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ORIGINAL ARTICLE / ÖZGÜN MAKALE

The intracranial effects of flow reversal during transcarotid artery revascularization

Transkarotid arter revaskülarizasyonu esnasında akımın tersine çevrilmesinin intrakraniyal etkileri

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ABSTRACT

Background: This study aimed to assess intraoperative cerebral hemodynamic responses and embolic events during transcarotid artery revascularization via transcranial Doppler, near-infrared spectroscopy, and bispectral index monitoring.

Methods: Twelve patients (7 males, 5 females; mean age: 72.8±9.0 years; range, 63 to 91 years) undergoing transcarotid artery revascularization with simultaneous transcranial Doppler, near-infrared spectroscopy, and bispectral index monitoring were analyzed in this retrospective study between September 2017 and December 2019. The mean flow velocity and pulsatility index of the middle cerebral artery, alongside near-infrared spectroscopy and bispectral index values, before flow reversal, during flow reversal, and after flow reversal phases were investigated. The presence and frequency of high-intensity transient signals were recorded to evaluate embolic incidents.

Results: Significant reductions in middle cerebral artery mean flow velocity were noted during flow reversal (40.58±10.57 cm/sec to 20.58±14.34 cm/sec, p=0.0004), which subsequently returned to and exceeded baseline values after flow reversal cessation (53.33±17.69 cm/sec, p=0.0005). Near-infrared spectroscopy (71±4.4% to 66±6.2%) and bispectral index (45.71±8.5 to 40.14±8.1) values mirrored these hemodynamic changes, with notable decreases during flow reversal, and recoveries after flow reversal. The highest concentration of high-intensity transient signals was observed during stent deployment, signifying a critical embolic phase. No perioperative neurological complications or other significant adverse events were documented.

Conclusion: Transcranial Doppler, near-infrared spectroscopy, and bispectral index effectively monitor cerebral hemodynamics and embolic potential during transcarotid artery revascularization, providing real-time data crucial for optimizing perioperative management. These findings underscore the clinical value of multimodal monitoring in improving patient outcomes in transcarotid artery revascularization procedures.

Keywords: Carotid artery disease, cerebral hemodynamics, neuroprotection systems, transcarotid artery revascularization, transcranial Doppler.

ÖZ

Amaç: Bu çalışmada, transkraniyal Doppler, near-infrared spectroskopi ve bispektral indeks monitörizasyonu ile transkarotid arter revaskülarizasyonu sırasında ameliyat anındaki serebral hemodinamik yanıtlar ve embolik olaylar değerlendirildi.

Çalışma planı: Bu retrospektif çalışmada Eylül 2017 ve Aralık 2019 tarihleri arasında eş zamanlı transkraniyal Doppler, near-infrared spectroskopi ve bispektral indeks monitörizasyonu ile transkarotid arter revaskülarizasyonu yapılan 12 hasta (7 erkek, 5 kadın; ort. yaş: 72.8±9.0 yıl; dağılım, 63-91 yıl) analiz edildi. Akım tersine çevirme öncesi, akım tersine çevirme sırasında ve akım tersine çevirme sonrası evrelerde orta serebral arterin ortalama akış hızı ve pulsatilite indeksi yanı sıra near-infrared spectroskopi ve bispektral indeks değerleri incelendi. Yüksek yoğunluklu geçici sinyallerin varlığı ve sıklığı, embolik olayları değerlendirmek için kaydedildi.

Bulgular: Akım tersine çevirme sırasında orta serebral arterin ortalama akış hızında anlamlı düşüşler gözlendi (40.58±10.57 cm/sn'den 20.58±14.34 cm/sn'ye, p=0.0004); bu değerler akımın tersine çevirilmesinin sonlandırılmasından sonra başlangıç değerlerine geri dönerek bazal değeri aştı (53.33±17.69 cm/sn, p=0.0005). Near-infrared spectroskopi (71±4.4%'den 66±6.2%'ye) ve bispektral indeks (45.71±8.5'ten 40.14±8.1'e) değerleri, akım tersine çevirme sırasında belirgin düşüşler ve tersine çevirme sonrası iyileşmeler ile bu hemodinamik değişiklikleri yansıttı. Yüksek yoğunluklu geçici sinyallerin en yüksek konsantrasyonu stent yerleştirilmesi sırasında gözlemlenmiş olup, kritik bir embolik fazı işaret etti. Perioperatif nörolojik komplikasyon veya başka advers olaylar kaydedilmedi.

Sonuç: Transkranial Doppler, near-infrared spectroskopi ve bispektral indeks, transkarotid arter revaskülarizasyonu sırasında serebral hemodinamiyi ve emboli potansiyelini etkili bir şekilde monitörize ederek perioperatif yönetimin optimizasyonunda kritik olan gerçek zamanlı veriler sağlamaktadır. Bu bulgular, transkarotid arter revaskülarizasyonu işlemlerinde hasta sonuçlarını iyileştirmede multimodal monitörizasyonun klinik değerini vurgulamaktadır.

Anahtar sözcükler: Karotis arter hastalığı, serebral hemodinamik, nöroproteksiyon sistemleri, transkarotid arter revaskülarizasyonu, transkraniyal Doppler.

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This study has been read during annual meeting of the American Society of Anesthesiologists in 2020 that held virtually.

Carotid artery disease (CAD) is a potential precursor to ischemic stroke, which ranks as the fifth leading cause of death and the foremost cause of long-term disability in the USA.[1] Approximately 30% of ischemic strokes are associated with CAD.[2,3] To mitigate the risk of stroke in patients with significant carotid stenosis, both carotid endarterectomy (CEA) and carotid artery stenting (CAS) are employed as revascularization strategies.[4,5]

In 2015, transcarotid artery revascularization (TCAR), utilizing a specially designed transcarotid flow reversal neuroprotection system, emerged as a novel technique for CAS. This transcervical approach circumvents the embolic risks associated with navigating through the aortic arch and supraaortic vasculature, making it particularly advantageous for patients with severe carotid tortuosity or complex aortic arch anatomy. Transcarotid artery revascularization enables surgeons to directly access the common carotid artery (CCA), initiating a high-rate, temporary, and dynamic cerebral blood flow reversal to safeguard the brain during CAS. Vascular surgeons are increasingly adopting TCAR as an alternative to CEA and CAS, particularly for high-risk patients with carotid artery stenosis. This preference is backed by its association with lower stroke and death rates and significantly fewer new lesions on diffusion-weighted magnetic resonance imaging (MRI) compared to CAS with distal protection, as demonstrated in recent studies.[6,7]

Despite being an innovative and minimally invasive procedure, the cerebrovascular flow dynamics during TCAR procedures have not been thoroughly elucidated. The “flow reversal” concept is better understood by examining alterations in intracranial circulation and embolic events using transcranial Doppler (TCD). Cerebral oximetry via near-infrared spectroscopy (NIRS) and the bispectral index (BIS) could elucidate the neuroprotective strategies employed during TCAR when used alongside TCD monitoring. The aim of this study was to evaluate the findings from intraoperative TCD monitoring before, during, and after the flow reversal phases of TCAR and to correlate these findings with NIRS and BIS values.

PATIENTS AND METHODS

The TCAR surgery database of the Houston Methodist Hospital was reviewed between September 2017 and December 2019. Twelve consecutive patients (7 males, 5 females; mean age: 72.8±9.0 years; range, 63 to 91 years) who underwent TCAR with TCD, cerebral oximetry, and BIS monitoring were included in this retrospective study (Table 1). Patients who did not have an appropriate temporal window for obtaining the TCD signal could not be monitored

Table 1. Patient characteristics (n=12)

	Transcarotid artery revascularization patients		
	n	%	Mean±SD
Patient demographics			
Age (year)			72.8±9
Sex			
Male	7	58.3	
Cardiovascular risk factors			
Hypertension	10	83.3	
Diabetes	7	58.3	
Hyperlipidemia	8	66.7	
Smoking	5	41.7	
Coronary arterial disease	4	33.3	
Peripheral arterial disease	5	41.7	
Anatomic and procedural characteristics			
Previous ipsilateral carotid intervention	7	58.3	
Symptomatic	3	25	
Stenosis ≥90%	4	33.3	
Contralateral occlusion ≥50%	6	50	

SD: Standard deviation.

during the procedures and were excluded. Additionally, procedures without BIS or NIRS monitorization were excluded from the study.

Patient documentation was reviewed from medical records for demographic data, past medical history, presentation, imaging, and postoperative outcomes. Intraoperative data were collected from the procedural notes. Four-channel live case recordings were also reviewed for procedural phases and TCD images, which included TCD monitor, vital parameters, fluoroscopy images, and three-dimensional reconstructed computed tomography angiography images (Figure 1).

All TCAR procedures were performed under general anesthesia by two vascular surgeons. Following a standard general anesthesia protocol, induction was achieved with 1.5 mg/kg of propofol, 1 mcg/kg of fentanyl, and 0.6 mg/kg of rocuronium. Maintenance of anesthesia was managed with 1 MAC (minimum alveolar concentration) of sevoflurane in 40% oxygen after induction. Standard monitoring included intra-arterial blood pressure, electrocardiography, pulse oximetry, body temperature, end-tidal carbon dioxide, cerebral oximetry with NIRS, and the BIS.

The technique of TCAR has been previously described.[8,9] Briefly, the proximal CCA was exposed following a small transverse incision at the base of the neck. After gaining vascular access at the CCA, a carotid angiogram was performed. The ENROUTE sheath (Silk Road Medical, Sunnyvale, CA, USA) was placed the CCA over the wire. An 8-French (Fr) sheath was inserted percutaneously in the common femoral vein, which provides passive reversal of the blood flow from the carotid artery through a circuit and filters the blood that involves temporarily reversing the blood flow in the carotid artery to prevent plaque debris from traveling towards the brain during the procedure. Once the CCA was clamped proximally to the sheath, the flow reversal was introduced. After crossing the lesion with a wire, predilation was performed with a 3- to 4-mm balloon catheter, the lesion was stented with a self-expanding system, and finally, postdilated with a 4- to 6-mm balloon catheter. The decision to predilate or postdilate was left to the operator's decision. Bivaluridin was used for intraoperative anticoagulation, and clopidogrel 75 mg daily was prescribed for all patients postoperatively.

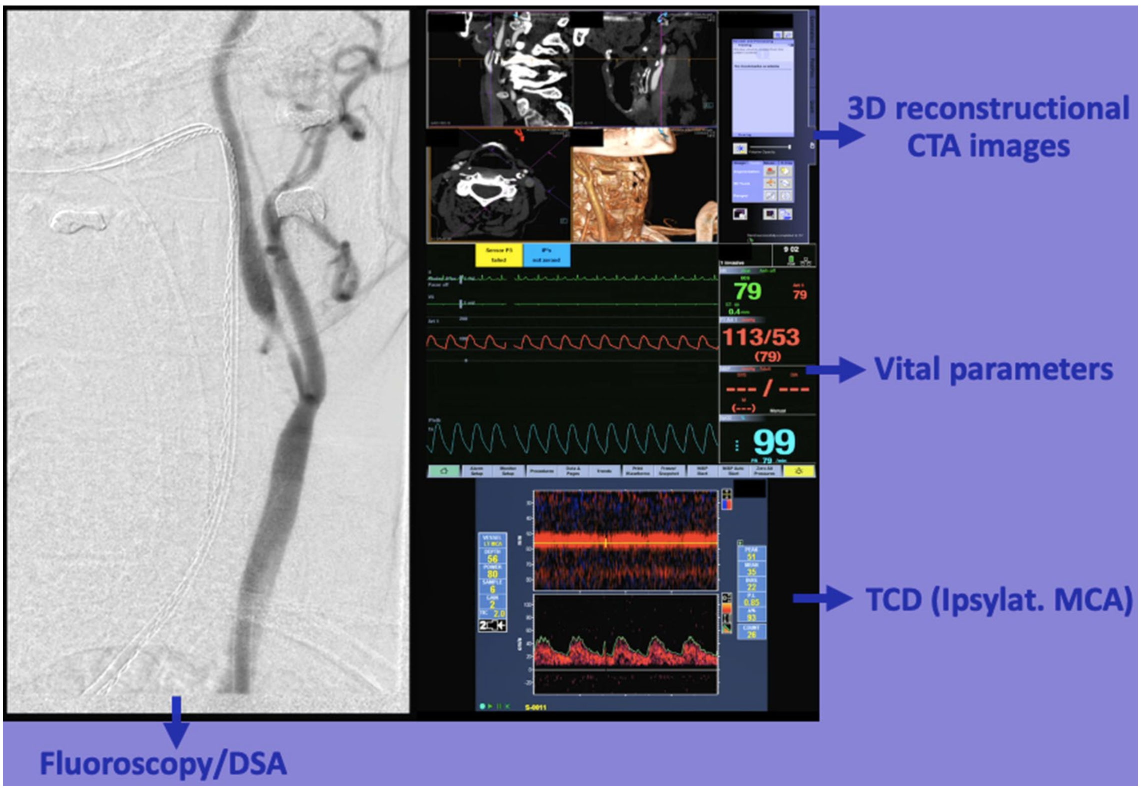

Figure 1. Four-channel live case recordings for procedural phases, which included a TCD monitor, vital parameters, fluoroscopy images, and three-dimensional reconstructed CTA images.

TCD: Transcranial Doppler; CTA: Computed tomography angiography; MCA: Middle cerebral artery; DSA: Digital subtraction angiography.

Preoperatively, all patients underwent a complete TCD examination (power-mode Doppler, Spencer Technologies PMD-100; Spencer Technologies, Seattle, WA, USA) to assess intracranial flow status and the presence of concomitant intracranial stenosis. A 2-MHz transducer with a 13-mm circular probe surface was used to insonate the ipsilateral middle cerebral artery (MCA). A commercially accessible probe-holding head frame device (Marc 600 series; Spencer Technologies, Seattle, WA, USA) was utilized to sustain the temporal bone window imaging.

During the entire procedure, MCA was monitored for cerebral flow status and high-intensity signals (HITS).

Table 2. Mean flow velocity and pulsatility index of MCA parameters and MAP alterations within the phases

Patient no.		Baseline	Before flow reversal	During flow reversal	After flow reversal
1	MAP (mmHg)	82	75	72	98
	MFV (cm/sec)	44	42	31	70
	PI	0.97	0.85	1.21	1.14
2	MAP (mmHg)	101	80	84	99
	MFV (cm/sec)	46	43	0	76
	PI	0.98	1.19	0	0.89
3	MAP (mmHg)	88	97	86	101
	MFV (cm/sec)	32	29	18	39
	PI	1.11	1.19	1.35	1.35
4	MAP (mmHg)	110	89	92	83
	MFV (cm/sec)	42	30	27	29
	PI	0.68	0.78	0.42	0.87
5	MAP (mmHg)	118	88	112	114
	MFV (cm/sec)	29	28	0	49
	PI	1.09	1.39	0	0.81
6	MAP (mmHg)	94	139	125	88
	MFV (cm/sec)	46	36	0	42
	PI	0.78	0.83	0	1.23
7	MAP (mmHg)	122	93	90	85
	MFV (cm/sec)	50	53	50	54
	PI	0.92	1.03	1.01	1.54
8	MAP (mmHg)	78	87	95	127
	MFV (cm/sec)	42	41	20	52
	PI	0.99	0.88	1.69	0.96
9	MAP (mmHg)	94	97	96	93
	MFV (cm/sec)	37	36	31	33
	PI	1.36	1.13	1.02	1.37
10	MAP (mmHg)	87	83	81	97
	MFV (cm/sec)	58	35	18	43
	PI	0.76	0.63	0.6	0.68
11	MAP (mmHg)	93	102	106	94
	MFV (cm/sec)	51	46	25	62
	PI	0.88	1.02	0.35	0.82
12	MAP (mmHg)	91	129	136	124
	MFV (cm/sec)	75	66	27	91
	PI	0.85	0.85	0.42	0.64

MCA: Middle cerebral artery; MAP: Mean arterial pressure; MFV: Mean flow velocity; PI: Pulsatility index.

In addition to baseline, several TCD parameters were recorded and evaluated in all procedural steps: lesion crossing, predilation, stent deployment, postdilation, and removal of devices. Additionally, the mean flow velocity (MFV) of MCA, pulsatility index of MCA, and HITS count for all phases were also analyzed. Consensus Committee guidelines were used for the calculation number of HITS.[10] The number of HITS was counted by two observers to ensure high reliability during different procedural phases independently. Bolus contrast injections for angiographic runs were not included in the analysis due to the high amount of artifacts on the recording.

Mean flow velocity and pulsatility index of the ipsilateral MCA, cerebral oximetry via NIRS, BIS, and mean arterial pressure (MAP) values were monitored to understand cerebral flow changes with flow reversal in phases: baseline, before flow reversal, flow reversal, and after flow reversal (Table 2). The number of HITS was counted during different procedural phases: lesion crossing, predilation, stent deployment, and removal of devices (Figure 2).

Primary endpoint was MFV changes with flow reversal phase and its correlation with NIRS and BIS values. Secondary endpoints were total procedural HITS numbers, HITS numbers in different phases of the procedures, in-hospital mortality, neurological events, reintervention, and major adverse events, including bleeding, myocardial infarction, and cardiac arrest that required cardiopulmonary resuscitation.

Statistical analysis

All statistical analyses were performed with the Stata statistical software package, version 12 (StataCorp LP, College Station, TX, USA). Normally distributed continuous variables were presented as mean ± standard deviation (SD), nonnormally distributed continuous variables were presented as median (min-max). Categorical variables were presented as number (%). A p-value <0.05 was considered statistically significant.

RESULTS

Patient characteristics are presented in Table 1 in detail. Seven patients had a previous ipsilateral CEA operation, and three patients were symptomatic before the intervention. Four patients had more than 90% ipsilateral carotid artery stenosis, while half of the patients had more than 50% contralateral carotid artery stenosis. Hypertension and diabetes mellitus were the most common comorbidities.

The baseline MFV of MCA was 46±12.16 cm/sec, and MAP was 96.5±13.76 mmHg for all patients. Mean flow velocity significantly decreased with the beginning of the flow reversal phase (40.58±10.57 to 20.58±14.34 cm/sec, p=0.0004), while MAP was not changed (96.5±19.16 to 97.9±18.71 mmHg, p>0.05). With the flow reversal cessation, there was a statistically significant increase in MFV within 5 min (20.58±14.34 to 53.33±17.69 cm/sec, p=0.0005), and MAP change was not significant once again (97.9±18.71 to 100.25±14.32 mmHg, p>0.05). We observed a 16% improvement in comparison to baseline in MFV values after flow reversal (46±12.16 to 53.33±17.69 cm/sec); however, this result was not statistically significant. Mean flow velocity was altered significantly, while MAP did not change significantly between phases.

The mean baseline ipsilateral NIRS was 71±4.4% and BIS was 47.93±16.39 for all patients. Mean

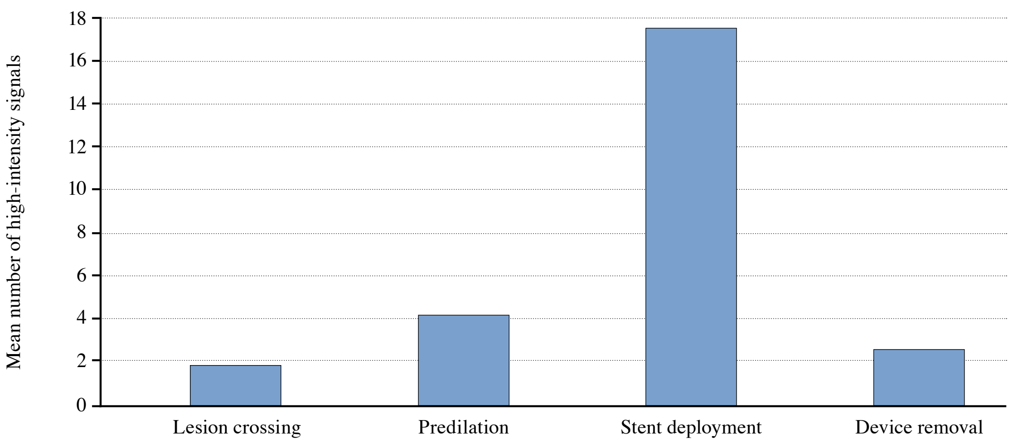

Figure 2. Mean number of high-intensity signals in phases.

NIRS (71±4.4% to 66±6.2%, p=0.001) and BIS (45.71±8.5 to 40.14±8.1; p=0.0009) values decreased significantly upon initiation of flow reversal phase. After flow reversal phase was terminated; ipsilateral NIRS and BIS values increased significantly compared to flow reversal values (66±6.2% to 70.7±4.2%, p=0.0009; 40.14±8.1 to 46.4±10.5, p=0.01; respectively).

There were statistically significant correlations between the percentage decrease upon the initiation of flow reversal and the percentage increase with flow reversal cessation between MFV of MCA, NIRS, and BIS values (p=0.00006 and p=0.0004, respectively).

During the entire procedure, the number of HITS per case ranged from 2 to 74, and the mean number was 29 for all patients. The mean number of HITS per phase was also evaluated separately (Figure 2). The mean number of HITS was 1.08±3.17 (range, 0 to 11) during lesion crossing, 3.42±6.52 (range, 0 to 17) while predilation, 16.83±22.33 (range, 0 to 60) at stent deployment, 1.85±3.33 (range, 0 to 9) during postdilation, and 0.72±2.41 (range, 0 to 8) after device removal. The greatest number of HITS occurred during stent deployment, except for three patients.

Postoperatively, there was no stroke, local complications, or cranial nerve injury in any patient. During follow-up, a transient ischemic attack, which immediately resolved without any deficit, was observed in one patient. There were no deaths or myocardial infarctions at 30 days.

DISCUSSION

To the best of our knowledge, this study is the first to report TCAR evaluation using TCD monitoring, NIRS, and BIS concomitantly. While decreasing MCA flow during flow reversal, our TCD results revealed an increase in flow upon cessation of flow reversal. Near-infrared spectroscopy and BIS values demonstrated a significant correlation with TCD, and their utilization alongside TCD could strengthen the clinical management of TCAR.

A recent meta-analysis has demonstrated the short-term and long-term efficacy and safety of TCAR.[11] Moreover, two prospective, single-arm, multicenter studies (ROADSTER and ROADSTER2) have also shown that TCAR was associated with satisfactory outcomes, such as the rates of freedom from stroke, transient ischemic attack, and death in the perioperative period following the procedure.[8,12] In the context of such favorable postoperative prognoses of TCAR, comparative studies were performed to compare it with conventional therapies,[13,14] and this emerging technique also partly presented superiority over the transfemoral procedure. A 2019 meta-analysis found that the transcarotid approach reduced the risk of stroke when contrasted with transfemoral carotid artery stenting (TF)-CAS.[15] Additionally, a high-volume multicenter study suggested that TCAR with dynamic flow reversal significantly mitigated the rate of stroke/death compared to TF-CAS.[16]

Although a substantially higher medical risk is present in patients undergoing TCAR, the rates of in-hospital postoperative stroke, stroke/death, and stroke/death/myocardial infarction were similar between 1,182 patients who underwent TCAR and 10,797 who had CEA.[17] Transcarotid artery revascularization has added benefits of shorter operative times and decreased rates of cranial nerve injuries. These promising results have led to an increased use of TCAR. Similarly, in our study, despite having a decrease in flow velocity during the flow reversal phase, there were no perioperative strokes, and the low numbers of HITS on TCD suggest that TCAR could be a safe alternative for carotid revascularization. However, little is known about the cerebral hemodynamics and embolization rates during flow reversal.

In the Society for Vascular Surgery Vascular Quality Initiative, Schermerhorn et al.[17] reported that early clinical trials evaluating the safety and efficacy of TCAR suggest variable practice patterns with respect to the use of anesthesia and intraoperative neurological monitoring in those patients undergoing transcervical CAS with cerebral flow reversal. After cross-clamping the carotid artery and active flow reversal, the contralateral carotid and vertebral arteries are relied upon to perfuse the ipsilateral brain via an intact circle of Willis. Active cerebral flow reversal likely results in symptomatically reduced brain perfusion in fewer than 5% of TCAR cases. The use of surveillance techniques, such as TCD, NIRS, and BIS, allows for the identification of intraoperative complications and offers medicolegal protection.[18] The well-established modalities in the literature on CEA used for detecting cerebral perfusion have been reasonably well adopted for TCAR.

Strokes occurring after TCAR procedures have been noted to result from a mix of the same pathological causes identified in CEA procedures. These include embolic events, watershed strokes, and strokes due to hypertension. Carotid cross-clamping and cerebral flow reversal could create a similar, but not identical, brain stressor as observed in CEA.[19,20]

Although induced hypertension, hypothermia, and hypnotics have been advocated in the past to reduce end-organ ischemia, the evidence supporting their use is poor at best.[19]

Considering the complexity of cerebral function and hemodynamics, it is unsurprising that composite approaches toward intraoperative monitoring, integrating combined measures of cerebral perfusion, oxygenation, and metabolic status, have gained impact on perioperative neurologic injury attenuation. Transcranial Doppler ultrasonography provides relevant perioperative information for patients at high risk for cerebral hyperperfusion, hypoperfusion, or embolization. It delivers accurate, real-time information on cerebral hemodynamics and embolic events in the cerebral vessels without ionizing radioactive exposure.

Nonetheless, combining various monitoring modalities that reflect different aspects of cerebral perfusion status, such as NIRS, TCD, and BIS, may provide an extended window for the prevention, early detection, and prompt intervention in ongoing hypoxic/ischemic neuronal injury, and thereby may improve neurologic outcomes. Such an approach would minimize the impact of the inherent limitations of each monitoring modality while the individual components complement each other, thus enhancing the accuracy of the acquired information. However, current literature has failed to demonstrate any clear-cut clinical benefit of these monitoring modalities on outcome prognosis or to validate goal-directed treatment protocols.

Several monitoring techniques have been suggested over the years to address this issue, yet none have been accepted as the standard method. Near-infrared spectroscopy is based on measuring the oxyhemoglobin fraction in the microvasculature under the cerebral cortex; it can continuously and noninvasively monitor the cerebral oxygen saturation of target brain tissue, indirectly reflecting cerebral blood flow during CEA. Thus, it has been adopted as a monitoring tool, and a correlation between NIRS and TCD monitoring values has also been confirmed.[21,22] However, the NIRS value may be influenced by the extracranial oxygen metabolism and is susceptible to changes in blood pressure and arterial oxygen saturation, which is validated by our results showing significant correlation with flow changes at the different stages of the TCAR procedure.

A prospective observational study on CEA patients indicated that the sensitivity and specificity of NIRS monitoring for intraoperative hypoperfusion were 64.3% and 90.0%, resulting in a strong consistency with TCD monitoring results.[23] Regarding outcome prognosis, a cohort study involving 466 patients subjected to CEA under general anesthesia reported an association of brain regional oxygen saturation deterioration of at least 20% during temporary internal carotid artery clipping with a significantly enhanced risk of ischemic stroke and postoperative cognitive dysfunction, respectively.[24] Moreover, baseline regional oxygen saturation values lower than 50% increased the likelihood of ischemic stroke in the early postoperative period.[24] A Cochrane review assessed the comparative efficacy of monitoring cerebral hemodynamics (TCD and carotid stump pressure), cerebral oxygen metabolism (jugular venous oxygen saturation and NIRS), or cerebral functional state (EEG and somatosensory evoked potentials) in CEA surgeries in terms of selective shunting use and neurologic outcome optimization.[25] No clear superiority of one form of monitoring over another could be demonstrated.

The principle of flow reversal in TCAR can be better comprehended by examining alterations in intracranial circulation and the incidence of emboli, which can be observed using TCD. In their study, Olivere et al.[26] reported a single-center retrospective study of patients with carotid artery stenosis undergoing TCAR with intraoperative TCD monitoring of the MCA. Their primary outcomes included changes in MCA velocity and embolic signals observed throughout the TCAR procedure. In their series of 11 patients who underwent TCAR with TCD monitoring of the ipsilateral MCA, the mean MCA velocity at baseline was 50.6±16.4 cm/sec. The MCA flow decreased significantly upon initiation of flow reversal (50.6±16.4 cm/sec to 19.1±18.4 cm/sec). Similar to our study, embolic events were recorded at the time of reinitiation of antegrade flow as compared to baseline and upon initiation of flow reversal, although they did not utilize NIRS and BIS for comprehensive neuromonitoring.

In the PROOF study, where the safety and feasibility of TCAR were assessed, 33 patients underwent diffusion-weighted MRI before and after the TCAR procedures.[27] Five patients exhibited evidence of new ischemic brain lesions, but without clinical sequelae. Bonati et al.[28] compared TCAR with CEA and CAS in terms of cerebral embolic rates through postoperative diffusion-weighted MRI. Their results showed that TCAR is as safe as CEA and superior to CAS. Lastly, in our previous study, we compared CEA, CAS, and TCAR patients with TCD monitoring based on the number of HITS.[29] Our results also confirmed that

TCAR has lower HITS than CAS, in addition to being comparable with CEA.

The small number of patients included is a limitation of this study. Additionally, using postoperative diffusion-weighted MRI imaging and performing the surgeries under regional anesthesia would have significantly contributed to validating our findings.

In conclusion, transcarotid artery revascularization represents a novel, minimally invasive alternative for carotid artery revascularization. Given the absence of randomized controlled trials comparing transcarotid artery revascularization with other established carotid revascularization techniques, this retrospective analysis is a crucial step in initially assessing outcomes. The use of cerebrovascular monitoring through transcranial Doppler, along with near-infrared spectroscopy and bispectral index, is strongly advised for transcarotid artery revascularization procedures as a reliable and effective means to gather insights about this new technique. Multimodal cerebral monitoring offers immediate feedback on cerebral blood flow and oxygenation.

Ethics Committee Approval: The study protocol was approved by the Institutional Review Board (IRB) (date: 30.11.2023, no: PRO00023895). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: Institutional Review Board approved this study protocol with a waiver of informed consent since all the evaluations made from existing institutional data.

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

Author Contributions: Idea/concept, design: A.B.L., Z.G.; Control/supervision: A.B.L., Z.G., M.G.; Data collection and/or processing, analysis and/or interpretation: B.T.C., P.L.; Literature review: P.L., P.T.; Writing the article: B.T.C.; Critical review: A.B.L., Z.G., M.G., C.S.B.; Materials: B.T.C., P.L., P.T.; Other: TCAR procedures done by A.B.L., C.S.B.

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