Optimization of cardiac output by incremental fluid administration is associated with iatrogenic haemodilution and a paradoxical decrease in oxygen delivery

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Background and Goal of Study: Fluid administration may cause iatrogenic haemodilution that may eventually lead to avoidable blood transfusions [1]. We examined the effects of incremental fluid loading aimed at increasing the cardiac output (CO) on non-invasive (SpHb) and laboratory determined (BHb) haemoglobin levels.

Materials and Methods: After informed consent, 40 adult patients undergoing major gastrointestinal or vascular surgery were included. Oxygen saturation (SpO₂) and SpHb were continuously measured by a Radical-7 Pulse CO-Oximeter (Masimo Inc.). BHb and PaO₂ were intermittently measured (ABL800 Radiometer). CO and stroke volume (SV) were continuously measured using a minimally invasive uncalibrated CO monitoring system (Vigileo, Edwards). Oxygen delivery (DO₂) was calculated as $CO \times ((BHb \times 1.38 \times SpO_2) + (PaO_2 \times 0.0031))$. Baseline values were recorded after induction of anaesthesia (T0) and 5 min after the administration of a 250 ml colloid fluid challenge (FC) (T1). In patients whose SV increased $\geq 10\%$ compared to T0, another FC was given and all parameters recorded 5 minutes after its completion (T2). The same protocol was repeated at T2 and T3 values were obtained. Student's paired and unpaired tests, Wilcoxon signed rank test and ANOVA were used where appropriate.

Results and Discussion: All 40 patients received one FC (T1), 32 patients received 2 FCs (T2), and 20 patients received 3 FCs (T3). Figure 1 represents the median values of SpHb, BHb, CO and DO₂ and their percentiles during the study and the number of patients studied at each time point. There was a statistically significant decrease in SpHb and BHb after each FC associated with a significant increase of CO and DO₂ in comparison with T0 values.

Figure 1: SpHb, BHb, CO and DO₂ values during the study.

Among the 20 patients who received 3 FCs and reached T3, the CO and the DO₂ increased between T0-T1 and T1-T2. However, after the last FC the CO remained unchanged but the DO₂ decreased significantly (T2-T3, figure 2). The SpHb and BHb decreased similarly after each FC (Figures 2 and 3). The decrease in SpHb and the BHb after the infusion of 750 ml colloids was 1.66 ± 0.67 and 1.7 ± 0.7 g/dL, respectively.

This significant decrease in Hb values explains the observed decrease in the DO₂. There was a gradual increase in the mean SV between T0-T1, T1-T2, and T2-T3. However, the DO₂ remained unchanged between T0-T1, increased significantly only from T1-T2 and decreased significantly between T2 and T3.

Figure 2: Evolution of SpHb, BHb, CO and DO₂ values in patients receiving 3 fluid challenges (T3)

Figure 3: Error grid plot based on clinical concordance categories defining the level of agreement between $\Delta SpHb$ and ΔBHb data pairs in patients who received 3 FC (T3). Zone 1 (yellow): SpHb and BHb change in the same direction and to the same extent, resulting in correct treatment decisions. Zone 2 (magenta): SpHb and BHb change in the same direction but not to the same extent, resulting in exaggerated or insufficient therapy. Zone 3 (green): SpHb changes while BHb is constant or vice versa, reflecting unnecessary or necessary but withheld therapy. Zone 4 (red): opposite changes in SpHb and BHb, resulting in opposite treatment.

Conclusions: Fluid loading in goal-directed therapy may cause a paradoxical decrease in DO₂ due to iatrogenic haemodilution. The continuous monitoring of SpHb provides real-time reflection of hemodilution. The changes observed in the SpHb trend are similar to the changes in intermittent BHb values.