ISSN: 2717-8161 REVIEW ARTICLE

New Trend Med Sci 2024; 5(Supplement Issue):137-142 https://dergipark.org.tr/tr/pub/ntms

Use of Somatic Oximetry in Traumatic Organ Injuries

Başar Erdivanlı[1*]

[1]Department of Anesthesiology and Reanimation, Faculty of Medicine, Recep Tyyip Erdoğan University, Rize, Türkiye

Article History
Received 13 Dec 2023
Accepted 17 July 2024
Published Online 28 July 2024

***Corresponding Author**
Başar Erdivanlı
Department of Anesthesiology and Reanimation
Faculty of Medicine
Recep Tayyip Erdoğan University
Rize, Türkiye.
Phone: +90 5057800730
E-mail: berdivanli@gmail.com

Doi:10.56766/ntms.1389876

Authors' ORCIDs
Başar Erdivanlı
https://orcid.org/0000-0002-3955-8242

Abstract: Somatic oximetry, despite its frequent application in the clinical assessment of trauma patients, suffers from a notable dearth of randomized controlled trials, leading to an absence of systematic reviews or a defined level of evidence pertaining to its clinical utility. Somatic oximetry can provide information not only in direct monitoring of traumatized tissue but also in monitoring standardized areas such as the thenar region, shedding light on compensatory mechanisms of the body. The employment of the vascular occlusion test in somatic oximetry affords dynamic measurements, presenting a valuable tool for assessing the efficacy of diverse therapeutic interventions. Recent research findings establish that somatic oximetry plays a pivotal role in gauging the need for resuscitation during the initial evaluation of trauma patients. Furthermore, its application extends to monitoring oxygenation levels in damaged extremities and superficially located internal organs, particularly in the pediatric population. Despite the demonstrated benefits, a significant impediment to the widespread adoption of standardized somatic oximetry, specifically utilizing StO2, arises from the prevalent practice of amalgamating data from trauma and cardiac arrest patients. This practice hinders the establishment of a standardized evaluation protocol before the completion of resuscitation efforts. Consequently, the potential of somatic oximetry in mitigating secondary damage remains inadequately explored and warrants further rigorous scientific investigation. © 2024 NTMS.

Keywords: Monitoring, Physiologic/instrumentation; Near-Infrared; Oximetry; Trauma; Injuries.

1. Introduction

Near-infrared spectroscopy (NIRS) technology has revolutionized the ability to continuously monitor the oxygenation of superficial tissues, providing valuable insights into tissue perfusion and oxygen supply. This non-invasive technique employs the principles of light absorption and scattering to measure changes in the concentration of oxygenated and deoxygenated hemoglobin in tissues. Thus, the key advantage of NIRS is its ability to provide real-time information about tissue oxygen levels. It offers a non-stop window into the oxygen status of the tissue, which is particularly critical in scenarios such as trauma care, surgery, and intensive care units.

Critics have raised concerns about the specificity of

Cite this article as: Erdivanlı B. Use of Somatic Oximetry in Traumatic Organ Injuries. *New Trend Med Sci.* 2024; 5(Supplement Issue):137-142.Doi:10.56766/ntms.1389876

NIRS values, as they include contributions from both arterial and venous circulation [1]. While this critique is valid, it's crucial to understand that NIRS is capable to provide a holistic view of tissue oxygenation. Rather than pinpointing the source of oxygenation, NIRS serves as an indicator of overall tissue health and oxygen supply. Recent research has explored ways to enhance the specificity of NIRS data through advanced signal synthesis and processing techniques, which may improve its clinical utility.

The vascular occlusion test is a notable application of NIRS. This test involves temporarily blocking blood flow to a specific region, allowing for the assessment of tissue oxygen requirements. It's a rapid and practical way to understand how well tissues can adapt to changes in oxygen supply, providing insights into vascular function and potential issues with tissue perfusion [2]. The vascular occlusion test can capture a range of physiological parameters, including patient-specific anatomical variations, hemoglobin concentration, hemoglobin structure, cardiac output, pH, and body temperature (Figure 1).

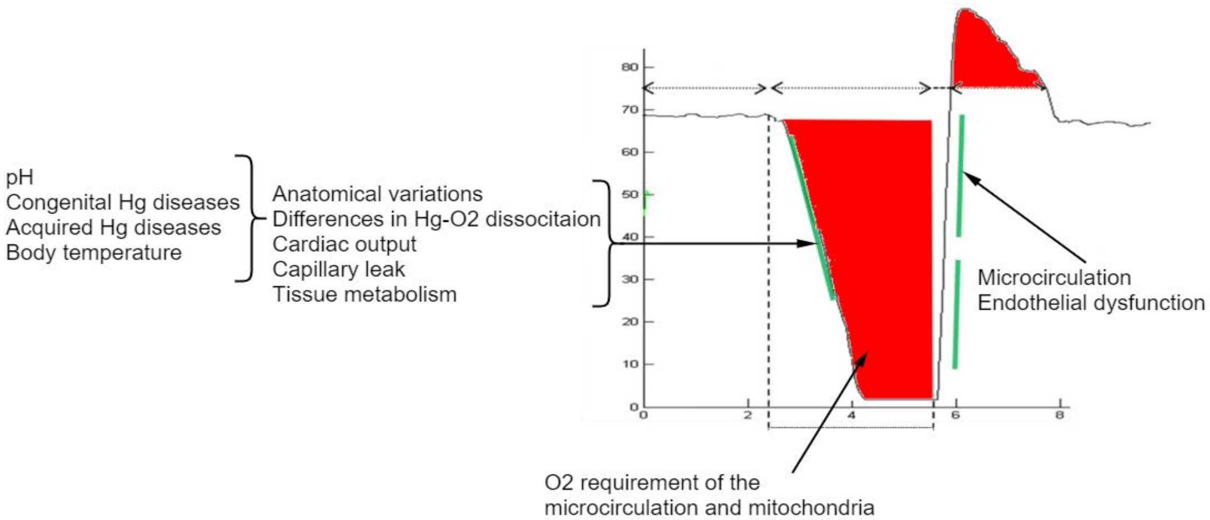

Figure 1: The descriptive nature of the vascular occlusion test is given. The descent on the left side gives the rate of desaturation of tissue oxygen saturation, which is related to the fitness of the patient. The ascend on the right side gives the rate of resaturation of tissue oxygen saturation, which is related to the state of the microcirculation, which is mainly determined by the endothelial function. The area under the curve inbetween the two green lines is positively correlated to the oxygen requirement of the tissue, and if they are active, the mitochondria. Finally, the small red area above the baseline may indicate the antioxidant capacity of the tissue.

Despite all of this convenience and benefits, the literature on the use of somatic oximetry (stO2) in trauma patients predominantly consists of case reports and observational studies. While these studies have provided valuable insights into the potential utility of stO2 in clinical settings, there is a growing need for more robust evidence in the form of randomized controlled trials (RCTs) to establish its efficacy. Additionally, the majority of observational studies conducted in the field of Emergency Medicine are not specific to trauma patients, rather the data for trauma patients and cardiac arrest patients are often presented in a combined manner.

StO2 holds the promise of being a crucial tool for assessing the intensive care needs of trauma patients and optimizing treatment. Trauma patients present a unique set of challenges, including varying degrees of tissue damage, hemorrhage, and fluctuations in oxygen demands. The real-time, non-invasive monitoring provided by stO2 can offer valuable insights into the dynamic nature of tissue oxygenation in these complex cases.

This review aims to examine the current status of somatic oximetry's clinical use in trauma patients by thoroughly analyzing relevant studies and data. The goal is to provide a comprehensive understanding of the potential advantages and limitations of stO2 in this patient group, including its role in early detection of tissue hypoxia, guiding resuscitation efforts, and improving patient outcomes.

1.1. Does somatic oximetry fit into the initial assessment of traumatic organ injury?

The earliest reports of stO2 use in trauma patients are from intensive care units. The prototype NIRS devices were compared with arterial base deficit, lactate, gastric mucosal pH and mixed venous hemoglobin oxygen saturation [3]. It was concluded that the skeletal muscle stO2 is capable to reflect whole body oxygenation status. Following studies showed that stO2 non-invasively derived from the thenar region is able to quantify the severity of hemorrhagic shock [4]. A multicentre study including 383 patients showed that stO2 was noninferior to base deficit when used to predict multiple organ dysfunction or death [5].

Following the validation of thenar muscle-derived stO2, shown to be comparably accurate to the earlier invasive monitors, investigations delved into its standalone efficacy. A notable single-center study focused on somatic oximetry in adult trauma patients, showcasing several strengths including a robust patient cohort, a concise data collection period of 9 months, and inclusion of diverse trauma types (head, chest, abdomen, and extremity). The study's key finding emphasized that the initial rate of deoxygenation, in conjunction with age and Glasgow Coma Scale score, successfully predicted the necessity for life-saving interventions. However, the study lacked insights into the correlation between organ injury and specific outcomes, such as blood product transfusions or mechanical ventilation. Notably, reported outcomes like a Glasgow Coma Scale Score <15 were deemed insufficiently informative. A nuanced exploration of these associations is crucial for a comprehensive understanding of somatic oximetry's predictive value in trauma management [6].

A study including 325 patients found the stO2 value of 65% as the cutoff for marked increase in consumption of packed red bood cell [7].

A study including 184 pediatric trauma patients reported that stO2 value<70% and a heart rate increased above 2 standard deviations predicts need for life saving interventions during the pediatric intensive care unit stay [8]. The study exhibits several limitations, such as the absence of a defined protocol for determining which cases should be monitored with NIRS and which should not. However the study reported the results of monitored and not monitored groups. The main limitation is that prehospital rate of life saving interventions was similar between groups with lower and higher stO2 values (64,6% vs 52,2%), which suggests that the outcome measured the response to prehospital interventions, which were neither standardized nor explained. Also the number of patients in each group were not balanced.

A recent prospective cohort study conducted over an 18-month period reported a two-fold increase in the rate of life-saving interventions in cases where the stO2 value was below 70% [9]. The strengths of this study include the inclusion of both blunt (67.6%) and penetrating (28.4%) traumas, a more homogeneous age group, and a balanced number of patients in each group. Reports from military medicine include valuable data related to the question. A case report series including data from 40 military personnel obtained within 3 months reports that initial stO2 value < 70% indicates clinical shock, and somatic oximetry is able to show improvement associated with resuscitation maneuvers [10]. The literature in military medicine reports that an stO2 value below 75% indicates the severity of injury and the effectiveness of resuscitative efforts [11].

Finally, thenar oximetry is capable to differentiate between mild, moderate and severe shock states [12].

1.2. Does somatic oximetry fit into the initial treatment of traumatic organ injury?

A major milestone in trauma literature investigated whether there is a difference between immediate or delayed fluid resuscitation in hypotensive trauma patients. The study found that there was a difference, but not in terms of reversing hypotension efficiently. Rather, it was interesting to learn that giving more fluids may harm the patient. In that study, patients who received around 2.5 liters of crystalloids instead of 375 ml died more frequently (38% vs 30%) [13]. A later study investigated the same question in rats and reported that immediate resuscitation lead to less mortality. However, stratifing the groups in terms of received fluids revealed once more that mortality had a positive correlation with the amount of fluids given [14]. These and many other studies formed the basis of low volume fluid resuscitation which is a component of damage control resuscitation.

It turns out that damage control resuscitation necessitates permissive hypotension during the initial assessment and organ repair to prevent unnecessary hemodilution and edema (Figure 2).

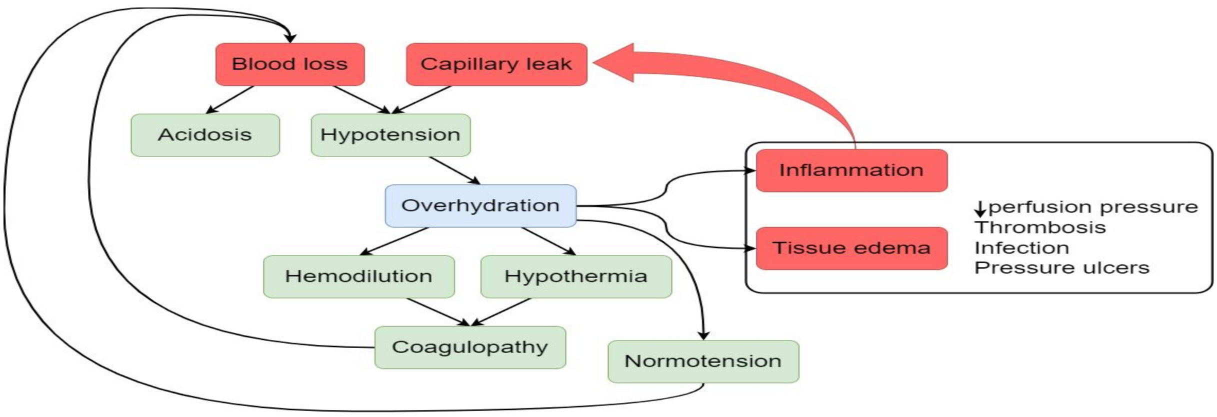

Figure 2: The physiologic mechanisms associated with overhydration, one of the aggressive resuscitation strategies, is given. The initial acidosis may, mprove tissue oxygenation with a right shift of the oxygen-hemoglobin dissociation curve, and hypotension may decrease the blood loss. On the contrary, overhydration may cause hemodilution and other side effects, all of which may promote further blood loss and inflammation. Please note that monitoring tissue oxygen saturation can both prevent and diagnose the harmful conditions given on the right rectangle. Thus tissue oxygen saturation is a goal-directed dynamic monitor.

The vascular occlusion test is the workhorse of near-infrared spectroscopy [15]. Although it is criticized for mixing arterial, venous, and tissue oximetry values, the different phases allow for a thorough evaluation of all these sites (Figure 1). It has been reported that the desaturation phase can identify hemorrhagic shock, whereas the resaturation phase can identify septic shock [16–19]. Thus, it is capable of identifying the causes shown on the right side of Figure 2.

1.3. Is there a potential for somatic oximetry to guide or individualize the therapeutic interventions?

Although somatic oximetry may not be an omnipotent marker capable to guide the therapy, it may be a very good complement to any form of disease with hypoperfusion. Acute compartment syndrome following limb injury is an established disease, which benefits most form somatic oximetry. An injured limb may be lost due to arterial dissection or compartment syndrome. Both civilian and military literature suggest that somatic oximetry is capable to detect an underperfused limb and quantitatively monitor the oxygenation of the limb, and monitor the benefit and harm of any therapeutic maneuver. ([20–22]. The key points to remember when using somatic oxymetry to monitor an injured limb are that 1) the most effective way is to also monitor the opposite limb, if possible and 2) a hyperemic state is expected in a sufficiently perfused limb during the first 72 hours of trauma [23,24].

As far as this literature review, there is no other established disease which may benefit from somatic oximetry, yet. The following parapgraphs will explain some of the controversy in the literature.

There is substantial amount of literature comparing cerebral oximetry with intracranial pressure monitors, cerebral microdialysis and jugular venous blood gas analysis in traumatic brain injury [25,26]. Intracranial pressure is an important parameter since its increase is related with decreased cerebral perfusion and neuronal death. Devices capable to continuously measure intracranial pressure via an intracranial catheter and adjust it via a peristaltic pump are invasive devices, with their own set of complications [27]. They ease the management of a patient with a tumor, hematoma or edema [28,29]. Subtle changes in intracranial pressure are overcome by the cerebral autoregulation. Due to that, the attending clinican should include all factors related to cerebral autoregulation (arterial blood pressure, partial pressure of arterial carbondoxide, body temperature and sedative drugs, just to name a few). Please note that NIRS (but not stO2) is mainly used to monitor cerebral autoregulation [30].

All the aforementioned monitoring approaches share a common limitation. This is exemplified in a patient scenario featuring head and thorax injuries coupled with cerebral edema and adult respiratory deficiency syndrome. The dilemma arises when implementing a lung-protective ventilation strategy. On one hand, this strategy may lead to normoxemia and gradual hypercapnia, subsequently triggering increased cerebral blood flow and exacerbating cerebral edema. The implications for neurological outcomes remain challenging to ascertain, with somatic oximetry and jugular venous blood gas analysis potentially yielding more favorable results, while intracranial pressure monitoring and cerebral microdialysis, contingent on their placement, may indicate less favorable outcomes. In light of these complex physiological dynamics, it should not be surprising that near-infrared spectroscopy has not proven efficacious in detecting intracranial hematomas. The intricate interplay of these monitoring modalities underscores the need for a nuanced understanding of their limitations and advantages in diverse clinical scenarios [31,32]. This review did not find any evidence indicating a potential for somatic oximetry to alleviate secondary injury or improve outcomes. Nor was it possible to identify any randomized controlled clinical study in English literature with an active arm using somatic oximetry as an intervention.

2. Conclusion

A recent study investigating the role of somatic oximetry in trauma patients found that alterations in somatic oximetry values are associated with occult shock 33. Considering the relationship between occult shock and infection rate and mortality in major trauma patients, somatic oximetry may be expected to become part of a multimodal monitoring approach 34. An additional advantage lies in the applicability of somatic oximetry in damage control resuscitation and low-volume fluid resuscitation. Furthermore, compelling evidence supports the capability of somatic oximetry to tailor treatment approaches for hemorrhagic shock and extremity injuries, thereby underscoring its potential for personalized and targeted interventions in critical care scenarios.

Limitations of the Study

This review has several limitations. Firstly, much of the literature on somatic oximetry consists of case reports and observational studies rather than randomized controlled trials, limiting the robustness of the conclusions. Additionally, many studies combine data from trauma and cardiac arrest patients, complicating the interpretation specific to trauma care. The variability in study designs, patient populations, and intervention protocols further complicates the synthesis of findings. Finally, the lack of standardized evaluation protocols and the potential publication bias towards positive outcomes should be considered when interpreting the results. Further rigorous research is needed to establish standardized guidelines and confirm the clinical utility of somatic oximetry in trauma patients.

Acknowledgement

None.

Conflict of Interests

The authors declare no competing interests.

Financial Support

The authors received no financial support for the research and/or authorship of this article.

Author Contributions

All authors contributed equally to the article.

Ethical Approval

None.

Data sharing statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Consent to participate

None.

Informed Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. Taylor DE, Simonson SG. Use of near-infrared spectroscopy to monitor tissue oxygenation. New Horizons: *Sci Pract Acute Med.* 1996; 4(4):420-25.
2. McLay KM, Fontana FY, Nederveen JP, et al. Vascular responsiveness determined by near-infrared spectroscopy measures of oxygen saturation. *Exp Physiol.* 2016; 101(1):34-40.
3. McKinley BA, Marvin RG, Cocanour CS, Moore FA. Tissue hemoglobin O2 saturation during resuscitation of traumatic shock monitored using near infrared spectrometry. *J Trauma.* 2000; 48(4):637-42.
4. Crookes BA, Cohn SM, Bloch S, et al. Can near-infrared spectroscopy identify the severity of shock in trauma patients? *J Trauma*. 2005; 58(4):806-16.
5. Cohn SM, Nathens AB, Moore FA, et al. Tissue oxygen saturation predicts the development of organ dysfunction during traumatic shock resuscitation. *J Trauma.* 2007; 62(1):44-54.
6. Guyette FX, Gomez H, Suffoletto B, et al. Prehospital dynamic tissue oxygen saturation response predicts in-hospital lifesaving interventions in trauma patients. *J Trauma Acute Care Surg*. 2012; 72(4):930-35.
7. Khasawneh MA, Zielinski MD, Jenkins DH, Zietlow SP, Schiller HJ, Rivera M. Low tissue oxygen saturation is associated with requirements for transfusion in the rural trauma population. *World J Surg.* 2014; 38(8):1892-97.
8. Balakrishnan B, Dasgupta M, Gajewski K, et al. Low near infrared spectroscopic somatic oxygen saturation at admission is associated with need for lifesaving interventions among unplanned admissions to the pediatric intensive care unit. *J Clin Monit Comput*. 2018; 32(1):89-96.
9. Ashby DW, Balakrishnan B, Gourlay DM, Meyer MT, Nimmer M, Drendel AL. Utilizing Near-Infrared Spectroscopy to Identify Pediatric Trauma Patients Needing Lifesaving Interventions: A Prospective Study. *Pediatr Emerg Care.* 2023; 39(1):13-19.
10. Beilman GJ, Blondet JJ. Near-infrared spectroscopy-derived tissue oxygen saturation in battlefield injuries: a case series report. *World J Emerg Surg.* 2009; 4:25.
11. Cap AP, Pidcoke HF, Spinella P, et al. Damage Control Resuscitation. *Mil Med.* 2018; 183(suppl_2):36-43.
12. Crookes BA, Cohn SM, Bloch S, et al. Can near-infrared spectroscopy identify the severity of shock in trauma patients? *J Trauma.* 2005; 58(4):806-16.
13. Bickell WH, Wall MJ, Pepe PE, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. *N Engl J Med.* 1994; 331(17):1105-109.
14. Santibanez-Gallerani AS, Barber AE, Williams SJ, Zhao Y, Shires GT. Improved survival with early fluid resuscitation following hemorrhagic shock. *World J Surg.* 2001; 25(5):592-97.
15. Booth E, Dukatz C, Ausman J, Wider M. Cerebral and somatic venous oximetry in adults and infants. Surg Neurol Int. 2010;1(1):75. doi:10.4103/2152-7806.73316
16. Lipcsey M, Woinarski NCZ, Bellomo R. Near infrared spectroscopy (NIRS) of the thenar eminence in anesthesia and intensive care. *Ann Intensive Care.* 2012; 2:11.
17. Futier E, Christophe S, Robin E, et al. Use of near-infrared spectroscopy during a vascular occlusion test to assess the microcirculatory response during fluid challenge. *Crit Care.* 2011; 15(5):R214.
18. Santora RJ, Moore FA. Monitoring trauma and intensive care unit resuscitation with tissue hemoglobin oxygen saturation. *Crit Care.* 2009; Suppl 5(Suppl 5):S10.
19. Ward KR, Ivatury RR, Barbee RW, et al. Near infrared spectroscopy for evaluation of the trauma patient: a technology review. *Resuscitation.* 2006; 68(1):27-44.
20. McMillan TE, Gardner WT, Schmidt AH, Johnstone AJ. Diagnosing acute compartment syndrome-where have we got to? *Int Orthop.* 2019; 43(11):2429-35.
21. Shuler MS, Roskosky M, Kinsey T, et al. Continual near-infrared spectroscopy monitoring in the injured lower limb and acute compartment syndrome: an FDA-IDE trial. *Bone Joint J*. 2018; 100-B(6):787-97.
22. Reisman WM, Shuler MS, Kinsey TL, et al. Relationship between near infrared spectroscopy and intra-compartmental pressures. *J Emerg Med.* 2013; 44(2):292-98.
23. Reisman WM, Shuler MS, Roskosky M, Kinsey TL, Freedman BA. Use of Near-Infrared Spectroscopy to Detect Sustained Hyperaemia Following Lower Extremity Trauma. Mil Med. 2016;181(2):111-115. doi:10.7205/MILMED-D-14-00689

24. Aedo-Martín D, Navarro-Suay R, García-Cañas R, Fernández-Gayol M, Vethencourt-Koifmann R, Areta-Jiménez FJ. Use of Oxygen Tissue Monitoring in Patients With Compartment Syndrome: Two Clinical Cases and Literature Review. *Mil Med.* 2019; 184(5-6):e475-e479.

25. Mathieu F, Khellaf A, Ku JC, Donnelly J, Thelin EP, Zeiler FA. Continuous Near-infrared Spectroscopy Monitoring in Adult Traumatic Brain Injury: A Systematic Review. *J Neurosurg Anesthesiol.* 2020; 32(4):288-99.

26. Forcione M, Ganau M, Prisco L, et al. Mismatch between Tissue Partial Oxygen Pressure and Near-Infrared Spectroscopy Neuromonitoring of Tissue Respiration in Acute Brain Trauma: The Rationale for Implementing a Multimodal Monitoring Strategy. *Int J Mol Sci.* 2021; 22(3):1-26.

27. Tavakoli S, Peitz G, Ares W, Hafeez S, Grandhi R. Complications of invasive intracranial pressure monitoring devices in neurocritical care. *Neurosurg Focus.* 2017; 43(5):E6.

28. Pierro ML, Shooshan NM, Deshmukh S, Hirschman GB. A Noninvasive Method for Monitoring Intracranial Pressure During Postural Changes. *Acta Neurochir Suppl.* 2021; 131:125-29.

29. Nag DS, Sahu S, Swain A, Kant S. Intracranial pressure monitoring: Gold standard and recent innovations. *World J Clin Cases.* 2019; 7(13):1535-53.

30. Roldán M, Kyriacou PA. Near-Infrared Spectroscopy (NIRS) in Traumatic Brain Injury (TBI). *Sensors (Basel).* 2021; 21(5):1-30.

31. Viderman D, Ayapbergenov A, Abilman N, Abdildin YG. Near-infrared spectroscopy for intracranial hemorrhage detection in traumatic brain injury patients: A systematic review. *Am J Emerg Med. 2021*; 50:758-64.

32. Kontojannis V, Hostettler I, Brogan RJ, et al. Detection of intracranial hematomas in the emergency department using near infrared spectroscopy. *Brain Inj.* 2019; 33(7):875-83.

33. Campos-Serra A, Mesquida J, Montmany-Vioque S, et al. Alterations in tissue oxygen saturation measured by near-infrared spectroscopy in trauma patients after initial resuscitation are associated with occult shock. *Eur J Trauma Emerg Surg*. 2023; 49(1):307-15.

34. Claridge JA, Crabtree TD, Pelletier SJ, Butler K, Sawyer RG, Young JS. Persistent occult hypoperfusion is associated with a significant increase in infection rate and mortality in major trauma patients. *J Trauma.* 2000; 48(1):8-15.

NTMS New Trends in Medicine Sciences
https://dergipark.org.tr/tr/pub/ntms