ISSN: 2717-8161 REVIEW ARTICLE

New Trends in Medicine Sciences

New Trend Med Sci 2024; 5(Supplement Issue):143-146 https://dergipark.org.tr/tr/pub/ntms

Investigating the Relationship Between Cerebral Oximetry and Arterial Blood Gas Parameters

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Article History
Received 19 Dec 2023
Accepted 17 July 2024
Published Online 28 July 2024

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Doi:10.56766/ntms.1406748

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Abstract: Cerebral oximetry, employing near-infrared spectroscopy (NIRS) through a transcutaneous membrane, is a non-invasive monitoring method designed to assess average regional tissue oxygenation in the frontal cortex. The literature consistently underscores its invaluable role in gauging cerebral tissue oxygen levels throughout the perioperative period. Notably, guidelines routinely recommend the use of NIRS in adult cardiac surgery.
In contrast, arterial blood gas analysis remains a standard practice in cardiac surgery to measure general systemic oxygenation. While arterial blood gas analysis provides insights into overall systemic oxygenation, NIRS focuses specifically on regional oxygenation within the brain tissue. This paper delves into the intricate relationship between NIRS and arterial blood gas parameters, shedding light on their correlation and significance in the context of assessing oxygenation levels. © 2024 NTMS.

Keywords: Cerebral Oximetry; Arterial Blood Gas; Cardiac Surgery.

1. Introduction

Cerebral oximetry and arterial blood gas (ABG) analysis represent distinct methodologies in the assessment of oxygen levels within the human body. Despite their shared objective of evaluating oxygenation, these methods diverge in terms of their application and measurement locations. ABG analysis entails the measurement of oxygen, carbon dioxide, pH, and other components using a sample extracted from the arterial system. This diagnostic test is commonly employed to appraise blood oxygen and carbon dioxide content, as well as to assess acid-base equilibrium and electrolyte levels. In contrast, cerebral oximetry and ABG analysis target different facets of oxygenation. Cerebral oximetry specifically gauges oxygenation in the brain tissue on a regional scale, whereas ABG analysis provides insights into overall systemic oxygenation [1].
Cerebral oximetry monitors employ non-invasive continuous monitoring through near-infrared spectroscopy (NIRS) technology to assess cerebral oxygenation. Numerous studies have demonstrated their effectiveness in evaluating cerebral tissue oxygen levels during cardiac surgeries, hypotensive surgeries,

Cite this article as: Turunc E, Dost B, Komurcu O and Ozdemir E. Investigating the Relationship Between Cerebral Oximetry and Arterial Blood Gas Parameters. *New Trend Med Sci.* 2024; 5(Supplement Issue):143-146.Doi:10.56766/ntms.1406748

and prolonged monitoring of patients in the trendelenburg position [2]. Beyond surgical settings, these monitors are now being employed in scenarios where cerebral blood flow (CBF) ceases, such as cardiac arrests, with the aim of sustaining cerebral blood flow through cardiopulmonary resuscitation. The operational principle is grounded in The measurement of near-infrared light with a specific wavelength of 750 - 100nm. The ability of near-infrared light to penetrate tissues and be absorbed by certain chromophores forms the basis of regional cerebral oxygen saturation measurement. In contrast to pulse oximeters, which primarily measure arterial blood flow, values for cerebral regional oxygen saturation (rSO_2) obtained from NIRS are predominantly reflective of venous blood, as venous blood constitutes ~75% of the blood flow in brain tissue. Consequently, oxygen saturation derived from NIRS serves as a representation of venous oxygen saturation for the respective organ [3]. Studies have indicated a positive linear correlation between cerebral oximetry and jugular venous saturations [4]. NIRS, a non-invasive technique, enables exploration of cerebral hemodynamics and oxygenation. Integrated with CBF measurements, it has the potential to unveil insights into oxygen distribution, metabolism and function. However, interpreting experimental results can be complex due to the influence of various factors on measured NIRS signals, encompassing both scalp and cerebral hemodynamics.

The interaction between Arterial Blood Pressure (ABP) and CBF has been thoroughly examined, playing a fundamental role in comprehending cerebral autoregulation. Previous studies have explored the influence of alterations in ABG levels on both ABP and CBF. Yet, the comprehensive characterization of the relationship between ABP, alterations in ABG, and NIRS signals remains an area that warrants further exploration [5]. The regulation of CBF is generally known to be directed by changes in the pH of cerebrospinal fluid, often influenced by pCO_2. Both high and low pH values exert a direct effect on the relaxation and contraction of smooth muscles. However, some findings suggest that $PaCO_2$ may act independently or in conjunction with pH. This effect is thought to extend beyond the regulation of smooth muscles, potentially affecting endothelial cells, nerves, and astrocytes. The results also indicate that arterial pCO_2 may have an impact on regulating smooth muscle contractility through the endothelium. Cerebral autoregulation is strongly linked to carbon dioxide partial pressure but is much less affected by changes in arterial oxygen saturation [6].

In a study of pediatric patients with repaired congenital heart disease, the relationship between cerebral and somatic regional oxygen saturation renal, splanchnic, and muscle regions was compared to blood gas lactate levels. Cerebral rSO_2 showed the strongest inverse correlation with lactate levels, followed by renal, splanchnic, and muscle rSO2. The average cerebral and renal rSO2 predicted a lactate level of 3.0 mmol/litre with 95% sensitivity and 83% specificity. Based on the findings, it is broadly inferred that an average cerebral and renal rSO_2 measured using NIRS, predicting values below 65%, may serve as an early indicator of increased lactate levels in acyanotic children following congenital heart surgery. This implies its potential utility in identifying global hypoperfusion associated with low cardiac output syndrome within this specific population [7].

In a meta-analysis conducted on children with congenital heart disease, the aim was to determine the correlation between venous oxygen saturations corresponding to NIRS oximetry. The findings demonstrate a robust correlation between cerebral NIRS oximetry and oxygen saturation levels in the superior vena cava or jugular vein. Additionally, renal NIRS oximetry exhibits a significant correlation with oxygen saturations in the inferior vena cava. Conversely, a weaker correlation was observed between cerebral NIRS oximetry and oxygen saturations in the inferior vena cava [8]. De Waal et al. demonstrated an increase in end-tidal CO_2, cerebral blood volume, and rSO_2, along with significant cerebral vasodilation, elevated $PaCO_2$ and increased CBF after insufflation in children undergoing laparoscopic fundoplication. In contrast, post-pneumoperitoneum rSO_2 values were similar to preoperative values. However, De Waal et al. established the initial rSO_2 values before insufflation after inducing moderate hypocapnia, detecting approximately a 25% increase in $PaCO_2$ during pneumoperitoneum [9]. In a study by Kaya et.al., evaluating whether lower pneumoperitoneum pressure than standard pressure during laparoscopic nephrectomy would allow higher cerebral oxygen saturation, a moderate positive correlation between cerebral rSO_2 and $PaCO_2$ was found [10].

Given this context, we conducted a comparative analysis of the correlation between intraoperative NIRS values and blood gas parameters in patients who underwent open-heart surgery at the Ondokuz Mayıs University Hospital Cardiovascular Surgery Operating Room between January 2021 and August 2023. The retrospective evaluation included intraoperative NIRS values and blood gas parameters of 170 patients. This study was approved by the Ondokuz Mayis University Clinical Research Ethics Committee (approval number; 2023/291). The statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) program, version 25 (IBM, Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was employed for normality tests. Descriptive statistics were presented as mean (± standard deviation) for quantitative data with normal distribution, and as median (interquartile range) for data without normal distribution, while frequencies (and percentages) were used for categorical data. The correlation between the lowest/highest blood gas parameters (pH, PaCO2, PaO2, lactate, hemoglobin) and cerebral rSO2 values was examined. The correlation between rSO2 and pH, pCO2, pO2, Hb, and lactate was assessed using the

Pearson correlation test. The correlation coefficient (r) values were interpreted as indicating a 'weak' relationship if r = 0.00–0.24, 'moderate' if r = 0.25–0.49, 'strong' if r = 0.50–0.74, and 'very strong' if r = 0.75-1.00. p value < 0.05 was considered statistically significant.

Patient and procedural characteristics are summarized in Table 1. Upon evaluating the results of our study, a positive correlation was observed between the decrease in rSO_2 and pH, PaO2, and hemoglobin values, while a negative correlation was noted with $paCO_2$ and lactate values (Fig.1). The increase in lactate levels, affecting cardiac output and potentially impairing oxygen delivery, was considered to contribute to the reduction in cerebral oxygenation. When considering the time effect on ABG, a correlation with cerebral rSO_2 is evident (Table 2).

Table 1: Patient demographic and surgical characteristics and clinical outcomes.

	n = 170
Age, years	60.3 ± 12.3
Sex, female/male n (%)	63 (37.1)/107 (62.9)
BMI (kg/m²)	27.1 ± 5.1
Comorbidities, n (%)	
Cardiovascular system[a]	38 (22.4)
Endocrine system[b]	29 (17.1)
Respiratory system[c]	5 (2.9)
> 1 more system	55 (32.4)
Surgery type, n (%)	
CABG	89 (52.4)
AVR/MVR	42 (24.7)
CABG + AVR	31 (18.2)
ASD	4 (2.4)
Bypass time (min)	146.2 ± 57
Cross-clamp time (min)	92.8 ± 44.1

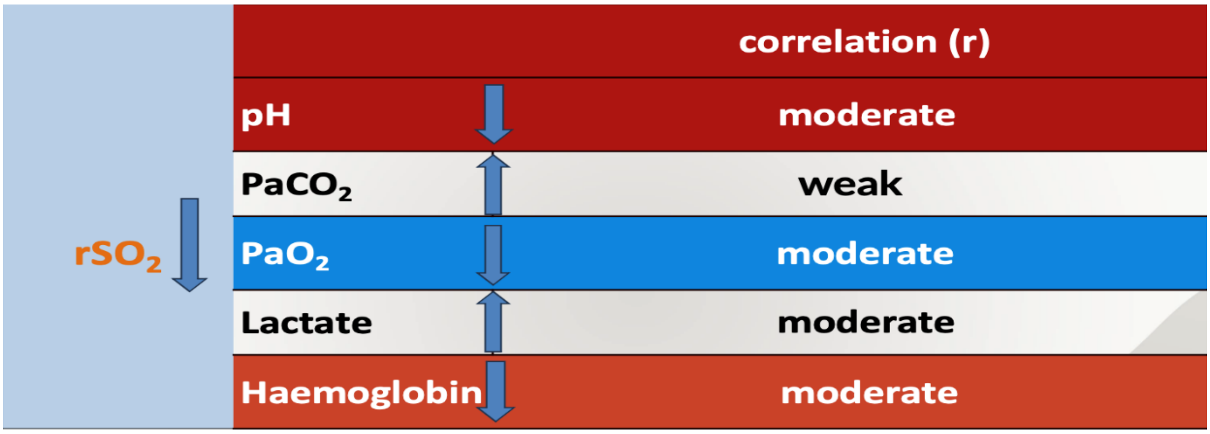
Continuous variables are presented as mean ± standard deviation and categorical variables are presented as counts (percentages). Statistically significant difference is highlighted in bold. *Abbreviations:*, *ASD* atrial septal defect, *AVR* aortic valve replacement, *BMI* body mass index, *CABG* coronary artery bypass grafting, *MVR* mitral valve replacement. [a]Hypertension,[b] Type 2 diabetes, [c] Asthma.

Table 2: Assessment of Correlation Coefficient (r) Values Between NIRS, Arterial Blood Gas, and Haemoglobin.

	pH		PaO_2		$PaCO_2$		Hb		Lactate	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
rSO_2 (right)	0.332	0.069	**0,255**	**0.002**	-0,190	0.872	**0,305**	**0.000**	**-0,347**	**0.038**
rSO_2 (left)	**0.325**	**0.001**	**0.308**	**0.022**	-0.191	0.185	**0.405**	**0.049**	-0.349	0.077

Significant difference is highlighted in bold. Abbreviations: *NIRS*: Near-Infrared Spectroscopy, *rSO_2:* Regional cerebral oxygen saturation; r: Correlation coefficient; *PaO_2:* Partial pressure of arterial oxygen; *$PaCO_2$:* Partial pressure of arterial carbon dioxide; *Hb:* Haemoglobin concentration.

Figure 1: The correlation between rSO2 and arterial blood gas parameters.



2. Conclusion

In summary, the role of cerebral oximetry as a pivotal protective monitor in safeguarding cerebral functions is underscored by its potential to provide valuable insights during various medical procedures. A thorough examination of existing literature yields no conclusive evidence supporting a direct correlation with ABG analysis. Nevertheless, the significance of cerebral oximetry should not be diminished; instead, it should be acknowledged as a complementary monitor, amplifying the capacity to improve patient outcomes across diverse surgical scenarios, encompassing both cardiac and non-cardiac procedures.

This perspective is fortified by a wealth of accumulating evidence and the widening spectrum of applications observed in clinical practice. Rather than positioning cerebral oximetry as a substitute for ABG analysis, it should be recognized as an invaluable ally, contributing to a more comprehensive understanding of oxygen dynamics and aiding in the nuanced management of patients undergoing surgery.

Limitations of the Study

Our study has several limitations. Firstly, the presence of clinical, physiological, and metabolic variations among patients can significantly impact both cerebral oximetry and blood gas analysis results, potentially weakening the correlation between the two methods. Secondly, technical constraints related to cerebral oximetry devices may hinder accurate measurements, particularly in conditions of low perfusion. Thirdly, the reliance on small sample sizes and the absence of long-term data limits our comprehensive understanding of the clinical benefits of cerebral oximetry and blood gas analysis. Lastly, the retrospective research design introduces inherent biases.

Acknowledgement

None.

Conflict of Interests

The authors declare that they have no conflict of interest.

Financial Support

This study not received financial support.

Author Contributions

BD: Conceived and designed the study, collected data, and wrote the manuscript. ET, EO: Contributed to data collection. ET, OK: Analyzed and interpreted results, participated in data collection. BD, ET, OK, EO: Involved in data collection. BD, ET: Contributed to study design, supervised the work, performed analysis, and provided data and analysis tools. All authors have read and approved the final version of the manuscript.

Ethical Approval

The study was commenced after receiving approval from the local ethics committee (Ondokuz Mayis University Clinical Research Ethics Committee (approval number; 2023/291)).

Data sharing statement

None.

Consent to participate

Informed consent was not applicable.

Informed Statement

The study complies with the principles of the Declaration of Helsinki. The consent of all the patients was obtained before commencing the study.

References

1. Wahr JA, Tremper KK, Samra S, Delpy DT. Near-infrared spectroscopy: theory and applications. *J Cardiothorac Vasc Anesth.* 1996; 10(3):406-18.
2. Tosh W, Patteril M. Cerebral oximetry. BJA Education. 2016;16(12):417-21.
3. Ghanayem NS, Hoffman GM. Near Infrared Spectroscopy as a Hemodynamic Monitor in Critical Illness. *Pediatr Crit Care Med*. 2016; 17(8 Suppl 1):S201-206.
4. Nagdyman N, Fleck T, Schubert S, et al. Comparison between cerebral tissue oxygenation index measured by near-infrared spectroscopy and venous jugular bulb saturation in children. *Intensive Care Med*. 2005; 31(6):846-50.
5. Murkin JM, Arango M. Near-infrared spectroscopy as an index of brain and tissue oxygenation. *Br J Anaesth*. 2009; 103 Suppl 1:i3-13.
6. Tekes A, Poretti A, Scheurkogel MM, et al. Apparent diffusion coefficient scalars correlate with near-infrared spectroscopy markers of cerebrovascular autoregulation in neonates cooled for perinatal hypoxic-ischemic injury. *AJNR Am J Neuroradiol.* 2015; 36(1):188-93.
7. Chakravarti SB, Mittnacht AJ, Katz JC, et al. Multisite near-infrared spectroscopy predicts elevated blood lactate level in children after cardiac surgery. *J Cardiothorac Vasc Anesth.* 2009; 23(5):663-7.
8. Loomba RS, Rausa J, Sheikholeslami D, et al. Correlation of Near-Infrared Spectroscopy Oximetry and Corresponding Venous Oxygen Saturations in Children with Congenital Heart Disease. *Pediatr Cardiol.* 2022; 43(1):197-206.
9. de Waal EE, de Vries JW, Kruitwagen CL, Kalkman CJ. The effects of low-pressure carbon dioxide pneumoperitoneum on cerebral oxygenation and cerebral blood volume in children. *Anesth Analg.* 2002; 94(3):500-505.
10. Kaya C, Ustun YB, Bilgin S, Koksal E, Ozden E, Dost B. Cerebral Oximetry after Low Pressure versus Standard Pressure Pneumoperitoneum in Laparoscopic Nephrectomy. *J Coll Physicians Surg Pak.* 2022; 32(3):346-51.