Normal jugular bulb oxygen saturation

A Chieregato, F Calzolari, G Trasforini, L Targa, N Latronico

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onitoring of jugular bulb vascular oxygen saturation ($S_{jO_2}$) is currently suggested in patients with severe head trauma as a global measure of the adequacy of the cerebral blood flow (CBF) to brain metabolic requirements. $S_{jO_2}$ in normal volunteers was first obtained by Gibbs et al in 1942, and then by Datsur et al in 1963. In 1945 Gibbs et al also showed that the $S_{jO_2}$ does not differ in simultaneous sampling of both right and left jugular bulbs. However, these physiological data were obtained by direct puncture of the jugular veins without radiological confirmation of the needle’s or catheter’s tip position.

Substantial extracerebral contamination with high oxygen saturation values may occur if the blood is withdrawn from the facial vein, joining a few centimetres below the jugular bulb and possibly from the inferior petrosal sinus, joining immediately below the jugular bulb. Contamination may also occur if the catheter is incorrectly positioned and blood withdrawal is too fast. Therefore, extracerebral blood contamination could have occurred in the two old series, and falsely high oxygen saturation values could have been obtained.

We sought to replicate the $S_{jO_2}$ measurements during angiographic catheterisation of the jugular bulb.

MATERIALS AND METHODS

The study was approved by the local review board, and written informed consent was obtained by the patients. The study was carried out on 12 patients (nine females; median age 39 years, range 25–72) with Cushing’s syndrome undergoing selective bilateral catheterisation of the inferior petrosal sinus. In addition, data from the two old series were reanalysed for comparison.

Results: $S_{jO_2}$ values (44.7%) were significantly lower than in the two old series, particularly concerning the normal lower limit (54.6% and 55.0% respectively). Comparative analysis suggests that contamination with the extracerebral blood of the facial veins and inferior petrosal sinuses was responsible for falsely high $S_{jO_2}$ values in the two old series.

Conclusions: The normal lower $S_{jO_2}$ limit is lower than previously recognised. This may have practical implications for treating severe head trauma patients.

**Background:** Normal values of the jugular bulb oxygen saturation were obtained in 1942 and in 1963. Correct catheter positioning was not confirmed radiologically.

**Objectives:** To replicate the measurements during angiographic catheterisation of the jugular bulb.

**Methods:** Oxygen saturation in the jugular bulb ($S_{jO_2}$), inferior petrosal sinus ($S_{ipsO_2}$), and internal jugular vein was bilaterally measured in 12 patients with Cushing’s syndrome undergoing selective bilateral catheterisation of the inferior petrosal sinus. In addition, data from the two old series were reanalysed for comparison.

**Results:** $S_{jO_2}$ values (44.7%) were significantly lower than in the two old series, particularly concerning the normal lower limit (54.6% and 55.0% respectively). Comparative analysis suggests that contamination with the extracerebral blood of the facial veins and inferior petrosal sinuses was responsible for falsely high $S_{jO_2}$ values in the two old series.

**Conclusions:** The normal lower $S_{jO_2}$ limit is lower than previously recognised. This may have practical implications for treating severe head trauma patients.

**Abbreviations:**
- $S_{jO_2}$: jugular bulb oxygen saturation
- $S_{ipsO_2}$: inferior petrosal sinus oxygen saturation
- ACTH: adrenocorticotropic hormone
- ANOVA: analysis of variance
- CBF: cerebral blood flow
- CMRO$_2$: cerebral metabolic rate of oxygen
- CNS: central nervous system
- CRH: corticotrophin releasing hormone
- $S_{jO_2}$: jugular bulb oxygen saturation
- $S_{ipsO_2}$: inferior petrosal sinus oxygen saturation

**Statistical analysis**

$S_{jO_2}$ values are presented as mean, upper (mean plus 2 standard deviations (SD)), and lower (mean minus 2 SD) limit. Precision of each point estimate was evaluated by 95% confidence intervals (95% CI). Comparison of the venous oxygen saturation in the jugular bulbs, inferior petrosal sinuses, and midlevel jugular veins was done using analysis of variance (ANOVA). $S_{jO_2}$ values from this series were compared to those from the two historical series by Gibbs and colleagues (50 healthy

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Differences between right and left SjO2, in simultaneous samples were not statistically significant, neither in the present series \((t = 0.1978, \text{two tailed } p = 0.8481)\) nor in the Gibbs series \((t = -0.1464, \text{two tailed } p = 0.8846)\); however, limits of agreement were wider in the latter. Results, expressed as mean difference (95% CI), and upper (95% CI) and lower (95% CI) limits of agreement were as follows: present study: 0.2% \((-1.2 \text{ to } 1.7)\); 3.7% \(1.2 \text{ to } 6.3\); –3.3% \(-5.8 \text{ to } -0.7\); Gibbs: –0.1% \((-1.3 \text{ to } 1.1)\); 6.5% \(4.4 \text{ to } 8.6\); –6.7% \(-8.8 \text{ to } -4.6\).

**DISCUSSION**

We found significantly lower SjO2 values in this series (44.7%) than reported in two old series (54.6%, 55.0%), the only ones in which SjO2 was measured in normal volunteers. The difference was not accounted for by the fact that patients in the present series had Cushing's syndrome. In fact, all patients had a syndrome of recent onset, whose pathogenesis, whether due to microadenoma of the pituitary or paraendocrine tumours, had yet to be defined. In addition, patients with severe unstable hypertension, in whom uncoupling of CBF and CMRO2 may occur, were excluded.

Three facts are relevant to explain our results. First, we used a digital angiography system and vascular catheters were exactly positioned in the dome of the jugular bulb. In the Gibbs and Datsur series the catheter positioning in the jugular bulb was blind, and cervical x ray confirmation of the final catheter position was not performed. Therefore, extracerebral blood contamination from the facial veins,10 as shown in this study, from the inferior petrosal sinuses may have occurred in some patients. Our results support this hypothesis showing that the SjO2 values in the old series were intermediate between SjO2 and SipsO2–SmidjO2 (extracerebral) in the present series. Second, blood samples in our study were withdrawn slowly, a factor that has been showed to avoid extracerebral blood contamination, provided that the catheter is correctly positioned in the jugular bulb.11

Third, we measured haemoglobin oxygen saturation by mean of a co-oximeter, the reference method based on three wavelength spectrophotometry,11 while Datsur et al used a two wavelength spectrophotometric method,12 and Gibbs et al the Van Slyke manometric method.13 The two latter methods overestimate oxygen saturation compared with the co-oximeter, particularly for the lower range of oxygen saturation, as is the case in venous samples.11

**Normal SjO2 limit lower than previously recognised: does it matter?**

SjO2 values below the lower normal limit have been defined as jugular desaturation—that is, situations of critical inadequacy of CBF to CMRO2, “from norms defined by Gibbs and coworkers’,14 and have been proven in a single study to independently affect the outcome of severe head trauma.15 However, the methods on how to summarise insult data such as jugular desaturation have only recently been defined,16 while in previous studies the jugular desaturation was simply dichotomised as present or absent, based on Gibbs’ data. Therefore, a new limit could modify the result. More

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**Figure 1** Oxygen saturation in the jugular bulb (SjO2) in the series by Gibbs (1942) and Datsur, and in the inferior petrosal sinus (SipsO2), midlevel jugular vein (SmidjO2), and jugular bulb in the present series.

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**Table 1** Oxygen saturation values in the jugular bulb (SjO2)

<table>
<thead>
<tr>
<th></th>
<th>Mean (95% CI)</th>
<th>Upper limit (95% CI)</th>
<th>Lower limit (95% CI)</th>
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<tbody>
<tr>
<td>Present series</td>
<td>57.1 (52.3 to 61.6)</td>
<td>69.5 (61.2 to 77.7)</td>
<td>44.7 (36.5 to 53.0)</td>
</tr>
<tr>
<td>Gibbs (1942)</td>
<td>62.0 (61.0 to 63.1)</td>
<td>69.4 (67.6 to 71.2)</td>
<td>54.6 (52.8 to 56.5)</td>
</tr>
<tr>
<td>Datsur (1963)</td>
<td>64.3 (62.4 to 66.2)</td>
<td>73.7 (70.4 to 76.9)</td>
<td>55.0 (51.7 to 58.2)</td>
</tr>
</tbody>
</table>
importantly, it is suggested that jugular desaturations, variously defined as SjO2 less than 50% or 54%,' are treated aggressively, although benefits are unproven. A new normal limit further weakens the legitimacy of such treatments.

This study included a small sample of patients and therefore conclusions should be taken cautiously. Due to the lack of invasiveness that can be attributed to the method itself, our results can be easily replicated. If the normal lower SjO2 limit is confirmed to be as low as 46%, redefinition of “normality” applied to SjO2 may have diagnostic, prognostic, and therapeutic implications.

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REFERENCES
Carpenter ranked Ferrier’s cerebral localisation among the greatest advances in the physiology of the nervous system made in the past 50 years. It formed a direct link between Jackson and Sherrington, with both of whom he had worked.

Born in Aberdeen, Ferrier studied there under Alexander Bain, on whose advice in 1864 he visited Heidelberg, to study psychology with Helmholtz and Wundt. Wundt had just (1862) completed the Beiträge zur theorie der sinnenausbreitung that contained the first statement of his “physiological psychology”. Ferrier completed his medical training at Edinburgh where Thomas Laycock,5 inclined him towards neurology.

He worked in London from 1880, and was appointed Professor of Neuropathology, King’s College Hospital, in 1889. But his research began earlier at The West Riding Lunatic Asylum, Wakefield. There he showed that stimulation of the cerebral cortex could produce movements and fits, and that cerebral functions were localised in definable discrete areas.

Before him, in 1886, Friedrich Albert Lange (1828–75) had distinguished localisation of symptoms. Broca, Lange (1828–75) had distinguished localised in definable discrete areas. and fits, and that cerebral functions were localised in definable discrete areas. There he showed that stimulation of the cerebral cortex could produce movements and fits, and that cerebral functions were localised in definable discrete areas. 

Ferrier used both ablation and electrical stimulation of the cerebellum. He was not obsessed by the anatomical localisation. The functions of the cerebrum were sensorimotor.

“From the complexity of mental phenomena and the participation in them of both motor and sensory substrata, any system of localization of mental faculties which does not take both factors into account must be radically false.” He thus anticipated 20th century holistic concepts of cerebral function.

“Ferrier was more than an experimenter; he was, rather, a philosopher who did not philosophise but who experimented,” remarks Rösch.6

By making lesions in the anterior frontal cortex, he deduced the effect on function: “while not actually deprived of intelligence ... they had lost the faculty of attentive and intelligent observation.”

Thus, the frontal lobes might subserve the function of selection and inhibition of competing ideas.

He dedicated his work to Jackson:

“To Dr. Hughes Jackson who from a clinical and pathological standpoint anticipated many of the more important results of recent experimental investigation into the functions of the cerebral hemispheres, this work is dedicated as a mark of the author’s esteem and admiration.” Ferrier The functions of the brain (1876).

Jackson, similarly, had been inspired by Spencer and frequently cited his writings. Sherrington, in turn, dedicated his lectures on The integrative action of the nervous system (1906) to Ferrier. And in his obituary notice of Ferrier for the Royal Society, “Sherrington remarked:

“Ferrier has done the most important research in proving cerebral localization, in placing it at the centre of neurological interest, and in providing the basis for a “scientific phenomenology”.”7

He continued his clinical work applying these experimental findings to patients, and encouraging surgeons to operate on intracranial lesions; thus, Rickard Godlee said he was a powerful force in initiating brain surgery.

Among many honours, he received an Hon DSc, University of Cambridge, in 1914 and in 1911 a Knighthood. He was elected FRS in 1876, FRCP in 1877, and Goulstonian Lecturer in 1878. Not least of this great pioneer’s achievements was the foundation of the journal Brain, with Hughlings Jackson, Sir John Bucknill, and Sir James Crichton-Browne.