Capnodynamic determination of cardiac output (effective pulmonary blood flow, EPBF) in pulmonary hypertension and inhaled nitric oxide treatment in pigs.

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Background

Pulmonary hypertension (PHT) is associated with significant anesthetic risks and major complications in children.

Effective pulmonary blood flow (CO_{EPBF}) has recently been validated for its ability to measure cardiac output (CO) in animals and children (1,2).

We have compared CO_{EPBF} with direct CO_2 Fick (CO_{Fick}) and invasive pulmonary artery flow probe (CO_{TS}), in a porcine model of hypoxia-induced selective pulmonary vasoconstriction.

$$ELV \cdot (FACO_2^{\,n} - FACO_2^{\,n-1}) = EPBF \cdot \Delta t^{\,n} \cdot (CvCO_2 - CcCO_2^{\,n}) - VTCO_2^{\,n}$$

The left side reflects the difference in CO_2 content in the lung between two breaths and the first term on the right side describes the circulatory supply of CO_2 in the alveolar compartment between two breaths.

ELV, effective lung volume (litre) containing CO_2 at the end of expiration; EPBF, effective pulmonary blood flow (liter/min); n, current breath; n-1, previous breath; $FACO_2$, alveolar CO_2 fraction; $CvCO_2$, venous carbon dioxide content (litre/litreblood); $CcCO^n_2$, lung capillary CO_2 content (calculated from $FACO_2$); $VTCO^n_2$, volume (litre) of CO_2 eliminated by the current, nth, breath; Δt^n, current breath cycle time (min).

Equation 1. Calculating effective pulmonary blood flow using mole balance

DC has been developed based on CO_2 elimination (VCO_2) by the lungs in ventilated patients and uses the Differential Fick's principle (1)*. **By continuously cycling betweeen breaths with normal I:E relationship and breaths with expiratory pause, variations in $EtCO_2$ are created. These variations are proportional to pulmonary blood flow (Equation 1).*** This provides continuous breath-by-breath cardiac output monitoring.

Methods

10 anaesthetized mechanically ventilated piglets (median weight 23.9 kg) were exposed to a hypoxic gas mixture -> selective pulmonary vasoconstriction. Pulmonary vasoconstriction was subsequently reversed with inhaled nitric oxide. Simultaneous recordings of CO_{EPBF}, CO_{Fick} and CO_{TS}.

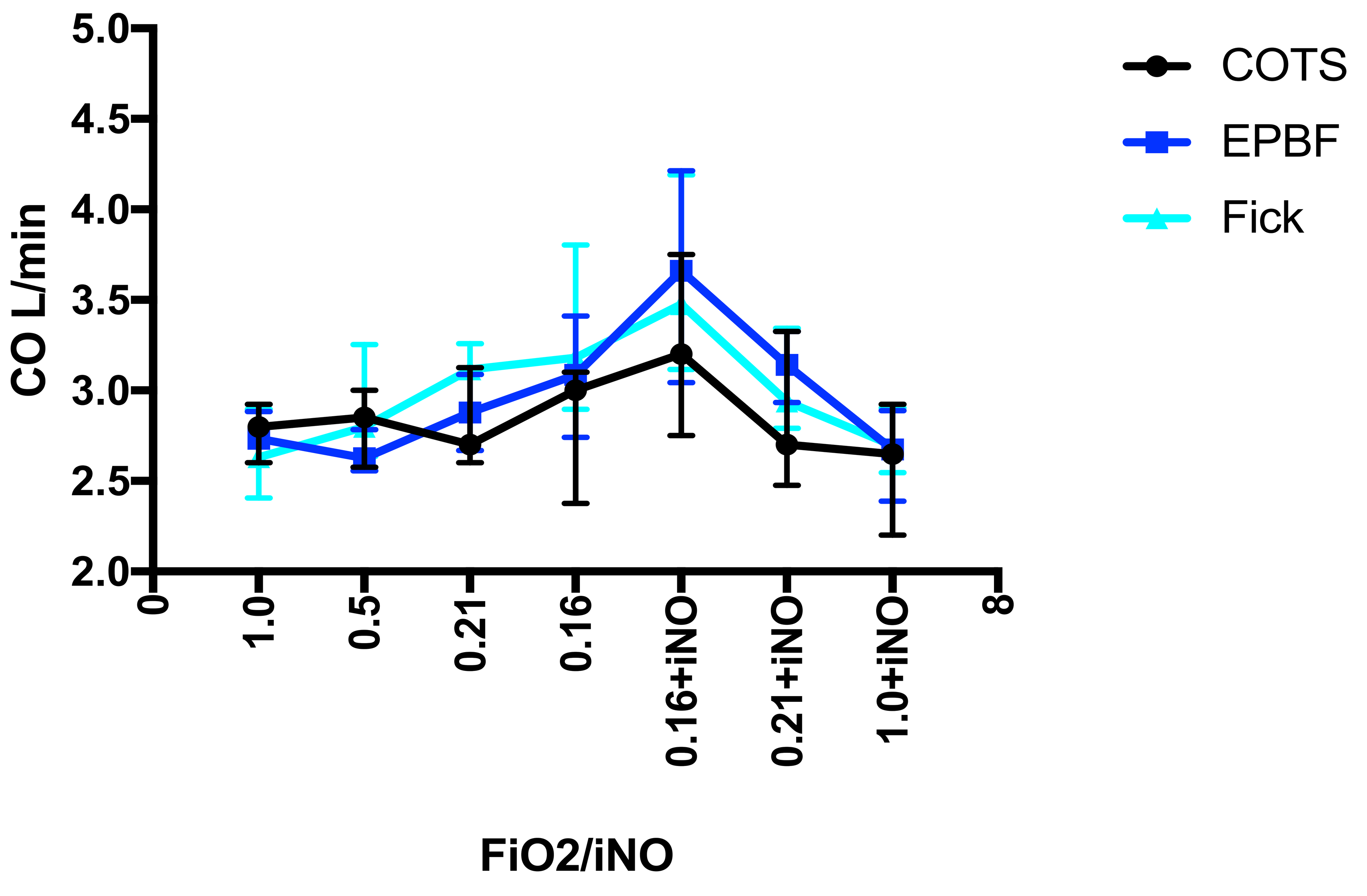

Fig1. Time plot CO. protocol. Median+/-range

Results

Overall bias between CO_{EPBF} and CO_{TS} was -0.25 L/min (limits of agreement -1 and +0.5 L/min), mean percentage error of 25%. Overall bias between CO_{EPBF} and CO_{Fick} was -0.08 L/min (limits of agreement -0.8 and +0.7 L/min) and a mean percentage error of 24%. The concordance rate was 90% for CO_{EPBF} when compared with CO_{TS} using a 15% exclusion zone.

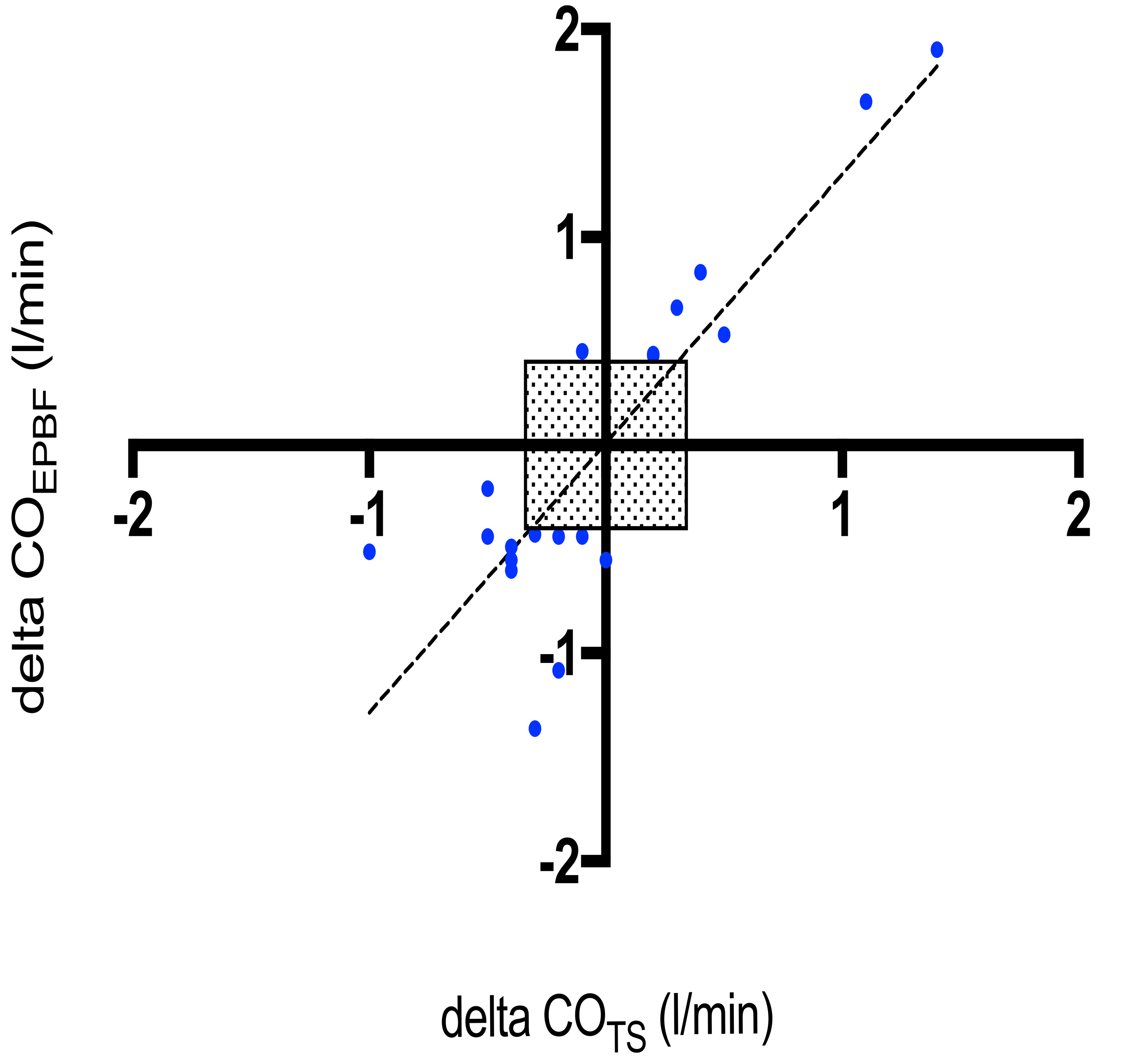

Figure 2. Four quadrant plot

Conclusion

Estimation of cardiac output with CO_{EPBF} is interchangeable with the highly invasive gold standard reference methods CO_{Fick} and CO_{TS}. CO_{EPBF} appears to be an accurate tool for monitoring absolute values and changes in cardiac output during hypoxia, pulmonary hypertension and inhaled nitric oxide treatment.

1. Hällsjö Sander C1, Hallbäck M, Wallin M, Emtell P, Oldner A, Björne H. Novel continuous capnodynamic method for cardiac output assessment during mechanical ventilation. Br J Anaesth. 2014; 112: 824-31.

2. Karlsson et al, Validation of capnodynamic determinations of cardiac output (Effective Pulmonary Blood Flow, EPBF) in anaesthetized children: a human and porcine study. In press BJA 2018.