**In vitro** oxyhaemoglobin saturation measurements in haemoglobin solutions using fibreoptic pulmonary artery catheters

C. S. KONG, I. G. RYDER, R. KAHN, L. GREGORY AND C. F. MACKENZIE

**Summary**

We compared *in vitro* oxyhaemoglobin saturations using two pulmonary artery catheters (catheter So₂) with oxyhaemoglobin saturations (So₂) measured by the IL282 co-oximeter and derived partial oxyhaemoglobin saturations (partial So₂) at different oxygen tensions (Po₂) in six solutions: whole blood, 50:50 mixture of whole blood and Plasmalyte A (haemodiluted blood), 50:50 mixture of whole blood and 8% pyridoxylated haemoglobin-polyoxyethylene (PHP) conjugate (WB-PHP), 75:25 mixture of 8% PHP and Plasmalyte A solution (PHP66), 50:50 mixture of 8% PHP and Plasmalyte A solution (PHP44) and stroma-free haemoglobin solution (SFH). Calculated Po₂ values (Po₂ vs So₂) were 3.79, 3.58, 3.49, 3.15, 3.04 and 2.07 kPa, respectively. However, if partial So₂ was used the curves were shifted to the left, reducing Po₂. Catheter So₂ correlated well with So₂ in whole blood (r² > 0.99 for both catheters), haemodiluted blood (r² > 0.98 for both catheters) and WB-PHP solution (r² = 0.94 for both catheters). In PHP44 (r² = 0.64 and r² = 0.57), PHP66 (r² = 0.40 for the Oximetrix and r² = 0.25 for the Edwards catheter) and SFH solutions (r² = 0.33 for the Oximetrix and r² = 0.22 for the Edwards catheters) both catheters performed poorly. We conclude that mixed venous oxyhaemoglobin saturations measured by oximetric pulmonary artery catheters are inaccurate in the presence of haemoglobin solutions. For accuracy a multi-wavelength co-oximeter should be used if blood containing PHP or SFH is to be analysed. (Br. J. Anaesth. 1995; 74: 201–208)

**Key words**


Investigations in our laboratory, using a dog model of haemorrhagic shock [1, 2], showed that haemoglobin solutions used during resuscitation interfered with the accuracy of mixed venous oxyhaemoglobin saturations (So₂) measured by two types of commercially available fibreoptic pulmonary artery catheters.

Pyridoxalated haemoglobin-polyoxyethylene conjugate 8% (PHP88) and stroma-free haemoglobin (SFH) are under investigation as blood substitutes. PHP is synthesized from SFH derived from outdated human red blood cells [3]. Pyridoxalation of haemoglobin reduces oxygen affinity, increasing Po₂ to 20.4 mm Hg (2.72 kPa) compared with 14.0 ± 1 mm Hg (1.87 ± 0.13 kPa) for SFH and 26.4 ± 0.4 mm Hg (3.52 ± 0.05 kPa) for whole blood. Conjugation with carboxymethyl–carboxymethoxy–polyoxyethylene increases the molecular weight which prolongs the intravascular half-life of PHP in comparison with SFH [3]. These modifications also reduce oxygen affinity and the risk of renal toxicity, and increase oncotic activity.

Measurement of So₂ during resuscitation in haemorrhagic shock can guide fluid therapy, and may be useful as a monitor of changes in cardiac output and oxygen transport [4, 5]. A previous study in dogs showed that the accuracy and stability of the Oximetrix P7110 Shaw Opticath catheter was superior to the Edwards Swan-Ganz Sat 2 catheter during adverse physiological conditions [6]. So₂, measured by fibreoptic reflectance spectrophotometry has been reported to be unreliable in various conditions, including methaemoglobinemia [7], hyperbilirubinaemia [8], hypertriglyceridaemia [9] and severe anaemia [10].

We therefore studied the effects of PHP and SFH on examples of two commonly used oximetric pulmonary artery catheters, the two-reference wavelength Swan-Ganz Sat 2 catheter (American Edwards Laboratories, Santa Ana., CA, USA) and the three-reference wavelength Oximetrix P7110 Shaw Opticath (Abbott Laboratories, Mountain View, CA, USA), on their ability to measure oxyhaemoglobin saturations (catheter So₂) during haemodilution with Plasmalyte A solution, PHP88 and SFH compared with oxyhaemoglobin saturations (So₂) and partial oxyhaemoglobin saturations (partial So₂) at different tonometered oxygen tensions (Po₂).

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The IL282 co-oximeter uses transmission spectrophotometry, and measures \( S_0 \) or the amount of oxyhaemoglobin expressed as a percent fraction of the amount of total haemoglobin \([11]\). It is defined by the following relationship:

\[
\frac{cHbO_2/(cO_2Hb + cHb + cHbCO + cHbMet)}{cO_2Hb/cHb}
\]

where \( cHbO_2, \) \( cHb, \) \( cHbCO, \) \( cMetHb, \) \( cHb = \) concentrations of oxyhaemoglobin, deoxyhaemoglobin, carboxyhaemoglobin, methaemoglobin and total haemoglobin, respectively.

Partial \( S_0 \) is the percentage fraction of the amount of oxyhaemoglobin in blood to the amount of haemoglobin able to bind oxygen \([11]\). Partial \( S_0 \) is obtained from the equations:

\[
\frac{cO_2Hb}{cO_2Hb + cHb} \times 100 \text{ or }
\frac{cO_2Hb}{cHb - cMetHb - cHbCO} \times 100
\]

### Materials and methods

\( P_0_2 \) of the test solutions was adjusted using the Macro Whole Blood Module K-102 of the Linear KGT-3/4 Tonometer (Linear Tonometers Inc., Commack, NY, USA). Peripheral venous blood (50 ml) obtained from one of the authors was heparinized and used to partially fill the blood tonometry chamber which was immersed in a water bath at 37 °C. Anti-foaming reagent (R-108) was then bubbled through the chamber. We did not use the *in vitro* test system described by Reynolds and colleagues \([12]\) because it appeared to require considerable quantities of blood and our haemoglobin solution supplies were limited.

The Oximetrix and Edwards catheters were inserted through lumens in the rubber stopper of the tonometer together with a blood sampling needle making an airtight seal. The catheters were then calibrated *in vitro* according to the manufacturer's specification before immersion into blood. In one study the variability between measurements of 10 different Oximetric catheters when calibrated in this manner was less than 1 % with a precision of ± 5 % \([9]\). In another study of \( S_0 \) from seven different catheters from the same two manufacturers, values were highly correlated \((r = 0.99)\) with co-oximetry \([13]\); thus only a single example of each of the two catheters was used. The positions of the catheters in blood were such that the tips were a fixed distance apart, and away from the surfaces of the chamber (fig. 1).

After a 20–30-min equilibration period, a blood sample was obtained anaerobically every 3–5 min and analysed by an IL282 co-oximeter (Instrumentation Laboratory, Lexington, MA, USA) and a Nova Stat Profile 5 blood-gas analyser (Nova Biomedical, Waltham, MA, USA). Several \( S_0 \) points were obtained on the oxyhaemoglobin dissociation curve as \( P_0_2 \) was changed. The catheter \( S_0 \) readings displayed on the computers of the two catheters were recorded immediately before blood sampling. \( P_0_2 \) was varied by equilibrating it with gas bubbled from cylinders containing different concentrations of oxygen (0, 4.02, 5.6 and 29.9 %), carbon dioxide (5 %) and balance nitrogen. These concentrations were chosen in order to obtain oxyhaemoglobin saturations close to 50, 75 and 100 %. The gas flow through the tonometer was set in accordance with the manufacturer's specifications. Duplicate blood samples were not obtained at each measurement point because the tonometer chamber has a capacity of only 50 ml and requires approximately 15 ml of blood or solution for it to function, thus only allowing a maximum of 30 ml for blood samples. In addition, the Nova Stat Profile 5 analyser has a \( P_0_2 \) variability coefficient between 2.35 and 2.60, so that variability between two identical samples would be less than 3 %.

Sodium bicarbonate 8.4 %, 0.5–1.5 ml was added to the tonometer chamber to maintain the pH of the solutions in the physiological range 7.3–7.4. It was necessary to correct for pH because the oxygen affinity and absorption spectrum of MetHb changes with pH \([12]\). The sampling and tonometry was repeated for five other solutions containing: (a) fresh whole blood diluted 50:50 with Plasmalyte A solution (haemodiluted blood), (b) PHP88 diluted 50:50 with fresh whole blood (WB–PHP), (c) PHP88 diluted 75:25 with Plasmalyte A solution (PHP66), (d) PHP88 diluted 50:50 with Plasmalyte A solution (PHP44) and (e) SFH.

\( P_0_2 \) was plotted against \( S_0 \) and the calculated partial \( S_0 \) (see above) to construct representative oxyhaemoglobin dissociation curves for each of the six solutions tested. \( S_0 \), partial \( S_0 \) and catheter \( S_0 \) in all solutions was assumed to be zero at a \( P_0_2 \) value of zero. \( S_0 \) at 13.33 kPa (100 mg Hg) and at 5.33 kPa (40 mm Hg) was obtained from the constructed curves, and the difference between these values taken as an approximation of oxygen extraction (see table 2).
In addition, linear regression analyses were used to determine the correlation between catheter $S_O^2$ on the catheter computer display monitor and $S_O^2$, which we have used as the "gold standard" in our study.

**Results**

pH, haemoglobin concentration (Hb), partial pressure of carbon dioxide ($P_{CO_2}$) and methaemoglobin concentration (cMetHb) for the solutions are shown in Table 1.

The haemoglobin oxygen dissociation curves and $P_{50}$ for the six solutions are shown in figures 2 and 3, when $P_{O_2}$ was plotted against $S_O^2$ and partial $S_O^2$, respectively. Table 2 shows $P_{50}$ and the arterial-venous oxyhaemoglobin saturation differences or extraction ratios, as defined by $S_O^2$ or partial $S_O^2$ at a $P_{O_2}$ value of 13.33 kPa minus $S_O^2$ or partial $S_O^2$ at $P_{O_2}$ 5.33 kPa.

The correlations for $S_O^2$ and those displayed on

<table>
<thead>
<tr>
<th>Solution</th>
<th>pH</th>
<th>$P_{CO_2}$ (kPa)</th>
<th>Hb (g dl$^{-1}$)</th>
<th>HbMet (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole blood</td>
<td>7.3 (0.03)</td>
<td>5.8 (0.4)</td>
<td>15.6 (0.6)</td>
<td>0.8</td>
</tr>
<tr>
<td>Haemodiluted</td>
<td>7.4 (0.05)</td>
<td>5.7 (0.6)</td>
<td>7.0 (0.0)</td>
<td>1.2 (0.3)</td>
</tr>
<tr>
<td>PHP-WB</td>
<td>7.3 (0.07)</td>
<td>5.8 (0.7)</td>
<td>10.7 (0.4)</td>
<td>8.7 (1.3)</td>
</tr>
<tr>
<td>PHP66</td>
<td>7.4 (0.01)</td>
<td>5.8 (0.2)</td>
<td>6.1 (0.0)</td>
<td>21.7 (1.9)</td>
</tr>
<tr>
<td>PHP44</td>
<td>7.4 (0.06)</td>
<td>5.1 (0.7)</td>
<td>3.7 (0.8)</td>
<td>22.5 (2.1)</td>
</tr>
<tr>
<td>SFH</td>
<td>7.4 (0.04)</td>
<td>5.3 (0.5)</td>
<td>7.8 (0.1)</td>
<td>12.0 (1.9)</td>
</tr>
</tbody>
</table>

Table 1. Mean (sd) variables in the haemoglobin solutions tested which affect the haemoglobin oxygen dissociation curve at 37 °C.

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Figure 2. Oxyhaemoglobin dissociation curves for (A) whole blood, (B) haemodiluted blood, (C) WB-PHP, (D) PHP66, (E) PHP44 and (F) SFH solutions, constructed by plotting $P_{O_2}$ vs $S_O^2$. $P_{50}$ and $S_O^2$ at 5.3 and 13.3 kPa are also given for each solution.
Figure 3 Oxyhaemoglobin dissociation curves for (a) whole blood, (b) haemodiluted blood, (c) WB-PHP, (d) PHP66, (e) PHP44 and (f) SFH solutions, constructed by plotting Po\textsubscript{2} vs partial So\textsubscript{2}. P\textsubscript{50} and partial So\textsubscript{2} at 5.3 and 13.3 kPa are also given for each solution.

Table 2 P\textsubscript{50} values obtained from plotting Po\textsubscript{2} vs So\textsubscript{2} (%) on the oxyhaemoglobin dissociation curves, and arterial-venous (A–V) oxyhaemoglobin saturation (So\textsubscript{2}) differences (%) of the solutions tested at 37 °C.

<table>
<thead>
<tr>
<th>Solution</th>
<th>P\textsubscript{50} (kPa)</th>
<th>A–V So\textsubscript{2} (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole blood</td>
<td>3.8</td>
<td>25.5</td>
</tr>
<tr>
<td>Haemodiluted blood</td>
<td>3.6</td>
<td>21.3</td>
</tr>
<tr>
<td>PHP-WB</td>
<td>3.5</td>
<td>19.8</td>
</tr>
<tr>
<td>PHP66</td>
<td>3.2</td>
<td>11.4</td>
</tr>
<tr>
<td>PHP44</td>
<td>3.0</td>
<td>11.4</td>
</tr>
<tr>
<td>SFH</td>
<td>2.1</td>
<td>3.5</td>
</tr>
</tbody>
</table>

the catheter computer monitors (catheter So\textsubscript{2}) are shown in figures 4 and 5. A summary of the linear regression analysis is shown in table 3.

In haemodiluted blood, PHP44, PHP66, WB/PHP and SFH solutions, both catheters tended to overestimate So\textsubscript{2} in the range 40–80 % and underestimate at So\textsubscript{2} > 85–90 %.

Discussion
Tonometry is a standard method when comparing laboratory blood-gas analysers [14]. Varying Po\textsubscript{2} and thus haemoglobin oxygen saturation by tonometrying with gases of different oxygen concentrations allowed us to investigate the accuracy of two examples of catheters used clinically in measuring oxygen saturations of haemoglobin solutions at 37 °C and constant Pco\textsubscript{2}. It also eliminated variability caused by cardiovascular and metabolic factors which can occur with in vivo studies [7, 15–17]. Blood sampling errors were minimized by using an anaerobic technique and immediate analysis by co-oximetry.
Reflectance spectrophotometry used by the oximetric catheters estimates the relative concentration of oxyhaemoglobin by measuring the ratio of reflected light intensities. Oxyhaemoglobin and deoxyhaemoglobin have different reflectance coefficients at the light wavelengths used by the monitors. This difference produces a change in the intensity of the light signal relative to incident light as the proportions of oxyhaemoglobin and deoxyhaemoglobin change. Interference may occur from reflectance of other forms of haemoglobin. In normal clinical use, blood flows away from the tip of the catheter. The catheter has been used satisfactorily to estimate cerebral venous oxyhaemoglobin saturation where the flow of blood is in the opposite direction [18]. The accuracy of these catheters in a pool of relatively stagnant whole blood did not seem to be affected.

PHP and SFH may be considered “abnormal haemoglobins” because of the high proportion of MetHb and their extracellular existence. Furthermore, in the case of PHP, the haemoglobin has been chemically modified. It is known that abnormal haemoglobins such as MetHb [7] and fetal haemoglobins [19] affect the oxyhaemoglobin dissociation curve and also the accuracy of oximetric methods of determining oxyhaemoglobin saturation. Thus one would expect that mixed venous oxyhaemoglobin saturations, as measured by fibreoptic reflectance spectrophotometry in a pulmonary artery catheter, may not represent the true haemoglobin oxygen saturation in the presence of abnormal haemoglobins.

The IL282 co-oximeter uses transmission spectrophotometry and measures oxyhaemoglobin satu-
Figure 5 Correlation between $S_O_2$ measured by the IL282 co-oximeter, and the Oximetrix (○) and Edwards catheters (□) in PHP66, PHP44 and SFH solutions. Dotted lines = 95% confidence limits.

Table 3 Summary of linear regression analyses for the haemoglobin solutions tested. Sol. = Solution, Cath. = Catheter, Oxi. = Oximetrix catheter, Ed = Edwards catheter

<table>
<thead>
<tr>
<th>Sol./Cath.</th>
<th>$Y$-intercept</th>
<th>Slope</th>
<th>se (slope)</th>
<th>$r^2$</th>
<th>se ($r^2$)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB/Oxi.</td>
<td>1.701</td>
<td>1.004</td>
<td>0.02</td>
<td>0.998</td>
<td>1.81</td>
<td>0.0001</td>
</tr>
<tr>
<td>WB/Ed</td>
<td>10.960</td>
<td>0.871</td>
<td>0.03</td>
<td>0.992</td>
<td>2.99</td>
<td>0.0001</td>
</tr>
<tr>
<td>Haemo/Oxi.</td>
<td>16.111</td>
<td>0.829</td>
<td>0.02</td>
<td>0.989</td>
<td>2.25</td>
<td>0.0001</td>
</tr>
<tr>
<td>Haemo/Ed</td>
<td>27.024</td>
<td>0.723</td>
<td>0.02</td>
<td>0.985</td>
<td>2.38</td>
<td>0.0001</td>
</tr>
<tr>
<td>WB-PHP/Oxi.</td>
<td>6.182</td>
<td>0.969</td>
<td>0.04</td>
<td>0.951</td>
<td>4.54</td>
<td>0.0001</td>
</tr>
<tr>
<td>WB-PHP/Ed</td>
<td>10.116</td>
<td>0.905</td>
<td>0.04</td>
<td>0.937</td>
<td>4.85</td>
<td>0.0001</td>
</tr>
<tr>
<td>PHP44/Oxi.</td>
<td>56.649</td>
<td>0.182</td>
<td>0.06</td>
<td>0.314</td>
<td>4.22</td>
<td>0.0001</td>
</tr>
<tr>
<td>PHP44/Ed</td>
<td>64.204</td>
<td>0.128</td>
<td>0.04</td>
<td>0.193</td>
<td>3.14</td>
<td>0.0003</td>
</tr>
<tr>
<td>PHP66/Oxi.</td>
<td>50.820</td>
<td>0.206</td>
<td>0.07</td>
<td>0.097</td>
<td>3.00</td>
<td>0.0107</td>
</tr>
<tr>
<td>PHP66/Ed</td>
<td>61.798</td>
<td>0.169</td>
<td>0.07</td>
<td>0.063</td>
<td>3.01</td>
<td>0.0537</td>
</tr>
<tr>
<td>SFH/Oxi.</td>
<td>50.820</td>
<td>0.206</td>
<td>0.07</td>
<td>0.097</td>
<td>2.20</td>
<td>0.0780</td>
</tr>
<tr>
<td>SFH/Ed</td>
<td>60.648</td>
<td>0.234</td>
<td>0.65</td>
<td>0.260</td>
<td>2.19</td>
<td>0.0330</td>
</tr>
</tbody>
</table>

In normal whole blood, with little HbCO or MetHb, the percentage oxyhaemoglobin saturation is similar to the percentage partial oxyhaemoglobin saturation. The IL282 has an accuracy of ±1% for $S_O_2$ (±2 SD) when pH is 7.0–7.4, MetHb is 0–10% and total haemoglobin is 12–16 g dl$^{-1}$ [20].
As MetHb concentrations in this study reached as high as 29.5%, the accuracy of $S_O_2$ in the samples of PHP44, PHP66 and SFH might have been affected.

A previous investigation [6] indicated that the Oximexrix 3 wavelength catheter (660, 740, 810 nm) responded more accurately in a changing physiological environment, and tended to drift less than the Edwards 2 wavelength (660, 810 nm) catheter. The additional wavelength of 740 nm is said to allow the Oximexrix catheter to correct for changes in packed cell volume (PCV) and blood flow, and vessel wall artefacts [17]. A more recent study [13] however suggested that there was no advantage in using a three-wavelength catheter. In our experiment the blood solutions had haemoglobin concentrations of 3.7 (so 0.8) to 15.6 (0.62) g dl⁻¹. The examples of the two catheters we studied both functioned well in whole blood (Hb 15.6 (0.62) g dl⁻¹) and haemodiluted blood (Hb 7.0 (0.04) g dl⁻¹), confirming two in vivo studies [21, 22]. A study by Lee, Tremper and Barker [10] also confirmed that performance was affected only when PCV was $< 10-15$% (equivalent to a haemoglobin concentration of 3.5-4.5 g dl⁻¹). In the PHP44, PHP66, WB-PHP and SFH solutions, the Oximexrix catheter tested in our study performed better than the Edwards catheter probably because of the additional wavelength [7].

PHP44 had a haemoglobin concentration of 3.7 (0.8) g dl⁻¹ and increasing MetHb (7.6-29.4%) during the experiment. These two factors probably accounted for the poor performance of the catheters in the PHP44 solution. Barker, Tremper and Hyatt [7], in a canine model, found that the Oximexrix catheter overestimated mixed venous oxyhaemoglobin saturation by an amount that increased in proportion to the concentration of MetHb. Reynolds and colleagues [12], in a recent in vitro study on pulse oximetry, showed that at very high levels of MetHb (39.5%) the pulse oximeter reading was almost independent of the actual value of partial $S_O_2$. It is known that haemoglobins, especially abnormal haemoglobins such as fetal haemoglobins, are very vulnerable to oxidation [23]. Despite the inclusion of maltose during lyophilization as a stabilizer, the PHP88 solution contained 16-17% MetHb. The reason may be that the crystalline powder was hydrated 9 months previously and then stored frozen ($-10.0^\circ$C). As a result of exposure to air, MetHb concentration may increase but the mechanism of the rapid increase in MetHb during our experiment was not clear. The causes may be related to the age of the PHP solution, oxidation by the bubbling oxygen, lack of oxygen radical scavengers [24, 25] or ongoing cellular reactions. Indeed, oxidation reactions of normal haemoglobin in storage are still not completely understood [23]. Although said to be safe and stable in cold storage for 1 yr (PHP66 has $< 10$% MetHb after 1 yr of storage at $10^\circ$C [26]), the high concentrations of MetHb detected in our study (MetHb 21.7 (1.8) % in PHP66) would be a cause for concern in clinical use.

Linear regression analyses were used to compare catheter $S_O_2$ with $S_O_2$ because neither the Bland and Altman analysis [21, 22], nor the correction factor used by Blomqvist [27] to account for random errors in the observed $S_O_2$ were applicable in assessing our data. In this study both catheters were unreliable at lesser $P_O_2$ tensions ($< 5.33$ kPa) in all solutions tested except whole blood. The lesser slope and greater $Y$-intercept value indicated that there would be a tendency toward overestimation of catheter $S_O_2$ compared with $S_O_2$ at oxyhaemoglobin saturations in the range 40-80% (table 3, figs 4, 5). This overestimation was more pronounced in PHP44, PHP66 and SFH solutions using the Edwards catheter. Clinically, this inaccuracy may be dangerous because falsely high readings may lead to inadequate resuscitation. At greater oxyhaemoglobin saturations (> 90%) the catheters tended to underestimate $S_O_2$ in PHP44 and SFH solutions. These differences may be explained by the high MetHb concentrations recorded during the study with these solutions. Similar findings were observed by Barker, Tremper and Hyatt [7] in their pulse oximetry studies in vivo and in vitro on blood with high concentrations of MetHb [12].

$P_O_2$ of fresh SFH varied from 1.0 to 2.13 kPa compared with 3.46 to 3.60 kPa in fresh normal whole blood [28]. PHP44, PHP66 and SFH solutions used in our study had $P_O_2$ values of 3.04, 3.15 and 2.07 kPa respectively at pH 7.4. This increased oxygen affinity may result from the lesser haemoglobin concentration, loss of tetrameric haemoglobin or lack of 2,3-diphosphoglycerate [28, 29]. In a previous experiment [3] on fresh PHP88, the oxyhaemoglobin dissociation curve was slightly shifted to the left and $P_O_2$ was found to be 2.72 (1.20) kPa at pH 7.4 and 37°C. Although the lesser haemoglobin content of PHP44, PHP66 and SFH may be a factor in the greater $P_O_2$ values in our study compared with others [3], the difference was reduced or eliminated if partial $S_O_2$ was plotted against $P_O_2$, that is the oxyhaemoglobin dissociation curve was shifted to the left. The $P_O_2$ values for whole blood, haemodiluted blood, PHP-WB, PHP44, PHP66 and SFH were 3.65, 3.53, 3.17, 2.58, 3.05 and 1.86 kPa, respectively (fig. 3).

The oxyhaemoglobin saturation difference (arterial–venous (A–V) $S_O_2$) between arterial ($P_O_2$ 13.33 kPa) and venous ($P_O_2$ 5.3 kPa) points for PHP88 was estimated at 20% [3]. This may be taken as the potential oxygen extraction. In our study the oxyhaemoglobin dissociation curve was shifted slightly to the left when PHP88 was added to an equal volume of whole blood (PHP–WB) indicating that oxygen affinity was greater than that of HbA ($P_O_2$ 3.49 kPa). Also, A–V $S_O_2$ values for WB–PHP were approximately 19.8% and 19.2% using $S_O_2$ and partial $S_O_2$ as the Y-axis, compared with 25.5% for fresh normal whole blood [28]. PHP44, PHP66 and SFH solutions used in our study had $P_O_2$ values of 3.04, 3.15 and 2.07 kPa, respectively at pH 7.4 and 37°C. Although the lesser haemoglobin content of PHP44, PHP66 and SFH may be a factor in the greater $P_O_2$ values in our study compared with others [3], the difference was reduced or eliminated if partial $S_O_2$ was plotted against $P_O_2$, that is the oxyhaemoglobin dissociation curve was shifted to the left. The $P_O_2$ values for whole blood, haemodiluted blood, PHP-WB, PHP44, PHP66 and SFH were 3.65, 3.53, 3.17, 2.58, 3.05 and 1.86 kPa, respectively (fig. 3).

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by the co-oximeter achieved in the WB-PHP solution was 90–92%. This correlated with MetHb concentrations of 7–8%. In other words, the maximum percentage of total haemoglobin available for oxygenation was 90–92%. If a two-wavelength Hemoximeter OSM 2 was used instead of a multi-wavelength co-oximeter, and the presence of MetHb was unknown or underestimated, a haemoglobin oxygen saturation reading of 90–92% might be wrongly ascribed to other causes.

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References