The Rate of Blood Withdrawal Affects the Accuracy of Jugular Venous Bulb

Oxygen Saturation Measurements

Basil F. Matta, M.B., F.R.C.A.,* Arthur M. Lam, M.D., F.R.C.P.C.†

Background: Accuracy of jugular venous oxygen saturation (SjvO₂) measurement depends on sampling of cerebral venous outflow blood not contaminated by systemic venous blood. The influence of the rate of blood withdrawal has not been determined.

Methods: The authors examined the effect of withdrawing blood at different rates from jugular venous bulb catheters (JVBC) on SjvO₂ in 10 mechanically ventilated patients undergoing neurological procedures. All patients received a standardized anesthetic consisting of propofol, fentanyl, vecuronium, and isoflurane. Routine monitors included electrocardiograph (ECG), invasive blood pressure, pulse oximetry, and a JVBC. During a period of stable anesthetic and surgical conditions, JVBC blood samples were drawn at 2, 4, and 10 ml/min using a calibrated pump (Harvard Pump model 900, Harvard Apparatus, South Natick, MA) during mild and moderate hypocapnia (arterial carbon dioxide tension [PaCO₂], 26.0 ± 0.5 and 33.0 ± 0.5 mmHg).

Results: Faster rates of withdrawal (10 and 4 ml/min vs. 2 ml/min) resulted in significantly higher SjvO₂ values at both levels of PaCO₂ (66.0 ± 3% and 61.2 ± 3%) vs. 56.9 ± 3% at PaCO₂ = 26.0 ± 0.5 mmHg, and 75.0 ± 3% and 71.3 ± 3% vs. 68.0 ± 3% at PaCO₂ = 33.0 ± 0.5 mmHg, respectively; P < 0.01).

Conclusions: The authors conclude that the SjvO₂ values measured with intermittent sampling are affected by the rate of withdrawing blood from the JVBC, probably as a result of extracranial contamination. They recommend blood samples should be drawn slowly (Key words: Brain arteriovenous oxygen content difference; cerebral blood flow equivalent; Equipment jugular venous bulb catheter.)

THE monitoring of jugular venous oxygen saturations (SjvO₂) has been shown to be useful in the intensive care of comatose head-injured patients and in the intra-operative treatment of patients undergoing neurosurgical procedures.1,2 We have observed that the rate with which a jugular venous blood sample is drawn can affect the SjvO₂ value, with higher rates of withdrawal yielding higher SjvO₂ values. A plausible explanation is that higher rates of withdrawal result in contamination of the sample with extracranial venous blood. We tested this hypothesis in 10 patients undergoing anesthesia for neurological procedures in whom a jugular venous bulb catheter (JVBC) was used as part of the clinical management.

Methods and Materials

With approval from the institutional Human Subjects Committee, informed written consent was obtained from 10 patients (American Society of Anesthesiologists1 (ASA) physical status 1 or 2; aged 31 ± 6 yr; weight, 83 ± 13 kg; hematocrit [Hct], 33 ± 4%) scheduled to undergo general anesthesia for neurological procedures. Patients with significant respiratory disease and those with cerebral arteriovenous malformations were excluded. With routine monitors in place (electrocardiograph [ECG], pulse oximetry, and noninvasive blood pressure), anesthesia was induced with propofol, 2.5 mg/kg, fentanyl, 3 μg/kg, and muscle relaxation was achieved with vecuronium, 0.1 mg/kg. After tracheal intubation, the lungs were ventilated with oxygen–air mixture and isoflurane (0.5–1.0% end-tidal). Repeated doses of fentanyl and vecuronium were administered when clinically indicated but not during the sampling periods. A radial arterial catheter was inserted for monitoring mean arterial pressure (MAP) and for blood gas sampling. A 5.25-inch, 16-gauge retrograde JVBC (Angiocath®, Becton and Dickinson, Sandy, Utah) was placed using an aseptic technique described previously.1 The position of the JVBCs was confirmed radiographically with the tip of the catheter seen at the level of and medial to the mastoid process. The catheter was con-
RATE OF BLOOD WITHDRAWAL AFFECTS SjvO₂ VALUE

<table>
<thead>
<tr>
<th>Rate of Withdrawal</th>
<th>2 ml/min (mean ± SD)</th>
<th>4 ml/min (mean ± SD)</th>
<th>10 ml/min (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pao₂ (mmHg) 26.0 ± 0.5</td>
<td>SjvO₂ % 56.9 ± 3</td>
<td>61.2 ± 3*</td>
<td>66.0 ± 3†</td>
</tr>
<tr>
<td>AVDO₂ (ml·dl⁻¹) 7.40 ± 0.6</td>
<td>6.72 ± 0.5*</td>
<td>5.92 ± 0.6*</td>
<td></td>
</tr>
<tr>
<td>CBFE (dl·min⁻¹·ml⁻¹) 0.15 ± 0.02</td>
<td>0.16 ± 0.02*</td>
<td>0.22 ± 0.05†</td>
<td></td>
</tr>
<tr>
<td>SjvO₂ % 68.0 ± 3</td>
<td>71.3 ± 3*</td>
<td>75.0 ± 3†</td>
<td></td>
</tr>
<tr>
<td>PaO₂ (mmHg) 33.0 ± 0.5</td>
<td>AVDO₂ (ml·dl⁻¹) 5.6 ± 0.6</td>
<td>5.06 ± 0.5*</td>
<td>4.5 ± 0.5†</td>
</tr>
<tr>
<td>CBFE (dl·min⁻¹·ml⁻¹) 0.20 ± 0.03</td>
<td>0.23 ± 0.04*</td>
<td>0.26 ± 0.04†</td>
<td></td>
</tr>
</tbody>
</table>

SjvO₂ = jugular bulb oxygen saturation; AVDO₂ = arteriovenous oxygen content difference; CBFE = cerebral blood flow equivalent (1/AVDO₂).

* Significantly different from samples drawn at 2 ml/min at P < 0.01.
† Significantly different from samples drawn at 4 ml/min at P < 0.05.

Connected to a pressure flush system (normal saline at 3 ml/h).

After the start of surgery and during stable anesthetic and surgical conditions, JVBC samples were drawn at 2, 4, and 10 ml/min using a calibrated pump (Harvard Pump model 900). An arterial blood sample was obtained simultaneously. This sampling was performed during moderate and mild hyperventilation (PaCO₂ 26.0 ± 0.5 and 33.0 ± 0.5 mmHg) with a 15-min period of stabilization at each PaO₂ (as reflected by unchanged end-tidal carbon dioxide). The order of hyperventilation was randomized. Blood samples were immediately analyzed using an automated blood gas analyzer (Nova Biomedical, Waltham, MA).

Data Analysis

The cerebral arteriovenous oxygen content difference (AVDO₂) was calculated using the equation: AVDO₂ = hemoglobin concentration (Hgb) x 1.39 x (SaO₂ - SjvO₂) + 0.003 x (PaO₂ - PjvO₂) vol%, where SaO₂ is arterial oxygen saturation, SjvO₂ is the jugular bulb oxygen saturation, PaO₂ is arterial oxygen tension, and PjvO₂ is the jugular bulb oxygen tension. The SjvO₂ data were analyzed using two-way analysis of variance (ANOVA) for repeated measures. When significance was found, a post hoc test (Fisher’s least significance difference) was used to delineate the differences. A P value < 0.05 was considered statistically significant.

Results

The main findings of the study are shown in Table 1. There was no change in the patients’ temperature, heart rate, MAP, or Hct during the study period. All JVBCs were inserted without complication and found to be in a satisfactory position, with the tip at the level of and just medial to the mastoid bone.

Faster rates of withdrawal (4 and 10 ml/min) resulted in significantly higher SjvO₂ and lower AVDO₂ values, which were evident at both levels of PaCO₂. The magnitude of increase in SjvO₂ at 10 ml/min (compared with the rate of 2 ml/min) was greater during moderate hyperventilation than during mild hyperventilation (9.09 ± 2.55% vs. 6.73 ± 1.25%). This difference did not reach statistical significance.

Discussion

In this study, we have shown that SjvO₂ measurements depend on the speed with which blood is drawn from the JVBC, with faster rates yielding higher SjvO₂ values. Various studies have suggested that the measurement of SjvO₂ may be useful in the treatment of those patients at risk for neurologic injury.¹⁻⁶ Recent attempts at determining the accuracy of continuous fiberoptic oximetry of jugular bulb venous blood have yielded conflicting results. Although readings from the fiberoptic oximetric catheter compared favorably with blood gas analysis of simultaneously drawn samples from the catheter in the intensive care unit,⁷⁻⁸ at least one study showed a poor correlation during cardiopulmonary bypass.⁹ The reasons for this inconsistency are unclear and may include the presence of anesthetic gases, head positioning, the type of catheters studied, or the rate at which the blood is withdrawn from the JVBC. In this study, we have attempted to highlight a possible source for this discrepancy.

Blood drained to the internal jugular veins from the sigmoid sinus is to a minor degree admixed with extracerebral blood. Sources of extracranial blood are the emissary and frontal veins draining into the superior vermis of the cerebellum. The presence of extracranial blood is more likely to occur in patients with increased intracranial pressure, increased intracranial compliance, decreased cerebral compliance, high jugular venous pressure, jugular venous ligation, temporary occlusion of the jugular veins, and trauma. The presence of extracranial blood may be confounding and should be noted in the determination of SjvO₂ values. Two R-wave suppression systems have been developed to minimize the effects of extracranial blood in the determination of SjvO₂.

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sagittal sinus, the cavernous sinus connection to the sigmoid sinus and the superior bulb of the internal jugular vein through the petrosal sinuses, and the cavernous sinus communication with the ophthalmic veins and pterygoid plexus. Despite all these connections, there is good evidence that all but a small proportion (3–7%) of the jugular venous bulb blood drains the cerebral hemispheres. However, below the jugular bulb, the internal jugular vein receives facial and retroanterior venous blood, causing a substantial extracranial admixture. Jakobsen et al.14 have shown that if the JVBC tip is placed >2 cm from the bulb, major extracerebral contamination can occur. It is possible that faster rates of withdrawal of blood may increase the blood admixture from the extracranial contributory veins, giving a falsely elevated SjvO2 reading.

The increase in SjvO2 value, although statistically significant, may not in the majority of patients be clinically significant. However, because AVDo2 or its reciprocal of cerebral blood flow equivalent (CBF = 1/AVDo2) are used as a measure of brain energy metabolism and are used to guide therapy in the neurologically injured patient, correct estimation of these variables is important. For example, if the SjvO2 value is overestimated by 5% (which may not be clinically significant at SjvO2 of 65%), the error in calculating the AVDo2 (assuming an arterial oxygen saturation of 100%) can be as much as 14%. The error is further increased during hyperventilation and at higher cerebral metabolic rates. During marked hyperventilation, cerebral blood flow (CBF) is reduced, and therefore, the risk of extracranial contamination increases. This is evident from our study wherein the errors in SjvO2 (and AVDo2) appeared to be greater at the lower PaO2. Similarly, with high cerebral metabolic rates (if CBF is normal or low) because the difference between cerebral arterial and venous blood oxygenation is great, the error is further highlighted. The estimation errors in AVDo2 and CBF are particularly important when the effects of drugs or therapeutic maneuvers are being monitored. In some situations, the true change in AVDo2 may be smaller than the measured ones because of contamination with extracerebral blood. Although not studied, other measured variables such as glucose consumption or lactate production can be expected to be affected in a similar manner. Calculation of cerebral metabolic rate for glucose or oxygen (CMRgO2) using the Fick's Principle (CMRgO2 = CBF x AVDo2) critically depends on accurate determination of SjvO2.

With the increase in the use of continuous fiberoptic monitoring of SjvO2 and as all available catheters require calibration against a simultaneously drawn blood sample, it is equally important to use a blood sample that is as representative as possible of the true SjvO2. The inconsistent rate of blood sample withdrawal during recalculation may account for some of the inaccuracies observed in the use of continuous fiberoptic jugular venous oximetry.

We should point out that our study did not prove that the rate of 2 ml/min is free of extracranial blood contamination. In choosing these rates of withdrawal, we try to use rates that are feasible and practical. Although a rate of 1 ml/min may further improve accuracy, it is not practical and does not allow rapid assessment of changes.

In conclusion, the rate with which blood is withdrawn from JVBC affects SjvO2 and CBEF values. To avoid overestimation of SjvO2 and CBEF, blood samples should be drawn slowly, at approximately 2 ml/min, particularly when the patient is hyperventilated or CBF is otherwise reduced pharmacologically (e.g., during barbiturate therapy).

References


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