The Evaluation of Cerebral Oxygenation in Ischaemic Stroke Patients

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ABSTRACT

Background: The technology of transcranial near infrared spectroscopy (NIRS) for the measurement of cerebral oxygen balance was introduced 25 years ago. Until very recently there has been only occasional interest in its use during surgical monitoring. Now numerical clinical studies have at least partly succeeded in overcoming the long standing misunderstanding in reading its value. Aim: Our aim is to evaluate the clinical significance of estimation of the regional cerebral oxygen saturation ($rSO_2$) in patients with ischaemic stroke by the cerebral oximetry during the acute phase. Thirty four patients were included in the current study with ischaemic stroke in the middle cerebral artery territory. Detailed clinical examination and appropriate lab investigations were done. The $rSO_2$ was determined by the Somanting INVOS 3100 near infrared spectroscopy (NIRS) within two weeks of admission. The blood gases values were noted too. The changes were evaluated along with Glasgow Coma Scale (GCS), and the patients were classified according to their outcome to reversible group (recovered) and to irreversible group of patients (died). Results: evaluation of all patients showed that the values of cerebral oxygenation positively correlated with the GCS, although insignificantly. The $rSO_2$ values were significantly higher in the reversible group of patients than in the irreversible group, after both the first and second weeks. The results of peripheral oxygenation did not correlate significantly either with the patients' outcome or with the cerebral oxygenation values. Conclusion: the cerebral oximetry can be used as a measure to evaluate the cerebral oxygenation during the acute phase of ischemic stroke, serving as a potentially useful marker for detection of cerebral oxygenation to judge the effectiveness of management and for the follow-up of patients with ischaemic stroke. (Egypt J. Neurol. Psychiat. Neurosurg., 2005, 42(2): 485-492).

INTRODUCTION

Cerebral oximetry is an indirect, continuous non-invasive method for measuring brain tissue oxygen saturation by near infrared spectroscopy (NIRS)$^1$. The feasibility of using near infrared light for the monitoring of cerebral oxygenation has been first demonstrated in 1977$^2$ by Jobsis. To date, cerebral oximetry has been widely used in the clinical studies of cerebral hemodynamics and the oxygen delivery to the cerebral tissue. Several case reports and small clinical studies have indicated that the cerebral oximetry can detect changes in the cerebral oxygen saturation resulting from the changes in the arterial blood pressure or oxygen saturation$^3$-5.

There are potential benefits of monitoring the cerebral oxygenation in patients who have ischemic stroke. The identification of cerebral oxygenation can potentially improve the outcome, can guide the physician to take a timely corrective action, and can serve as a useful tool in neuromonitoring of cases with cerebral ischemia$^6$-7.

SUBJECTS AND METHODS

The current study includes 34 patients with ischemic stroke admitted to our Neuro Critical
Care in the Neurology Department. The ischemic stroke was diagnosed by a computerized tomographic scan (CTS) of the brain within the first 24 hours after the onset of the stroke.

A detailed clinical neurological examination including assessment of consciousness level using GCS was carried out, and the blood gases values were noted too. All the patients were monitored with cerebral oximetry within the first and the second week of admission. Readings were recorded at the beginning and ending of each week, and then averages were calculated. Measurement of cerebral oxygenation using the Somanting INVOS 3100 near infrared spectroscopy (NIRS) offers continuous non-invasive monitoring of regional cerebral oxygen saturation and approved by FDA for investigation use. The cerebral oximetry device consists of:

1. Electronic computer display box, and a connecting cable (Fig. 1).

![Fig. (1): Electronic Computer Display Box and Connecting Cable.](image1)

2. A flexible probe called somasensor placed over the forehead 1 cm above the eye brows. This position places the light source and the sensor away from the frontal sinus. The sensor contains light emitting diodes (LEDs) and two light detectors which receive infrared light from underlying brain tissues. LEDs use two wave lengths of near infrared light at 730 to 810 nm measure the ratio of Hb to oxy Hb in the field beneath the oximetry probe and thus give an idea about changes in brain tissue Hb saturation. Infrared light penetrates all tissues including skin, muscle, tissue, skull, and brain tissue. Since the depth of penetration depends on the average light beam is proportional to the distance of the detector from light source.

Two detectors are placed a distance of 30 and 40 mm away from light source and 1-2 mm apart from each other, as shown in Figure (2). The first detector receives light attenuated by its passage through scalp, skull, and superficial brain ensuring extracerebral blood oxygen saturation and subtracted from deeper brain tissue detectors. The signal received from both detectors are processed together to produce approximate HbO2 saturation in the underlying brain tissue. The collecting infrared light are converted to digital information by the internal microcomputer and O2 saturation values are displayed in real time by the display unit.

![Fig. (2): The Somasensor probe.](image2)
Normally the vascular space in cerebral tissue consists of venous blood 75% and 25% of arterial is capillary blood. Hence the oximetery reading is weighted towards venous oxygen saturation\textsuperscript{10}. The average regional oxygen saturation equals 70% (arterial $O_2$ saturation is 100% and venous $O_2$ saturation is 60%). In practice, baseline assessment is essential for measurement of fluctuations during monitoring procedures\textsuperscript{11}.

**RESULTS**

Thirty four patients (20 male, and 14 female) admitted with an ischemic stroke in the middle cerebral artery territory, were included in the study. The mean age of patients was 54±17.7 years. The reversible group of patients was 20 patients and the irreversible group was 14 patients.

Table (1) shows positive correlation between the GCS outcome and the cerebral oxygenation in the reversible group of patients. It is insignificant, however, positive.

Table (2) shows positive correlation between the GCS outcome and the cerebral oxygenation in the irreversible group of patients. It is insignificant, however, positive.

Table (3) shows a significant difference in cerebral oxygenation between both group follow-up monitoring during both the first and second weeks.

Figure (3) shows that the rSO$_2$ is higher in the second week, however insignificant.

Figure (4) shows that the rSO$_2$ is lower in the second week, however, insignificant.

**Table 1.** The correlation between the Glasgow Coma Scale and cerebral oxygenation in the reversible group of patients within two weeks follow-up.

<table>
<thead>
<tr>
<th>Glasgow Coma Scale</th>
<th>Cerebral Oxygenation</th>
<th>P-value</th>
<th>Pearson correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Week</td>
<td>9.9±3.2</td>
<td>64.2±6.3</td>
<td>0.23</td>
</tr>
<tr>
<td>Second Week</td>
<td>11±3.4</td>
<td>65.1±9.1</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Significance is determined based on the $p$-value, where $p < 0.05$ means that the correlation is significant.

**Table 2.** The correlation between the Glasgow Coma Scale and cerebral oxygenation in the irreversible group of patients within two weeks follow-up.

<table>
<thead>
<tr>
<th>Glasgow Coma Scale</th>
<th>Cerebral Oxygenation</th>
<th>P-value</th>
<th>Pearson correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Week</td>
<td>10.4 ± 3.8</td>
<td>59.7 ± 8</td>
<td>0.8</td>
</tr>
<tr>
<td>Second Week</td>
<td>8.4 ± 2.9</td>
<td>51.5 ± 18.6</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Significance is determined based on the $p$-value, where $p < 0.05$ means that the correlation is significant.
Table 3. The comparison between reversible and irreversible groups of patients, as regard to the cerebral oxygenation follow-up within 2 weeks.

<table>
<thead>
<tr>
<th></th>
<th>Reversible Group Cerebral Oxygenation</th>
<th>Irreversible Group Cerebral Oxygenation</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Week</td>
<td>64.2 ± 6.3</td>
<td>59.7 ± 8</td>
<td>0.04</td>
</tr>
<tr>
<td>Second Week</td>
<td>65.1 ± 9.1</td>
<td>51.5 ± 18.6</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Fig. (3): The correlation between GCS outcome of the reversible group and the rSO$_2$ within 2 weeks follow-up.
DISCUSSION

The patients with acute stroke are at risk of hypoxemia and the degree of their oxygen desaturation increases depending on the severity of stroke\textsuperscript{12}. The cerebral metabolic rate of oxygen CMRO\textsubscript{2} can be estimated from NIRS data and the changes in (CMRO\textsubscript{2}) is related to changes in Hb concentration\textsuperscript{13}. The equalization of the cerebral blood flow and the oxygenation to the cerebral metabolism will prevent the secondary intracranial hypoxic insults and this forms essential aspects of neurological intensive care\textsuperscript{12}.

The use of this monitoring would be of great value when interpreted into clinical management for example the level at which the intracranial Hb saturation could dangerously change to produce cerebral injury, While the systemic hemodynamic and oxygenation would not predict that change\textsuperscript{14}. The results of this study show that peripheral oxygenation did not correlate significantly either with the patient's outcome or with the cerebral oxygenation values. This is in agreement with previous study of Pollord et. al.\textsuperscript{14}, and Demet G. et. al.\textsuperscript{8}, who found in their studies that there is no correlation between the rSO\textsubscript{2} and peripheral systemic oxygenation detected by pulse oximetery, suggesting that the peripheral oxygenation doesn't predict the cerebral tissue oxygenation.
The results of this study show that the cerebral oxygenation correlated with the clinical improvement after ischemic stroke. This means that there was an increase of rSO$_2$ from acute phase towards chronic phase positively with the increase of GCS scores during the period in spite that this was not statistically significant, as shown in table (1). This is in agreement of a previous study.

Also, results showed a correlation between the clinical deterioration of the acute ischemic patients and the results of cerebral oxygenation saturation. This means that there was a decrease in rSO$_2$ during the patients' follow up that correlated positively with the decrease of GCS scores in spite that this was not statistically significant, table (2). This is in agreement with a previous study which reported that changes in baseline of rSO$_2$ caused by vasospasm effectively decrease oxygenation supply in the affected hemisphere.

The large falls in values of cerebral O$_2$ saturation indicate that collateral blood supply is inadequate, the matching of cerebral blood flow by using Trans Cranial Doppler (TCD) and regional oxygen saturation can give information about the underlying pathophysiological disturbance which the clinician wishes to monitor. In the study of Yao et. al., it was reported that there is a decrease in blood oxygen in earlier stages of focal cerebral ischemia. However a later study confirmed the ability of INVOS 3100 NIRS to detect rapid tissue vascular oxy Hb desaturation in the brain during circulatory arrest and clarified in his study that the NIRS reading results may be near normal because of sequestered cerebral venous blood in capillaries and venous capacitance vessels and contribution from overlying tissues, while in regionally or globally ischemic but metabolizing brain oxygen saturation decreases because oxygen supply is insufficient to meet metabolic demands.

When comparing the cerebral oxygenation results of both the reversible and the irreversible groups, there was a significant difference between the mean cerebral oxygenation values, Table 3. Previously it was reported that transient neurological events occurred more frequently in patients undergoing cardiovascular surgery with sustained drop of rSO$_2$ below 55%, so recovery of rSO$_2$ below 55% should be addressed without delay.

With the ability to detect brain oxygen imbalances sooner and intervene earlier in patients with ischemic stroke, the patient's outcome could be improved. Recently, a technique for the non-invasive monitoring cerebral tissue oxygenation is developed using the photon emission theory, and dual wave length (760-850 nm), to measure absolute changes in the oxygenated, deoxy Hb, total Hb concentration. It is applied over the ischemic focus confirmed by magnetic resonance imaging (MRI) and the reconstructed NIRS topograms shows an area of decrease optical density over the ischemic area. It can none invasively trace the cortical hemodynamic changes induced by ischemia at real time and could be a practical tool for stroke prediction and rehabilitation.

This study concludes that cerebral oximetry can be used as a measure to evaluate the cerebral oxygenation during acute phase of ischaemic stroke. It is a potentially useful marker for follow-up and the outcome of ischemic stroke patients.

**REFERENCES**


الملخص العربي
تقدير مدى استخدام المخ للأكسجين في مرضى الاحتشاء الدماغي

بدأ عرض البحث في تسجيل مدى استخدام المخ للاكسجين عن طريق الابتعاد تحت الدماء تحت المخ حدود سنة سابقة، حتى الوقت الحاضر، بدأ الاهتمام باستخدامه عرضياً فقط أثناء المراقبة الجراحية. يوجد الآن عدة دراسات اكلينيكية تجد وجيزاً في النتائج على مدى التطول لسوء فهم قراءات الجهاز.

الغرض من البحث:
هو تقييم الأهمية الإكلينيكية لقيمة مدى استخدام المخ للاكسجين في مرضى الاحتشاء الدماغي أثناء المرحلة الحادة للمريض.

وقد أشتمل هذا البحث على أربعة وثلاثون مريضاً مصابون بالاحتشاء الدماغي نتيجة إصابة الشريان الوسطي المخيخ.

وقد تم تحصيل كل المرضى فحصًا طبيًا كاملًا مع عمل المعالج الطبيعي اللازمة وقد تم تحديد مستوى استخدام الأكسجين للمخ عن طريق جهاز السومانك 3100 باستخدام الابتعاد تحت الدماء الضوئية عبر المخ خلال أسبوعين من حزام المرضى وقد تم تحديد نسبة الغازات بالدم أيضاً. كما تم تسجيل مستوى الوعي باستخدام مقياس جلاسكو للميغوالوبية وقد تم تصنيف المرضى تبعاً لنتائج الغيبوبة إلى حالات قابلة للتحسين من حيث درجة الوعي وحالات لم يسترجعوا درجة وعيهم حتى قوا الوفاة.

نتائج البحث:
توافقت نتائج البحث لمدى استخدام المخ للاكسجين إيجابياً مع نتائج مقياس جلاسكو للميغوالوبية على الرغم من أنها لم تكن ذات قيمة إحصائية، إلا أن نتائج قيم استخدام المخ للاكسجين، فقد كانت ذات قيمة إحصائية أعلى في المرضى الذين تحسنت درجة وعيهم عن مجموعة المرضى الذين لم تتحسن درجة وعيهم فقاً فواحة في خلال أسابيع من المتابعة. بينما لم تكن نتائج مستوى الأكسجين بالدم ذات قيمة إحصائية عند مقارنتها مع نتائج مقياس مستوى الوعي ونتائج استخدام المخ للاكسجين.

وستتطلب من هذا البحث أن قياس مدى استخدام المخ للاكسجين في المرحلة الحادة لمرضى الاحتشاء الدماغي يمكن استخدامه ويمكن أن يستعمل كعلامة للحكم على مدى كفاءة العلاج والمتابعة في المرحلة الحادة.