ORIGINAL RESEARCH

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Feasibility and Efficacy of Carotid Stenting in Patients with Contralateral ICA Occlusion

Kontralateral ICA Oklüzyonu Olan Hastalarda Karotis Stentlemenin Uygulanabilirliği ve Etkinliği

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Abstract

Objective: This study was conducted to assess the feasibility, safety, and efficacy of carotid artery stenting (CAS) in patients with severe ipsilateral carotid artery stenosis and contralateral internal carotid artery occlusion (CCO) and compare the outcomes with a matched control group without contralateral occlusion.

Method: A retrospective study was conducted on 247 patients treated with CAS between April 2020 and July 2024. Of these, 21 patients with CCO were matched 1:1 to a control group without CCO based on age and sex. Procedural success, periprocedural complications, and short- to mid-term follow-up outcomes (median follow-up: 24 months) were analyzed.

Results: Technical success was accomplished in every case. Two periprocedural complications were identified in each group. Three patients in the CCO group and two in the control group died during the follow-up, with myocardial infarction determined to be the cause of death in one patient from each group. No new ischemic cerebrovascular events were recorded in either group during the follow-up period.

Conclusion: CAS is a feasible and effective treatment for patients with severe carotid stenosis and CCO, yielding outcomes comparable to patients without contralateral occlusion.

Keywords: Angioplasty, carotid stenosis, cerebrovascular stroke

Öz

Amaç: Çalışmanın amacı kontralateral internal karotis arter oklüzyonu (KKO) olan ve ciddi ipsilateral karotis arter stenozu bulunan hastalarda karotis arter stentleme (KAS) işleminin uygulanabilirliğini, güvenliğini ve etkinliğini değerlendirmek; bu sonuçları kontralateral karotis arter oklüzyonu olmayan eşleştirilmiş kontrol grubu ile karşılaştırmaktır.

Yöntem: Nisan 2020 ile Temmuz 2024 tarihleri arasında KAS uygulanan 247 hasta ile retrospektif bir çalışma yapıldı. Bu hastalardan KKO'ya sahip 21 hasta, yaş ve cinsiyet açısından 1:1 oranında eşleştirilmiş kontrol grubu ile karşılaştırıldı. Prosedürel başarı, periprosedürel komplikasyonlar ve kısa-orta dönem takip sonuçları (medyan takip süresi: 24 ay) analiz edildi.

Bulgular: Hastaların tamamında teknik başarı sağlandı. Periprosedürel komplikasyonlar her iki grupta da ikişer hastada gözlendi. Takip süresi boyunca KKO grubunda 3 hasta, kontrol grubunda ise 2 hasta hayatını kaybetti; her iki grupta da birer hastada miyokard enfarktüsü ölüm nedeni olarak belirlendi. Takip süresi boyunca hiçbir hastada yeni iskemik serebrovasküler olay saptanmadı.

Sonuç: KAS, ciddi karotis stenozu ve KKO'su olan hastalar için uygulanabilir ve etkili bir tedavi seçeneğidir. Bu hasta grubundaki sonuçlar, kontralateral oklüzyonu olmayan hastalarla karşılaştırılabilir düzeydedir.

Anahtar kelimeler: Anjiyoplasti, karotis stenozu, serebrovasküler inme

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Introduction

Stroke stands as the third major cause of mortality, preceded by coronary artery disease and cancer, with ischemic events associated with over 80% of all strokes (1,2). Among these, 15-20% of ischemic strokes result from carotid artery stenosis, and approximately 10% of patients with carotid artery stenosis also present with contralateral internal carotid artery (ICA) occlusion (CCO) (3). Revascularization methods, including carotid endarterectomy (CEA) and carotid artery stenting (CAS), are available for long-term stroke risk mitigation in individuals with severe carotid stenosis, regardless of symptom status. The North American symptomatic CEA trial demonstrated a heightened perioperative stroke risk in patients with CCO undergoing CEA relative to those without (4). Similarly, findings from the asymptomatic carotid atherosclerosis study trial indicated an increased risk of perioperative stroke, as well as higher rates of periprocedural mortality and non-fatal myocardial infarction in patients with CCO undergoing CEA (5). While CEA remains the standard treatment for stroke prevention, CAS has gained increasing acceptance in carotid revascularization due to technological advancements and expanding clinical expertise in managing carotid stenosis (6). Patients with carotid stenosis and CCO have traditionally been regarded as high-risk candidates for CEA or CAS (7). In recent years, however, some high-risk patients have been deemed suitable for CAS when the procedure is carried out by an experienced operator with careful selection criteria applied to optimize outcomes (8).

The aim of the current study was to compare the technical success, efficacy, and safety of CAS, as well as periprocedural complications and follow-up outcomes in patients with CCO versus those without CCO, serving as confirmatory research that reinforces existing findings while focusing on patient data within the CCO group.

Materials and Methods

Ethical committee approval was received from the Ethics Committee of University of Health Sciences Turkey, Başakşehir Çam and Sakura City Hospital (approval number: 2024-72). The study was conducted in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of in 2000. Following this, a retrospective study was conducted on patients with atherosclerotic stenosis of the extracranial ICA who underwent CAS at a single institution between April 2020 and July 2024. In the study group, inclusion criteria encompassed patients with contralateral ICA occlusion and ≥70% stenosis in the ipsilateral ICA, while exclusion criteria included non-elective cases, acute stroke, intracranial tumors, and hemorrhage. In the control group, patients with ≥70% ICA stenosis and a patent contralateral ICA were included, whereas those with contralateral ICA occlusion or near-occlusion, as well as non-elective cases, acute stroke, intracranial tumors, and hemorrhage were excluded. All patients initially referred for stent placement due to carotid stenosis underwent Doppler ultrasound imaging followed by either computed tomography angiography or contrast-enhanced magnetic resonance angiography of the head and neck. Patients confirmed to have ≥70% stenosis via non-invasive imaging were subsequently scheduled for cerebral digital subtraction angiography (DSA) with the intent to perform CAS. However, in 11 cases, stenting was not carried out due to the absence of significant hemodynamic stenosis on DSA, and in three cases, anatomical constraints precluded stent placement. As a result, 247 subjects who had CAS performed during the course of the study were retrospectively analyzed, and 23 patients with CCO were identified. Two of these patients were excluded due to insufficient follow-up data. Ultimately, 21 patients with CCO who underwent CAS were included in the analysis.

Propensity score matching (1:1 nearest-neighbor) was applied to form the control group, using propensity scores derived from logistic regression with standardized "age" and "sex" used as predictors. During the matching process, patients with contralateral ICA occlusion or near-occlusion were excluded. Propensity scores were utilized to select the most comparable control group patients from a cohort of 182 participants. This created a demographically and clinically similar control group, while minimizing bias and ensuring unique pairings. Next, a comparative evaluation was carried out between patients who underwent CAS for severe carotid stenosis with CCO and patients without CCO or near-occlusion. The outcomes analyzed included technical success, safety, procedural efficacy, peri-procedural complications, and short- to mid-term follow-up. The study comprehensively assessed demographic characteristics, comorbidities, procedural access, plaque composition, collateral circulation patterns in the study group, technical success, and periprocedural complications, alongside short- to mid-term outcomes such as restenosis, ischemic events, and all-cause mortality. Additionally, procedural data encompassed intraprocedural thromboembolic events, periprocedural stroke, and access site complications, while clinical outcomes were evaluated hyperperfusion-related complications, myocardial

infarction, major and minor ischemic strokes, and mortality over the follow-up period. Angiographic findings were also recorded specifically for patients in the CCO group.

The procedures were performed by interventional radiologists with a minimum of four years of experience in carotid stenting. All CAS procedures were conducted electively, and all patients gave their written informed consent for participation prior to the procedure. To ensure adequate antiplatelet activity, dual antiplatelet therapy was administered to the patients (aspirin 100 mg/day and clopidogrel 75 mg/day) for at least seven days before the procedure, with efficacy confirmed via resistance testing. Continuous monitoring of oxygen saturation, ECG, and blood pressure was started at the initiation of the procedure. After local site preparation and anesthesia, an 8-French femoral sheath was inserted into the femoral artery under ultrasound guidance. An intra-arterial heparin dose of 70-100 U/kg was administered via the sheath to prevent thrombotic complications. Four-vessel angiography was subsequently carried out, and a long sheath (Fubuki XF, Asahi Intecc, USA) was advanced into the targeted common carotid artery (CCA) to facilitate the procedure. A micro guidewire was used to traverse the stenotic segment, enabling the deployment of a distal embolic protection device. In cases where the protection device or stent could not cross the lesion, a 3-mm balloon catheter (Simpass, Simeks, Turkey) was employed for pre-dilation over a 0.014-inch guidewire.

A distal protection device (Spider FX, Covidien, MN, USA, or FilterWire EZ, Boston Scientific, MA, USA) was placed in the distal cervical ICA. The stents were sized to match the diameter of the distal CCA and were deployed from the unaffected ICA segment across the stenosis to the CCA to ensure complete plaque coverage. A secondary telescoping stent was positioned if additional coverage was needed. In all cases, post-stent balloon angioplasty using a 5-mm balloon (Simpass, Simeks, Turkey) was carried out to optimize luminal expansion. Intravenous atropine was administered as needed to manage hemodynamic instability, including bradycardia, asystole, or hypotension during balloon inflation. At the conclusion of the procedure, a final cerebral angiography was carried out after removing the distal embolic filter.

The patients were continuously monitored for their cardiac and neurological status for 24 hours postoperatively, with hourly neurological evaluations. Discharge typically occurred on postoperative day 1 or 2. Follow-up evaluations, including neurological assessments and duplex ultrasonography, were carried out on the day after the procedure and at 1, 6, and 12 months in the first year, followed by annual reviews to assess vessel patency, restenosis, or other complications. Postoperatively, the patients were advised to continue a combination of aspirin (100 mg/day) and clopidogrel (75 mg/day) as antiplatelet treatment for a minimum of six months, with aspirin therapy continued indefinitely.

Statistical Analysis

Data entry and statistical analyses were carried out using the SPSS for Windows version 18.0 software package (SPSS Inc., Chicago, IL, USA). The normality of data distribution was evaluated using both visual methods (histograms and probability plots) and analytical methods (Shapiro-Wilk test). The numerical data were presented as the median (1^{st}-3^{rd} quartile), while categorical variables were summarized using frequency distributions and percentages. Comparisons of non-normally distributed numerical data and categorical variables were carried out using the Mann-Whitney U test. The chi-square test was employed for categorical variable assessment, with statistical significance established at $p<0.05$.

Results

The study included a total of 42 participants, with 21 patients in the study group and 21 in the control group. The mean age of the cohort was 69.5 years (interquartile range: 67.0-71.5); among the participants, 32 were males and 10 were females. The age and gender distribution, as well as smoking history, were similar between both groups (p=0.850, p=0.999, and p=0.525, respectively). No statistically significant differences were identified regarding the prevalence of hypertension, diabetes mellitus, coronary artery disease, hyperlipidemia, or peripheral arterial disease between the two groups (p>0.05). However, cerebrovascular disease was significantly more prevalent in the study group (66.7%), compared to the control group (23.8%) (p=0.005). Further details are presented in Table 1.

Procedural access was obtained from the right side in 57.1% of the cases in both groups (p=0.999). Balloon pre-dilatation before stent deployment was carried out in 23.8% of the study group and 14.3% of the control group; this difference did not reach statistical significance (p=0.348). Post-dilatation was carried out in all cases in both groups. Symptomatic presentations were observed in 57.1% of the study group and 52.4% of the control group, with no significant difference between the two groups (p=0.500).

The overall complication rate was 9.5% in both groups (p=0.999). Evaluation of the plaque composition indicated that 28.6% of plaques in the study group could be classified as soft, while 71.4% were mixed. In the control group, 33.3% of plaques were soft, 9.5% were calcified, and 57.1% were mixed. The follow-up periods were comparable between the two groups (p=0.371). A summary of these findings is provided in Table 2.

Among the patients in the control group, 85.7% (n=18) had normal-to-mild contralateral ICA stenosis, while 14.3% (n=3) exhibited moderate contralateral ICA stenosis. Angiographic evaluation of the occluded ICA in the study group revealed cerebral arterial filling through the anterior communicating artery (ACoA) alone in 9.5% (n=2) of the cases, through the posterior communicating artery (PCoA) alone in 19% (n=4) of the cases, through both the ACoA

Table 1. Comparison of age, gender, smoking status, and comorbidities between the study and control groups

Feature	All subjects (n=42) n (%)	Study group (n=21) n (%)	Control group (n=21) n (%)	p
Age (years)/median (1st-3rd quartile)	69.5 (67.0-71.5)	70.0 (65.5-75.5)	69.0 (67.5-71.0)	0.850[a]
Gender				
Male	32 (76.2)	16 (76.2)	16 (76.2)	0.999[b]
Female	10 (23.8)	5 (23.8)	5 (23.8)	
Smoking status				
No	16 (38.1)	9 (42.9)	7 (33.3)	0.525[b]
Yes	26 (61.9)	12 (57.1)	14 (66.7)	
Comorbidities				
Hypertension	36 (85.7)	17 (81.0)	19 (90.5)	0.331[b]
Diabetes mellitus	19 (45.2)	11 (52.4)	8 (38.1)	0.352[b]
Coronary artery disease	25 (59.5)	15 (71.4)	10 (47.6)	0.116[b]
Hyperlipidemia	8 (19.0)	2 (9.5)	6 (28.6)	0.116[b]
Peripheral artery disease	7 (16.7)	4 (19.0)	3 (14.3)	0.500[b]
Cerebrovascular disease	19 (45.2)	14 (66.7)	5 (23.8)	**0.005**[b]

[a]: Mann-Whitney U test, [b]: Chi-square test

Table 2. Comparison of procedural characteristics between the study and control groups

Variables	All subjects (n=42) n (%)	Study group (n=21) n (%)	Control group (n=21) n (%)	p
The side of stent angioplasty				
Right	18 (42.9)	9 (42.9)	9 (42.9)	0.999[a]
Left	24 (57.1)	12 (57.1)	12 (57.1)	
Predilatation				
No	34 (81.0)	16 (76.2)	18 (85.7)	0.348[a]
Yes	8 (19.0)	5 (23.8)	3 (14.3)	
Presence of symptoms				
No	19 (45.2)	9 (42.9)	10 (47.6)	0.500[a]
Yes	23 (54.8)	12 (57.1)	11 (52.4)	
Complications				
No	38 (90.5)	19 (90.5)	19 (90.5)	0.999[a]
Yes	4 (9.5)	2 (9.5)	2 (9.5)	
Plaque composition				
Soft	13 (31.0)	6 (28.6)	7 (33.3)	-
Calcific	2 (4.8)	-	2 (9.5)	
Mixed	27 (64.3)	15 (71.4)	12 (57.1)	
Follow-up duration (months)/median (1st-3rd quartile)	24.0 (11.0-36.0)	24.0 (10.0-43.0)	20.0 (11.0-31.5)	0.371[b]

[a]: Chi-square test, [b]: Mann-Whitney U test

and PCoA in 57.1% (n=12) of the cases, and through the ACoA, PCoA, retrograde flow via the ipsilateral ophthalmic artery, or leptomeningeal collaterals in 14.3% (n=3) of the cases (Figures 1, 2). A subgroup analysis using the chi-square test assessed the impact of plaque composition, cerebral collateral circulation, and comorbidities, on CAS outcomes in both the study and control groups, revealing no statistically significant differences.

The technical success rate, defined as the effective resolution of stenosis after stent placement, was 100% in both groups. During the periprocedural period, one patient in the occlusion (study) group experienced hypotension requiring adrenergic medication. One patient in the control group developed hypotension requiring medical treatment, another experienced bradycardia lasting 24 hours, and a third had concurrent hypotension and bradycardia requiring intervention. Transient hypotension occurred in both groups but was excluded as a periprocedural complication since it resolved spontaneously or with short-term isotonic saline infusion without adrenergic support.

Two complications were documented in the occlusion (study) group. One patient experienced an ipsilateral

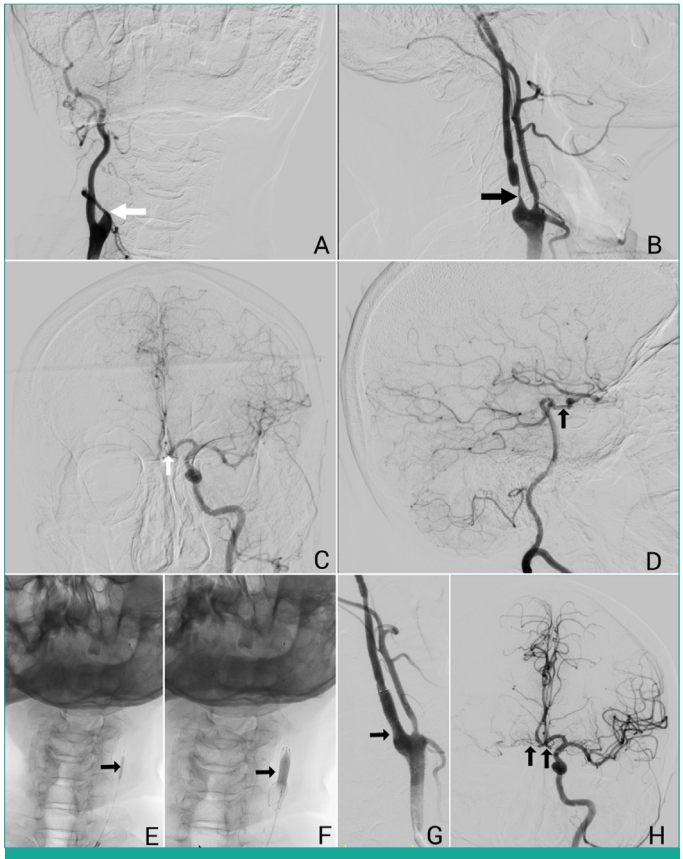

Figure 1. A. Anteroposterior digital subtraction angiography (DSA) of the cervical region demonstrating occlusion of the right internal carotid artery (ICA) (white arrow). B. Left lateral projection of the cervical DSA demonstrating severe stenosis of the proximal left ICA (black arrow). C. Anteroposterior cranial DSA obtained from the left ICA demonstrating that, except for the right anterior cerebral artery territory, the right cerebral hemisphere is not opacified via the anterior communicating artery (white arrow). D. DSA of the circle of Willis, performed prior to stent angioplasty, confirming good collateral flow from the left vertebral artery via the posterior communicating artery (black arrow). E, F. Balloon angioplasty carried out prior to stent placement to treat the stenosis, followed by in-stent balloon dilatation (black arrows). G, H. Post-procedural lateral cervical and anteroposterior cranial angiograms demonstrating an increased ICA diameter and the restoration of intracranial blood flow, respectively (black arrows)

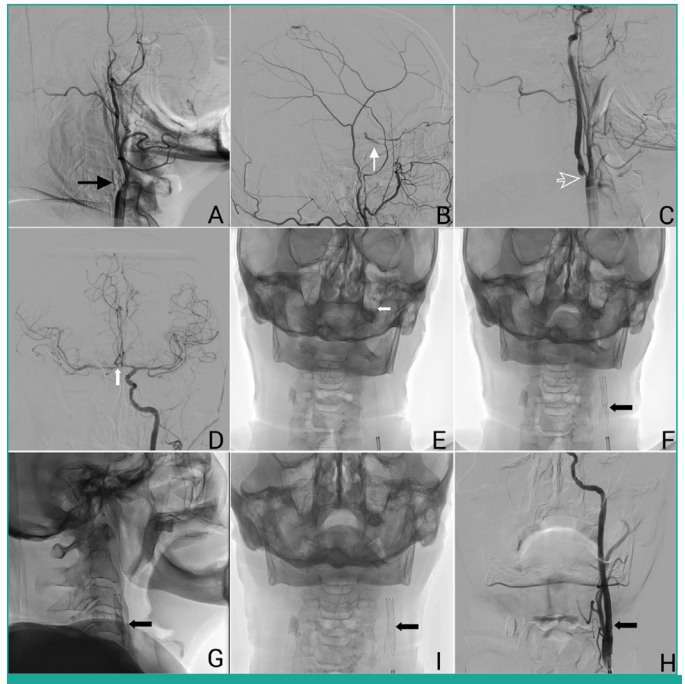

Figure 2. A. Lateral digital subtraction angiography (DSA) of the cervical region, obtained via the right common carotid artery, revealing complete occlusion of the right internal carotid artery (ICA) (black arrow). B. Cranial lateral view images obtained from the right common carotid artery demonstrating collateral flow through the ipsilateral ophthalmic artery on the occluded side (white arrow). C. The left lateral projection of the cervical region DSA revealing severe narrowing of the proximal segment of the left ICA (white arrow). D. Anteroposterior cranial DSA of the circle of Willis demonstrating effective flow to the right cerebral hemisphere from the left ICA through the anterior communicating artery (white arrow). E-G. AP cervical images demonstrating the placement of a distal protection device, lateral cervical view showing stent angioplasty extending from the ICA to the CCA to cover the stenotic segment, followed by in-stent balloon angioplasty, respectively (arrows). I, H. Anteroposterior cervical image following in-stent balloon angioplasty demonstrates optimal stent diameter. Post-procedure AP cervical angiogram shows improvement in the diameter of the ICA (black arrows)

cerebral embolism, with complete clinical recovery during the follow-up. Another patient developed a minimal ipsilateral frontal subarachnoid hemorrhage four days after stent placement, followed by ipsilateral frontal lobar hemorrhage one day later, leading to a fatal outcome (Figure 3). Two complications were also reported in the control group. One patient experienced transient contralateral hand weakness, which was resolved within a few days, while another patient had ipsilateral cerebral embolism, presenting with dysarthria and weakness in the contralateral upper and lower extremities. This patient was discharged with a modified Rankin score of 3 following rehabilitation. No statistically significant difference was noted in the overall complication rates between the two groups (p=0.999).

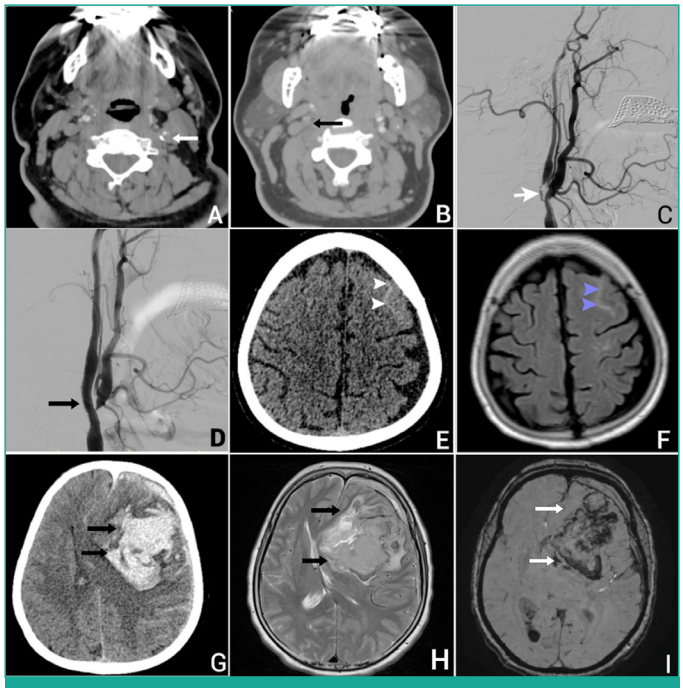

Figure 3. A. Preprocedural computed tomography angiography (CTA) demonstrating a high-grade stenosis of the left internal carotid artery (ICA) caused by a mixed-type plaque (white arrow). B. Preprocedural CTA shows occlusion of the right ICA (black arrow). C. The left lateral projection of cervical digital subtraction angiography (DSA) demonstrating significant stenosis in the proximal segment of the left ICA (white arrow). D. The stenosis was effectively managed with the placement of a stent spanning the carotid bifurcation (black arrow). E. Non-contrast axial brain computed tomography demonstrating hyperdensity in the left frontal cerebral sulcus, suggestive of subarachnoid hemorrhage (arrowheads). F. Brain magnetic resonance imaging (MRI) FLAIR sequence demonstrating hyperintensity in the left frontal cerebral sulcus, consistent with subarachnoid hemorrhage (arrowheads). G-I. Axial non-contrast brain CT, T2 weighted MRI, and susceptibility weighted imaging demonstrating a large parenchymal hematoma in the left frontal lobe, causing midline shift and compressing the lateral ventricles, respectively (arrows)

No new ischemic cerebrovascular events were observed in either group during the follow-up. The study group reported three patient deaths, one due to early postoperative intracranial hemorrhage secondary to hyperperfusion syndrome, one from pulmonary infection, and another from myocardial infarction. Two deaths were recorded in the control group, one resulting from heart failure-related volume overload and the other from myocardial infarction, which was unrelated to the vascular interventions.

Discussion

Severe stenosis of the carotid artery, when accompanied by CCO, can further compromise cerebral hemodynamics and elevate the risk of ischemic events in the brain (9). CEA is widely recognized as the superior treatment for symptomatic stenosis, whereas most studies have demonstrated that CAS is not inferior to CEA in managing asymptomatic stenosis (10-12). CCO is believed to heighten the risk of stroke during CEA, primarily because clamping the target artery can further compromise cerebral blood flow. This effect is considered to be unrelated to the embolic risk associated with the procedure. Consequently, there is a growing consensus that CAS may offer a safer alternative in patients who also have CCO, because it eliminates the requirement for arterial clamping.

The current study confirmed that CAS represents a feasible and effective treatment choice for patients with severe carotid stenosis, regardless of the presence or absence of CCO. The technical success rate was 100% in both groups, underscoring the procedural reliability of CAS in this high-risk population. No significant differences were observed in periprocedural complication rates or short- to mid-term outcomes between the two groups, with the overall complication rate at 9.5% in both cohorts. Importantly, although cerebrovascular disease was significantly more prevalent in the CCO group, this did not translate into a higher incidence of new ischemic events during follow-up.

In a previous study, neurological events, including both TIA and stroke, were recorded in 60% of the patients (n=82) with contralateral ICA, in whom the progression of asymptomatic carotid stenosis was being followed (13). The incidence of neurological events was comparable in the current study and was 66.7% among the 21 patients with contralateral ICA occlusion, showing these complications. Despite the smaller sample size in the current study, the

similarity in the outcomes suggests that the results are reliable, could be applicable to a broader population, and highlight the potential clinical relevance of our study in this specific cohort.

We analyzed the patterns of cerebral arterial collateral circulation in patients with contralateral ICA occlusion and severe ipsilateral ICA stenosis (≥70%) (Figure 1). We observed collateral flow through the ACoA alone in 9.5% (n=2), PCoA alone in 19% (n=4), both ACoA and PCoA in 57.1% (n=12), and ACoA, PCoA, and retrograde flow via the ipsilateral ophthalmic artery; or leptomeningeal collaterals in 14.3% (n=3) of the cases. A previous study conducted in a larger cohort of 38 patients reported collateral pathways via ACoA alone in 15.8%, PCoA alone in 7.9%, and both ACoA and PCoA in 13.2% of the cases (14). The methodological differences between the two studies must be considered when analyzing these findings. The published study excluded patients with ipsilateral ICA stenosis greater than 50%, whereas we specifically included patients with contralateral ICA occlusion and severe ipsilateral stenosis ≥70%. This difference in inclusion criteria most likely accounts for the variations in collateral distribution and rates observed between the two studies. In our cohort, the higher hemodynamic burden caused by severe ipsilateral stenosis most likely promoted the recruitment of multiple collateral pathways, particularly the combined utilization of ACoA and PCoA, which we observed in 57.1% of the cases. In contrast, the exclusion of patients with significant ipsilateral stenosis in the published study may explain the lower prevalence of multi-pathway collaterals and, the relatively higher proportion of single-pathway collateral flow. Our findings underscore the critical impact of the severity of ipsilateral stenosis on the development and recruitment of cerebral collateral circulation in patients with contralateral ICA occlusion. The greater demand for alternative perfusion routes in the setting of advanced stenosis likely drives the activation of more extensive collateral pathways. Further studies involving larger patient populations with standardized inclusion criteria are required for a more thorough understanding of the impact of stenosis severity on collateral flow patterns and their clinical implications.

Previous studies have reported periprocedural complication rates of 3.6% in a cohort of 416 patients undergoing CAS over a 10-year period and 3.95% in a group of 152 high-risk patients (15,16). We observed a periprocedural complication rate of 9.5% (n=2), in the current study, which is notably higher than previous reports. This discrepancy may be attributed to the relatively smaller size of the sample in our study, as a limited number of patients can amplify the impact of individual complications.

Cerebral hyperperfusion syndrome (CHS) presents with a spectrum of clinical symptoms resulting from cerebral damage caused by vasogenic edema or intracerebral hemorrhage. Given its non-specific and variable presentation, CHS can be easily misdiagnosed, potentially leading to a life-threatening progression of the condition. Headache has been identified as the most common presenting symptom in CAS, and is reported in approximately 35% of all cases (17). However, it is noteworthy that nearly two-thirds of the patients do not report a prior history of headache, indicating that the absence of headache is not sufficient to exclude CHS (17). The underlying pathophysiology of CHS is not yet fully understood, but is thought to involve a combination of elevated cerebral blood flow and associated clinical symptoms. Pre-perioperative blood pressure control is essential to reduce the risk of CHS (18). A meta-analysis involving 8,731 patients undergoing CAS reported an overall incidence of CHS at 4.6%, aligning with findings of the current study where 4.8% (n=1) of patients developed CHS (17). In previous studies, patients with and without CCO exhibited no differences in the occurrence of in-hospital composite events, such as non-fatal myocardial infarction and stroke, after CAS, corroborating the findings of the current study (19,20).

Previous studies with longer follow-up durations (56 months and 4 years) reported stroke rates of 3.7% to 5.3%, myocardial infarction rates of 9.3% to 15.4%, and mortality rates of 22.2% to 31.4% (21,22). We observed a lower rate of such events, although the median follow-up period in the current study was also shorter at 24 months. We observed mortality in 14.3% of the patients in the occlusion (study) group and 9.5% of the patients in the control group. MI was observed in 4.8% of the patients in each group, and no ischemic cerebrovascular events were recorded in either group. The lower incidence in our findings may be attributed to the shorter follow-up period, highlighting the need for extended follow-up to better evaluate long-term outcomes in this patient population.

The findings of this study indicate that CAS may be a viable treatment option for patients with CCO, especially those at high risk for CEA. Although no significant differences were observed in complications or short- to mid-term outcomes between patients with and without CCO, these results should be interpreted cautiously due to certain

limitations. Contralateral occlusion may not necessarily be a contraindication for CAS if thorough pre-procedural planning and careful intra-procedural techniques are applied. Additionally, the assessment of collateral flow during the planning phase may help identify patients who could benefit most from CAS.

Study Limitations

The primary strength of the current study lies in its matched cohort design, which minimizes potential confounders and enhances the validity of all comparisons between the CCO and control groups. Additionally, the inclusion of long-term follow-up data provides valuable insights into the durability of CAS outcomes in these populations. However, the study is subject to certain limitations, most notably the inherent biases resulting from its retrospective design and the sample size, which limits the generalizability of the findings. Furthermore, the single-center design may not fully account for variations in procedural techniques, operator expertise, or experience of the interventionalist across different institutions. Additionally, differences in stent type and design, as well as patient age, may have influenced the outcomes of CAS and should be considered among the study's limitations. Moreover, the absence of a CEA or medical management control group limits direct comparison of outcomes across different treatment strategies, which could provide further clinical insight.

Conclusion

This study indicates that CAS may be a safe and viable treatment option for patients with CCO, with outcomes comparable to those without CCO. While these findings contribute to the growing body of evidence, they should be interpreted cautiously due to certain limitations. Further research with larger patient groups and extended follow-up is needed to validate these results and better define the role of CAS in this population.

Ethics

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of University of Health Sciences Turkey, Başakşehir Çam and Sakura City Hospital (approval number: 2024-72). The study was conducted in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of in 2000.

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Footnotes

Authorship Contributions

Concept: M.C., M.F.A., Ç.E., T.G., Design: M.C., A.D., O.T., T.G., Data Collection or Processing: M.B., Ç.E., O.T., Analysis or Interpretation: M.B., A.D., M.F.A., O.T., Literature Search: M.C., M.B., Ç.E., Writing: M.C., A.D., M.F.A., T.G.

Conflict of Interest: No conflict of interest was declared by the authors.

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