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Original Article

Comparison of the efficacy and safety of double-microcatheter versus stent-assisted coiling in the embolization of wide-necked intracranial aneurysms

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Abstract: *Objectives:* To compare the efficacy and safety of double-microcatheter coiling (DMC) versus stent-assisted coiling (SAC) for the management of wide-necked intracranial aneurysms (WNIA), and to assess the influence of serological biomarkers on early neurological recovery. *Methods:* A retrospective study was conducted on 230 patients with ruptured WNIA that were treated at Zhejiang Provincial People's Hospital Bijie Hospital from May 2020 to October 2024. Patients were assigned to the SAC (n=121) or the DMC (n=109) groups. Perioperative indicators, including serum matrix metalloproteinase-9 (MMP-9), neuron-specific enolase (NSE), S100β protein, National Institutes of Health Stroke Scale (NIHSS), and Barthel Index (BI) were recorded. Functional outcomes at 6 months were assessed using the modified Rankin Scale (mRS), and complications were documented. *Results:* Operative time (132.14 ± 16.72 min vs. 142.58 ± 18.36, *P*<0.001) and hospital stay (11.07 ± 2.94 d vs. 12.24 ± 3.31 d, *P*=0.005) were markedly shorter in the DMC group. Postoperative serum MMP-9 (P=0.003), NSE (P=0.008), and S100β (P=0.002) levels were markedly lower in the DMC group. The DMC group showed better NIHSS and BI scores at all postoperative time points (all P<0.05). The overall complication rate was lower in the DMC group (13.76% vs. 28.93%, P=0.005). However, no significant difference was observed in 6-month mRS scores between groups (P=0.371). *Conclusions:* In patients with ruptured WNIA, DMC is associated with shorter operation times, lower perioperative complication rates, reduced systemic inflammation, and faster early neurological recovery compared with SAC. Despite these early advantages, both techniques demonstrate comparable long-term functional outcomes at 6 months.

Keywords: Double-microcatheter coiling, stent-assisted coiling, wide-necked intracranial aneurysm, embolization, biomarkers

Introduction

Wide-necked intracranial aneurysms (WNIA) are difficult to treat in neurovascular interventional therapy [1, 2]. These aneurysms are prone to rupture, leading to subarachnoid hemorrhage (SAH), which is associated with high morbidity and mortality, posing a significant clinical problem [3]. WNIA are typically defined by a neck width greater than 4 mm or a dome-to-neck ratio below 2, and they often exhibit unfavorable hemodynamic and morphological features that complicate endovascular treatment [4, 5]. Conventional embolization of WNIA is associated with major shortcomings, including incomplete occlusion, coil prolapse, and increased risk of the aneurysm recurrence or re-rupture [6]. Therefore, there is a critical need for improved endovascular techniques to achieve safe and durable aneurysm occlusion.

Existing studies primarily focused on adjunctive techniques designed for aneurysms with complex neck morphology. Stent-assisted coiling (SAC) involves placing a stent across the aneurysm neck, providing a mechanical scaffold to prevent coil prolapse and facilitate stable coil packing [7, 8]. Despite these advantages, SAC requires long-term antiplatelet therapy and is associated with stent-related complications, which limit its clinical application [9]. Double-microcatheter coiling (DMC) uses two microcatheters within the aneurysm sac, allowing simultaneous or sequential coil deployment to

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form a more complex and stable coil structure without the need for a permanent implant [10, 11].

Beyond mechanical challenges, aneurysm progression and postoperative recovery are influenced by inflammation and neuronal injury [12]. Matrix metalloproteinase-9 (MMP-9) is an enzyme that degrades extracellular matrix and participates in vascular remodeling, neuron-specific enolase (NSE) and S100β protein serve as markers of neuronal injury [13]. Postoperative elevations of these biomarkers reflect the extent of vascular and neural tissue stress, which may differ between SAC and DMC techniques.

This study aims to compare the efficacy and safety of SAC versus DMC for ruptured WNIA. The novelty of this study lies in its integration of clinical outcomes with serum biomarkers of inflammation and neuronal injury. This approach provides a more comprehensive understanding of postoperative patient status and may guide clinicians in optimizing treatment strategies for these complex aneurysms.

Materials and methods

Study cases

A retrospective analysis was performed on 230 patients with ruptured WNIA who underwent coil embolization at Zhejiang Provincial People's Hospital Bijie Hospital from May 2020 to October 2024. Inclusion criteria: ① age ≥18 years; ② ruptured saccular WNIA confirmed by digital subtraction angiography (DSA), defined as aneurysm neck width >4 mm or dome-to-neck [D/N] ratio <2, and the presence of subarachnoid hemorrhage (SAH) [14]; ③ time from onset to surgery ≤24 hours; ④ Hunt-Hess grade I-III [15]; ⑤ complete medical records and follow-up data accessible. Exclusion criteria: ① concomitant intracranial organic diseases; ② severe hepatic and renal insufficiency, malignancy, heart failure, or other serious systemic diseases; ③ history of previous cranial surgery or intracranial intervention; ④ recurrent or multiple aneurysms; ⑤ presence of acute or chronic infections; ⑥ coagulation disorders; ⑦ presence of neurological or psychiatric disorders.

According to the operative techniques used for coil embolization during surgery, patients were assigned to either the stent-assisted coiling (SAC) group (n=121) or the double-microcatheter coiling (DMC) group (n=109). All patients completed a minimum follow-up of 6 months after the procedure.

Ethical statement

This study was conducted in strict adherence to the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Institutional Review Board (IRB) of Zhejiang Provincial People's Hospital Bijie Hospital. Due to the retrospective design of the study and the use of anonymized medical records, the IRB waived the requirement for written informed consent. All patient data were de-identified and handled confidentially throughout the research process to protect patient privacy.

Coil embolization

Stent-assisted coiling (SAC): The surgery was performed under general anesthesia. The right femoral artery waived the requirement, and a 6F catheter sheath was inserted and continuously flushed with heparinized saline to maintain patency; A dose of 4,000 units of heparin was administered intravenously, followed by continuous infusion of 1,000 U/h. Additionally, 6 mL of Xinweining (tirofiban hydrochloride and sodium chloride injection) was injected intravenously, followed by continuous infusion at 4 mL/h via a micro-pump. Under DSA guidance, the positions of the aneurysm neck and sac were confirmed. Guided by a micro guidewire, a stent microcatheter was navigated into the parent artery. After shaping the coil microcatheter, its tip was advanced into the aneurysm sac. Appropriate stents and coils were selected based on aneurysm morphology, and embolization was performed with stent deployment. After confirming satisfactory embolization, all microcatheters were withdrawn, and hemostasis was achieved at the puncture site with routine pressure dressing.

Double-microcatheter coiling (DMC): The procedure was performed under general anesthesia. A 6F guiding catheter was inserted via femoral artery puncture and positioned in the petrous segment of the internal carotid artery ipsilateral to the aneurysm. The optimal positions of the parent artery and the aneurysm were confirmed using 3D-DSA. An appropriate

microcatheter was selected and shaped according to the anatomical relationship between the parent artery and aneurysm. Under the guidance of a roadmap and along a microguidewire, the microcatheter tip was advanced into the aneurysm sac, and coils were selected based on the aneurysm dimensions. A 3D framing coil was first deployed to establish a stable framework within the aneurysm. A second microcatheter was introduced via an additional Y-valve connected to the guiding catheter. Coils were alternately deployed through the two microcatheters to achieve dense aneurysm packing, with periodic assessment of coil placement and parent artery patency. After completion of embolization, all microcatheters were withdrawn, and hemostasis was achieved at the puncture site by applying pressure.

Outcome evaluation

Perioperative conditions: Operative time and hospital stay were recorded for both groups of patients.

Serum biomarkers: Serum levels of MMP-9, NSE, and S100β were assessed using enzyme-linked immunosorbent assay (ELISA) kits (ab246539, ab217778, ab314846, Abcam, China) before surgery and 7 days after surgery.

Neurological deficit: The NIHSS was used to evaluate neurological deficits preoperatively and at 1, 3, and 6 months postoperatively. The NIHSS ranges from 0 to 42, with lower scores indicating less severe neurological deficits. The Cronbach's α coefficient for this scale is 0.92 [16].

Daily living activities: The Barthel index (BI) was employed to evaluate patients' independence in daily activities preoperatively and at 1, 3, and 6 months postoperatively. Score ranges from 0 to 100, with higher scores signifying greater independence. Specifically, a score of 100 indicates complete independence, 61-99 indicates mild dependence, 41-60 indicates moderate dependence, ≤40 indicates severe dependence, and 0 indicates complete paralysis. The inter-rater reliability (kappa value) ranges from 0.63 to 1.00 [17].

Prognosis: The modified Rankin scale (mRS) was utilized to evaluate functional outcomes at 6 months after surgery. Scores range from 0 (no symptoms) to 6 (death), with 0-2 indicating a favorable prognosis and 3-6 indicating an unfavorable prognosis. Specifically, 1, denotes minor symptoms without significant functional disability; 2, indicates slight disability but independent in daily activities; 3, moderate disability requiring some help but can walk independently; 4, moderate to severe disability requiring assistance in daily activities; 5, severe disability requiring long-term bed rest; 6, death. The kappa value for this scale ranges from 0.81 to 0.95 [18].

Complications: All complications occurring during the 6-month follow-up period were recorded, including postoperative ischemia, intimal injury, vasospasm, and hydrocephalus.

Statistical analysis

Data were analyzed using SPSS 29.0 statistical software (IBM Corp., Armonk, NY, USA). Continuous variables were first tested for normality using the Shapiro-Wilk test. It was verified that all continuous variables in this study adhered to a normal distribution and were reported as mean ± standard deviation (M ± SD). Between-group comparisons for continuous variables were conducted using independent samples t-tests. Categorical variables were presented as frequencies (proportions) [n (%)], with between-group comparisons performed employing the χ^2 test. Spearman and Pearson correlation analyses were utilized to examine the relationship between serum biomarkers and patient prognosis. Two-tailed $P< 0.05$ was considered statistically significant.

Results

Baseline information

Baseline demographic and clinical characteristics were comparable between the SAC and DMC groups (**Tables 1**, **2**). There were no significant differences in age, sex, body mass index (BMI), smoking or alcohol consumption status, hypertension, hyperlipidemia, diabetes, or coronary heart disease (all $P>0.05$). Similarly, aneurysm characteristics, including neck width, D/N ratio, body width, aneurysm location, Hunt-Hess grade, and time from onset to surgery, were comparable between the two groups (all $P>0.05$).

Table 1. Comparison of demographic characteristics between the two groups

Parameter	SAC group (n=121)	DMC group (n=109)	t/χ^2	P
Sex [n (%)]			0.620	0.431
Male	75 (61.98%)	62 (56.88%)		
Female	46 (38.02%)	47 (43.12%)		
Age (years)	65.27 ± 7.34	64.18 ± 8.02	1.078	0.282
BMI (kg/m^2)	23.81 ± 3.12	24.06 ± 3.35	0.573	0.567
Smoking [n (%)]			0.035	0.851
Yes	57 (47.11%)	50 (45.87%)		
No	64 (52.89%)	59 (54.13%)		
Drinking [n (%)]			0.001	0.973
Yes	48 (39.67%)	43 (39.45%)		
No	73 (60.33%)	66 (60.55%)		
Hypertension [n (%)]			0.657	0.418
Yes	73 (60.33%)	60 (55.05%)		
No	48 (39.67%)	49 (44.95%)		
Hyperlipidemia [n (%)]			0.178	0.673
Yes	39 (32.23%)	38 (34.86%)		
No	82 (67.77%)	71 (65.14%)		
Diabetes [n (%)]			0.605	0.437
Yes	39 (32.23%)	30 (27.52%)		
No	82 (67.77%)	79 (72.48%)		
Coronary heart disease [n (%)]			0.244	0.621
Yes	45 (37.19%)	44 (40.37%)		
No	76 (62.81%)	65 (59.63%)		

Notes: SAC, stent-assisted coiling; DMC, double-microcatheter coiling; BMI, body mass index.

Table 2. Comparison of clinical features between the two groups

Parameter	SAC group (n=121)	DMC group (n=109)	t/χ^2	P
Aneurysm neck width (mm)	7.29 ± 2.36	7.23 ± 2.28	0.180	0.857
D/N ratio	1.62 ± 0.39	1.59 ± 0.47	0.573	0.567
Aneurysm body width (mm)	4.65 ± 1.42	4.61 ± 1.44	0.207	0.836
Aneurysm location [n (%)]			0.558	0.455
Anterior circulation	64 (52.89%)	63 (57.80%)		
Posterior circulation	57 (47.11%)	46 (42.20%)		
Hunt-Hess grading [n (%)]			0.884	0.643
I	75 (61.98%)	62 (56.88%)		
II	23 (19.01%)	26 (23.85%)		
III	23 (19.01%)	21 (19.27%)		
Time from onset to surgery (h)	9.37 ± 2.84	9.05 ± 2.91	0.836	0.404

Notes: SAC, stent-assisted coiling; DMC, double-microcatheter coiling; D/N, dome to neck.

Perioperative conditions

Perioperative data were compared between the SAC and DMC groups (**Figure 1**). The SAC group had a significantly longer operative time (P<0.001) and hospital stay (P=0.005) compared with the DMC group. These differences may reflect the greater technical complexity and postoperative care requirements associated with SAC procedures.

Serum biomarkers

As shown in **Table 3**, preoperative serum levels of MMP-9 (P=0.486), NSE (P=0.464), and S100β (P=0.603) did not differ significantly between the two groups. After surgery, the SAC group exhibited significantly higher levels of MMP-9 (P=0.003), NSE (P=0.008), and S100β (P=0.002) compared with the DMC group, indicating greater inflammatory response and neuronal injury in patients undergoing SAC.

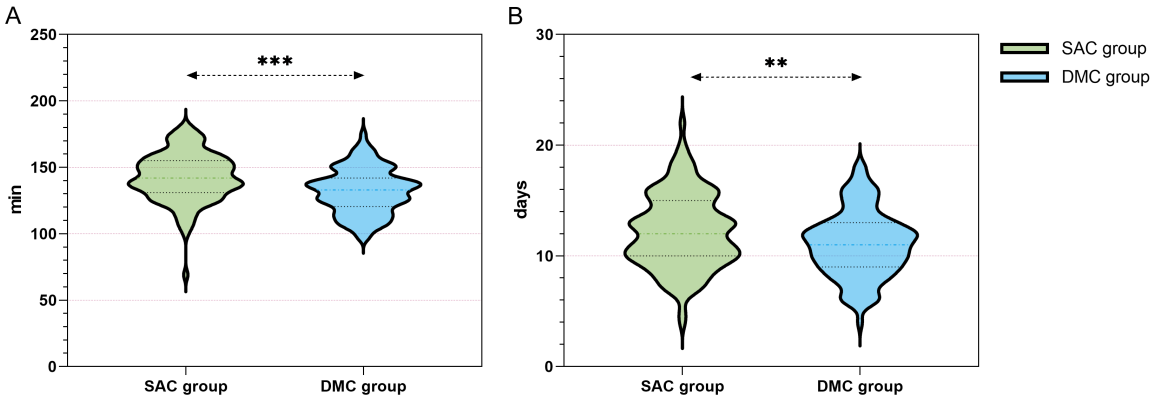


Figure 1. Comparison of perioperative conditions between two groups. A. Operative time; B. Hospital stay; **: P<0.01; ***: P<0.001. Notes: SAC, stent-assisted coiling; DMC, double-microcatheter coiling.

Table 3. Comparison of serum biomarker levels between the two groups (ng/mL)

Parameter	SAC group (n=121)	DMC group (n=109)	t	P
MMP-9				
Preoperative	78.34 ± 12.67	79.52 ± 13.08	0.697	0.486
Postoperative 7 d	138.75 ± 16.43	132.26 ± 15.9	3.040	0.003
NSE				
Preoperative	26.83 ± 4.15	27.24 ± 4.37	0.733	0.464
Postoperative 7 d	44.62 ± 5.37	42.79 ± 5.02	2.667	0.008
S100β				
Preoperative	2.17 ± 0.49	2.21 ± 0.51	0.520	0.603
Postoperative 7 d	3.29 ± 0.63	3.05 ± 0.54	3.148	0.002

Notes: SAC, stent-assisted coiling; DMC, double-microcatheter coiling; MMP-9, matrix metalloproteinase-9; NSE, neuron-specific enolase; S100β, central nervous system-specific protein β.

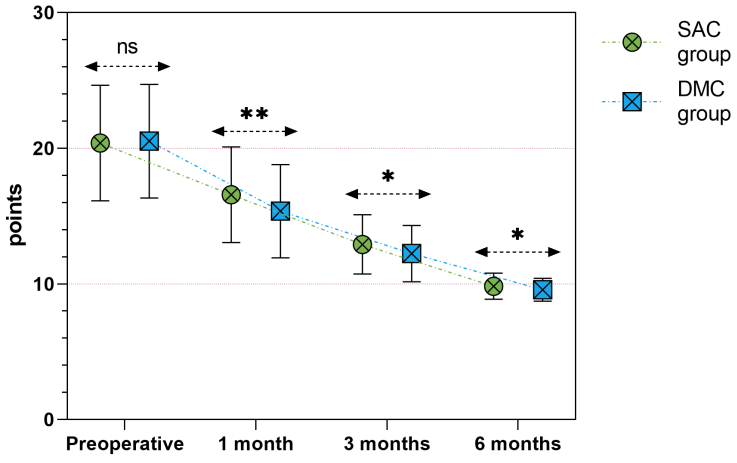


Figure 2. Comparison of NIHSS scores between two groups. Notes: ns: no significant; *: P<0.05; **: P<0.01. SAC, stent-assisted coiling; DMC, double-microcatheter coiling; NIHSS, national institutes of health stroke scale.

Neurological deficit

NIHSS scores of the two groups are summarized in **Figure 2**. Before surgery, the two groups had comparable scores (P=0.801). At 1 month postoperatively, the SAC group demonstrated significantly higher NIHSS scores than the DMC group (P=0.009). This difference remained significant at 3 months (P=0.017) and 6 months (P=0.031), indicating slower neurological recovery in the SAC group.

Daily living activities

BI scores of the two groups are shown in **Table 4**. Before surgery, the two groups had similar BI scores (P=0.398). At 1 month postoperatively, the DMC group showed significantly higher BI scores than the SAC group (P=0.002), indicating superior functional independence. This advantage persisted at 3 months (P=0.008) and 6 months (P=0.017), suggesting better functional recovery over time in the DMC group.

Prognosis

As shown in **Table 5**, no significant differences were observed between the SAC and DMC

Table 4. Comparison of BI scores between the two groups (points)

Parameter	SAC group (n=121)	DMC group (n=109)	t	P
Preoperative	35.26 ± 7.83	36.15 ± 8.06	0.847	0.398
Postoperative 1 month	42.53 ± 6.75	45.38 ± 6.93	3.157	0.002
Postoperative 3 months	54.17 ± 6.24	56.43 ± 6.58	2.663	0.008
Postoperative 6 months	63.94 ± 5.67	65.71 ± 5.49	2.398	0.017

Notes: SAC, stent-assisted coiling; DMC, double-microcatheter coiling; BI, Barthel index.

groups in terms of mRS scores at post-operative 6 months (P=0.371). In addition, proportions of patients with favorable (mRS 0-2) and unfavorable (mRS 3-6) outcomes were comparable, indicating similar long-term functional prognosis.

Complications

The incidence of complications within the 6-month follow-up is presented in **Table 6**. The overall incidence rate was significantly higher in the SAC group compared with the DMC group (P=0.005), suggesting that SAC may be associated with greater perioperative risk.

Correlation analysis

To further investigate the clinical relevance of postoperative serum biomarkers, correlation analyses were performed between biomarker levels on postoperative day 7 and 6-month functional outcomes (**Table 7**). Postoperative MMP-9 levels showed a weak but statistically significant negative correlation with 6-month BI scores (r=-0.175, P=0.008), suggesting that higher MMP-9 levels were associated with poorer functional independence at six months. However, no significant correlations were observed between MMP-9 and 6-month NIHSS scores (r=-0.041, P=0.541) or mRS-based favorable prognosis (r=0.013, P=0.845).

For NSE and S100β, no notable correlations were observed with any 6-month prognostic indicators, including NIHSS (NSE: r=-0.060, P=0.363; S100β: r=-0.048, P=0.465), BI (NSE: r=-0.087, P=0.188; S100β: r=-0.091, P=0.169), or mRS favorable prognosis (NSE: r=0.034, P=0.608; S100β: r=0.067, P=0.311). These findings indicate that while elevated acute-phase biomarkers, particularly MMP-9, may reflect early postoperative neuronal and vascular stress and are associated with a trend toward reduced functional independence, they do not independently determine the long-term functional prognosis as assessed by mRS at six months.

Discussion

This study compared DMC and SAC for the treatment of ruptured WNIA. Both DMC and SAC are effective in securing complex lesions, but they differ in perioperative procedures, biological responses, and recovery patterns.

The DMC procedure demonstrated several advantages, including shorter procedure time, lower levels of systemic inflammatory and neuronal injury markers, faster early neurological recovery, and fewer complications. In contrast, the SAC group was associated with longer surgery and hospital stay. These differences likely reflect the increased technical complexity of SAC, which requires precise stent navigation and deployment in the parent vessel, as well as careful management of antiplatelet therapy to prevent in-stent thrombosis [19, 20]. The additional steps and monitoring requirements may explain the extended hospitalization observed in the SAC group [21].

Mechanistically, DMC uses two microcatheters in a planned sequence to create a stable coil framework, simplifying the embolization process [22]. DMC does not require permanent intravascular implants. Consequently, long-term antiplatelet therapy is not needed, which may contribute to faster postoperative recovery and shorter hospital stays [23]. These findings are consistent with previous studies, which have reported that stent-assisted techniques require more time and resources than simpler methods like DMC [24].

Elevated MMP-9, NSE, and S100β levels in the SAC group suggest greater extracellular matrix degradation, vascular inflammation, and neuronal injury. MMP-9 degrades collagen IV and elastin, potentially compromising vessel wall integrity [25]; elevated NSE indicates more pronounced neuronal injury, likely due to microemboli or hemodynamic disturbances during stent deployment [26]; and increased S100β

Table 5. Comparison of prognosis between the two groups [n (%)]

Parameter	SAC group (n=121)	DMC group (n=109)	χ^2	P
mRS scores			0.801	0.371
Favorable prognosis (0-2 scores)	108 (89.26%)	101 (92.66%)		
Unfavorable prognosis (3-6 scores)	13 (10.74%)	8 (7.34%)		

Notes: SAC, stent-assisted coiling; DMC, double-microcatheter coiling; mRS, modified Rankin scale.

Table 6. Comparison of the incidence of complications between the two groups [n (%)]

Parameter	SAC group (n=121)	DMC group (n=109)	χ^2	P
Overall incidence rate	35 (28.93%)	15 (13.76%)	7.751	0.005
Postoperative ischemia	12 (9.92%)	2 (1.83%)	5.215	0.022
Intimal injury	8 (6.61%)	5 (4.59%)	0.441	0.507
Vasospasm	11 (9.09%)	5 (4.59%)	1.797	0.180
Hydrocephalus	4 (3.31%)	3 (2.75%)	0.020	0.888

Notes: SAC, stent-assisted coiling; DMC, double-microcatheter coiling.

Table 7. Correlation analysis between postoperative serum biomarkers and functional outcomes

Parameter 1	Parameter 2	r	P
MMP-9 (Postoperative 7 d)	NIHSS (Postoperative 6 months)	-0.041	0.541
MMP-9 (Postoperative 7 d)	BI (Postoperative 6 months)	-0.175	0.008
MMP-9 (Postoperative 7 d)	mRS scores (Good prognosis)	0.013	0.845
NSE (Postoperative 7 d)	NIHSS (Postoperative 6 months)	-0.060	0.363
NSE (Postoperative 7 d)	BI (Postoperative 6 months)	-0.087	0.188
NSE (Postoperative 7 d)	mRS scores (Good prognosis)	0.034	0.608
S100β (Postoperative 7 d)	NIHSS (Postoperative 6 months)	-0.048	0.465
S100β (Postoperative 7 d)	BI (Postoperative 6 months)	-0.091	0.169
S100β (Postoperative 7 d)	mRS scores (Good prognosis)	0.067	0.311

Notes: MMP-9, matrix metalloproteinase-9; NSE, neuron-specific enolase; S100β, central nervous system-specific protein β; NIHSS, national institutes of health stroke scale; BI, Barthel index; mRS, modified Rankin scale.

indicates astroglial damage [27]. Notably, higher biomarker levels in the SAC group correlated with worse early neurological outcomes, supporting their potential role as early indicators of procedural neuroinflammation and neuronal injury.

The DMC group demonstrated better neurological recovery, as indicated by consistently lower NIHSS and BI scores throughout the follow-up period. These findings were consistent with the observed biomarker profiles, as patients in the DMC group had lower postoperative levels of neuronal injury markers. This provides a plausible biological explanation for more favorable post-operative recovery. Reduced neural tissue injury during the perioperative period may facilitate faster and better functional recovery, ultimately improving patients' ability to perform daily activities [28]. These findings are clinically relevant, suggesting that DMC may offer meaningful benefits in terms of early postoperative recovery and quality of life.

Despite these advantages, the improvements in early and intermediate neurological recovery did not translate into a significant difference in long-term functional outcomes at 6 months. Patients were split into favorable outcome and unfavorable outcome groups based on mRS scores, with comparable proportion of patients achieving favorable outcomes. These results suggest that although DMC may facilitate a faster and smoother postoperative recovery, both procedures ultimately achieve similar long-term functional outcomes when evaluated using a global disability scale, and this is consistent with previous studies [29].

The SAC group exhibited a significantly higher overall complication rate. Specifically, postoperative ischemic events occurred more frequently in the SAC group, which may be attributable to stent-related thromboembolic complications. The presence of stent struts can promote platelet aggregation, and although dual antiplatelet therapy is routinely administered, it may not completely eliminate the risk of ischemic events while simultaneously

increasing the risk of hemorrhagic complications [30]. Vasospasm was also observed more frequently in the SAC group, likely due to greater mechanical stimulation of the vascular wall during stent navigation and sustained inflammatory responses associated with elevated MMP9 [31]. In contrast, no significant intergroup differences were observed in the incidence of intimal injury or hydrocephalus, suggesting that these complications may be more closely related to the severity of the initial subarachnoid hemorrhage than to the embolization technique itself. These findings indicate that the elevated complication risk associated with SAC stems primarily from thromboembolic events and procedure-related vessel irritation, rather than a uniform increase across all complication categories [32].

Our finding that DMC was associated with shorter operative time, fewer complications, and faster early neurological recovery is partially consistent with study by Shim et al. [23], which reported favorable safety and efficacy of the DMC technique in the treatment of small ruptured aneurysms. However, their cohort did not include biomarker analysis. In contrast, most previous comparative studies have primarily focused on angiographic occlusion rates or long-term recanalization, whereas few have integrated serological markers of inflammation and neuronal injury to explore the biological mechanisms underlying differences in clinical recovery. The comparable 6-month mRS outcomes between SAC and DMC groups corroborates prior reports indicating that diverse embolization strategies for wide-neck aneurysms can achieve similar long-term functional independence when successful anatomical occlusion is achieved [29]. Nonetheless, the early biochemical and clinical advantages associated with DMC may represent a favorable treatment option for patients with limited physiological reserve or those at high bleeding risk who are unsuitable candidates for prolonged antiplatelet therapy following stent placement.

Several limitations of this study should be acknowledged. First, this was a single-center retrospective study, which may have introduced selection bias despite the comparable baseline characteristics observed between groups. Second, the follow-up period was only six months. Although this duration was sufficient to evaluate perioperative safety and short-term functional outcomes, it was inadequate for assessing long-term outcomes. Third, detailed angiographic follow-up data were not incorporated into the present analysis, limiting our ability to correlate biomarker alterations and clinical outcomes with the durability of aneurysm occlusion. Future studies should focus on multicenter prospective investigations, ideally randomized controlled trials with larger sample sizes and extended follow-up periods. Comprehensive angiographic assessments should also be incorporated to further elucidate the relationship between perioperative biological responses, clinical recovery, and long-term aneurysm occlusion. In addition, emerging technologies, including bioresorbable stents and next-generation flow-diverting devices, warrant further investigation.

Conclusion

In the treatment of ruptured wide-necked intracranial aneurysms (WNIA), DMC was associated with a shorter operative time, lower postoperative levels of inflammatory and neuronal injury biomarkers, and a reduced incidence of perioperative complications, compared with SAC. However, the two treatment strategies produced comparable long-term functional outcomes at postoperative 6 months. These findings suggest that DMC may offer advantages in perioperative safety and early postoperative recovery while achieving long-term efficacy comparable to that of SAC in the treatment of ruptured WNIA.

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Disclosure of conflict of interest

None.

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