Correlation between hypertonic saline transit time measured with EIT and cardiac output

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Abstract: Here we analysed EIT data from experiments in healthy swine models undergoing one or two lung mechanical ventilation for 24 hours. We measured the heart-to-lung and right-to-left heart transit times of a 10 ml bolus of hypertonic saline by EIT and tested their correlation with cardiac output measured by transpulmonary thermodilution.

1 Introduction

Assessing the trend over time of cardiac output is essential to guide personalised fluid resuscitation, to verify the impact of mechanical ventilation settings and to follow up recovery from myocardial injury. Pulmonary artery catheters (PAC) remain the clinical gold standard for measuring cardiac output, but less invasive monitoring should be developed. To date, most systems still require an arterial catheter and, possibly, a central line [1]. Here we explored the correlation between cardiac output and .the transit time (TT) of a hypertonic saline bolus measured by electrical impedance tomography (EIT). Significant correlation could suggest a potential for less invasive monitoring for trends of cardiac output over time by EIT plus a central line.

2 Methods

The study was approved by the Italian Ministry of Health, Rome, Italy (Aut. No. 246/2022-PR, Protocol No. 568EB.34 (ex 32)). We analysed data from 28 healthy swine studied in our laboratory, comprising n=134 independent cardiac output (CO) measurements performed with the thermodilution method (Vigilance, Edwards, US) by means of a PAC. Immediately after, EIT data were acquired at a 50 Hz sampling frequency (Pulmovista, Drager, Germany). An end-inspiratory pause was performed and a 10 ml bolus of 5% NaCl was injected via jugular central line [2]. These measures were performed after 2, 6, 12, 18 and 24 hours of controlled mechanical one-lung ventilation with tidal volume 7.5 ml/kg (OLV7.5, n=46), with tidal volume 15 ml/kg (OLV15, n=58) and two-lung ventilation with tidal volume 15 ml/kg (n=30). The impedance change corresponding to the hypertonic bolus flowing through the pulmonary circulation was analysed. Baseline drift was subtracted by piecewise linear fitting, as previously described [3]. Indicator transit time through lung circulation was modelled as a gamma-variate, which was fitted to data with the method of moments [4]. The fitted curve was then subtracted to data, so that three peaks corresponding to saline passage through the right heart (RH), the lungs and the left heart (LH) were apparent (Fig. 1A-B).

For each of the three peaks the first order temporal moment was calculated as in equation (1).

$$\mu'_1 = \frac{-\sum t * Z(t)}{\sum C\,(t)} \quad (1)$$

Z(t) is impedance over time and t is time

The right heart to lung ($TT_{RH\text{-}lung}$) and the right to left heart ($TT_{RH\text{-}LH}$) transit times were calculated as the difference between the corresponding moments.

Coefficients of correlation and p-values were calculated from Spearman’s rank correlation.

3 Results

Cardiac output ranged between 1.7 and 6.8 l/min. We disclosed a significant non-linear correlation between cardiac output and both transit times: $TT_{RH\text{-}lung}$ (ρ=-0.41; p<0.001) and $TT_{RH\text{-}LH}$ (ρ=-0.45; p<0.001) (Fig. 1C-D).

4 Conclusions

Hypertonic saline transit times measured by EIT are correlated with cardiac output and could be used as a less invasive measure to assess CO trends over time.

References

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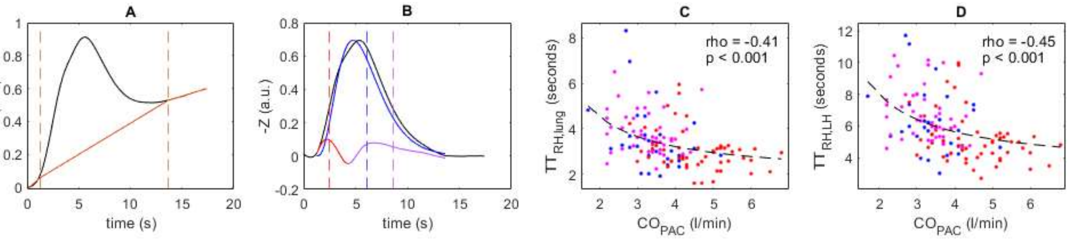

Figure 1: A – Impedance change due to the hypertonic saline bolus. Bolus arrival and end time are displayed as orange dashed lines, the estimated drift as an orange solid line. B – Impedance after detrending (black line). Blue line is the fitted gamma-variate, passage through the right and left heart are displayed respectively as a red and a purple solid line. First temporal moments are identified by vertical dashed lines of corresponding colours. C and D – transit times plotted versus cardiac output measured at the PAC, blue dots correspond to controls, red dots to OLV7.5, magenta dots to OLV15 animals (see text).