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ORIGINAL ARTICLE / ÖZGÜN MAKALE

Evaluation of mid- and long-term outcomes following carotid endarterectomy with a double-layer primary arteriotomy closure technique

Çift katman primer arteriotomi kapama tekniği ile karotis endarterektomi sonrasında orta ve uzun dönem sonuçlarının değerlendirilmesi

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ABSTRACT

Background: This study aims to evaluate the mid- and long-term outcomes of patients who underwent carotid endarterectomy with double-layer primary arteriotomy closure technique.

Methods: Between January 2011 and January 2021, a total of 94 patients (58 males, 36 females; mean age: 66.5±8.5 years; range, 40 to 82 years) who underwent carotid endarterectomy were retrospectively analyzed. Doppler ultrasonography, computed tomography or magnetic resonance angiography, and digital subtraction angiography were utilized during follow-up. Stenoses of 50% and above were defined as restenosis.

Results: The mean carotid clamp time was 11.72±2.30 and the mean follow-up was 54.18±27.71 months. Two patients (2.1%) underwent revision due to bleeding and hematoma. No new cerebrovascular events were observed in the postoperative period (<30 days). During the follow-up, six (6.4%) patients with ≥50% stenosis on the same side and 14 (14.9%) patients with stenosis on the opposite side were identified. Primary patency rates were found to be 99% at one year, 95.4% at three years, 90% at five years, 71% at seven years, and 71% at nine years. Age was the only independent risk factor affecting survival.

Conclusion: Our study results suggest that this technique can be used safely in patients with appropriate internal carotid artery diameter with favorable mid- and long-term patency rates.

Keywords: Carotid endarterectomy, patch closure, primary closure.

ÖZ

Amaç: Bu çalışmada, çift katman primer arteriotomi kapatma tekniği ile karotis endarterektomi uygulanan hastaların orta ve uzun dönem sonuçları değerlendirildi.

Çalışma planı: Ocak 2011 - Ocak 2021 tarihleri arasında, karotis endarterektomi uygulanan toplam 94 hasta (58 erkek, 36 kadın; ort. yaş: 66.5±8.5 yıl; dağılım: 40-82 yıl) retrospektif olarak incelendi. Takip sürecinde Doppler ultrasonografi, bilgisayarlı tomografi veya manyetik rezonans anjiyografi ve dijital substraksiyon anjiyografi yöntemleri kullanıldı. %50 ve üzerindeki darlıklar, restenoz olarak tanımlandı.

Bulgular: Ortalama karotis klemp süresi 11.72±2.30 dk. ve ortalama takip süresi 54.18±27.71 ay idi. İki hastaya (%2.1) kanama ve hematom nedeniyle revizyon yapıldı. Ameliyat sonrası dönemde (<30 gün) yeni bir serebrovasküler olay gözlenmedi. Takip süresince aynı tarafta %50 ve üzeri darlık gelişen altı hasta (%6.4) ve karşı tarafta darlık tespit edilen 14 hasta (%14.9) belirlendi. Birinci yılda primer açıklık oranı %99, üçüncü yılda %95.4, beşinci yılda %90, yedinci yılda %71 ve dokuzuncu yılda %71 olarak bulundu. Yaş, sağkalımı etkileyen tek bağımsız risk faktörü idi.

Sonuç: Çalışma sonuçlarımız, bu tekniğin uygun internal karotis arter çapına sahip hastalarda orta ve uzun dönemde yüksek açıklık oranları ile güvenle kullanılabileceğini göstermektedir.

Anahtar sözcükler: Karotis endarterektomi, primer kapatma, yama ile kapatma.

Since Dr. M. DeBakey's[1] successful carotid endarterectomy (CEA) and primary closure (PC) of arteriotomy operation in 1953, this technique has continued to be the most effective treatment for carotid artery stenosis. It is effective in preventing ischemic strokes in symptomatic and selected asymptomatic internal carotid artery (ICA) stenosis.[2] Over time, patch closure (PaC) methods have been

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developed to prevent restenosis. For this purpose, prosthetic (Dacron®), venous (saphenous vein), and bioprosthetic (bovine pericardium) patch materials are commonly used.[2] Another method is the eversion endarterectomy, which is preferred by some centers as a simple and reliable technique.[3]

Based on the European Society for Vascular Surgery (ESVS) 2023 Clinical Practice Guidelines on the Management of Atherosclerotic Carotid and Vertebral Artery Disease, PaC is recommended as Class 1 in CEA.[4] However, recent studies demonstrating that PC is not inferior to PaC have reignited discussions on this matter.[5-7] In their literature review, AbuRahma et al.[8] found that PaC and eversion endarterectomy were superior to PC. On the other hand, Zenonos et al.[9] concluded that PC during CEA in conjunction with contemporary medical treatment could lead to outcomes comparable or superior to PaC. In our study, a modified technique is described which limits narrowing of the artery during the standard PC technique. In the studies comparing arteriotomy closure techniques after CEA, PaC is reported as superior to PC;[2,8] however, the double-layer closure technique described in our study may contribute to the re-evaluation of this situation (Table 1).

As a clinic utilizing this modified PC of arteriotomy closure technique following CEA, in the present study, we aimed to evaluate the mid- and long-term outcomes following CEA with a double-layer PC technique.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Başkent University, Adana Dr. Turgut Noyan Hospital, Department of Cardiovascular Surgery between January 2011 and January 2021. A total of 203 patients who routinely underwent CEA using double-layer PC technique were screened. For the evaluation of carotid stenosis, computed tomographic angiography (CTA) or magnetic resonance angiography (MRA) was used. The decision for CEA was made based on the consensus assessment conducted with the neurology, radiology and vascular surgery departments for all patients. The degree of stenosis was calculated according to the North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria. The indications for CEA included symptomatic patients with carotid artery stenosis of 50 to 99% and asymptomatic patients with severe stenosis of 70 to 99%. Symptomatic carotid stenosis was defined as an acute transient ischemic attack or neurological event lasting for 24 h or more within six months. Demographic and operative data, medical records during follow-ups, and survival status of the patients were examined. Finally, a total of 94 patients (58 males, 36 females; mean age: 66.5±8.5 years; range, 40 to 82 years) with complete data during follow-up examinations were included in the study. A written informed consent was obtained from each patient. The study protocol was approved by the Baskent University, Faculty of Medicine, Ethics Committee (date: 10.10.2023, no: KA23/349). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical technique

All patients underwent surgery under general anesthesia without the use of shunt and cerebral monitoring. The surgery commenced with a longitudinal incision made anterior to the sternocleidomastoid muscle, followed by the dissection of the platysma muscle and subcutaneous tissues. Attention was paid to preserving the adventitial layer during the exposure and taping of the common carotid artery (CCA), ICA, and external carotid artery (ECA). Carotid body blockade with lidocaine was routinely applied to prevent bradycardia and hypotension.

After systemic heparinization, achieving an activated clotting time (ACT) >250 sec, CCA was clamped first, followed by ECA and finally ICA. The stump pressure from the ICA was measured before clamping it. Following longitudinal arteriotomy, endarterectomy was performed. Following the removal of atherosclerotic tissues (Figure 1a), the media layer of the artery is sutured with a continuous technique using 6/0 polypropylene suture (Figure 1b). Clamps were, then, successively removed from CCA, ECA, and ICA. The closure was finalized by suturing the preserved adventitial layer as the second layer with a continuous suture technique using the same suture (Figure 1c). The purpose of suturing the second layer adventitially was to prevent narrowing of the vessel diameter and enhance bleeding control. Carotid clamp times and retrograde pressure recordings from ICA were documented for all patients. After hemostasis without reversing heparin with protamine, subcutaneous drains were routinely placed, and the platysma and overlying subcutaneous tissues were closed with continuous subcutaneous suture technique, while the skin was closed using a subcutaneous technique.

Postoperative medication

All patients were extubated on the operating table. In the first six postoperative hours, anticoagulation with enoxaparin, 60 mg (0.6 mL), was administered to all patients who were under high risk for

Table 1. Trials about primary closure and patch closure

Supporting primary closure	Against primary closure
Zenonos et al.,[9] retrospective clinical study, 111 patients, In conjunction with contemporary medical management, primary closure during CEA may yield results comparable or superior to patch angioplasty	Abu Rahma et al.,[15] Literature Review, Carotid patching or ECEA was superior to PC
Cheng et al.,[5] retrospective, 240 patients, Primary closure has the advantage of reducing cross-clamp times and eliminating graft-specific complications when compared with patch angioplasty	Cheng SF et al.,[12] randomised, 790 patients, restenosis was more common after primary closure than conventionally with a patch closure. Patch closure is the treatment of choice to avoid restenosis.
Jonsson et al.,[14] retrospective cohort, 9,205 patients, There was an increased risk of ipsilateral stroke <30 days in patients operated on with primary closure compared with eversion CEA and patch angioplasty. There was no difference between primary closure, different patch types, or eversion after the perioperative phase.	Huizing et al.,[13] systematic review, on the basis of moderate-quality evidence, perioperative stroke rate was lower after PAC compared with PRC. The rate of restenosis was higher after PRC, although the clinical significance of this finding in terms of long-term stroke prevention remained unclear
Liu et al.,[16] retrospective, 126 patients, here are no differences in postoperative and middle-term outcomes between PAC and selective PRC, whereas PRC technique can save operation time and shorten the intraoperative carotid clamp time. PRC can be safely applied in patients with a greater than 5 mm internal carotid artery (ICA)	Aburahma et al.,[8] Literature review, CEA with primary closure had higher late restenosis rates. There is level 1 evidence to support CEA with patching or eversion over primary closure and there is also no significant difference between the use of various patches.
Maertens et al.,[17] retrospective, 213 patients, Primary closure appears to be an equivalent closure technique compared with patch angioplasty when used in selected patients.	
Nana et al.,[19] retrospective, 1,357 patients, Excellent outcomes were achieved with all types of closure techniques with low rates of MACE and other adverse events during long-term follow-up after CEA.	
Qumsiyeh et al.,[20] retrospective, 851 patients, Primary arterial closure is safe and expeditious in appropriately selected high-risk patients.	

CEA: Carotid endarterectomy; ECEA: Eversion carotid endarterectomy; PC: Primary closure; PAC: Patch closure; PRC: Primary closure.

thromboembolism and without bleeding issues. From the first postoperative day onwards, dual antiplatelet therapy (clopidogrel 75 mg + acetylsalicylic acid 100 mg) and atorvastatin 20 mg were initiated.

Patient follow-up

After discharge, patients had their first postoperative follow-up on the first week at the cardiovascular surgery outpatient clinic. Subsequent follow-ups were conducted in both cardiovascular surgery and neurology outpatient clinics. Follow-up intervals were scheduled at one, three, six, and 12 months in the first year and then annually. Depending on the physician's preference during follow-up, Doppler ultrasonography, CT, or MRA, and digital subtraction angiography (DSA) were utilized.

Outcome evaluation

Primary outcome measures for early (≤30 days) and late outcomes were ipsilateral stroke, contralateral stroke, and death. Acute neurological deficit that occurred after surgery, lasted 24 h or longer, and was radiologically proven to be due to ischemia, was defined as postoperative stroke. We defined postoperative stroke as an acute symptomatic neurological defect lasting for 24 h or more with consistent cerebral ischemia with evidence on a radiological image. In addition to primary outcome measures, parameters such as surgical complications, length of stay, reoperations were included in the analysis. Stenoses of 50% and above were defined as restenosis. Whether the patients were still alive or not

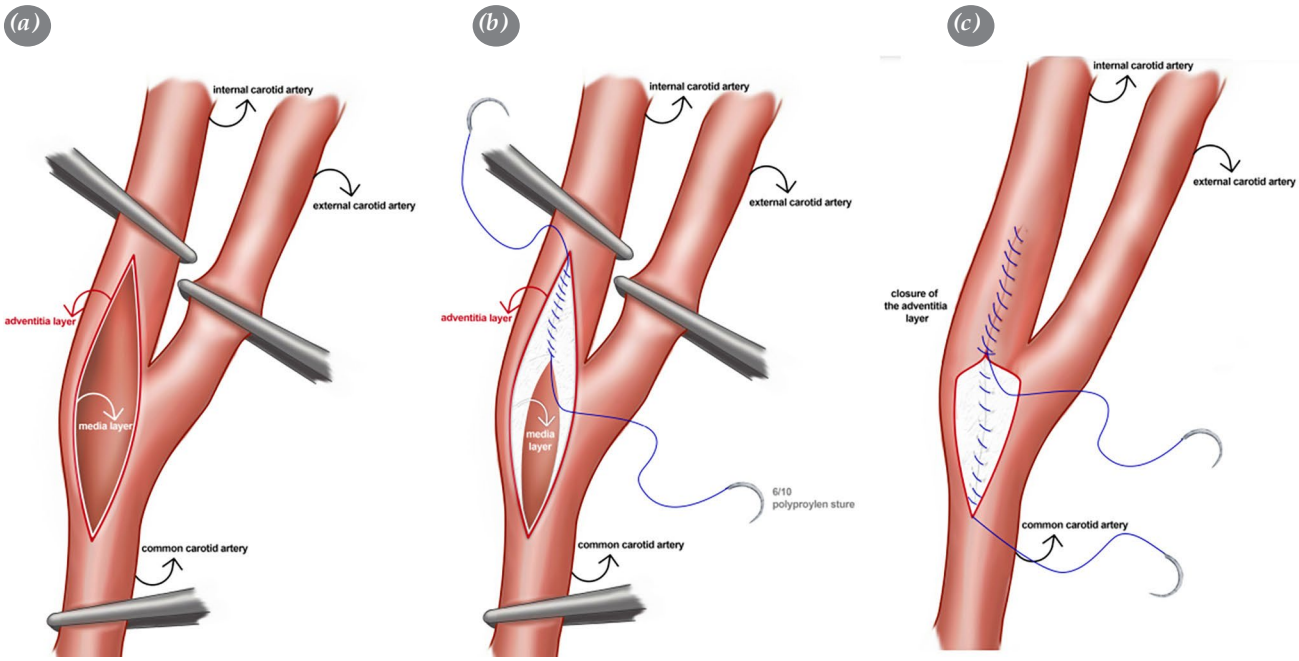

Figure 1. (a) Following the removal of atherosclerotic tissues, the media and adventitia layers identified. **(b)** The media layer of the artery is sutured with a continuous technique using 6/0 polypropylene suture. **(c)** The vascular clamps removed from CCA, ECA, and ICA. The closure was finalized by suturing the preserved adventitial layer as the second layer with a continuous suture technique using the same suture.

CCA: Common carotid artery; ECA: External carotid artery; ICA: Internal carotid artery.

was determined on the basis of hospital records and telephone calls.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD) or median (min-max), while categorical variables were expressed in number and frequency. The Kaplan-Meier survival analysis was employed for primary patency rates and long-term survival rates. Binary logistic regression analysis was used for regression analyses, and Cox regression analysis was utilized to identify factors affecting survival. A p value of <0.05 was considered statistically significant.

RESULTS

Of a total of 94 patients, 42 (44.7%) were symptomatic. The demographic and clinical parameters of the patients are summarized in Table 2. The mean clamp time was 11.72±2.30 min, the mean stump pressure was 52.72±19.38 mmHg, and the mean hospital stay was 2.98±1.98 days. Two (2.1%) patients underwent revision due to bleeding and hematoma. These patients was on warfarin due to atrial fibrillation, and surgery was performed when the international normalized ratio (INR) value dropped below 1.5, while low-molecular-weight heparin was used for this bridging period. No significant surgical focus was detected and only oozing type bleeding was observed during the surgical exploration. The cause of the bleeding was considered as late effects of long-term anticoagulation. One patient died following postoperative myocardial infarction in the early postoperative period. No newly developed cerebrovascular events were observed in the perioperative period (<30 days). The patients were followed for a mean of 54.18±27.71 months. During the follow-up, late mortality was observed in 14 patients. The causes of mortality were myocardial infarction (n=1), cancer-related death (n=1), viral pneumonia (n=1), cerebrovascular event (n=1), and other causes (n=10).

During the follow-up, six patients (6.4%) with ≥50% stenosis on the same side and 14 patients (14.9%) with stenosis on the opposite side were identified. Patients with stenosis on the same side were medically followed closely, as they were clinically

Table 2. Demographics and perioperative data (n=94)

	n	%	Mean±SD	Min-Max
Age (year)			66.5±8.5	
Sex				
Male	58	61.7		
Female	36	38.3		
Hypertension	81	86.2		
Hyperlipidemia	48	51.1		
Diabetes mellitus	34	36.2		
Family history	3	3.2		
Myocardial infarction	7	7.4		
Congestive heart failure	5	5.3		
Chronic obstructive pulmonary disease	10	10.6		
Smoking	14	14.9		
Peripheral arterial disease	3	3.2		
Stroke/transient ischemic attack	42	44.7		
Chronic renal failure/disease	4	4.3		
Perioperative data				
Cross-clamp time (min)			11.72±2.30	5-20
Postoperative data				
Hospital stay (day)			2.98±1.98	
Revision for bleeding/hematoma	2	2.1		
30 day mortality	1		54.18±27.71	
Follow-up (month)				
Ipsilateral stenosis during follow-up	6	6.4		
Contralateral stenosis during follow-up	14	14.9		
Late mortality	14			

SD: Standard deviation.

Table 3. Logistic regression analysis results of factors affecting ipsilateral stenosis

			95% CI for OR	
	p	OR	Lower	Upper
Age	0.245	0.938	0.843	1.045
Sex	0.901	0.883	0.124	6.286
Myocardial infarction	0.050	30.592	0.997	938.760
Redo	0.999	0.000	0.000	-
Hypercholesterolemia	0.203	0.243	0.027	2.143
Hypertension	0.433	3.256	0.171	62.131
Diabetes mellitus	0.363	0.335	0.032	3.532
Smoking	0.547	2.454	0.132	45.496
Chronic obstructive pulmonary disease	0.999	0.000	0.000	-
Peripheral arterial disease	0.999	0.000	0.000	-
Stroke	0.672	1.592	0.185	13.695

CI: Confidence interval; OR: Odds ratio.

Table 4. Logistic regression analysis result of factors affecting contralateral stenosis

			95% CI for OR	
	p	OR	Lower	Upper
Age	0.595	1.023	0.940	1.114
Sex	0.689	1.310	0.350	4.896
Myocardial infarction	0.089	9.937	0.707	139.737
Redo	0.999	0.000	0.000	-
Hypercholesterolemia	0.447	0.581	0.143	2.354
Hypertension	0.065	19.591	0.830	462.359
Diabetes mellitus	0.160	0.300	0.056	1.611
Smoking	0.754	1.410	0.164	12.101
Chronic obstructive pulmonary disease	0.579	0.448	0.026	7.641
Peripheral arterial disease	0.999	0.000	0.000	-
Stroke	0.411	0.532	0.118	2.394

CI: Confidence interval; OR: Odds ratio.

asymptomatic. Two of the patients with stenosis on the opposite side underwent CEA.

No independent risk factor affecting the development of new stenosis was identified (Tables 3 and 4). While examining the primary patency rates, they were found to be 100% at six months, 99% at one year, 95% at two years, 95.4% at three years, 95% at four years, 90% at five years, 83% at six years, and 71% at seven to nine years (Figure 2).

Regarding survival rates, they were found to be 88% at one year, 84% at two years, 84% at three years, 81% at four years, 81% at five years, 81% at six years and 70% at seven to nine years (Figure 3). Age was the only independent risk factor affecting survival (Table 5).

DISCUSSION

Using this novel technique, we achieved primary patency, complication, mortality, and overall patency rates comparable to those reported in contemporary studies employing the patch angioplasty technique. Notably, no postoperative cerebrovascular events were observed. During follow-up, ipsilateral restenosis occurred in six patients, while contralateral restenosis was identified in 14 patients. The 10-year primary

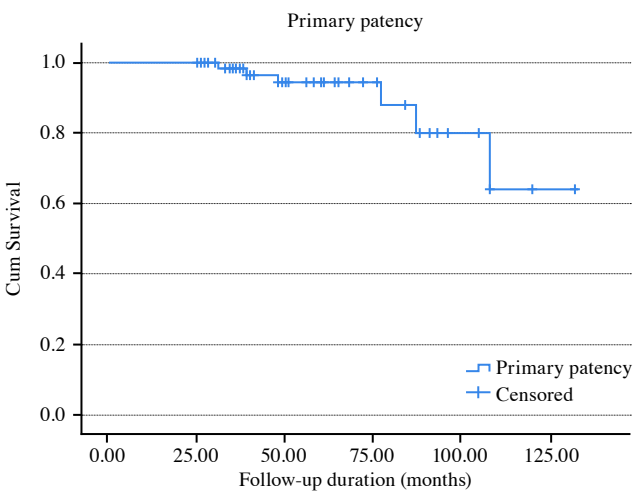

Figure 2. Primary patency during the follow-up period.

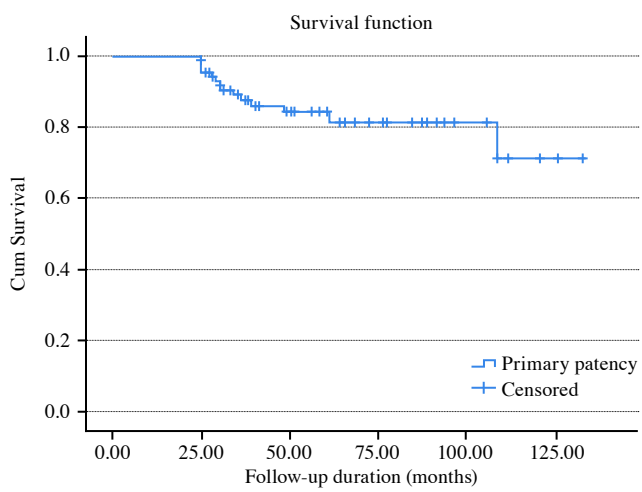

Figure 3. Survival curve during the follow-up period.

Table 5. Cox regression analysis results of factors affecting survival

			95% CI for OR	
	p	OR	Lower	Upper
Obstruction	0.886	0.000	0.000	1.823E+49
Contralateral obstruction	0.111	0.260	0.050	1.363
Age	0.028	1.114	1.012	1.227
Sex	0.409	1.692	0.485	5.902
Myocardial infarction	0.499	2.394	0.191	30.076
Redo	0.952	0.000	0.000	1.714E+136
Diabetes mellitus	0.560	0.679	0.184	2.500
Stroke	0.675	0.738	0.178	3.055
Congestive heart failure	0.917	0.000	0.000	2.998E+72
Hypercholesterolemia	0.350	0.484	0.106	2.215
Hypertension	0.277	3.585	0.359	35.790
Smoking	0.300	2.503	0.442	14.178
Chronic obstructive pulmonary disease	0.920	0.897	0.108	7.450
Peripheral arterial disease	0.237	5.628	0.322	98.395

CI: Confidence interval; OR: Odds ratio.

patency rate was 71%. No independent risk factors for restenosis could be identified. The 10-year overall survival rate was 70%, with age emerging as the only independent predictor of survival.

While the primary goals of CEA are the elimination of stenosis and the prevention of stroke, maintaining the achieved patency for an extended period is of utmost importance to prevent future adverse events. The widely adopted PaC method has gained popularity and secured a high recommendation level in guidelines. Autologous vein, synthetic, or bioprosthetic patch materials are commonly used for this purpose. In particular, in cases where the vessel diameter is small, providing a larger opening and the lower restenosis rates found in studies have positioned this method favorably, leading to a shift away from PC. However, disadvantages such as a long clamping time, patch material complications including rupture, bleeding, aneurysm development, and, rarely, the risk of infection when synthetic materials are used are also present.[10] The main findings of our study suggest that the CEA procedure can be performed safely and rapidly with the described double-layer suture technique, achieving satisfactory patency rates in the long term while avoiding from the risks of PaC technique.

Although PC has been relegated to the background in many studies related to CEA, it still remains a method still employed by many vascular surgeons. Its simplicity, short cross-clamping time, and low risk of bleeding and infection are advantageous aspects. However, luminal narrowing can be a disadvantage, particularly in cases where the arterial diameter is small.[11] On the other hand, it should be noted that evidence regarding the disadvantage of luminal narrowing is based on studies using the classical method of PC. We have been performing the double-layer PC method at our institute for the past three decades, and our clinical observations indicate that this technique is advantageous due to the significantly reduced risk of luminal narrowing.

Recent studies indicating that PC is not inferior to PaC have reignited discussions on this topic.[5-7,9] Cheng et al.[12] evaluated the long-term results of 790 patients who underwent CEA using PaC, PC, and eversion methods. While they found no significant difference in long-term restenosis between eversion and PaC methods, they observed a higher risk of restenosis with PC compared to PaC. Huizing et al.[13] compared PC and PaC in their systematic review. It was concluded that the perioperative stroke rates were lower with PaC, and the restenosis rates were higher with PC. However, according to the Grading of Recommendation Assessment, Development, and Evaluation (GRADE), which is used to assess the methodological quality of randomized studies, these

findings have a moderate level of evidence, and the clinical significance of restenosis rates in PC is not clear. In a study evaluating the results of symptomatic carotid artery stenosis in the Swedish National Database, the risk of ipsilateral stroke within 30 days was higher in those undergoing PC. However, beyond the perioperative phase, there was no significant difference between PC, PaC, and eversion endarterectomy techniques.[14] AbuRahma et al.[8] in their review and meta-analysis evaluating PC, PaC, and eversion techniques found that patch and eversion techniques were superior to PC, and there was no significant difference between the patch materials used. In a recent study published by the aforementioned authors, similar results were obtained, emphasizing the superiority of PaC over PC with high-level evidence and noting the higher long-term restenosis rates with PC.[15]

Contrary to these significant studies favoring PaC, numerous studies have supported PC. Cheng et al.,[5] in their study, reported that CEA with PC was a safe and effective surgical approach based on short-term outcomes. Liu et al.[16] in their single-center study compared PC and PaC. It was concluded that the closure technique did not affect perioperative and long-term outcomes. The study suggested that the PC technique could be safely applied in selected patients with ICA diameter larger than 5 mm. Maertens et al.[17] conducted a retrospective study based on short-term outcomes in selected patients and, reported that PC and PaC were equivalent. In a systematic review and meta-analysis by Marsman et al.,[18] including 12 randomized clinical trials, they evaluated 2,187 participants with symptomatic stenosis of ≥50% in terms of PaC and PC. They found not significant differences between closure methods in terms of stroke within 30 days, all-cause mortality, and any serious adverse events.

Nana et al.[19] evaluated the long-term outcomes of CEA closure techniques (PC, PaC, and eversion) in their multi-center study. In this study, PC was performed in patients with ICA diameter of ≥7 mm. The results of the study showed similar rates of survival, restenosis, and cerebrovascular events for all three techniques. The recently published study by Qumsiyeh et al.[20] evaluated 851 patients who underwent CEA (PC: 277, PaC: 574). Similar rates of restenosis, postoperative stroke, and stroke-free survival were found for both closure methods. In the study conducted by Chung et al.,[6] 1,044 patients were retrospectively analyzed, and with propensity score matching, 435 patients with PC were compared with 476 patients with PaC. The analysis revealed no significant differences in perioperative and long-term outcomes between the two closure methods.

Restenosis concerns are rooted in the long-term effects on the endothelium caused by changes in flow characteristics resulting from luminal narrowing in standard PC or expansion associated with PaC. It would be beneficial to explore studies that evaluate the flow dynamics and biomechanical effects of PC and PaC methods on the carotid bulb. In a study conducted by Harrison et al.,[21] where they created three-dimensional carotid bifurcation models for each group (healthy, PC, 5 mm patch, and 8 mm patch), they performed flow dynamic studies and demonstrated that flow separation and recirculation in the bifurcation increased proportionally with patch width in cases where a patch was applied. According to the wall shear stress (WSS) and oscillatory shear index (OSI) maps created for each model, it has been demonstrated that areas with low WSS and high OSI are the least present in PC. Different expressions of shear stress are believed to be involved in different stages of the pathogenesis of atherosclerosis. Regions with consistently low WSS have been associated with the early development of the atherosclerosis. High WSS, on the other hand, is thought to have atheroprotective effects. Similar to low WSS, region with elevated OSI heve been suggested to play a role in early atherosclerosis. Therefore, low WSS and high OSI are associated with plaque formation, endothelial dysfunction, and arterial occlusion.[22] Avrahami et al.[23] found that PC had higher WSS and OSI values compared to PaC. This finding suggests that, based on these parameters, PC may be the preferred method. In their study, Kazantsev et al.[24] created a computer simulations of CEA surgery with various patch configurations and created geometric models of the carotid bifurcation accordingly. The study concluded that PC negatively affects flow by narrowing the lumen, while using a very wide patch creates an aneurysm-like formation with extensive recirculation areas. Optimal hemodynamic results were achieved with a patch width of approximately 3 mm. As seen in these studies, main concern about the PC is the narrowing of the artery, which can be eliminated by using the double-layer closure technique we described.

In our study, the mean cross-clamp time was 11.72±2.30 min. Notably, no shunts were used in

any of the patients, and the absence of perioperative cerebrovascular events can likely be attributed to the relatively short cross-clamp duration. We believe that the double-layer PC technique facilitates shorter cross-clamp times and thereby reduces the risk of prolonged cerebral hypoperfusion, which is more commonly associated with the PaC technique. Additionally, avoiding shunt use may lower the risk of embolic complications. These advantages of our technique appear to contribute to a lower incidence of postoperative adverse events. Although, the advantage cerebral monitoring is emphasized by some reports, the routine use of shunts and neuromonitoring are not supported by the recent guidelines.[4,25,26] In addition to the technique we applied, the simplification of the procedure (no shunt, no monitoring) allowed for a reduction in ischemia time. We believe that this contributed to our favorable outcomes. The need for revision due to bleeding in only two patients may be considered a positive contribution of using the adventitial layer in the second layer closure. The detection of significant stenosis (>50%) on the same side in only six patients, and the nine-year patency rate of 71%, is similar to previous studies, emphasizing that the PC method for endarterectomy is not inferior to PaC.[6,7]

This study was designed to present the outcomes of our double-layer PC technique rather than to promote PC over PaC. Nevertheless, it is worth noting that the Society for Vascular Surgery (SVS) guidelines state that PC can be safely performed when the ICA diameter exceeds 6 mm.[25] In our study, ICA diameter was not considered a criterion, and the double-layer PC technique was routinely applied to all patients over an extended period. Taken together, this finding suggests that the double-layer PC technique may be feasible even in cases with ICA diameters below the SVS-recommended threshold. Future studies incorporating these variables may potentially support a revision of the current SVS threshold.

Our study has some limitations. Firstly, it is a single-center and retrospective study without a comparison of closure techniques. Only the mid- to long-term outcomes of patients on whom we performed PC were evaluated. Secondly, there was no assessment of ICA diameters, and the PC method was applied to all patients regardless of arterial diameter; however, the presence of a very low rate of restenosis indicates that the diameter may not have such an important role in the long-term patency. Thirdly, the limited number of patients included in the evaluation is another limitation. We did not experience any problems when the media layer was carefully sutured in cases where it was fragile and the adventitia layer was also sutured as a second layer. However, in cases where suturing the media layer is not possible, it may be appropriate to choose other methods.

In conclusion, although current guidelines strongly recommend patch closure following carotid endarterectomy,[4] a considerable number of centers continue to prefer primary closure. Recent studies have shown that, in appropriately selected patients, primary closure is not inferior to patch closure in terms of clinical outcomes. Moreover, some studies emphasize that selecting the appropriate patch size is critical for achieving optimal hemodynamic results. Our findings support this perspective by demonstrating that the double-layer primary closure technique can offer favorable outcomes without the need for patching, potentially broadening the applicability of PC in clinical practice. Considering our results and the literature, the following conclusions can be drawn: The patch closure method recommended in the guidelines cannot be ignored. This method is particularly appropriate in cases with a small internal carotid artery diameter and in female patients. If the internal carotid artery diameter is suitable, the primary closure method can be safely preferred. It should be kept in mind that patch closure may not always provide the best hemodynamic results. Using a larger patch than necessary can disrupt flow dynamics and lead to early restenosis. The double-layer primary closure technique described in our study has similar mid- and long-term patency rates to patch closure. We believe that this technique, which aims to shorten the time for cross clamping in carotid endarterectomy and avoid the complications of patches, can be applied in selected cases. Further well-designed, prospective, randomized-controlled studies are needed to compare primary closure and patch closure techniques. In addition, studies related to flow dynamics and hemodynamics along with computer-assisted modeling, could facilitate the decision.

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

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