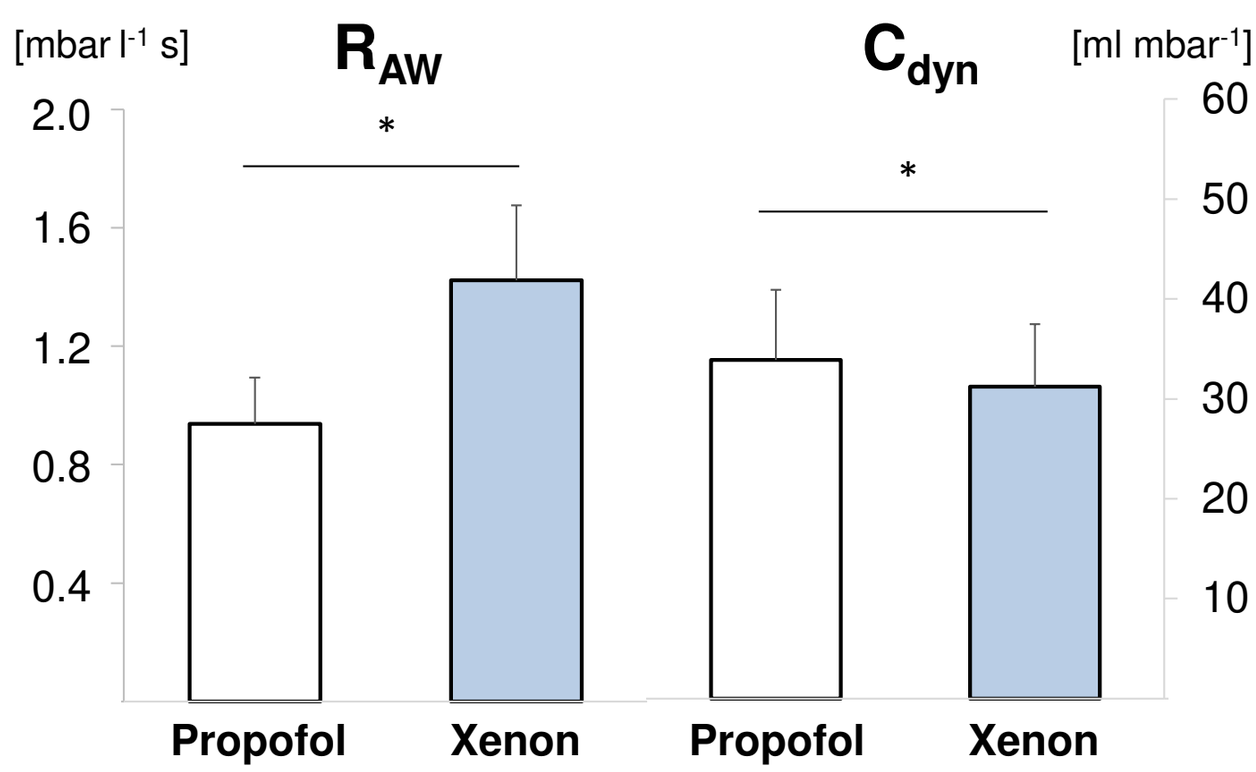

Figure 3 *Airway resistance (R_{AW}) and dynamic compliance (C_{dyn}) during propofol and consecutive xenon-based anaesthesia; mean ±SD; *p<0.05*

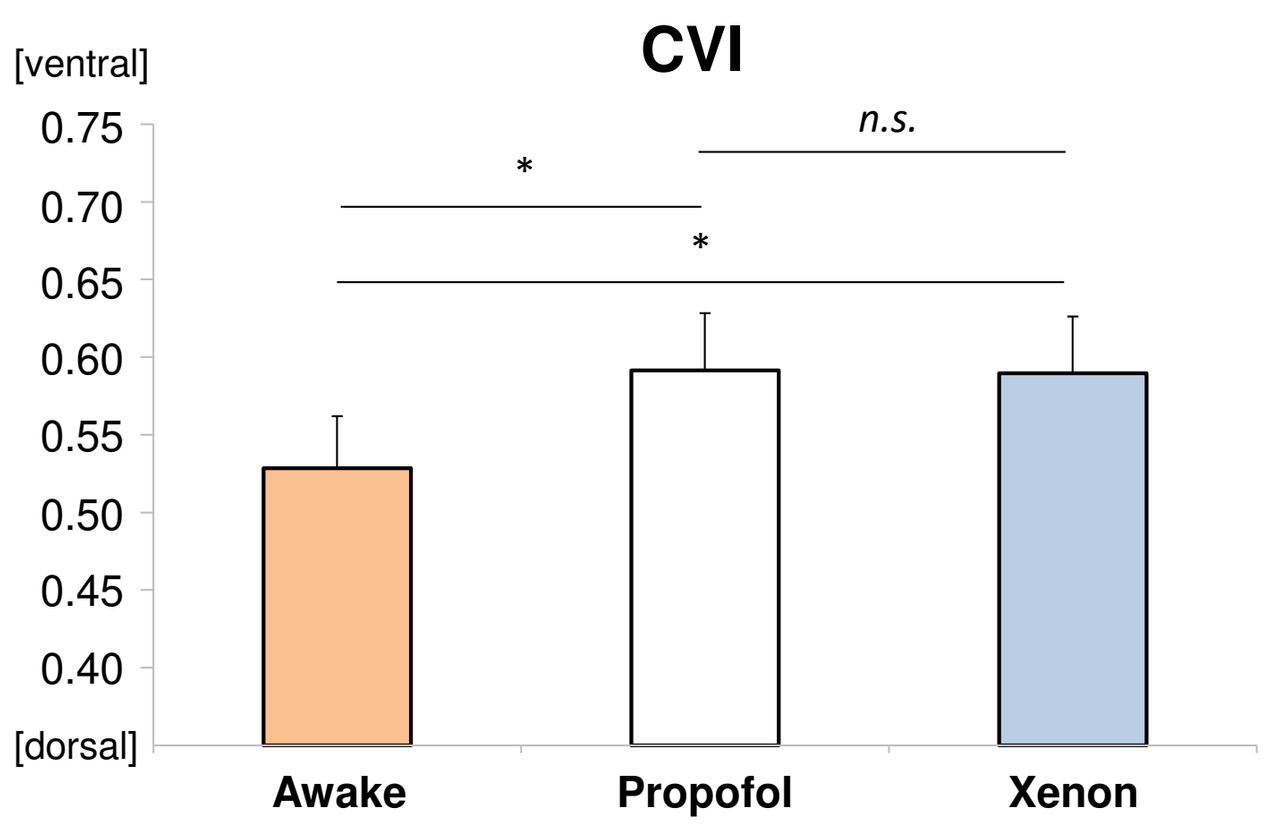

Figure 4 *Center of Ventilation Index (CVI) before induction of anaesthesia, during propofol and consecutive xenon-based anaesthesia; mean ±SD; *p<0.05*

[1] Anesthesiology 2015;122:1312-26 [2] Acta Anaesthesiol Scand 1999;43:1060-4 [3] Int Care Med 2009;35:1900-06