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Original Article

Changes in Cerebral Oxygen Saturation Monitored by Near-Infrared Spectroscopy (NIRS) and Their Relation to Complications in Carotid Endarterectomy Surgery (CEA)

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ABSTRACT

Introduction: Carotid endarterectomy (CEA) prevents stroke in patients with severe carotid stenosis. Near-infrared spectroscopy (NIRS) enables real-time monitoring of cerebral oxygen saturation, helping reduce neurological complications. This study examines changes in oxygen saturation and their link to surgical outcomes.

Methods: This descriptive-analytical study was conducted on CEA patients at Razi Hospital, Rasht (2020–2021). Data included demographics, cerebral oxygen saturation (rSO2) changes (measured by INVOS®), and hemodynamic parameters. Descriptive and inferential statistical tests were used for analysis.

Results: Among 40 CEA patients studied, 72.5% were male and 27.5% female. Significant changes were observed in cerebral oxygen saturation (Channel 1: 65.93, Channel 2: 66.00, $P < 0.05$) and hemodynamic parameters. Early postoperative complications occurred in 47.5% of patients, with cardiac issues (32.5%) being the most common, followed by neurological complications (10%) and surgical site hematomas (5%). No surgical site infections were reported. No significant correlation was found between cerebral oxygen saturation or hemodynamic changes and postoperative complications.

Conclusion: Monitoring cerebral oxygen saturation using NIRS is recognized as a practical and effective tool for optimizing the management of carotid endarterectomy surgery. The findings underscore the importance of integrating NIRS monitoring into standard surgical protocols to enhance clinical outcomes and potentially reduce the duration of hospital stays for patients.

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Introduction

CEA is a proven surgical procedure for patients with more than 70% carotid artery stenosis or symptomatic patients with more than 50% stenosis. This procedure involves removing an atherosclerotic plaque from the carotid artery to restore normal blood flow to the brain. CEA has been shown to significantly reduce the risk of stroke in appropriately selected patients (1). Carotid artery stenting (CAS) is considered a less invasive alternative in selected cases, especially for patients at high surgical risk due to comorbidities. CAS involves placing a stent to open the carotid artery while compressing the atherosclerotic plaque against the vessel wall (2). Adequate brain blood flow is essential for brain function, and fluctuations during surgery can cause ischemic events. Monitoring cerebral oxygenation during CEA is crucial for minimizing complications. Techniques like NIRS, transcranial Doppler (TCD), and SSEPs help ensure proper brain oxygenation. NIRS detects changes in cerebral oxygen saturation, enabling doctors to quickly intervene and prevent potential complications (3, 4). CEA patients may experience complications such as stroke, myocardial infarction, neurological deficits, and surgical site issues, requiring careful monitoring for timely intervention and recovery (5, 6).

Different anesthesia techniques, such as general, local, and regional anesthesia, are available for CEA patients. The choice of anesthesia typically depends on the preferences of the surgeon, anesthesiologist, and patient, as well as whether brain monitoring or carotid intra-arterial shunting is used during the surgery (7).

A decrease in EEG wave intensity or blood flow velocity in the middle cerebral artery on one side may indicate cerebral ischemia. In such cases, intra-arterial carotid shunting with clamp removal helps maintain blood flow during surgery. The need for shunting can be assessed using stump pressure, and some surgeons opt to shunt all patients based on a fixed protocol, bypassing intraoperative brain monitoring (8). NIRS monitoring helps assess brain oxygenation during surgery, detect ischemic changes, and ensure an adequate oxygen supply to prevent neurological issues (9).

This study aims to explore the relationship between preoperative cerebral oxygen levels and postoperative complications in carotid endarterectomy using NIRS to monitor regional oxygen saturation. By assessing this method's predictive value, the study investigates how it correlates with neurological and non-neurological outcomes, hospital costs, and length of stay. NIRS technology offers real-time data on oxygen saturation, potentially identifying ischemic complications that may not be detected through other parameters.

Materials and Methods

This descriptive-analytical study was conducted on patients undergoing CEA at Razi Hospital in Rasht between 2020 and 2021. The entire study population was included in the sample, meaning no sampling process was needed. Data were collected using a researcher-designed checklist, which extracted relevant information from the patient's medical records and the output from the INVOS® device, which measures cerebral oxygen saturation through NIRS. Inclusion Criteria: The study included patients diagnosed with carotid atherosclerosis who were candidates for carotid endarterectomy and admitted to Razi Hospital during 2020–2021.Exclusion Criteria: Patients who underwent emergency surgery or whose medical records were incomplete were excluded. The collected data were coded and analyzed using IBM SPSS Statistics version 27. Descriptive statistics were used to summarize the data, with means and standard deviations for continuous variables and frequencies and percentages for categorical variables. The Kolmogorov-Smirnov test was used to assess the normality of the data. To evaluate trends in cerebral oxygen saturation and hemodynamic changes (at various stages: before anesthesia, at the start of surgery, during carotid clamping, after unclamping, and at the end of surgery), repeated measures analysis was conducted. The t-test was employed to explore relationships between hemodynamic changes, cerebral oxygen saturation, and postoperative complications, as well as gender. Pearson’s correlation was used to examine the relationship between age and the changes in cerebral oxygen saturation and hemodynamics. The chi-square test was used to assess the connection between underlying medical conditions and postoperative complications.

Results

Among the 40 patients included in the study, 29 (72.5%) were male and 11 (27.5%) were female. The average age of all patients was approximately 67.45 years, with a standard deviation of around 6.84 years (Table 1). The youngest patient was a 48-year-old female, and the oldest was a 77-year-old male. Additionally, the average age for male patients was 69 years, with a standard deviation of 5.75 years, while for

female patients, the average age was 63.36 years, with a standard deviation of 8.04 years. All 40 patients (100%) had at least one underlying medical condition. Fourteen patients (35%) had two underlying conditions, and four patients (10%) had three underlying conditions. Specifically, 27 patients (67.5%) had a history of hypertension, 11 patients (27.5%) had diabetes, 20 patients (50%) had a history of kidney disorders, and 2 patients (5%) had other respiratory diseases (Table 2).

Table 1: Frequency of Underlying Diseases

Underlying Disease	Frequency	Percentage
History of at least one underlying disease	40	100%
Hypertension	27	67.5%
Diabetes	11	27.5%
Kidney disease	2	5%
Other (Respiratory)	2	5%

Table 2: Mean Brain Oxygen Saturation Levels

Time Point	RspO2 L	RspO2 R
Extubation	72.25	70.22
Clamp Off	66.47	66.77
Clamp On	64.30	64.87
Incision	64.75	65.97
Induction	64.65	65.47
0	64.07	62.72

The analysis of mild postoperative complications in patients who underwent carotid endarterectomy showed that hypertension was the most common complication, occurring in 13 cases (68.42% of all complications) and affecting 32.5% of the patients. Hematoma was observed in 2 cases (10.52% of complications), affecting 5% of the patients. No infections were reported, making up 0% of the complications. In total, 19 mild postoperative complications were recorded, impacting 47.5% of the patients (Table 3).

Table 3: Frequency and Distribution of Mild Postoperative Complications in Carotid Endarterectomy Patients

Mild Postoperative Complications	Frequency	% Frequency Among Complications	% Frequency Among Patients
Hypertension	13	68.42%	32.5%
Hematoma	2	10.52%	5%
Infection	0	0%	0%
Total	19	100%	47.5%

According to the data analysis and results shown in (Figure 1 and Figure 2), only 1 patient (2.5%) passed away, while 39 patients (97.5%) were discharged from the hospital.

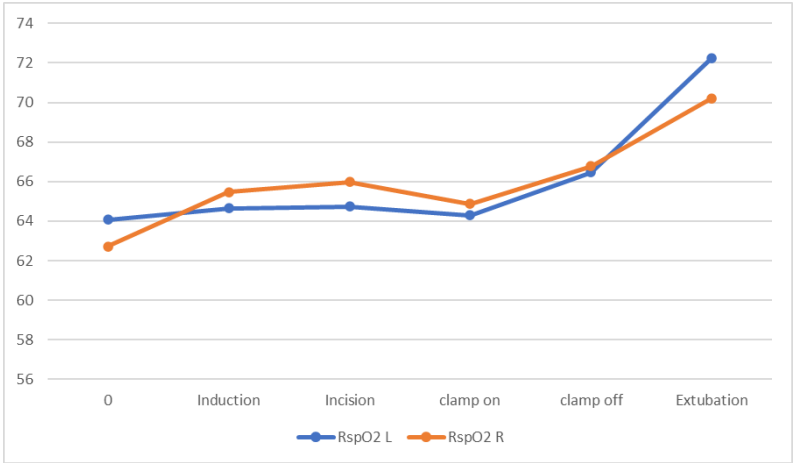

Figure 1: Overlaid line chart of the average cerebral oxygen saturation levels of patients in two channels.

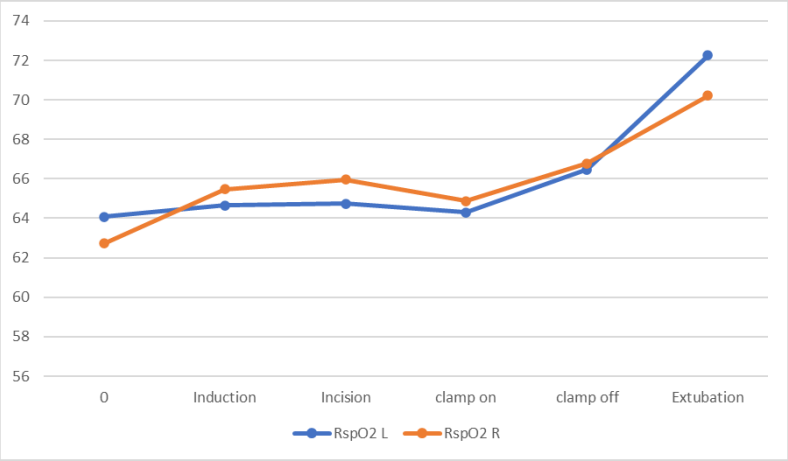

Figure 2: Stacked line chart of patients' average blood pressure

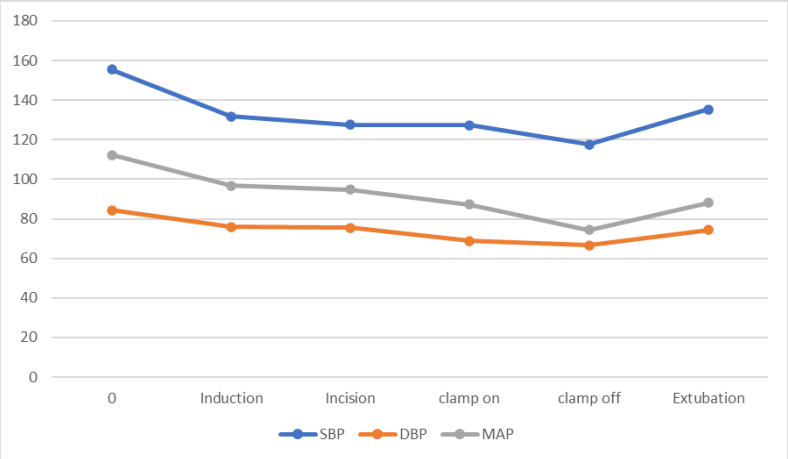

Figure 3: Variable frequency of early postoperative complications

Discussion

Given the significance of carotid artery endarterectomy (CEA), establishing a relationship between brain oxygen levels during surgery and postoperative complications could greatly influence the prediction of surgical outcomes and help implement necessary precautions to minimize these complications. This study aimed to evaluate the changes in brain oxygen saturation and early postoperative outcomes in patients undergoing carotid artery endarterectomy. We examined 40 patients referred to the hospital for the procedure. According to global reports, men constitute about 70% of CEA patients. In our study, 29 patients (72.5%) were male, and 11 patients (27.5%) were male. These findings were consistent with other studies, some of which showed a higher incidence of carotid artery stenosis in men and the importance of surgical intervention in this group. These studies showed that men are at higher risk for carotid artery stenosis, probably due to a higher prevalence of risk factors such as smoking, hypertension, and hyperlipidemia. Some studies found no significant gender-related differences in cerebral oxygen saturation during surgery. These findings are consistent with the results of our research and suggest that gender does not directly affect intraoperative changes in cerebral oxygenation. (10-13). Our study found that the average age of patients undergoing carotid endarterectomy (CEA) was 67.45 years, consistent with the typical age range of 65-75 years. Additionally, no significant gender differences were observed in NIRS readings during surgery, aligning with findings from other cardiovascular surgery studies. (14).

Regarding the frequency of underlying conditions, all patients (100%) had at least one underlying disease. The most common conditions were hypertension (67.5%), diabetes (27.5%), and a history of neurological disorders (50%). These findings are consistent with other studies in which 65–70% of

patients had cardiovascular disease. Similarly, a study reported that approximately 75% of CEA patients had underlying cardiovascular diseases such as hypertension or previous myocardial infarction(15).

Our study demonstrated significant fluctuations in cerebral oxygen saturation (Sat O2) during carotid endarterectomy. Specifically, Sat O2 increased initially after anesthesia induction, decreased during the clamp stage, and then increased again after the clamp. These findings align with results from other studies that noted similar patterns of oxygen saturation fluctuations during the clamping and unclamping phases of carotid endarterectomy, highlighting the importance of maintaining stable Sat O2 levels to reduce the risk of neurological deficits. Our results emphasize the need for timely intervention when Sat O2 levels decrease during surgery (16, 17).

In this study, significant changes in blood pressure, including systolic, diastolic, and mean arterial pressure, were observed during surgery. Blood pressure decreased during clamping and improved after clamp removal, reflecting changes in vascular resistance due to surgical events. These findings highlight the importance of blood pressure management to prevent hypo-perfusion and promote recovery, as supported by previous research(18, 19).

Regarding postoperative complications, 47.5% of patients experienced mild complications. The most common were cardiovascular disturbances (32.5%), followed by mild neurological issues (10%) and hematomas (5%). These results align with prior studies, which identified cardiovascular and neurological complications as key risks. However, brain oxygen saturation fluctuations during surgery did not consistently predict these postoperative complications(20).

Overall, the outcomes were positive, with 97.5% of patients discharged successfully and only 2.5% mortality. This low mortality rate suggests that carotid endarterectomy is generally a safe procedure when appropriately managed, consistent with findings from other studies that report low mortality rates for the procedure (20, 21).

Conclusion

In conclusion, our study highlights the importance of closely monitoring brain oxygen levels and hemodynamic parameters during carotid endarterectomy. While fluctuations in brain oxygen saturation and blood pressure were observed, they did not consistently predict postoperative complications. Additionally, the analysis of data related to changes in cerebral oxygen saturation levels revealed that most variables did not significantly affect these changes in both NIRS channels, and no significant correlation was found between intraoperative changes in cerebral oxygen saturation and postoperative complications. Despite these fluctuations, the overall low mortality and high discharge rates suggest that carotid endarterectomy remains a safe and effective procedure with appropriate perioperative care, consistent with other studies in the field.

Consent for Publication

Consent was taken from the small ruminant fatteners located at the place to present their goats for slaughter service.

Ethics Approval and Consent to Participate

All participant data were kept confidential, and results were presented in aggregate form. This thesis's ethics code is IR.GUMS.REC.1399.475.

Authors' contributions

Study concept and design: H. Kh. & H. H..; acquisition of data: A. Sh., drafting of the manuscript: M. F.; critical revision of the manuscript for important intellectual content: H. H. & H. Kh.; statistical analysis: H. E. K.

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Data Availability Statement

Data on personnel requests can be accessed from the corresponding author.

Conflicts of Interest

The authors declare no conflicts of interest.

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