Static and dynamic characteristics of sheep chest wall during mechanical ventilation

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Background & aims

- Sheep are increasingly used as experimental animal model for respiratory diseases in recent years; however, to date knowledge of respiratory mechanics in this species remains lacking.
- The aim of this study was to assess the elastic, resistive and viscoelastic mechanical properties of the chest wall in healthy sheep during mechanical ventilation, in the whole inspiratory capacity range.

Methods

- After sedation, anesthesia and intubation, the rumen of 10 healthy sheep (26-52 kg) was evacuated to avoid related complications, such as abdominal tympanism and aspiration. Animals were then paralyzed and mechanically ventilated in supine position with constant tidal volume (V_{tidal}, 7-8 ml/kg) and variable inspiratory flow ($\dot{V}_{insp}$).
- Chest wall mechanics assessment has been possible thanks to the esophageal pressure recording (P_{es}).
- Mechanical measurements were performed on P_{es} using the technique of rapid airway occlusion during constant-flow inflation, which consists in rapidly interrupting a constant-flow inflation and maintaining lung volume constant during a 5-s post-inspiratory hold (**figure 1**).

- Elastic properties were assessed by static elastance ($E_{st,cw}$) (Eq. 1).
- Resistive properties were measured in terms of interrupter resistance ($R_{int,cw}$), i.e. the ratio between the pressure drop at interruption and the immediately preceding $\dot{V}_{insp}$ (Eq. 2).
- Viscoelastic properties were indexed by the slow pressure decay following end-inspiratory interruption ($\Delta P_{visc,cw}$) (Eq. 3).

$$\mathbf{E_{st,cw}} = \frac{(\mathbf{P_{st}} - \mathbf{P_{ee}})}{\mathbf{V_{tidal}}} \quad \textit{Eq. 1}$$

$$\mathbf{R_{int,cw}} = \frac{(\mathbf{P_{max}} - \mathbf{P_1})}{\dot{\mathbf{V}}_{\mathbf{insp}}} \quad \textit{Eq. 2}$$

$$\mathbf{\Delta P_{visc,cw}} = (\mathbf{P_1} - \mathbf{P_{st}}) \quad \textit{Eq. 3}$$

- Measurements were performed at PEEP 0 (ZEEP), 5, 10 and 15 cmH_2O, to characterize chest wall mechanics in the whole inspiratory capacity range.

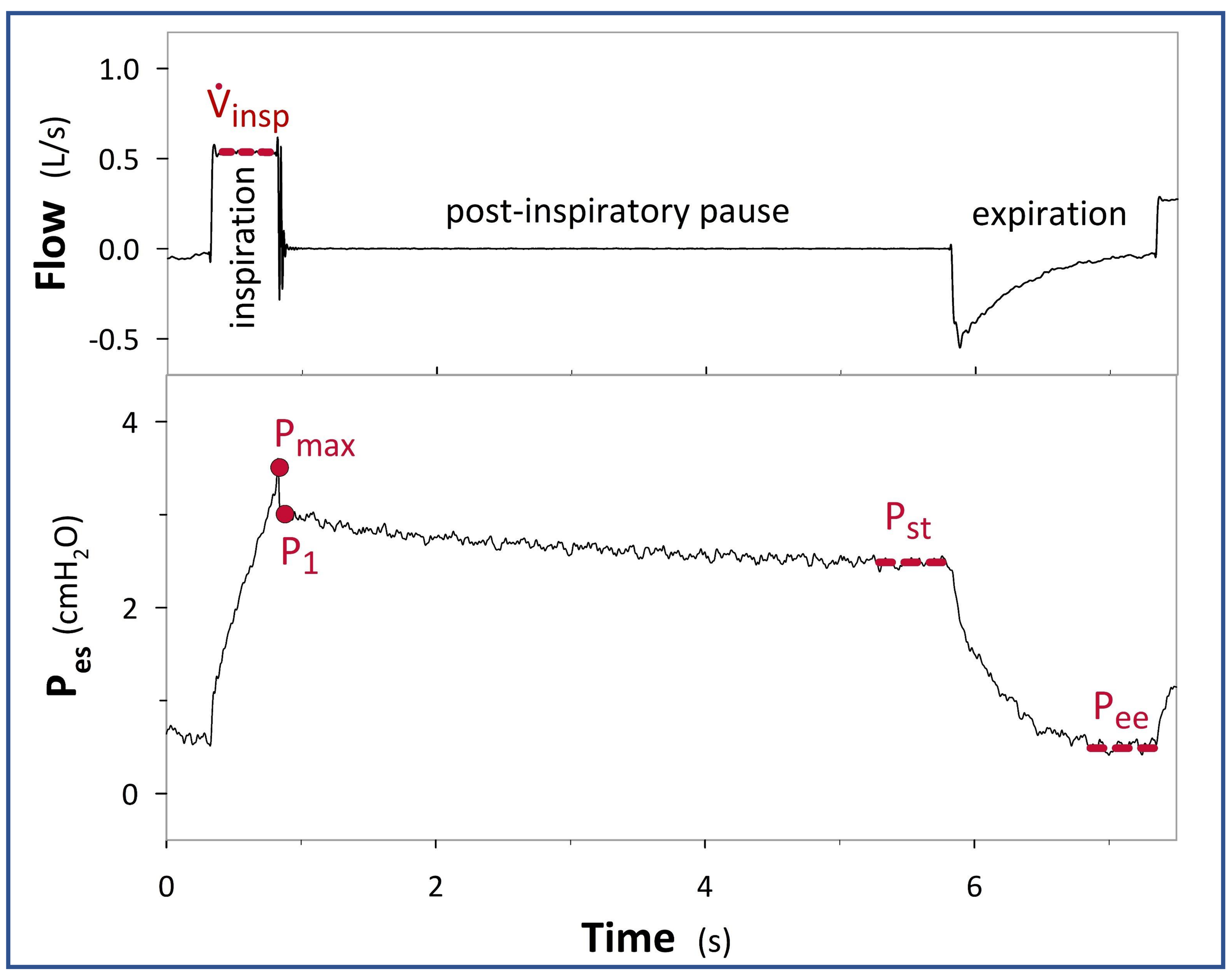
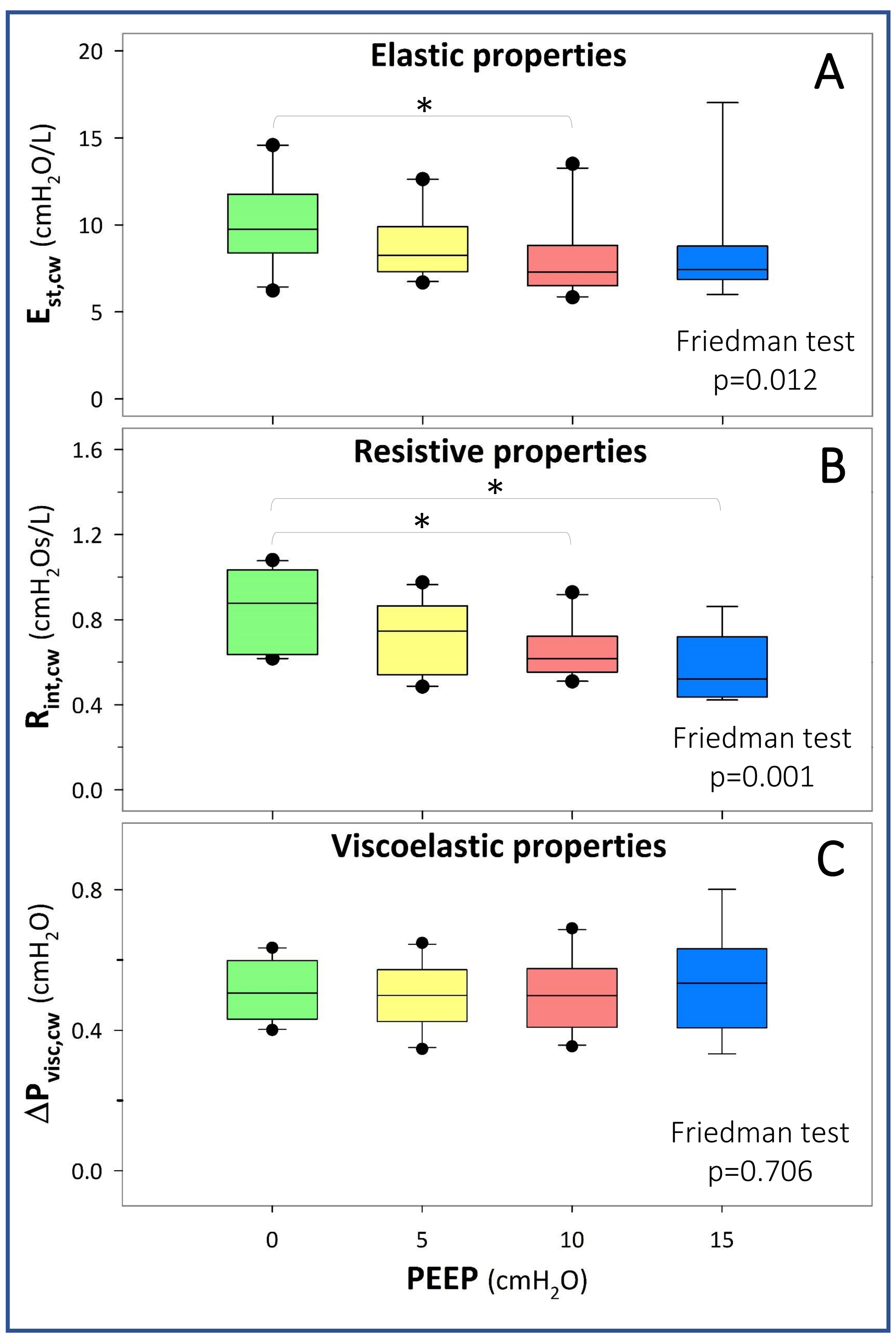


Figure 1. Representative "test breath" showing the technique of rapid airway occlusion during constant-flow inflation, at PEEP 5 cmH_2O.

Results

- Data are expressed as median(IQR), unless otherwise specified.



- At PEEP 0, 5, 10, and 15 cmH_2O, end-inspiratory volume was 42(12), 59(10), 79(9) and 89(5) % of the vital capacity, respectively.
- $E_{st,cw}$ decreased moderately from ZEEP to PEEP 10 cmH_2O (from 9.74(1.91) to 7.30(1.32) cmH_2O/L) (**figure 2**, panel A).
- $R_{int,cw}$ fell by 41% from ZEEP to PEEP 15 cmH_2O (from 0.88(0.38) to 0.52(0.26) cmH_2Os/L) (**figure 2**, panel B).
- On the contrary, $\Delta P_{visc,cw}$ did not vary significantly with PEEP (**figure 2**, panel C).

Figure 2. $E_{st,cw}$ (A), $R_{int,cw}$ (B) and $\Delta P_{visc,cw}$ (C) at each PEEP level; * $p<0.05$.

- The relation between $\Delta P_{visc,cw}/\dot{V}_{insp}$ ($\Delta R_{visc,cw}$, Eq. 4) and inspiratory duration (Ti) could be described at all PEEP levels as an exponential rise to maximum (**figure 3**), as reported for other species.
- The constants describing this relation, $R_{visc,cw}$ and $\tau_{visc,cw}$ (Eq. 4), were similar at all PEEP values.

$$\mathbf{\Delta R_{visc,cw}} = \frac{\mathbf{\Delta P_{visc,cw}}}{\dot{\mathbf{V}}_{\mathbf{insp}}} = \mathbf{R_{visc,cw}}\left(\mathbf{1} - \mathbf{e}^{-\frac{\mathbf{Ti}}{\tau_{\mathbf{visc,cw}}}}\right) \quad \textit{Eq. 4}$$

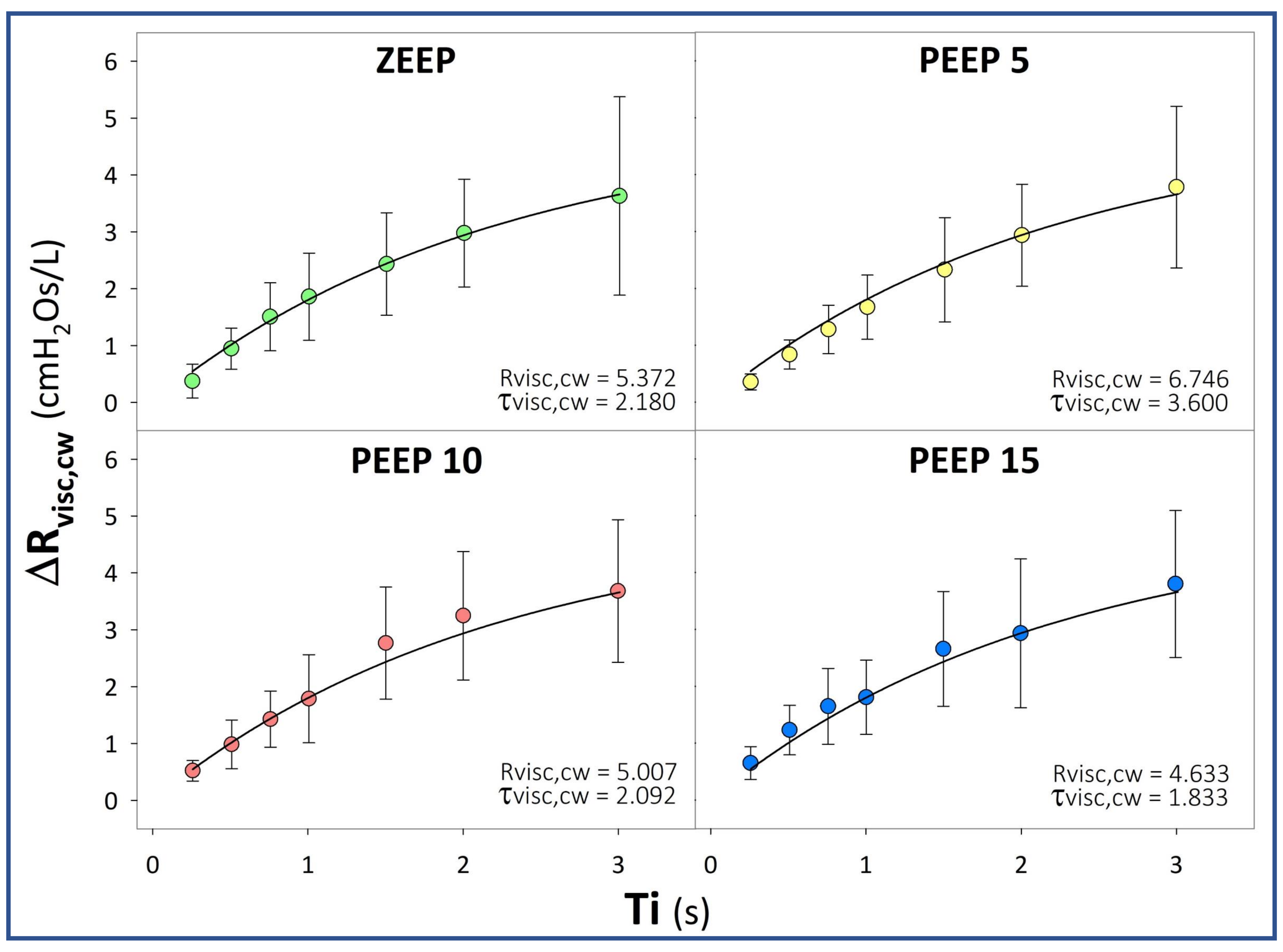


Figure 3. Relations between Ti and $\Delta R_{visc,cw}$ at each PEEP level, with corresponding $R_{visc,cw}$ and $\tau_{visc,cw}$ values. Circles and bars are mean±SD.

Conclusions

- Elastic and viscoelastic properties of sheep chest wall are relatively invariant in the inspiratory capacity range, while interrupter resistance tends to decrease with increasing volume.
- This implies that, in this species, elastic or viscoelastic modifications of lung mechanics induced by an experimental disease affecting the lung only, can be monitored in terms of corresponding mechanical variations at the level of the whole respiratory system, even in presence of a concomitant change in the operating lung volume.
- Conversely, when estimating airway resistance from interrupter resistance of the whole respiratory system, small variations of airway resistance may be masked by changes of chest wall resistance, but only when lung volume varies considerably.