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Research Progress on Influencing Factors Related to Postoperative Recurrence After Endovascular Interventional Treatment of Intracranial Aneurysms

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Abstract: Intracranial aneurysm is a common disease of the cerebrovascular system, and its rupture can lead to subarachnoid hemorrhage with extremely high mortality and disability rates. Endovascular interventional therapy has become a mainstream treatment modality due to its advantages of minimal invasiveness, safety, and rapid recovery; however, postoperative aneurysm recurrence remains a significant clinical challenge. This article systematically reviews the recent research progress on factors influencing recurrence after endovascular treatment of intracranial aneurysms, summarizing and analyzing the evidence from four dimensions: aneurysm morphological characteristics, treatment techniques and material selection, the patient's systemic baseline condition, and hemodynamic mechanisms. Studies indicate that aneurysm size, neck width, immediate Raymond-Roy occlusion grade, packing density, and treatment modality are core factors affecting recurrence. Hypertension, smoking, and the standardized use of aspirin can modulate the risk of recurrence through vascular wall inflammation and repair pathways. The application of flow diverter devices has significantly reduced the long-term recurrence rate of complex aneurysms. This article also summarizes the limitations of current research and discusses future directions for constructing individualized risk prediction models, aiming to provide a reference for reducing the recurrence rate and optimizing treatment strategies in clinical practice.

Keywords: Intracranial aneurysm; endovascular treatment; postoperative recurrence; influencing factors; research progress

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1. Introduction

Intracranial aneurysm (IA) is an abnormal outpouching of the intracranial arterial wall caused by localized defects, with a population prevalence of approximately 3%–5%. Subarachnoid hemorrhage resulting from aneurysm rupture carries extremely high mortality and disability rates, posing a serious threat to human health [1]. Since electrolytically detachable coils were introduced into clinical practice in the 1990s, endovascular interventional techniques have developed rapidly, progressively expanding from coil embolization alone to stent-assisted coiling, flow diverter implantation, intrasaccular flow disruptors, and other technical systems. With continuously broadening therapeutic indications, endovascular treatment has become one of the first-line treatment options for intracranial aneurysms.

However, compared with surgical clipping, the problems of aneurysm recurrence and recanalization after endovascular treatment have remained prominent. Early literature reported that the recurrence rate after coil embolization

alone could exceed 20%, and approximately half of these patients required retreatment. Although the overall recurrence rate has declined significantly with the widespread adoption of new materials and techniques, the long-term recurrence of complex aneurysms—such as large, wide-necked, and posterior circulation aneurysms—cannot be overlooked. Aneurysm recurrence not only increases the economic burden and procedural risk of retreatment for patients but also signifies a persistent potential threat of rupture and hemorrhage.

Elucidating the factors influencing aneurysm recurrence after endovascular intervention and their underlying mechanisms is of great clinical value for precise preoperative risk assessment, intraoperative treatment strategy optimization, and individualized postoperative follow-up management. In recent years, researchers worldwide have conducted numerous cohort studies and mechanistic investigations focusing on aneurysm morphology, treatment modality, patient baseline characteristics, and biomechanical mechanisms, and some of the conclusions have gradually been translated into clinical guiding principles. This article provides a systematic review of the influencing factors and latest research progress concerning recurrence after endovascular interventional treatment of intracranial aneurysms.

2. Influence of Aneurysm Morphological Characteristics on Recurrence

The anatomical and morphological features of an aneurysm constitute the innate basis determining the risk of postoperative recurrence, for which the relevant research evidence is the most substantial and the conclusions are highly consistent.

2.1. Aneurysm Size

The maximum diameter of the aneurysm is one of the most stable independent risk factors for predicting recurrence. Multiple large-sample studies have confirmed that a larger aneurysm diameter is associated with a higher risk of postoperative recurrence. The recurrence risk for large aneurysms with a diameter greater than 10 mm is two to three times that of small aneurysms, while for giant aneurysms with a diameter greater than 25 mm, the recurrence rate after coil embolization alone can exceed 40%. The underlying mechanism is that larger aneurysms are subjected to stronger intra-aneurysmal hemodynamic impact forces and more pronounced coil compaction; moreover, it is difficult to achieve adequate packing density, and the endothelialization process at the aneurysm neck is slow, resulting in persistent blood flow impingement on the neck and the formation of recanalization channels [2]. Specific studies on posterior communicating artery aneurysms have similarly demonstrated a significant positive correlation between aneurysm size and recurrence, with size being an independent predictor in multivariate analysis.

2.2. Neck Width and Dome-to-Neck Ratio

Wide-necked aneurysms (neck $\geq$ 4 mm or dome-to-neck ratio $<$ 2) have consistently posed a challenge for interventional treatment. A wide neck makes stable coil positioning difficult and tends to leave a residual neck, with a stronger direct hemodynamic impact on the neck region, leading to a significantly higher postoperative recurrence rate than that of narrow-necked aneurysms. The recurrence rate of wide-necked aneurysms treated with traditional coil embolization alone can reach over 30%, whereas stent-assisted techniques, by covering the neck and altering the inflow angle of blood flow, can effectively reduce the recurrence risk of wide-necked aneurysms. A smaller dome-to-neck ratio indicates a more pronounced tendency for recurrence, and this parameter better reflects the unfavorable hemodynamic conditions than neck width alone.

2.3. Aneurysm Morphology and Location

Aneurysms with irregular morphology, such as lobulated, multiloculated, or those with daughter sacs, carry a higher recurrence risk than regularly shaped spherical aneurysms. Irregular morphology often suggests heterogeneity of the aneurysmal wall structure and complex flow patterns, making it more likely for residual flow channels to persist locally after embolization. Regarding location, aneurysms at bifurcation sites or locations subjected to strong hemodynamic

impact—such as the anterior communicating artery, posterior communicating artery, and basilar tip—have relatively higher recurrence rates than sidewall aneurysms. Posterior circulation aneurysms, due to their deep anatomical location and limited operative space, often have a lower rate of satisfactory immediate occlusion compared with anterior circulation aneurysms, and correspondingly have a higher long-term recurrence risk [3]. Furthermore, special types such as dissecting aneurysms and blood blister-like aneurysms, because of the persistent pathological processes in the aneurysm wall itself, have significantly higher risks of recurrence and progression compared with ordinary saccular aneurysms.

3. Treatment-Related Factors Influencing Recurrence

The choice of treatment strategy and the quality of the procedure are modifiable factors determining postoperative recurrence and represent the main focus of clinical intervention.

3.1. Immediate Occlusion Grade (Raymond-Roy Classification)

The degree of occlusion demonstrated on immediate postoperative cerebral angiography is the strongest predictor of long-term recurrence. The internationally adopted Raymond-Roy classification categorizes occlusion outcomes into three grades: Class I, complete obliteration; Class II, residual neck; and Class III, residual aneurysm. Numerous studies have confirmed that the risk of recurrence rises in a stepwise manner with higher immediate occlusion grades [4]. A multivariate analysis focusing on recurrence after retreatment showed that the Raymond-Roy grade after the second embolization was an independent risk factor, with complete occlusion significantly reducing the risk of re-recurrence compared with subtotal occlusion. For aneurysms achieving Raymond-Roy Class I occlusion at the initial treatment, the long-term recurrence rate is generally below 5%, whereas for those with Class III residual filling, the recurrence rate can exceed 50%, with the majority of recanalization becoming evident within one to two years post-procedure.

3.2. Packing Density

Packing density refers to the ratio of coil volume to aneurysm volume and is a quantitative indicator of the compactness of embolization. Insufficient packing density is a direct cause of coil compaction and recanalization of the aneurysm sac. It is generally accepted that a packing density greater than 20%–25% significantly reduces the recurrence rate, whereas below this threshold the recurrence risk is markedly elevated. In large aneurysms, even when multiple coils are deployed, the actual packing density often remains low due to the large volume, which is a major reason for the high recurrence rate of large aneurysms [5]. In recent years, precisely calculating aneurysm volume using three-dimensional angiography to guide the selection of coil specifications has helped improve the target packing density and reduce the recurrence risk.

3.3. Treatment Modality

There are significant differences in recurrence rates among different interventional treatment approaches, as summarized in **Table 1**.

Table 1. Comparison of aneurysm recurrence rates among different endovascular treatment modalities

Treatment modality	Representative technique	Applicable aneurysm type	Reported recurrence rate in literature	Main advantages
Simple coil embolization	Electrolytically detachable coil	Small narrow-necked saccular aneurysm	15%–25% (5-year)	Simple operation no antiplatelet therapy required
Stent-assisted coil embolization	Laser-cut stent/ braided stent	Wide-neck and bifurcation aneurysms	8%–15% (mid-to-long term)	Remodels aneurysm neck improves packing density

Treatment modality	Representative technique	Applicable aneurysm type	Reported recurrence rate in literature	Main advantages
Flow diverter	Pipeline and other flow-diverting stents	Large/giant wide-neck sidewall aneurysms	3%–8% (5-year)	Hemodynamic remodeling complete endothelial reconstruction
Intrasaccular flow disruptor	WEB device	Wide-neck bifurcation aneurysms	5%–12% (mid-to-long term)	No long-term dual antiplatelet therapy safe operation

As shown in **Table 1**, traditional simple coil embolization alone is associated with the highest recurrence rate and is mainly suitable for morphologically simple, narrow-necked small aneurysms. Stent-assisted coiling, through the "scaffolding" effect and flow-diverting properties of the stent, significantly reduces the recurrence rate of wide-necked aneurysms, decreasing it by approximately 50% compared with coiling alone. The emergence of the flow diverter (FD) represents a revolutionary breakthrough in interventional concepts. By means of a high-density metal mesh, it redirects blood flow in the parent artery, induces intra-aneurysmal thrombosis and endothelialization, and does not rely on intrasaccular packing. Multiple long-term follow-up studies have shown that the 5-year complete occlusion rate of FD for large/giant internal carotid artery aneurysms can reach 85%–95%, with a recurrence rate of only approximately 5%, which is far lower than that of traditional embolization modalities. A meta-analysis including 33 studies demonstrated a recurrence rate of only 8% in the FD group compared with 27% in the coil group, a highly statistically significant difference. For the retreatment of recurrent aneurysms, FD also exhibits favorable efficacy, with a 12-month occlusion rate exceeding 90% post-procedure.

4. Influence of Systemic Patient Factors and Lifestyle

The patient's underlying diseases and lifestyle habits indirectly modulate the process of aneurysm recurrence by affecting vascular wall repair capacity, inflammatory status, and hemodynamic conditions.

4.1. Hypertension

Hypertension is a common risk factor for the development, progression, rupture, and post-treatment recurrence of intracranial aneurysms. Chronic hypertension leads to degeneration of elastic fibers in the arterial wall and apoptosis of smooth muscle cells, impairing the repair capacity of the vessel wall; simultaneously, increased hemodynamic impact accelerates recanalization of the aneurysm neck after embolization. Several clinical studies have observed that the recurrence rate after interventional treatment is significantly higher in patients with poorly controlled hypertension than in those with normal blood pressure [6]. Long-term postoperative control of systolic blood pressure below 140 mmHg may help reduce the risk of recurrence. Studies focusing on recurrent aneurysms have also found a higher prevalence of hypertension in the recurrence group, suggesting the importance of blood pressure management.

4.2. Smoking

Smoking can increase the risk of aneurysm recurrence through multiple mechanisms. Nicotine and oxidative products in tobacco impair vascular endothelial function, inhibit endothelial cell proliferation and migration, and delay the endothelialization process at the aneurysm neck; they also exacerbate chronic inflammation of the vascular wall, promote the expression of matrix metalloproteinases, and degrade the extracellular matrix. Epidemiological data show that the postoperative recurrence rate in smokers is approximately 1.5 to 2 times higher than that in non-smokers, and the risk of recurrence is dose-dependent. Smoking cessation is one of the most cost-effective interventions for reducing postoperative recurrence.

4.3. Influence of Antiplatelet Agents

The effect of antiplatelet agents such as aspirin on aneurysm recurrence has been a research focus in recent years. A single-center study with up to 10 years of follow-up clearly demonstrated that regular aspirin use significantly reduces the rate of aneurysm recanalization after coil embolization. The underlying mechanisms may involve aspirin's inhibition of platelet activation, reduction of microthrombus formation and disorganized organization within the aneurysm sac, and attenuation of chronic inflammation of the vascular wall. However, for patients treated with stent-assisted coiling or flow diverters, dual antiplatelet therapy is primarily used to prevent in-stent thrombosis, and its independent impact on recurrence requires further validation in larger-scale studies [7]. The current clinical consensus recommends standardized antiplatelet therapy for patients treated with stents and FDs, which not only prevents ischemic complications but may also contribute to reducing long-term recurrence.

4.4. Other Systemic Factors

Diabetes mellitus may increase the risk of recurrence by impairing vascular endothelial function and delaying wound healing, but the current evidence is inconclusive. Data on the association between components of the metabolic syndrome, such as hyperlipidemia and obesity, and aneurysm recurrence are limited. Furthermore, patients with hereditary connective tissue disorders such as autosomal dominant polycystic kidney disease and Marfan syndrome have congenitally defective vascular walls, which significantly increases both the recurrence rate and the risk of de novo aneurysm formation; lifelong close follow-up is required for these patients.

5. Advances in Hemodynamic and Biological Mechanisms

In recent years, the development of computational fluid dynamics (CFD) and vessel wall imaging techniques has provided new perspectives for explaining aneurysm recurrence from a mechanistic standpoint.

Hemodynamic factors are the core driving force of aneurysm recurrence. Persistently high wall shear stress, high blood flow velocity, and flow impingement at the aneurysm neck region after embolization are the main reasons for coil compaction, incomplete endothelial coverage, and the eventual formation of recanalization channels. CFD studies have shown that aneurysms with a fast inflow jet and high wall shear stress at the neck have a significantly higher probability of postoperative recurrence, whereas those with intrasaccular flow stasis and sufficient energy dissipation are more likely to achieve stable occlusion. Flow diverters achieve high occlusion rates and low recurrence rates by substantially reducing the blood flow volume and velocity entering the aneurysm sac and reversing the unfavorable hemodynamic pattern.

In terms of biological mechanisms, aneurysm recurrence is not merely a physical process of coil compaction; it also involves an imbalance between inflammation and repair within the vascular wall. Persistent activation of chronic inflammation in the aneurysm wall and overexpression of matrix metalloproteinases lead to degradation of the extracellular matrix, forming the pathological basis for progressive aneurysm enlargement and recanalization after embolization. High-resolution vessel wall magnetic resonance imaging (VWI) studies have found that marked aneurysm wall enhancement indicates active intramural inflammation, and such aneurysms are more prone to postoperative recurrence and progression. A study on repeatedly recurrent aneurysms showed that circumferential wall enhancement is a relevant risk factor for predicting multiple recurrences. This finding provides a theoretical rationale for the use of anti-inflammatory drugs to prevent aneurysm recurrence, and the value of agents with anti-inflammatory properties, such as statins, in aneurysm management is attracting increasing attention.

6. Conclusion

In summary, recurrence after endovascular treatment of intracranial aneurysms is the result of multiple interacting factors. Anatomical features such as aneurysm size, neck width, and irregular morphology constitute the inherent basis for recurrence; the degree of immediate embolization, packing density, and the choice of treatment technique are the

key controllable determinants of recurrence; systemic factors such as hypertension and smoking modulate the risk of recurrence by affecting vascular repair and hemodynamic status; and hemodynamic disturbance and chronic vascular wall inflammation represent the core pathological mechanisms of recurrence.

Current research has largely identified the major risk factors for recurrence, but several limitations remain: most studies are single-center retrospective analyses, with few prospective cohort studies; the interactions and relative weights of the various factors have not been fully elucidated; and large-sample, long-term follow-up data specific to the Chinese population are still insufficient. Future research directions should focus on the following aspects: first, integrating morphological, hemodynamic, and serum biomarkers to construct an accurate individualized risk prediction model for recurrence; second, further optimizing the indications and procedural standards for novel technologies such as flow diverters to reduce the recurrence rate of complex aneurysms; and third, exploring the role of pharmacological therapies, including anti-inflammatory and endothelial-protective agents, in preventing recurrence, thereby achieving a transition from mere anatomical obliteration to biological cure.

In clinical practice, the risk stratification for recurrence should be thoroughly assessed for each patient, and the optimal treatment strategy should be selected individually based on the aneurysm characteristics, striving to achieve dense embolization or a satisfactory hemodynamic remodeling effect at the initial treatment. Postoperatively, risk factors such as hypertension and smoking must be strictly controlled, pharmacotherapy should be standardized, and a long-term imaging follow-up system should be established to detect recurrence early and intervene in a timely manner, thereby continuously improving the long-term prognosis of patients with intracranial aneurysms.

Disclosure statement

The author declares no conflict of interest.

References

[1] Tan S, 2023, Application of new magnetic resonance angiography techniques in the followup of intracranial aneurysms after interventional treatment. Nanchang University.

[2] Li GF, Guo SF, Zhuang SJ, et al., 2017, Application of a pressurized infusion alarm device in endovascular interventional treatment of intracranial aneurysms. Chinese Journal of Interventional Radiology (Electronic Edition), 5(4): 254-258.

[3] Li QM, Li YJ, 2015, Analysis of 38 cases of intraprocedural rupture during endovascular interventional treatment of intracranial aneurysms. World Latest Medicine Information, 15(15): 66-67.

[4] Wen MC, Li JS, Dai LQ, et al., 2014, Intraprocedural aneurysm rupture during endovascular interventional treatment of intracranial aneurysms: a report of 157 cases. Modern Diagnosis and Treatment, 25(2): 298-300.

[5] Luan L, Feng X, Wang M, 2012, Application of total intravenous anesthesia with remifentanil combined with propofol under doublelumen laryngeal mask airway ventilation in interventional treatment of intracranial aneurysms. Chinese Metallurgical Industry Medical Journal, 29(2): 165-166.

[6] Luan L, Feng X, Wang M, 2012, Application of total intravenous anesthesia with remifentanil combined with propofol under doublelumen laryngeal mask airway ventilation in interventional treatment of intracranial aneurysms. Chinese Community Doctors (Medical Specialty), 14(2): 36.

[7] Yu JL, Xu K, Wang HL, 2008, Analysis and management of 7 cases of intraprocedural rupture during endovascular interventional treatment of intracranial aneurysms. Chinese Journal of Nervous and Mental Diseases, 34(12): 728-730.