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Extended Follow-Up Analysis of Intracranial Bifurcation Aneurysms Managed with Braided Stent-Assisted Coil Embolization: A Single-Center Experience

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Abstract

Objective: This study retrospectively analyzed clinical and angiographic follow-up data of patients who underwent braided stent-assisted coil embolization for intracranial bifurcation aneurysms in a single-center series.

Methods: Between July 2023 and September 2025, 90 patients with unruptured intracranial bifurcation aneurysms were treated with braided stent-assisted coil embolization. Wide-neck aneurysms were defined as those with a neck diameter >4 mm or a dome-to-neck ratio <2 (1). All patients received dual antiplatelet therapy and underwent follow-up digital subtraction angiography (DSA) at 6 and 12 months, and magnetic resonance angiography (MRA) at 24 months. The degree of occlusion was evaluated according to the Roy–Raymond Occlusion Classification (RROC) (2).

Results: The mean age was 59.9 years (range 28–79), and 48% of patients were female. Aneurysm locations were anterior communicating artery (n=38), middle cerebral artery (n=31), and basilar tip (n=21). All procedures were completed successfully with no technical failures. Periprocedural complications occurred in 3.3% of cases, all transient and without permanent morbidity. Complete occlusion (RROC Grade 1) increased from 35.6% immediately post-procedure to 84.4% at 24 months. Seven patients required retreatment with flow-diverter stents beyond 24 months due to residual aneurysm filling (3,4).

Conclusion: Braided stent-assisted coil embolization is a reliable endovascular approach for treating intracranial bifurcation aneurysms. It demonstrates high procedural success, low complication rates, and progressive aneurysm occlusion during follow-up. The shelf and mild flow-diverting effects of braided stents contribute to durable long-term results, particularly in wide-neck and complex aneurysms.

Keywords: Intracranial aneurysm, braided stent, coil embolization, bifurcation aneurysm, endovascular treatment

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Örgülü Stent Destekli Koil Embolizasyonu ile Tedavi Edilen İntrakraniyal Bifurkasyon Anevrizmalarının Uzun Dönem Takip Analizi: Tek Merkez Deneyimi

Öz

Amaç: Bu çalışmada örgülü stent destekli koil embolizasyonu ile tedavi edilen intrakraniyal bifurkasyon anevrizmalarının uzun dönem klinik ve anjiyografik sonuçları retrospektif olarak değerlendirildi.

Yöntemler: Temmuz 2023 – Eylül 2025 tarihleri arasında, rüptüre olmamış intrakraniyal bifurkasyon anevrizması bulunan 90 hasta örgülü stent destekli koil embolizasyon yöntemiyle tedavi edildi. Geniş boyunlu anevrizma, boyun çapı >4 mm veya kubbe-boyun oranı <2 olarak tanımlandı (1). Tüm hastalara çiftli antiplatelet tedavi uygulandı ve 6. ile 12. aylarda DSA, 24. ayda MRG anjiyografi ile takip yapıldı. Oklüzyon durumu Roy–Raymond sınıflamasına göre değerlendirildi (2).

Bulgular: Ortalama yaş 59,9 (28–79) olup hastaların %48'i kadındı. Anevrizma yerleşimleri: ACoA (n=38), MCA (n=31), baziler tepe (n=21). Tüm olgularda teknik başarı sağlandı. %3,3 oranında, tamamı geçici olmak üzere işlem sırasında komplikasyon izlendi. Tam oklüzyon oranı (RROC Grade 1) işlem sonrası %35,6 iken, 24. ayda %84,4'e yükseldi. Yedi hasta, 24. ay sonrası rezidü nedeniyle flow-diverter stent ile yeniden tedavi edildi (3,4).

Sonuç: Örgülü stent destekli koil embolizasyonu, intrakraniyal bifurkasyon anevrizmalarının tedavisinde güvenli, etkili ve uzun vadede başarılı bir yöntemdir. Özellikle geniş boyunlu ve kompleks yapılı anevrizmalarda "shelf" etkisi ve akım yönlendirici özellikleriyle uzun dönem oklüzyon başarısını desteklemektedir.

Anahtar kelimeler: İntrakraniyal anevrizma, örgülü stent, koil embolizasyonu, bifurkasyon anevrizması, endovasküler tedavi.

INTRODUCTION

Endovascular treatment of intracranial bifurcation aneurysms remains technically challenging due to their wide-neck morphology and the need to preserve critical branch vessels. Stent-assisted coiling has emerged as an effective strategy to enhance coil stability, prevent prolapse into the parent artery, and reduce recurrence rates in complex vascular configurations[1–3].

The interwoven design of braided stents provides enhanced neck coverage and serves as a scaffold that minimizes coil herniation toward the parent artery—a phenomenon termed the "shelf effect"[5]. This structural advantage allows for more durable and complete neck coverage, which has been shown to improve long-term angiographic outcomes[5–7].

Furthermore, because of their higher metal coverage ratio, braided stents can exert mild flow-diverting effects, altering intra-aneurysmal hemodynamics and promoting gradual thrombosis[8–10]. Although these effects are less pronounced than those seen with dedicated flow-diverter devices, they appear to contribute significantly to progressive aneurysm occlusion and stability, particularly in partially compacted or wide-neck aneurysms[9–11].

The present study retrospectively analyzes the angiographic evolution and clinical outcomes of bifurcation aneurysms treated with braided stent-assisted coiling, emphasizing occlusion dynamics, procedural safety, and retreatment rates in long-term follow-up.

METHODS

Patient Population

Between July 2023 and September 2025, a total of 90 patients with unruptured intracranial bifurcation aneurysms underwent braided stent-assisted coil embolization at our institution. Only patients with complete angiographic and clinical follow-up data were included in the analysis. Ethical approval for

this study was obtained from the Clinical Research Ethics Committee of Gazi Yaşargil Training and Research Hospital, University of Health Sciences (Date: 24.10.2025, Decision No: 676).

Antiplatelet Protocol and Periprocedural Management

All patients received dual antiplatelet therapy (aspirin + ticagrelor) initiated five days before the procedure. During intervention, systemic anticoagulation was maintained using intravenous heparin to achieve an activated clotting time (ACT) between 250–300 seconds[12,13].

Procedures were performed under general anesthesia using Canon Alphenix and Siemens Artis angiography systems. Optimal working projections were individually selected based on aneurysm morphology.

A microcatheter was positioned within the aneurysm sac, and a second microcatheter navigated into the parent artery for stent deployment. The stent was deployed by gradual retraction of the delivery system to jail the microcatheter within the aneurysm. To enhance the shelf effect, the stent wire was gently advanced to expand the stent against the vessel wall while maintaining microcatheter stability.

Microcatheter "kickback" occurred in seven patients but was successfully managed with microwire support, allowing all procedures to be completed without technical failure[14,15]. Ticagrelor was preferred over clopidogrel due to its more predictable pharmacodynamic profile and rapid onset of platelet inhibition. Platelet function testing was not routinely performed, which is considered a limitation of this study.

Devices Used

The following braided stents were utilized according to aneurysm size and vessel anatomy:

- ACCERO (Acandis, Germany)
- LEO / LEO Baby (Balt, France)
- LVIS / LVIS Junior (MicroVention, USA)

Follow-Up Protocol

Post-procedural imaging follow-up included:

- Digital Subtraction Angiography (DSA): at 6 and 12 months
- Magnetic Resonance Angiography (MRA): at 24 months

Aneurysm occlusion was assessed using the Roy–Raymond Occlusion Classification (RROC) (2):

- Grade 1: Complete occlusion
- Grade 2: Residual neck
- Grade 3a–3b: Residual aneurysm

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 25.0 (Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages.

Changes in RROC grade distribution and retreatment rates were evaluated descriptively.

RESULTS

Patient Characteristics

In this study, 90 patients were analyzed. Ages ranged from 28 to 79 years, with a mean age of 59.9 years. Of these, 43 patients (48%) were female.

Aneurysm locations were distributed as follows:

- Anterior communicating artery (ACoA): 38 cases
- Middle cerebral artery (MCA): 31 cases
- Basilar tip: 21 cases

Angiographic outcomes of anterior communicating artery aneurysms are summarized in Table I. All procedures were

technically successful, with no failures in stent deployment or coil placement.

Table I: Changes in Roy–Raymond Occlusion Classification (RROC) in Anterior Communicating Artery (ACoA) Aneurysms Over Time

Time Point	Grade 1	Grade 2	Grade 3a	Grade 3b
Post-procedure	18	14	4	2
6 months	25	8	3	2
12 months	27	6	3	2
24 months	29	4	2	2

Technical Success and Complications.

The overall technical success rate was 100%.

• One patient with an ACoA aneurysm developed acute in-stent thrombosis immediately following stent deployment. Complete recanalization was achieved through intra-arterial tirofiban infusion, with no lasting neurological deficit.

• One MCA aneurysm patient presented with transient facial palsy two days post-discharge. Diffusion-weighted imaging (DWI) revealed a small ischemic focus in the right basal ganglia; the patient fully recovered without sequelae (modified Rankin Scale [mRS] 0).

• Another patient developed a transient headache accompanied by small DWI-positive ischemic spots in the right frontoparietal region, without neurological deficit.

In one MCA bifurcation aneurysm, follow-up angiography revealed occlusion of the inferior trunk, which was retrogradely filled by pial collaterals. The patient remained asymptomatic throughout the follow-up period.

The overall periprocedural complication rate was 3.3%, and all were transient without permanent morbidity[14,15,23,24]. Changes in RROC grades for middle cerebral artery aneurysms are presented in Table II.

Table II: Changes in Roy–Raymond Occlusion Classification (RROC) in Middle Cerebral Artery (MCA) Aneurysms Over Time

Time Point	Grade 1	Grade 2	Grade 3a	Grade 3b
Post-procedure	10	13	5	3
6 months	12	10	5	4
12 months	14	9	4	4
24 months	15	8	3	3

Angiographic Outcomes (RROC Classification)

Roy–Raymond Occlusion Classification (RROC) results:

• Immediately post-procedure:

o Grade 1 (Complete occlusion): 32 patients

o Grade 2 (Residual neck): 40 patients

o Grade 3a/3b (Residual aneurysm): 18 patients

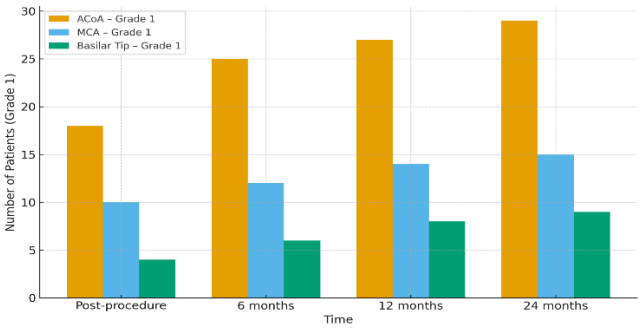
• At 24-month follow-up:

o Grade 1: 76 patients (84.4%)

o Grade 2: 14 patients (15.6%)

o Grade 3: 0 patients

The rate of complete occlusion improved markedly from 35.6% post-procedure to 84.4% at 24 months, indicating progressive aneurysm thrombosis and durable vessel remodeling associated with the braided stent's hemodynamic effects[5–9,11]. The progression of complete occlusion (RROC Grade 1) over time is illustrated in Graphic 1. Angiographic follow-up results of basilar tip aneurysms are shown in Table III.



Graphic 1. Bar chart showing RROC Grade 1 progression over time in ACoA, MCA, and Basilar Tip aneurysms.

Table III: Changes in Roy–Raymond Occlusion Classification (RROC) in Basilar Tip Aneurysms Over Time

Time Point	Grade 1	Grade 2	Grade 3a	Grade 3b
Post-procedure	4	9	5	3
6 months	6	8	4	3
12 months	8	6	4	3
24 months	9	5	4	3

Retreatment

Seven patients underwent retreatment with flow-diverter stents beyond the 24-month follow-up due to persistent aneurysm filling. Retreatment with flow-diverter stents was technically successful in all seven patients. No major periprocedural complications were recorded. During subsequent clinical follow-up, no new neurological deficits or mortality were observed, and all patients maintained functional independence (modified Rankin Scale score 0–1).

This corresponds to a retreatment rate of 7.8%, which aligns with previously reported rates (5–10%) in comparative studies of stent-assisted coiling versus flow diversion[10,11,19,20,22].

No cases of delayed rupture, permanent neurological deficit, or device migration were observed during the follow-up period.

DISCUSSION

This study demonstrates that braided stent-assisted coil embolization is a highly effective and safe endovascular treatment for intracranial bifurcation aneurysms, yielding high rates of technical success, progressive aneurysm occlusion, and low complication rates. The improvement in complete occlusion from 35.6% immediately post-procedure to 84.4% at 24 months highlights the long-term hemodynamic remodeling capacity of these devices.

The mechanical “shelf effect” generated by braided stents provides a stable platform at the aneurysm neck, improving coil packing density and preventing coil herniation into the parent artery[5,6,13]. This feature is particularly advantageous in bifurcation aneurysms where maintaining patency of branch vessels is critical[7,8]. Compared with laser-cut stents, braided designs exhibit superior neck coverage and conformability, which enhance coil stability and promote more uniform neointimal growth across the aneurysm neck[9,10,13,14].

Another important aspect is the flow-modifying behavior of braided stents. Owing to their higher metal coverage (18–28%), these devices produce mild flow-diversion effects, reducing inflow velocity and fostering progressive intra-aneurysmal thrombosis[8–10]. This delayed but consistent occlusion progression explains the improvement in RROC grades observed in our cohort over the 24-month follow-up period. Similar trends have been reported in prior series evaluating LVIS, LEO, and ACCERO stents[9,14-16].

In addition to mechanical stability, the hemodynamic remodeling induced by braided stents likely contributes to long-term durability. As endothelialization proceeds across the stent struts, the parent artery undergoes structural reconstruction, creating a neo-endothelial layer that effectively isolates the aneurysm from circulation[17,18]. This mechanism, though less potent than that seen with dedicated flow-diverter stents, achieves an optimal balance between aneurysm occlusion and branch vessel preservation in bifurcation anatomy[19–21].

Our results are consistent with large multicenter series, where stent-assisted coiling achieved occlusion rates exceeding 80% at mid- to long-term follow-up, with retreatment rates of 5–10%[10,11,17,19]. In this cohort, the absence of permanent neurological morbidity supports the safety of the technique, provided that appropriate antiplatelet management and operator experience are ensured.

Another clinical advantage of braided stents lies in their deliverability and adaptability to

tortuous vascular anatomy. Devices such as LVIS Jr. and LEO Baby allow treatment of smaller distal branches while maintaining sufficient radial force and flexibility[16,18]. These attributes are crucial for managing aneurysms at the MCA bifurcation or basilar tip, where vessel angulation can complicate device navigation and deployment[5,7,21].

Although our findings affirm the reliability of braided stent-assisted coiling, certain limitations must be acknowledged. The study's retrospective design and single-center nature limit its generalizability. Additionally, different stent brands were used, introducing minor variations in metal coverage and hemodynamic performance. However, all procedures were conducted using a standardized protocol, ensuring internal consistency. In addition, the use of magnetic resonance angiography instead of digital subtraction angiography at the 24-month follow-up may have led to underestimation of small residual aneurysm filling.

Future research should focus on prospective comparative trials assessing braided stent-assisted coiling versus next-generation flow diverters specifically in bifurcation aneurysms. Advanced imaging modalities such as computational fluid dynamics (CFD) and quantitative MRA flow analysis could further elucidate hemodynamic changes following braided stent deployment.

Overall, this study supports the concept that braided stent-assisted coiling combines the mechanical advantages of stent scaffolding with the hemodynamic benefits of partial flow diversion, providing a durable and safe reconstructive solution for complex bifurcation aneurysms.

CONCLUSION

Braided stent-assisted coil embolization represents a safe, effective, and durable endovascular option for the treatment of intracranial bifurcation aneurysms. The combination of high technical success, low complication rates, and progressive angiographic improvement over time underscores its value in contemporary neurointerventional practice.

The shelf effect and mild flow-diverting characteristics of braided stents provide enhanced neck reconstruction and long-term aneurysm stability, particularly in wide-neck and morphologically complex aneurysms.

With careful patient selection, appropriate antiplatelet preparation, and technical expertise, this approach offers excellent long-term outcomes while minimizing retreatment rates.

Future prospective, multicenter, and comparative studies are warranted to further establish its role relative to dedicated flow-diverter technologies in the management of bifurcation aneurysms.

Ethical approval: Ethical approval for this study was obtained from the Clinical Research Ethics Committee of Gazi Yaşargil Training and Research Hospital, University of Health Sciences (Date: 24.10.2025, Decision No: 676).

Conflict of Interest: The authors declared no conflicts of interest.

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