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Gold standard must be solid gold

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Dear Editor,
In search of an optimal haemodynamic treatment strategy, much interest has risen in advanced haemodynamic monitoring in paediatric patients. Therefore, it was with great interest that we read the article by Floh and colleagues [1].

However, we do have concerns about their validation study of the transpulmonary ultrasound dilution (TPUD) technology in paediatric patients after biventricular repair.

In this study, TUPD is validated against the oxygen-Fick (O_2F) method, that can be regarded as the gold standard of cardiac output (CO) measurement in a clinical setting.

Prerequisites for the O_2F method are: accurate measurements of oxygen consumption, arterial oxygen content and mixed venous content ($CmvO_2$). Any error in measurement in these vital parameters will directly result in an inaccurate calculation of CO. $CmvO_2$ calculation demands sampling of blood via a pulmonary artery catheter. In this study, central venous blood was sampled from the internal jugular vein (86 %), subclavian vein (6 %), femoral vein (6 %) and right atrium (3 %). It is known that central venous oxygen saturation ($ScvO_2$) does not reflect mixed venous oxygen saturation ($SmvO_2$) and that the difference between these parameters is influenced by the venous sampling site, presence of left-to-right shunt, redistribution of blood flow, level of consciousness (anaesthesia) and myocardial oxygen consumption. Limits of agreement (LOA) between $SmvO_2$ and $ScvO_2$ range from ± 15 to ± 25 % (see Table. 1).

Use of erroneous venous oxygen saturation in this order to calculate venous oxygen content, which is used in the Fick equation, may overestimate cardiac output up to sixfold (see Fig. 1) Hence, the O_2F method is not applied as should be and therefore, cannot be regarded as gold standard under these conditions.

Table 1 Limits of agreement between mixed oxygen saturation (PA) and central venous oxygen saturation (SVC)

Patients	LOA (= 1.96xSD) (%)
Adults in shock [2]	±21.3
Children post cardiac surgery [3]	
Day 0	±25.3
Day 1	±15.9
Day 2	±16.5
Day 3	±16.5
Day 4	±14.3

Fig. 1 Example calculation to demonstrate the effect of the use of erroneous venous oxygen saturation values to calculate cardiac output using the Fick equation

Weight	5 kg
Hemoglobin, Hb	8 mmol/L (12.9 g/dL)
Arterial oxygen saturation, SaO_2	99%
Mixed venous oxygen saturation, $SmvO_2$	75%
Oxygen consumption, VO_2	8 mL/kg/min = 40 mL/min
LOA $SmvO_2$ versus $ScvO_2$	± 20%

$$Oxygen\ Content\ (mL/L) = Hb(g/L) \times sO_2(gradient) \times 1.36$$ [contribution pO_2 is neglected]

$$Cardiac\ Output = \frac{VO_2}{CaO_2 - CmvO_2}\ (L/min)$$

Calculated Cardiac Output →
- (ScvO2 55%) → 0.519 L/min = 104 mL/kg/min = 55%
- (SmvO2 75%) → 0.951 L/min = 190 mL/kg/min = **100%**
- (SmvO2 95%) → 5,708 L/min = 1142 mL/kg/min = 600%

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Transpulmonary ultrasound dilution technology is extensively validated in an experimental animal model under several haemodynamic circumstances against a true gold standard, transit time flow probes, with an error percentage less than 30 % [4–6].

In our opinion, this study demonstrates the opposite from its original intention, namely that the O_2F method is imprecise when incorrectly applied with the use of central venous oxygen content instead of mixed venous oxygen content.

Conflicts of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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