Comparison of EIT-derived regional lung opening pressures with global measures of lung mechanics.

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Abstract: A low-flow pressure-volume curve is often used to assess the mechanical properties of the lungs in mechanically ventilated patients. We compared the curve's lower point of maximal curvature, derived from 4 different sigmoid models, with the mean dorsal lung opening pressure, determined with EIT.

1 Introduction

A low-flow pressure- (P) volume (V) curve is the result of a diagnostic manoeuvre that is frequently used to analyse the mechanical lung properties of patients with acute respiratory failure. In clinical studies, setting the positive end-expiratory pressure 2 mbar above the lower point of maximum curvature (LPMC) of this curve has been an essential part of "lung-protective" ventilation strategies leading to improved clinical outcomes [1,2]. Several sigmoid models to describe the shape of the curve and to identify the LPMC have been proposed [3-6]. However, these models may yield significantly different results [7]. In the present study, we compared the LPMC values, derived from four different models, with the mean dorsal lung opening pressure (ROP), determined with EIT.

2 Methods

We analysed a standardised low-flow P-V curve in 21 intensive care unit patients mechanically ventilated with the Evita XL ventilator (Dräger Medical, Lübeck, Germany). EIT data were recorded with the GOE-MF II device (CareFusion, Yorba Linda, USA) at a scan rate of 25 images per second.

The ventilation data were fitted to the following four model equations by non-linear optimisation with a Nelder-Mead simplex algorithm using Matlab (The MathWorks Inc., Natick, USA) (Figure 1).

Venegas [3]: $$V(P) = a + \frac{b}{1 + e^{-\frac{P-c}{d}}} \quad (1)$$

Pelosi [4]: $$V(P) = \frac{b}{1 + e^{-\frac{P-c}{d}}} \quad (2)$$

Henzler [5]: $$V(P) = \frac{V_0 - V_0 e^{-kP}}{1 + e^{-\frac{P-c}{d}}} \quad (3)$$

Heller [6]: $$V(P) = a + \frac{b}{\left(1 + e^{-\frac{P-c}{d}}\right)^s} \quad (4)$$

For models 1 and 2, the LPMC was calculated from the fitting parameters c and d according to the equation:

$$LPMC = c - 1.317d \quad (5)$$

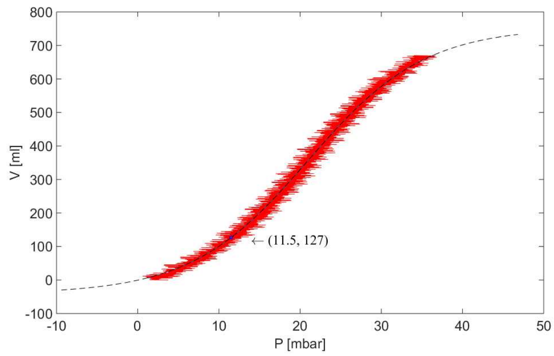

Figure 1: Example of a sustained inflation P-V curve, fitted to equation 1. In this example, the LPMC was identified at a pressure of 11.5 mbar. Red line: measured P-V data. Black line: fitted model curve.

For model 3, the minimum of the second derivative, corresponding to the LPMC, was calculated numerically after computing a second-order approximation of the second derivative of the fitted model. For model 4, the LPMC was calculated according to:

$$LPMC = c - d\ln\frac{(3s+1) - \sqrt{5*s^2+6s+1}}{2s^2} \quad (6)$$

ROPs were determined as described in reference [8]. The mean ROP of the dorsal region of interest was compared to the LPMC values derived from the four models by linear regression and by the Bland-Altman analysis.

3 Results

We found a mean dorsal ROP of 9.2±3.6 (mean±SD) mbar and LPMC values of 5.7±4.9, 11.2±2.7, 7.7±3.7 and 5.6±4.3, mbar for models 1, 2, 3 and 4, respectively. The best correlation between LPMC and the mean dorsal ROP was found for model 2 ($r^2 = 0.48$; $p = 0.0005$; bias + 2 mbar, 95% limits of agreement -3.1 to +7.0). The models 1, 3 and 4 showed weaker correlations (r^2=0.09, 0.19 and 0.29, respectively) and broader 95% limits of agreement.

4 Conclusions

In our study, we found that the Pelosi model lead to LPMC values with the closest correlation to the mean dorsal lung opening pressures.

References

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