Prognostic Nutrition Index May Predict Cerebral Embolic Events Following Carotid Artery Stenting Procedure

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ABSTRACT

Introduction: Cerebral embolism after carotid artery stenting (CAS) remains a matter of concern in frailty patients. The prognostic nutrition index (PNI), which provides an objective assessment of nutritional status, is a useful prognostic indicator in cardiovascular diseases. We aim to determine the value of pre-procedural PNI in predicting cerebral embolism including stroke, transient ischemic attack (TIA), and silent new ischemic cerebral lesions (SNICLs).

Patients and Methods: We retrospectively evaluated 138 patients (mean age= 70.6 ± 6.7 years, male= 99) who underwent CAS. Inclusion criteria were as follows: i) availability of all medical records including albumin value and lymphocyte count, ii) having cranial imaging after CAS, iii) having symptomatic carotid stenosis 50-99% or asymptomatic carotid stenosis ≥60-99%. The study population was divided into two subgroups according to the presence of cerebral embolism as cerebral embolism (+) cerebral embolism (-) groups.

Results: Among the study population, 22 patients (16%) had at least 1 SNICL, seven patients (5.0%) had an ischemic stroke, and five patients (3.6%) had TIA. The cerebral embolism (+) group had a significantly lower PNI, older age, more frequent history of stroke, a higher proportion of type III aortic arch, and longer fluoroscopy time than the cerebral embolism (-) group. Low PNI was identified as one of the independent predictors of cerebral embolism (OR= 0.808; 95% CI= 0.670-0.975; p= 0.026), and PNI lower than 44.7 predicted cerebral embolism with a sensitivity of 70.6% and a specificity of 61.1% (AUC= 0.739; 95% CI= 0.651 to 0.827; p< 0.001).

Conclusion: The current data suggest that PNI is an independent prognostic factor for cerebral embolic complications after CAS procedures.

Key Words: Stroke; magnetic resonance imaging; carotid artery; stent endovascular

Prognostik Beslenme İndeksi, Karotis Arter Stentleme Prosedürünü Takiben Serebral Embolik Olayları Öngörebilir

ÖZET

Giriş: Karotis arter stentleme (KAS) sonrası serebral emboli, kırılgan hastalarda endişe konusu olmaya devam etmektedir. Beslenme durumunun objektif bir değerlendirmesini sağlayan prognostik beslenme indeksi (PBİ), kardiyovasküler hastalıklarda faydalı bir prognostik göstergedir. İnme, geçici iskemik atak (GİA) ve sessiz yeni iskemik serebral lezyonlar dahil olmak üzere serebral emboliyi öngörmede prosedür öncesi PBİ'nin değerini belirlemeyi amaçlıyoruz.

Hastalar ve Yöntem: KAS uygulanan 138 hastayı (ortalama yaş= 70.6 ± 6.7 yıl, erkek= 99) geriye dönük olarak değerlendirdik. Dahil edilme kriterleri şu şekildeydi: I) albümin değeri ve lenfosit sayısı dahil tüm tıbbi kayıtların bulunması, II) KAS sonrası kraniyal görüntüleme olması ve III) %50-99 semptomatik karotis darlığı veya asemptomatik karotis darlığının ≥%60-99 olması. Çalışma popülasyonu serebral emboli varlığına göre serebral emboli (+) serebral emboli (-) grupları olarak iki alt gruba ayrıldı.

Bulgular: Çalışma popülasyonunda 22 hastada (%16) en az 1 SYİSL, yedi hastada (%5.0) iskemik inme ve beş hastada (%3.6) GİA vardı. Serebral emboli (+) grubunda, serebral emboli (-) grubuna göre anlamlı olarak daha düşük PBİ, ileri yaş, daha sık inme öyküsü, daha yüksek tip III aortik ark oranı ve daha uzun floroskopi süresi vardı. Düşük PBİ, serebral embolizmin bağımsız ön gördürücülerinden biri olarak tanımlandı (OR= 0.808; %95 CI= 0.670-0.975; p= 0.026) ve PBİ< 44.7 olması, %70.6 duyarlılık ve %61.1 özgüllük ile serebral embolizmi öngördürdü (AUC= 0.739; %95 CI= 0.651 ila 0.827; p< 0.001).

Sonuç: Mevcut veriler, PBİ'nin KAS prosedürleri sonrası serebral embolik komplikasyonlar için bağımsız bir prognostik faktör olduğunu göstermektedir.

Anahtar Kelimeler: İnme; manyetik rezonans görüntüleme; karotis arter; stent endovasküler

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INTRODUCTION

Carotid artery stenting (CAS) is increasingly being used in recent times for endovascular treatment as a less invasive alternative to carotid endarterectomy (CEA)[1,2]. Technical advances such as proximal balloon occlusion and the availability of filter devices have reduced cerebral embolic complications; therefore, CAS is considered a more viable therapeutic option[3]. Based on clinical research, the outcomes of CAS performed by experienced surgeons, particularly with the use of embolic protection devices, are similar to those of CEA, although CAS was shown to be associated with a higher incidence of postoperative cerebral embolism[3-5]. Therefore, the high risk of cerebral ischemic complications, including silent new ischemic cerebral lesions (SNICL), stroke, and transient ischemic attacks (TIA) is a known limitation of CAS[6]. Some recent studies have focused on the risk factors associated with post-CAS SNICL, although the results are inconsistent[6-8]. CAS outcomes can only be improved by minimizing postoperative ischemic events.

The Prognostic Nutrition Index (PNI) is a scoring system that indicates the nutritional status and serves as a determinant of morbidity and mortality in patients with cardiovascular diseases[9-12]. However, limited data are available regarding its role in carotid artery disease or its association with ischemic complications, such as SNICL[9-11]. In this study, we investigated the role of preoperative PNI as a predictor of post-CAS cerebral ischemic complications.

PATIENTS and METHODS

Study Design and Patient Selection

This retrospective study included 138 patients who underwent CAS for carotid artery revascularization at our tertiary center between January 2017 and April 2021. Following were the inclusion criteria for this study: availability of medical records showing serum albumin and lymphocyte levels, availability of cranial imaging performed 48 hours after CAS, and symptomatic internal carotid artery (ICA) stenosis (50-99%) or asymptomatic ICA stenosis ≥60-99% based on computed tomographic angiography (CTA) or digital subtraction angiography (DSA) findings. Following were the exclusion criteria: intracranial bleeding, intracranial arteriovenous malformation or aneurysm, total occlusion of the carotid artery, uncontrolled diabetes mellitus, a history of coagulation disorders, intolerance or allergies to antiplatelet therapy, malignancy, CAS secondary to vasculitis, active infection, recent major surgery, a history of systemic inflammatory disease, or end-stage renal disease necessitating renal replacement therapy, or unavailability of records showing preoperative serum albumin or lymphocyte levels. Demographic data, physical examination findings, laboratory test findings, and operative data were obtained from the hospital's electronic database. Grading and evaluation of carotid stenosis were performed based on guidelines in the literature[13]. TIA was defined as a brief episode of neurological dysfunction due to focal cerebral ischemia without permanent cerebral infarction[14]. Ischemic stroke was defined as an episode of neurological dysfunction due to focal cerebral, spinal, or retinal infarction[15,16]. An experienced neurologist performed detailed neurological evaluation 48 hours before and after the operation in patients with suspected neurological disorders. Patients with a history of TIA, retinal ischemic event, or ischemic stroke within the last six months were considered symptomatic[14-16]. Morphological evaluation of the degree of stenosis was performed using CTA of the supra-aortic trunk together with Doppler ultrasonography. All patients underwent pre-procedure evaluation for malnutrition using the PNI. The PNI was calculated using the following formula: 10x serum albumin (g/dL)+ (0.005xlymphocytes/μL)[12]. The study was performed in accordance with the principles of the Declaration of Helsinki and was approved by the local Institutional Review Board (Ethics Committee approval number 2021/11).

Endovascular Treatment of Carotid Artery Stenosis

All procedures were performed by two invasive cardiologists with greater than 10 years' experience in carotid stenting. All risks were explained in detail to all patients, and written informed consent was obtained prior to the procedure. Medical treatment (acetylsalicylic acid 100 mg/day+clopidogrel 75 mg/day) was initiated in all patients at least five days preoperatively. All carotid endovascular interventions were performed via the percutaneous transfemoral route under local anesthesia (conscious sedation was used as deemed appropriate by the surgeon). Electrocardiography, oxygen saturation and blood pressure monitoring were performed in all patients throughout all procedures. Diagnostic angiography was performed, and unfractionated heparin (100 units/kg) was administered at the commencement of the procedure. The procedure was initiated using a femoral 8-French sheath, and stent diameters were determined following bilateral carotid artery angiography and cerebral DSA. An embolic protection device (EmboShield®, Abbott Vascular, IL, USA) was placed in the distal extracranial carotid artery. The stent (Xact®, Abbott Vascular, IL, USA) was advanced through the guide catheter. Balloons were used either before or after stent dilation, at the discretion of the cardiologist. Intravenous atropine (1 mg) was prophylactically administered to patients in whom the heart rate reduced to <60 beats/min after carotid ballooning or after stenting in patients with heart rate <60 beats/min before CAS and in those with heart rate >60 beats/min. Atropine administration was ineffective

against hypotension immediately after CAS in a few patients; the blood pressure returned to normotensive values after rapid intravenous infusion of physiological saline solution. Finally, angiography was performed to evaluate vascular structures associated with CAS.

Post-Procedure Follow-Up

All patients were transferred to the coronary intensive care unit after CAS and underwent clinical, neurological, and hemodynamic follow-up during the first 24 hours postoperatively. Patients with hypotension continued to receive intravenous physiological saline solution and positive inotropic agent infusions, if indicated. Antihypertensive therapy was discontinued during intensive care follow-up. Cranial imaging was performed over 48 hours after CAS even in asymptomatic patients for evaluation of possible cerebral microembolism.

Clinical and Neurological Imaging for Evaluation of Cerebral Embolism

Magnetic resonance imaging (MRI) with or without CTA was performed for the evaluation of cerebral embolic events. In addition to the delineation of the vascular structure, CTA demonstrated the detailed anatomical orientation of the vessel with regard to the brain parenchyma and bone tissue and clearly showed intravascular pathologies, if any. CT findings of early ischemic changes included a hyperdense artery, loss of gray-white matter separation, insular stripe, and lentiform nucleus effacement[14-16]. MRI findings of early cerebral infarction included the absence of normal blood flow, arterial enhancement, gyral edema on T1-weighted imaging, sulcal effacement, and loss of gray-white matter separation[5,16]. Some patients underwent brain MRI [diffusion-weighted imaging (DWI)] 48 hours pre- and postoperatively. MRI was performed using a 16-channel head coil, and data were recorded using a 1.5 T scanner (Aera®, Siemens Medical Systems, Enlargen, Germany). DWI was performed using echo-planar imaging in the axial plane at 6000/89 ms repetition time/echo time, 1736 kHz bandwidth, 4-mm slice thickness, and 0 and 1000 mm^2/s b-values. Pre- and postoperative DWI findings were interpreted by a single radiologist with greater than six years of experience in neuroradiology. The radiologist was blinded to patients' clinical and operative data. Perioperative neurological status was evaluated by an experienced neurologist with greater than 10 years of experience. SNICL was defined as a new hyperintensity observed on postoperative DWI compatible with signal loss on an apparent diffusion coefficient map on the ipsilateral side.

SNICL also included ischemic lesions and the absence of neurological symptoms associated with ischemia. The following scales were considered for neurological evaluation by an experienced neurologist: a detailed history was obtained regarding any loss/impairment of consciousness, signs of lateralization, speech disorder, headache, or combinations of these features. The patients' level of consciousness was evaluated before the intervention. Dysarthria detected during the neurological examination was defined as a speech disorder, and aphasia was considered a sign of lateralization. We also recorded findings of facial paralysis (central), hemiparesis, and evidence of possible pyramidal involvement.

Study Endpoint

The primary endpoint was cerebral embolism including SNICLs that developed within 48 hours after CAS.

Statistical Analysis

All statistical analyses were performed using the SPSS software, version 24.0 (SPSS Inc., Chicago, IL, USA). Pre-procedural parameters, procedural data, and post-procedural outcomes were compared between patients with and without cerebral embolism. The normal distribution hypothesis was tested using graphical (histograms, probability curves) and numerical methods (Kolmogorov-Smirnov and Shapiro-Wilk tests). Normally distributed continuous variables are expressed as mean ± standard deviation and non-normally distributed continuous variables as median values (25^{th}-75^{th} percentiles) and were compared using the student-t or Mann-Whitney U test. Categorical variables are presented as frequencies and percentages, and differences between proportions were calculated using the Chi-square or Fisher exact test. Correlational analyses were performed using the Pearson or Spearman's correlation tests. Variables that showed a p-value of <0.05 on univariable analysis were subjected to multivariable logistic regression analysis to determine independent predictors of cerebral embolism. We used 95% confidence intervals (CI) to estimate the precision of the odds ratio (OR) in each model. Cut-off values for regression variables were calculated using receiver operating characteristic (ROC) analysis. All tests were two-tailed, and $p< 0.05$ was considered statistically significant.

RESULTS

The study included 138 patients (mean age 70.6 ± 6.7 years, 99 men). In the study group, 24 patients (17.4%) showed at least one new hyperintense lesion on DWI, seven patients (5.0%) had an ischemic stroke, and five patients (3.6%) experienced a TIA. The SNICL number was between 1 and 15, with lesion diameter varying from 2 to 8 mm.

Based on the occurrence of cerebral embolism, the study group was subcategorized into the cerebral embolism-positive and cerebral embolism-negative groups. Table 1 summarizes the intergroup comparison of baseline demographic and clinical characteristics of patients. No intergroup difference was

Table 1. Comparison of the demographic, clinical and angiographic characteristics of patients with and without cerebral embolism

Parameters	All Patients (n= 138)	Cerebral embolism (+) (n= 36)	Cerebral embolism (-) (n= 102)	P
Age, years	70.6 ± 6.7	77.1 ± 3.3	68.2 ± 5.9	<0.001
Gender, male, n (%)	99 (71.7)	29 (80.6)	70 (68.6)	0.172
Coronary artery disease, n (%)	66 (47.8)	19 (52.8)	47 (46.1)	0.489
Congestive heart failure, n (%)	8 (5.8)	3 (8.3)	5 (4.9)	0.449
Hypertension, n (%)	105 (76.1)	29 (80.6)	76 (74.5)	0.465
Diabetes mellitus, n (%)	55 (39.9)	14 (38.9)	41 (40.2)	0.890
History of stroke, n (%)	64 (46.4)	22 (61.1)	42 (41.2)	0.039
Aortic arch type				
Type I, n (%)	95 (68.8)	15 (41.7)	80 (78.4)	
Type II, n (%)	18 (13)	8 (22.2)	10 (9.8)	0.001
Type III, n (%)	20 (14.5)	12 (33.3)	8 (7.8)	
Type IV, n (%)	5 (3.6)	1 (2.8)	4 (3.9)	
Preprocedural symptoms, n (%)	89 (66.9)	27 (79.4)	62 (62.6)	0.073
Contralateral stenosis, n (%)	37 (27.8)	8 (23.5)	29 (29.3)	0.518
Stenosis degree, (%)	85.3 ± 9.2	83.7 ± 7.6	85.9 ± 9.8	0.218
Lesion length, mm	17.2 ± 6.1	18.7 ± 5.9	16.7 ± 6.1	0.098
Fluoroscopy time, min	17.9 ± 9.6	21.6 ± 11.5	16.4 ± 8.4	0.001
Predilatation, n (%)	30 (21.7)	7 (19.4)	23 (22.5)	0.698
Postdilatation, n (%)	97 (70.3)	23 (63.9)	74 (72.5)	0.328
Residual stenosis, (%)				
<10	118 (85.5)	32 (88.9)	86 (84.3)	
10-20	19 (13.8)	4 (11.1)	15 (14.7)	0.716
20-30	1 (0.7)	0	1 (1)	
CCA-ICA Angle, (degree)	33.5 ± 12.5	41.2 ± 10.7	29.8 ± 9.6	<0.001
Proximal Tortuosity Index	111.1 ± 35.9	138.2 ± 17.1	99.6 ± 35.4	<0.001
Distal Tortuosity Index	132.5 ± 38.4	161.7 ± 25.5	120.2 ± 36.2	<0.001
Prognostic Nutritional Index	45.6 ± 5.8	42.4 ± 4.9	47.2 ± 5.7	<0.001

CCA: Common carotid artery, ICA: Internal carotid artery.

observed in sex, hypertension, coronary artery disease, congestive heart failure, diabetes mellitus, pre-procedural symptoms, and contralateral carotid artery stenosis. Patients in the cerebral embolism-positive group were significantly older than those in the cerebral embolism-negative group (Figure 1A), with a greater prevalence of stroke history. The prevalence of type III aortic arch was significantly higher in the cerebral embolism-positive than in the cerebral embolism-negative group (33.3 vs. 7.8%, p= 0.001). The overall fluoroscopy time was significantly longer in the cerebral embolism-positive than in the cerebral embolism-negative group (21.6 ± 11.5 vs. 16.4 ± 8.4 min, p= 0.001) (Figure 1B). No intergroup difference was observed in the length or degree of carotid artery stenosis. No intergroup differences were observed in the incidence of pre-dilatation, post-dilatation, and degree of residual stenosis (Table 1). The common carotid artery-ICA angle (41.2 ± 10.7 vs. 29.8 ± 9.6º, p< 0.001) (Figure 1C), proximal tortuosity index (138.2 ± 17.1 vs. 99.6 ± 35.4, p< 0.001), and distal tortuosity index (161.7 ± 25.5 vs. 120.2 ± 36.2, p< 0.001) were significantly greater in the cerebral embolism-positive than in the cerebral embolism-negative group (Table 1). PNI was significantly lower in the cerebral embolism-positive than in the cerebral embolism-negative group (42.4 ± 4.9 vs. 47.2 ± 5.7, p< 0.001) (Table 1).

Variables that showed a p-value of <0.05 on univariate analysis were subjected to multiple logistic regression analysis to determine the independent predictors of cerebral embolism. Old age (OR= 1.294, 95% CI= 1.083-1.546, p= 0.004), type

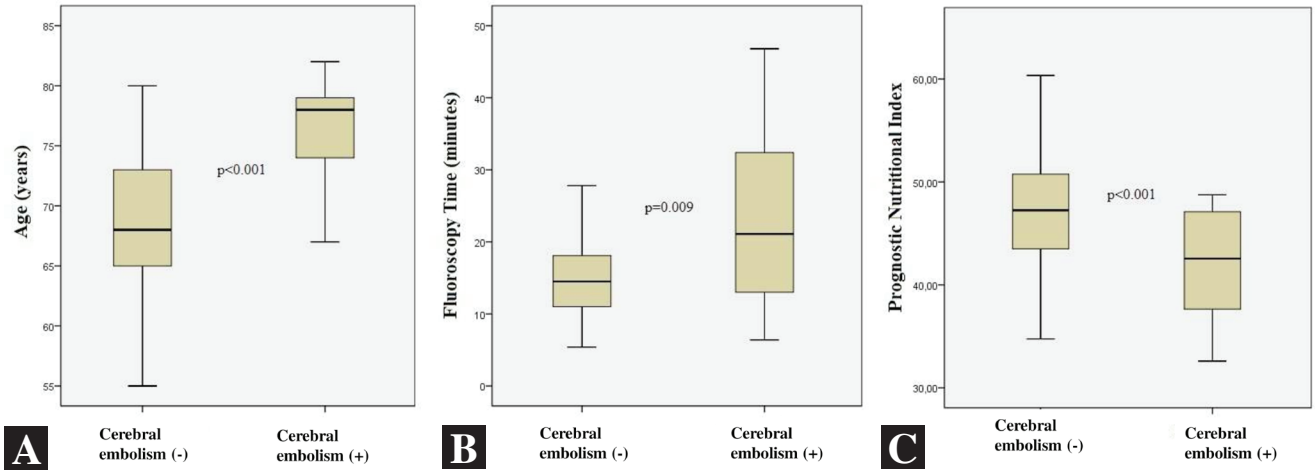

Figure 1. The box-plot graphs comparing age **(A)**, fluoroscopy time **(B)**, and prognostic nutrition index **(C)** between patients with and without cerebral embolism.

Table 2. Regression analysis of potential predictor factors for cerebral embolism

	Univariate analysis		Multivariable analysis	
Variables	**OR (95% CI)**	**p**	**OR (95% CI)**	**p**
Old age	1.431 (12.54-1.633)	<0.001	1.294 (1.083-1.546)	0.004
History of stroke	2.245 (1.032-4.885)	0.041	3.043 (0.661-13.996)	0.153
Type III aortic arch	1.458 (1.051-3.136)	0.001	1.096 (1.035-2.478)	0.036
Long fluoroscopy time	1.061 (1.017-1.108)	<0.001	1.068 (1.031-1.378)	0.022
High CCA-ICA Angle	1.082 (1.041-1.125)	0.001	1.049 (0.978-1.126)	0.178
High PTI	1.043 (1.025-1.062)	0.001	1.025 (0.990-1.062)	0.164
High DTI	1.033 (1.018-1.048)	0.001	1.015 (0.993-1.038)	0.190
Low PNI	0.841 (0.774-0.912)	<0.001	0.808 (0.670-0.975)	0.026

CCA: Common carotid artery, CI: Confidence interval, ICA: Internal carotid artery OR: Odds ratio, PTI: Proximal tortuosity index, DTI: Distal tortuosity index, PNI: Prognostic nutritional index.

III aortic arch (OR= 1.096, 95% CI= 1.035–2.478, p= 0.036), lengthy fluoroscopy time (OR= 1.068, 95% CI= 1.031-1.378, p= 0.022), and low PNI (OR= 0.808, 95% CI= 0.670-0.975, p= 0.026) were shown to be independent predictors of cerebral embolism (Table 2).

Based on ROC curve analysis, age >73.5 years predicted cerebral embolism with sensitivity of 83.3% and specificity of 75.5% [area under the curve (AUC)= 0.895, 95% CI= 0.840-0.950, p< 0.001], fluoroscopy time >14.9 min predicted cerebral embolism with sensitivity of 58.1% and specificity of 56.1% (AUC= 0.625, 95% CI= 0.497-0.752, p= 0.041), and PNI< 44.7 predicted cerebral embolism with sensitivity of 70.6% and specificity of 61.1% (AUC= 0.739, 95% CI= 0.651-0.827, p< 0.001) (Figure 2).

The study population was categorized into the following groups based on the PNI cut-off value (44.7) determined by ROC curve analysis: patients with PNI< 44.7 (low-PNI group) and those with PNI≥ 44.7 (high-PNI group). Table 3 shows a comparison of the demographic, clinical, and angiographic characteristics of patients with low and high PNI. Cerebral embolism was significantly more common in the high-PNI than in the low-PNI group (42.3 vs. 16.3%, p= 0.001). Moreover, the prevalence of stroke history (p= 0.015) was significantly higher and total fluoroscopy time was significantly longer (p= 0.034) in the high-PNI than in the low-PNI group (Table 3). PNI and age (r= -0.246, p= 0.004) showed a statistically significant but weak negative correlation, whereas total fluoroscopy time and age (r= 0.295, p= 0.002) showed a statistically significant but weak positive correlation (Figure 3).

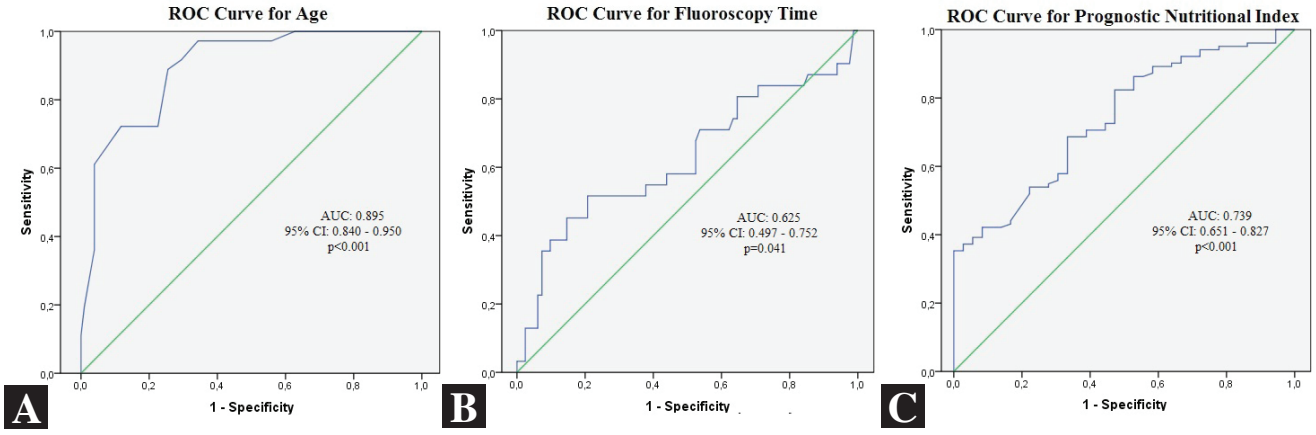

Figure 2. Receiver operating characteristic (ROC) curve revealing the AUC for age **(A)**, fluoroscopy time **(B)**, and prognostic nutrition index **(C)** to predict the presence of cerebral embolism after carotid artery stenting.

AUC: Area under the curve, CI: Confidence interval.

DISCUSSION

The major findings of the current study include: *(i)* Low PNI was significantly associated with cerebral embolism. *(ii)* Type III aortic arch, old age, lengthy fluoroscopy time, and low PNI were independent predictors of cerebral embolism on multivariate analysis.

Improved availability and accessibility of healthcare have led to increased life expectancy in an aging population; therefore, the prevalence of frailty has increased[17]. Advanced age serves as a risk factor for cerebral embolic complications[2,6]. Geriatric patients show significantly higher in-hospital post-CAS major cerebral embolic complications, such as stroke or mortality[1,6,18]. In this study, we observed a significant correlation between advanced age and cerebral embolic events (for example, TIA or stroke), which concurs with the findings reported in the literature[6,7,9,18]. Frailty and carotid artery disease share some pathophysiological mechanisms, including malnutrition, bleeding, and thrombotic risk, all of which worsen the clinical outcomes in this patient population. Frailty refers to age-induced vulnerability to disease and is a useful predictor of perioperative outcomes[19,20]. CAS is indicated as a minimally invasive approach in patients in whom CEA is considered a high-risk procedure. Reportedly, frailty measured by the five-factor modified frailty index serves as an independent predictor of perioperative stroke and mortality in patients who undergo CAS[19]. Malnutrition, an indicator of morbidity and mortality in many cardiovascular diseases, is significantly associated with frailty and is widely prevalent in the geriatric population[21-24]. PNI was used to assess perioperative nutritional status and predicted surgical morbidity and mortality in patients who underwent gastrointestinal surgery[12]. Reportedly, PNI also predicts mortality in infectious and inflammatory heart disease[10,11,22]. Caliskan et al. have recently indicated that the decreased PNI (<53.8) independently predicts impairment of coronary flow reserve in patients with inflammatory bowel disease[23]. Recent research has confirmed an association between PNI and mortality in atherosclerotic cardiovascular diseases that require revascularization, as well as in pulmonary embolism[24-26]. Previously, Peng et al. reported that chronic kidney disease patients with low PNI had a significant increase risk of cardiovascular disease and all-cause mortality (HR= 3.07, 95% CI= 1.51-6.25 and HR= 2.18, 95% CI= 1.28-3.72, respectively)[27]. Another study by Dong et al. reported a negative linear relationship between PNI score and contrast-associated acute kidney injury in patients undergoing coronary angiography complicated with coronary artery disease[28]. In 2019, Teker et al. demonstrated that there was statistical significance between malnutrition (low PNI) and renal complications, hemorrhage, and mortality after coronary artery bypass graft surgery[29]. Another interesting study by Tai et al. reported that PNI could be a candidate adjunctive predictor of coronary artery aneurysms in patients with Kawasaki disease[30]. Several studies have investigated the prognostic role of certain biochemical and hematological parameters in patients who undergo CAS[9,31,32]. Öcal et al. suggested that PNI may be a novel prognostic biomarker for CAS[9]. However, our literature search did not yield any studies reporting the role of PNI as a predictor of cerebral embolism in elderly patients.

Complex vascular anatomy, including aortic arch type, is known to increase the risk of neurological complications[6,7,33] and contributes to the technical difficulty associated with carotid artery cannulation[34]. However, recent research has shown no correlation between the aortic arch type and cerebral embolism[7]. We recently observed that large ICA and external carotid artery angles predicted SNICL in CAS[6]. However, in the current study, contrary to the findings reported in the literature, we did not observe this association with regard to the prediction of cerebral embolism[6]. The disparity between our findings and those reported in the literature may be attributable to the retro-

Table 3. Comparison of the demographic, clinical and angiographic characteristics of patients with low and high PNI

Parameters	PNI< 44.7 (n= 52)	PNI≥ 44.7 (n= 86)	p
Age, years	71.9 ± 7.3	69.8 ± 6.1	0.076
Gender, male, n (%)	35 (67.3)	64 (74.4)	0.369
Coronary artery disease, n (%)	24 (46.2)	42 (48.8)	0.760
Congestive heart failure, n (%)	3 (5.8)	5 (5.8)	0.991
Hypertension, n (%)	39 (75)	66 (76.7)	0.816
Diabetes mellitus, n (%)	20 (38.5)	35 (40.7)	0.795
History of stroke, n (%)	31 (59.6)	33 (38.4)	0.015
Aortic arch type			
Type I, n (%)	31 (59.6)	64 (74.4)	0.151
Type II, n (%)	11 (21.2)	7 (8.1)	
Type III, n (%)	8 (15.4)	12 (14)	
Type IV, n (%)	2 (3.8)	3 (3.5)	
Preprocedural symptoms, n (%)	33 (63.5)	56 (69.1)	0.497
Contralateral stenosis, n (%)	11 (21.2)	26 (32.1)	0.169
Stenosis degree, (%)	85.3 ± 8.1	85.4 ± 9.8	0.970
Lesion length, mm	17.6 ± 5.3	16.9 ± 6.6	0.531
Fluoroscopy time, min	20.6 ± 12.5	16.6 ± 7.4	0.034
Predilatation, n (%)	13 (25)	17 (19.8)	0.470
Postdilatation, n (%)	34 (65.4)	63 (73.3)	0.327
Residual stenosis, (%)			
<10	45 (86.5)	73 (84.9)	0.733
10-20	7 (13.5)	12 (14)	
20-30	0	1 (1.2)	
CCA-ICA Angle, (degree)	35.8 ± 12.2	32.1 ± 12.6	0.094
Proximal Tortuosity Index	115.5 ± 38.9	108.4 ± 34.1	0.260
Distal Tortuosity Index	140.5 ± 32.2	127.6 ± 41.2	0.057
Cerebral Embolism, n (%)	22 (42.3)	14 (16.3)	
Silent DWI Lesion, n (%)	13 (61.9)*	11 (73.3)*	0.001
TIA, n (%)	3 (14.3)*	2 (13.3)*	
Stroke, n (%)	5 (23.8)*	2 (13.3)*	0.715

CCA: Common carotid artery, DWI: Diffusion weighted imaging, ICA: Internal carotid artery, PNI: Prognostic nutritional index, TIA: Transient ischemic attack.
*The percentage values were calculated among patients with cerebral embolism.

spective design of this study, the inclusion of all cerebral embolic events, and the exclusion of cases in which data regarding preoperative serum albumin and lymphocyte levels were unavailable. Notably, Faggioli et al. reported a significant association between proximal and distal carotid tortuosity and the risk of post-CAS ischemic stroke[35]. However, in this study, we observed no correlation between proximal and distal carotid tortuosity and cerebral embolism, including ischemic stroke.

Some studies have reported an association between perioperative data (for example, lesion characteristics, fluoroscopy time, and filter devices, among other variables) and in-hospital adverse events (stroke, TIA, or mortality). Lengthy operation time is a known risk factor for embolic events[6,36,37]. Despite the positive correlation reported between stroke or TIA and the degree of stenosis and lesion length[36], we observed no such correlation in this study. Cerebral protection using filter devices significantly decreases the risk of post-CAS cerebral embolism[37,38], although studies have shown a high incidence of post-CAS cerebral microembolism. The use of distal protection filters during CAS in this study was associated with the

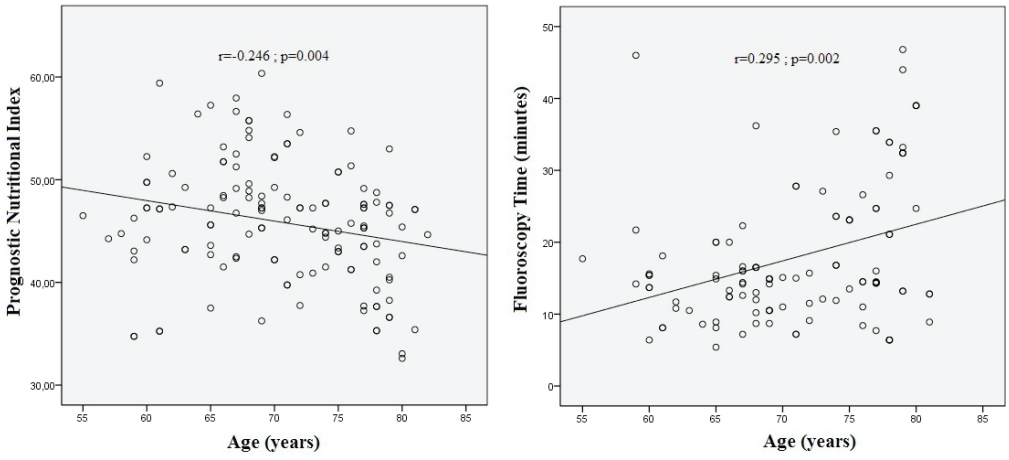

Figure 3. Scatter graphs summarising weak negative correlations between the age with prognostic nutrition index and weak positive correlations between the age with fluoroscopy time.

following disadvantages: (a) The balloon needs to be expanded before passing the lesion and somewhere before filter insertion, which may lead to cerebral embolism. (b) Filters are unable to capture residues with diameters that are smaller than the pore diameter. (c) Inappropriate filter placement may cause passage of particles between the filter and the vascular structure, which can predispose to SNICLs, which may even be asymptomatic. However, proximal balloon occlusion systems, which are placed before any device passes the lesion, differ from distal protection filters and are more convenient for the surgeon.

Some patients present with hyperintense lesions on DWI, without any accompanying neurological symptoms; studies are being performed to investigate these intriguing findings. Although the clinical significance of subclinical embolic events remains unclear, some researchers suggest that silent ischemia may be closely associated with increased neurocognitive dysfunction[39]. As these lesions can be better explained, it will be important to develop a system of preoperative risk classification to prevent or minimize silent embolic complications.

Study Limitations

Following are the limitations of this study: *(i)* the single-center retrospective design, the small sample size (n= 36), the use of only distal protection filters, and the unavailability of data regarding carotid plaque morphology are drawbacks of this study. *(ii)* Platelet inhibition and function were not evaluated in patients who underwent stent implantation. *(iii)* We did not measure levels of hormones that may affect PNI values.

CONCLUSION

PNI was an independent prognostic factor for post-CAS cerebral embolic complications. Immune nutritional status may play a key role in post-CAS prognosis. Therefore, low PNI serves as a significant risk factor for in-hospital cerebral embolism, including SNICL in patients who undergo CAS.

Ethics Committee Approval: The approval for this study was obtained from İstanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital Clinical Research Ethics Committee (Decision no: 2021/11, Date: 23.02.2021).

Informed Consent: This is retrospective study, we could not obtain written informed consent from the participants.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept/Design - AG; Analysis/Interpretation - AG, EGG, MÖ, CA, MK; Data Collection - All of authors; Writing - AG; Critical Revision - ME; Final Approval - AG; Statistical Analysis - AG, MK; Overall Responsibility - AG, FU, AKK, SK, ÖÇ, ME.

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