Continuous monitoring of jugular bulb oxyhaemoglobin saturation using the Edslab dual lumen oximetry catheter during and after cardiac surgery†

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Fibreoptic jugular bulb oximetry has been validated for use in the care of severely head-injured patients. We compared bench and fibreoptic methods of measuring jugular bulb oxyhaemoglobin saturation (SjO2) in 33 patients undergoing cardiac surgery both during cardiopulmonary bypass (CPB) and in the early postoperative period. After insertion of a fibreoptic reflectance oximetry catheter into the jugular bulb, it was calibrated against a bench oximeter. Comparisons were made while on CPB (n=60) and in the postoperative period for up to 18 h (n=215). There was negligible bias throughout. There were wide limits of agreement (mean difference ±2SD) between the two methods during operation (–20.29% to 18.05%), whereas after operation the limits of agreement were far narrower (–6.39% and 7.45%). Measurement of SjO2 by the fibreoptic method compared poorly with bench oximetry during CPB but there was good agreement between the two methods in the early postoperative period.

Keywords: heart, cardiopulmonary bypass; surgery, cardiovascular; measurement techniques, oximeters

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Bench oximetry is regarded as the gold standard method of measuring jugular bulb oxyhaemoglobin saturation (SjO2). However, its accuracy is dependent on regular maintenance and calibration in addition to the quality of the samples presented. Moreover, only intermittent measurements can be made by this method and there is a lag time between obtaining the blood sample and the result being available. In contrast, fibreoptic reflectance oximetry allows continuous and real-time measurement of SjO2. In patients after neurotrauma, we have found the Edslab 4-French gauge venous oximetry catheter (Baxter Healthcare Corporation, Irvine, CA, USA) to be both accurate and reliable.1 However, the performance of fibreoptic jugular bulb oximetry during cardiopulmonary bypass (CPB) is controversial.2–6 Furthermore, it has not been evaluated during the early postoperative period after cardiac surgery, when jugular desaturations have been reported to occur.7

The aims of this study were to compare measurement of SjO2 by the Edslab fibreoptic reflectance oximetry catheter with bench oximetry in a group of cardiac surgery patients, during CPB and in the postoperative period.

Patients and methods

Approval for the study was obtained from the Lothian Health Ethics Committee and 33 adult patients gave informed consent to take part in the study.

The anaesthetic and surgical technique were according to individual consultant practice. A standard CPB circuit was used with a membrane oxygenator (I-3500–2A, Aveco Cardiovascular Inc., Minnesota, USA) and non-pulsatile flow at a rate of 2.4 litre min–1 m –2 . The circuit was primed with Hartmann’s solution 2 litre and sodium bicarbonate 50 mmol. Alpha-stat acid–base management was used. Patient temperature (measured in the nasopharynx) while on CPB was controlled according to surgical practice and ranged from moderate to mild hypothermia (28–35°C). Re-warming was carried out with the heat exchanger set at no more than 10°C above nasopharyngeal temperature, and never exceeded 42°C.

An Edslab 4 French-gauge venous oximetry catheter was
inserted after induction of anaesthesia using a technique described previously by Souter and Andrews.\(^1\) The right internal jugular vein was preferentially cannulated after imaging the vessel with a Site–Rite ultrasound probe (Dymax Corporation, Pittsburgh, PA 15283, USA). Catheter position was checked radiographically after operation and all were found to be satisfactory (i.e. the tip of the catheter was projected above the lower border of the first cervical vertebra).

The catheters were connected to an optical module and the signal was processed and displayed by a Kontron Kolormon 7250 monitoring system (Kontron Instruments Ltd, Watford, Herts WD1 8XQ, UK). In accordance with the manufacturer’s recommendation, the signal quality indicator was not used to indicate the adequacy of the catheter tip position within the jugular bulb (Baxter Edslab Dual-Lumen Oximetry Catheters: instructions for use). In vivo calibration was carried out using a sample of jugular bulb blood that was analysed in an Instrumentation Laboratory 482 CO-oximeter (Instrumentation Laboratory Company, Lexington, MA 02173, USA), which measured haemoglobin concentration and oxyhaemoglobin saturation. The Edslab catheter relies on an accurate haemoglobin concentration being entered during calibration as, being a dual wavelength system, it does not compensate for changes in haemoglobin concentration, unlike triple wavelength systems. Therefore, if the haemoglobin concentration differed by more than 1.8 g dl\(^{-1}\) from the previous concentration entered into the system, then the more recent concentration was entered and the calibration updated, as instructed in the ‘Kolormon Saturated Venous Oxygen (\(S_{O_2}\)) Module 7279–Operating Manual’. All blood sampling was performed by one investigator (S. A. M.) who was not blinded to the \(S_{O_2}\) measurement displayed continuously on the Kontron monitor. At each sampling time, a 2-ml sample of blood was aspirated anaerobically over 30 s into a heparinized syringe while the \(S_{O_2}\) reading was stable. Slow aspiration reduces the risk of contamination of the sample with blood from extracranial tributaries to the internal jugular vein. Blood samples were analysed immediately. The accuracy of the bench oximeter was confirmed regularly throughout the study using standard quality control samples (IL MULTI-4 CO-Oximeter Control, Instrumentation Laboratory Company, Lexington, MA 02173, USA).

Comparison between continuous fibreoptic and bench oximetry saturation was made at two different times during CPB: just before re-warming and during re-warming when nasopharyngeal temperature reached 36°C. After operation, the fibreoptic catheters were again calibrated in vivo on the patient’s arrival in the intensive care unit (ICU). In 12 patients, further comparisons were made hourly for the first 12 h and finally at 18 h, while in the remaining 21 patients, comparisons were made hourly for the first 2 h and then at 6 h.

**Statistical methods**

As advocated previously for analysis of serial measurements,\(^5\) summary measures were created for each patient for both the intraoperative and postoperative periods. The summary measures were created as follows: at each sampling point two measurements of \(S_{O_2}\) were recorded (one from the fibreoptic catheter and one from the bench oximeter). The mean and difference between these two measurements were calculated. Next, the mean of the means and the mean of the differences were calculated for each patient for the intraoperative and postoperative periods. These values were used as the summary measures for further statistical analysis. Method comparison analysis was used to compare the fibreoptic and bench oximetry measurements.\(^5\) The variance between the intraoperative and postoperative data was analysed using the \(F\) test. The level of significance was set at 5%.

**Results**

Thirty patients had elective coronary artery bypass grafting and three had elective heart valve replacement. The right jugular bulb was cannulated in 30 patients. In three patients, the left side was cannulated either because of difficulty in cannulating the right side or because the left internal jugular vein was found to be larger when inspected using a Site-Rite ultrasound probe. Data were lost from three patients during operation (six sampling points) and from four patients after operation (four sampling points). This was because of technical difficulty with the monitoring equipment displaying the fibreoptic saturation or with the bench oximeter and, in one case, because of staff dealing with the cardiovascular instability of the patient obstructing access to the catheter. Thus a total of 60 intraoperative (mean 1.8 (range 0–2) samples per patient) and 215 postoperative (mean 6.5 (range 2–13) samples per patient) comparisons were analysed.

During operation, a small but insignificant negative bias was detected, while in the postoperative period there was an even smaller positive bias (Table 1; Figs 1, 2). The limits of agreement between the two methods were wide during operation but in the postoperative period they were considerably narrower. There was no relationship between mean saturation and the difference between saturations, as shown by the regression equations (Figs 1, 2).

A marked change in haemoglobin concentration was seen within individual patients during the intraoperative period. The mean magnitude of this change was 5.26 (sd 1.413) g dl\(^{-1}\). During the postoperative period, mean change was significantly less (2.02 (1.035) g dl\(^{-1}\) (\(P<0.05\)).

**Table 1** Comparison of bench and fibreoptic saturation measurements during and after operation. ***\(P<0.001\) compared with results during operation

<table>
<thead>
<tr>
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<th>During operative ((n=60))</th>
<th>After operation ((n=215))</th>
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<tbody>
<tr>
<td>Mean difference in (S_{O_2}) (bench minus fibreoptic) (%)</td>
<td>–1.12</td>
<td>0.53</td>
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<tr>
<td>Limits of agreement (mean diff.±2sd) (%)</td>
<td>–20.29 to 18.05</td>
<td>–6.39 to 7.45***</td>
</tr>
<tr>
<td>95% Confidence intervals of bias (mean diff. ± (t×SEM)) (%)</td>
<td>–4.69 to 2.45</td>
<td>–0.70 to 1.76</td>
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Discussion

Although there was very little bias overall, our results showed extremely poor agreement between the two methods of \( \text{S}_{\text{J}}\text{O}_2 \) measurement during operation. In contrast, the agreement was good after operation when values were comparable with those obtained using the catheter in head-injured patients managed in the ICU.\(^1\)

Previous investigators have found that measurement of continuous fibreoptic jugular bulb oximetry compared well with intermittent bench oximetry during CPB.\(^3\)\(^-\)\(^6\) Although in each of these studies a smaller number of patients were involved than in this study, more frequent blood samples were obtained, which could account for their greater accuracy using the two different methods. They each had a greater number of comparisons to analyse which would reduce the amount of variation obtained, and more frequent blood sampling would allow more regular updating of the haemoglobin concentration in the fibreoptic system which could lead to more accurate continuous measurement of \( \text{S}_{\text{J}}\text{O}_2 \).

In contrast, when Trubiano and colleagues compared the Opticath catheter with bench oximetry to measure \( \text{S}_{\text{J}}\text{O}_2 \) during CPB, they found poor agreement.\(^2\) This lack of agreement was even more marked than we found with the Baxter Edslab catheter in our study. The poorer agreement is likely explained by the Oximetrix-3 catheters used by Trubiano and colleagues which have been shown previously to have ‘considerable bias and variability of performance’.\(^10\)

When the accuracy of the Baxter Edslab catheter was compared with bench oximetry during intracranial surgery, it performed well and gave an accurate measure of \( \text{S}_{\text{J}}\text{O}_2 \).\(^11\) This difference in catheter performance between the study of Gunn and colleagues and ours could be a result of many different factors. First, Gunn and colleagues used a heparinized saline continuous flushing system that ensured patency of the catheter, and in a previous study by Fortune and colleagues, this improved the reliability of the catheter.\(^12\)

As Baxter Edslab catheters are heparin coated, we chose to flush the catheter with heparinized saline only after aspiration of blood which adequately maintained catheter patency but may not have optimized their accuracy. Second, the rate of aspiration of blood from the jugular bulb may have been too rapid in our study. Gunn and colleagues used an aspiration rate of \( \leq 2 \text{ ml min}^{-1} \), which was confirmed in a later report by Matta and Lam to be a rate at which contamination with extracranial blood would be acceptably low.\(^13\) Despite using a faster aspiration rate of 2 ml per 30 s, we found no significant bias between the methods of measurement. If our blood samples had been contaminated significantly with extracranial blood, a significantly positive bias would have occurred. Therefore, aspiration at this faster rate is probably acceptable. Moreover, slower rates of aspiration may introduce inaccuracy when there are rapid changes in \( \text{S}_{\text{J}}\text{O}_2 \) such as during rewarming on CPB.

The influence of temperature on oxyhaemoglobin saturation measurements has been highlighted by previous investigators.\(^14\)\(^-\)\(^15\) In our study, during hypothermic CPB, the catheter measured oxyhaemoglobin saturation at a lower temperature than the bench oximeter, which measured saturation in blood samples at 37°C. This should result in the catheter reading exceeding that of the bench oximeter because of a leftward shift of the oxyhaemoglobin dissociation curve with hypothermia. As no significant negative bias was observed, it is unlikely that temperature is an important factor in influencing the agreement.

What may be seen as a further limitation of our study is the fact that the anaesthetic technique was not standardized. This was because it was intended as an observational study and patients were included irrespective of the consultant anaesthetizing them, although each of the five consultants used a different anaesthetic technique.

Wall artefact can be a problem with fibreoptic jugular bulb catheters, and has been described by previous investigators as being caused by the catheter abutting the vessel wall, disturbing the light signal and leading to artefactual readings of \( \text{S}_{\text{J}}\text{O}_2 \).\(^4\)\(^-\)\(^8\) During cardiac surgery this could occur because of the lower flow of blood past the catheter during CPB and also changes in the position of the catheter tip relative to the jugular bulb as the patient’s position is altered on the operating table. Although adjusting the length of
catheter inserted may remedy this problem, we found it very difficult to manipulate the catheters during surgery because they were draped into the surgical field.

The accuracy of the fibreoptic measurement of $S_jO_2$ in the early postoperative period in the ICU after cardiac surgery has not been reported previously. In comparison with our results using the same type of catheter in head-injured patients managed in the ICU, our present study in cardiac surgery patients found a similar bias but slightly wider limits of agreement. This could be because head-injured patients were sedated, paralysed and undergoing mechanical ventilation, thereby minimizing artefactual readings which can result from patient movement. This was not the case in the present study where patients in the ICU were commonly regaining consciousness to allow them to be assessed and so were often moving.

In summary, measurement of $S_jO_2$ by the Baxter Edslab fibreoptic reflectance oximetry catheter compared poorly with bench oximetry during CPB. In contrast, using the same system, the fibreoptic and bench oximetry measurements of $S_jO_2$ agreed well in the early postoperative period after cardiac surgery.

Acknowledgement
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References
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