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Safety and Effectiveness of Stent-Assisted Coil Embolization for Ruptured Intracranial Aneurysm

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Abstract

Background: It has been conclusively established that intracranial aneurysms measuring a diameter below 7 mm pose a minimal risk of rupture. Conversely, those exhibiting irregular morphology or featuring the presence of a sac necessitate a more stringent and rigorous management approach. **Objective**: The primary aim of this study is to delve into the morphological features of ruptured aneurysms situated in distinct regions of the brain. Furthermore, we endeavor to assess the degree of safety and efficacy associated with stent-assisted embolization as a treatment modality for these ruptured aneurysms. **Methods**: This retrospective study encompassed a cohort of 467 patients who presented with intracranial ruptured aneurysms and were diagnosed through a combination of computed tomography (CT) and digital subtraction angiography (DSA) at Nanfang Hospital of Southern Medical University, spanning from January 2009 to December 2019. The following clinical parameters were meticulously recorded: aneurysm height, width, neck measurements, immediate Raymond grade assessments, and any perioperative complications experienced. **Results**: Within the study population, the average dimensions of ruptured aneurysms were found to be 4.26 ± 2.10 mm (width), 4.86 ± 2.38 mm (height), and 4.04 ± 1.87 mm (neck). Categorically, the most prevalent types of aneurysms were 170 cases of anterior communicating artery aneurysms (accounting for 36.4%), followed by 161 cases of posterior communicating artery aneurysms (34.5%), 56 cases of middle cerebral artery aneurysms (12.0%), 13 cases of anterior cerebral artery aneurysms (2.8%), 45 cases of paraclinoid aneurysms (9.6%), 6 cases of superior pituitary artery aneurysms

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(1.3%), 7 cases of anterior choroidal artery aneurysms (1.5%), and 9 cases of vertebrobasilar artery aneurysms (2.0%). Notably, 18 patients (3.9%) presented with ruptured aneurysms coexisting with ascus. Regarding treatment approaches, 228 cases (48.8%) underwent stent-assisted embolization, 234 cases (50.1%) received coils embolization, and 5 cases (1.1%) were treated with the dual-catheter technique. Immediately post-treatment, 422 patients (90.4%) attained a Raymond Class I status, with a procedure-related complication rate of 0.9%. Importantly, no statistically significant differences were observed in the incidence of perioperative complications across the three distinct treatment groups (P = 0.505). **Conclusion**: The outcomes of this study affirm the safety and efficacy of stent-assisted embolization as a treatment modality for ruptured aneurysms.

Keywords

Ruptured Intracranial Aneurysm, Interventional Therapy, Stent Assisted Embolization

1. Introduction

Cerebral aneurysms are focal, saccular protrusions that arise from intracranial arteries and affect approximately 3% - 5% of the population, mostly occurring at vessel bifurcations near the Willis circle. The expansion and potential bursting of these aneurysms are strongly linked to various factors, such as inflammation, vascular development, and the patient's general health status. Typically, smaller, regularly formed aneurysms are viewed as less prone to rupture, leading healthcare professionals to recommend close and regular monitoring for patients.

When it comes to treatment, interventional procedures have become the primary method for managing intracranial aneurysms. Techniques like coil embolization [1], stent-assisted coil embolization [2], balloon-assisted coil embolization [3], dual-catheter coil embolization [4], and flow diverter use [5] have markedly improved interventional therapy outcomes. These advancements have expanded the range of treatment options for clinicians, allowing them to create customized, effective, and safe treatment plans for patients with cerebral aneurysms.

Ruptured aneurysms have a sudden and severe onset, posing a significant challenge for neuro-interventional surgeons. Presently, aneurysms larger than 5 - 7 mm that haven't ruptured are recommended for treatment, and there are numerous instances of small ruptured aneurysms as well. [6] Dense coiling comes with the danger of bleeding during surgery, whereas loose coiling might not fully stop the bleeding. Stents can significantly enhance the success rate of treating wide carotid aneurysms, but administering antiplatelet drugs during the acute phase of subarachnoid hemorrhage can worsen bleeding. Although research indicates that antiplatelet drugs can alleviate vasospasm and improve prognosis post-SAH, caution is still advised when using stents in interventional procedures for ruptured aneurysms. [7]-[9] This article delves into the morphology of ruptured aneurysms and examines treatment options by reviewing cases from a single center.

2. Methods

2.1. General Information

Between the period of January 2009 and December 2019, a total of 467 patients were selected from the Neurosurgery Department of the Southern Hospital of Southern Medical University for the purpose of conducting this study. All of the patients had undergone confirmatory CT scans, revealing subarachnoid hemorrhage, and had a single intracranial aneurysm verified via DSA. These patients underwent endovascular treatment within 72 hours of the onset of symptoms, and there were no identifiable surgical barriers identified.

Patients who presented with traumatic or infected aneurysms, ruptured aneurysms in conjunction with additional neurological complications such as arteriovenous malformations, fistulas, multiple aneurysms, Moyamoya disease, recurrent aneurysms, or incomplete clinical or imaging data were excluded from the study.

Detailed information was gathered pertaining to the patients' ages, coexisting medical conditions, aneurysm location and characteristics, Hunt-Hess grade, the specific treatment methodologies employed, and any surgical complications that arose during the course of the procedures.

2.2. Antiplatelet Medication

Prior to the insertion of the guide catheter, 85 U/Kg of heparin was administered. Subsequently, an intravenous bolus of 5 ug/Kg of Tirofiban was given before the release of the stent, followed by a maintenance dose of 0.075 ug/Kg/min. Immediately subsequent to the procedure, 300 mg of Aspirin and either 180 mg of Ticagrelor or 300 mg of Clopidogrel were administered orally. Tirofiban administration was discontinued after 4 hours of initiating oral antiplatelet medication. The dosage of antiplatelet agents was adjusted according to the results of thromboelastography (TEG) and transitioned to Aspirin monotherapy for antiplatelet therapy at 6 months post-operatively.

2.3. Surgical Procedure

We performed the interventional treatment under the guidance of general anesthesia protocols. An arterial sheath of either 6F or 8F was inserted via a femoral artery puncture, ensuring precision and accuracy. Utilizing a guidewire, we positioned the catheter meticulously prior to executing DSA cerebral angiography with 3D reconstruction techniques. The dimensions of the parent artery, aneurysm size, and neck were precisely measured in order to attain a comprehensive understanding.

The primary objective of the treatment was to achieve curative embolization, with the aim of ensuring optimal clinical outcomes. Given the diversity of cases encountered, we employed a range of stent types, including Enterprise, LVIS, Solitaire, Leo, and Neuroform, tailored to the specific requirements of each individual patient. Enterprise stents are utilized in a vast majority of cases, exceeding 95% of all instances. For the management of blister-type aneurysms or dissecting aneurysms of the vertebral artery, we employ LIVS stents to facilitate the embolization process. In instances involving smaller vessels located at the distal end of the Willis artery, we prefer the utilization of the Nuroform stent.

2.4. Perioperative Evaluation

The Raymond-Roy Occlusion Classification is utilized to assess the status of aneurysms in the immediate postoperative period. Classification I signifies complete obliteration, Classification II denotes the presence of a residual neck less than 2 mm, and Classification III represents residual aneurysm. [10] Concerning perioperative surgery-related complications, they encompass the following: intraoperative aneurysm rupture, bleeding from the parent artery, increased postoperative subarachnoid blood volume, and postoperative neurological deterioration that may be attributed to fresh cerebral infarction or cerebral hemorrhage.

2.5. Statistical Methods

All data were analyzed utilizing SPSS 22.0 software, with differences among groups being evaluated through the employment of chi-square and non-parametric tests. A statistically significant difference was determined when the P-value was less than 0.05.

3. Results

3.1. Basic Patient Information

The mean age recorded was 52.15 ± 9.85 years, ranging from 8 to 78 years, with a gender distribution of 213 males (45.6%) and 254 females (54.4%). In terms of comorbidities, 271 patients (58%) presented with concomitant hypertension, and 63 patients (13.5%) were diagnosed with diabetes mellitus.

The Hunt-Hess grading system was applied, with the distribution as follows: Grade I in 100 patients (21.4%), Grade II in 136 patients (29.1%), Grade III in 188 patients (40.3%), Grade IV in 34 patients (7.3%), and Grade V in 9 patients (1.9%). Among these patients, the location of the aneurysm was determined as follows: 170 cases (36.4%) involving the anterior communicating artery, 161 cases (34.5%) affecting the posterior communicating artery, 56 cases (12.0%) located in the middle cerebral artery, 13 cases (2.8%) involving the anterior cerebral artery, 45 cases (9.6%) being paraclinoid aneurysms, 6 cases (1.3%) related to the superior pituitary artery, 7 cases (1.5%) of anterior choroidal artery aneurysms, and 9 cases (2.0%) involving vertebrobasilar artery aneurysms.

3.2. Aneurysm Morphology and Treatment Options

The average width, height, and neck measurements of the aneurysms were 4.26 ± 2.10 mm, 4.86 ± 2.38 mm, and 4.04 ± 1.87 mm, respectively. Among the studied cases, 18 (3.9%) involved ruptured aneurysms that were accompanied by a sac.

In terms of treatment modalities, stent-assisted embolization was employed in 228 cases (48.8%), coil embolization was performed in 234 cases (50.1%), and the double-catheter technique was used in 5 cases (1.1%); the average number of coils utilized per case was 5.0 ± 1.9.

Postoperative assessment, according to the Raymond classification revealed the following distribution: I (90.4%), II (9.0%), and III (0.6%), respectively. During the perioperative period, 4 patients (0.9%) experienced complications, including one case of intraoperative aneurysm rupture (anterior communicating artery aneurysm) and three cases of aneurysm-parent artery occlusion (one case in the middle cerebral artery, two cases in the vertebrobasilar artery).

Regarding the age of patients with ruptured aneurysms, the mean age ranged from 46.1 to 54.7 years old across different sites, with no statistically significant differences observed between groups. Notably, patients with ruptured vertebral artery or basilar artery aneurysm presented with the mildest symptoms despite having the largest mean aneurysm dimensions (5.71 ± 2.68 mm, 5.81 ± 2.94 mm, and 5.11 ± 2.20 mm, respectively), whereas patients with ruptured anterior choroidal aneurysm reported the most severe clinical symptoms despite their smallest mean aneurysm dimensions (3.41 ± 1.45 mm, 3.70 ± 2.72 mm, and 3.01 ± 1.40 mm, respectively), with statistical significance observed between groups (P = 0.032).

Table 1. Morphological characteristics, treatment options and perioperative complications of ruptured aneurysms in different sites.

	AcomA	PcomA	MCA	ACA	ICAP	SHA	ACHA	V-BA	P
Age	51.5 ± 9.3	52.4 ± 9.6	53.1 ± 12.6	51.1 ± 10.0	53.8 ± 8.6	51.7 ± 11.6	54.7 ± 10.9	46.1 ± 9.1	0.444
H-HGrade	2.25 ± 0.90	2.53 ± 0.94	2.55 ± 0.95	2.31 ± 0.95	2.22 ± 1.04	2.33 ± 1.21	3.43 ± 1.62	1.89 ± 0.93	0.032
Width	4.08 ± 1.91	4.15 ± 1.54	3.74 ± 1.80	4.08 ± 0.97	5.35 ± 3.01	5.02 ± 2.31	3.41 ± 1.45	5.71 ± 2.68	0.001
Height	4.45 ± 2.39	5.11 ± 2.07	4.49 ± 1.67	5.42 ± 1.67	5.36 ± 2.57	4.67 ± 2.43	3.70 ± 2.72	5.81 ± 2.94	0.001
Width/Height	1.01 ± 3.78	0.86 ± 0.28	0.87 ± 0.31	0.78 ± 0.17	1.07 ± 0.43	1.14 ± 0.34	1.03 ± 0.27	1.12 ± 0.59	<0.001
Neck	4.05 ± 1.93	4.01 ± 1.47	3.70 ± 1.82	4.08 ± 0.97	4.12 ± 1.52	3.37 ± 0.92	3.01 ± 1.40	5.11 ± 2.20	0.106
Coil No	4.86 ± 1.83	4.93 ± 1.49	4.71 ± 1.71	5.31 ± 1.18	5.82 ± 2.67	6.33 ± 2.42	5.00 ± 4.32	4.89 ± 3.30	0.012
Stent Use	88/170	69/161	26/56	4/13	27/45	5/6	4/7	5/9	0.006
Raymond Grade	1.06 ± 0.24	1.08 ± 0.27	1.13 ± 0.38	1.00 ± 0.00	1.20 ± 0.46	1.17 ± 0.41	1.00 ± 0.00	1.89 ± 0.61	<0.001
Complications	1/170	0/161	1/56	0/13	0/45	0/6	0/7	2/9	0.223

Anterior Communicating Artery (AComA), Middle Cerebral Artery (MCA), Vertebrobasilar Artery (V-BA), Anterior Cerebral Artery (ACA), Anterior Choroidal Artery (ACHA), Posterior Communicating Artery (PcomA), Superior Hypophyseal Artery (SHA), and Internal Carotid Artery (ICA).

Patients with superior hypophysial artery aneurysms utilized the highest average number of coils (6.33 ± 2.42) and had the highest incidence of stent placement (83.3%). Despite the larger size of vertebral and basilar artery aneurysms, the average number of coils used was 4.89 ± 3.30. Conversely, the anterior cerebral artery aneurysm had the lowest rate of stent utilization (30.8%). All anterior choroidal artery aneurysms and anterior cerebral artery aneurysms underwent immediate and successful healing. In stark contrast, posterior circulation aneurysms exhibited the poorest likelihood of immediate postoperative recovery, with the highest incidence of perioperative complications (22.2%) (Table 1).

3.3. Differences in Morphology, Characteristics, and Complications of Ruptured Aneurysms amongst Various Treatment Modalities

Among patients undergoing coil embolization, the aneurysm dimensions, including width, height, and neck size, were notably the smallest. The aneurysm width and neck size were comparable between patients treated with stent-assisted embolization and patients treated with double-catheter coil embolization. However, a statistically significant difference (P = 0.045) was observed with respect to the H-H grade, which was higher in the latter group. Although patients treated with stent-assisted embolization exhibited the highest immediate cure rate, they also had the highest perioperative complication rate (P = 0.505) (Table 2).

Table 2. Characteristics of aneurysm and incidence of perioperative complications in various interventional surgical techniques.

	SAE	CE	DCE	P
H-H Grade	2.28 ± 0.98	2.50 ± 0.94	2.60 ± 0.55	0.045
Width	4.82 ± 2.34	3.62 ± 1.27	4.84 ± 0.84	<0.001
Height	5.42 ± 2.53	4.24 ± 1.77	4.12 ± 0.37	<0.001
Width/Height	0.97 ± 0.40	0.92 ± 0.30	1.18 ± 0.24	0.090
Neck	4.53 ± 1.97	3.47 ± 1.20	4.68 ± 1.03	<0.001
Raymond	1.10 ± 0.31	1.11 ± 0.34	1.20 ± 0.45	0.895
Complications	3/228	1/234	0/5	0.505

Stent-assisted embolization (SAE), coil embolization (CE), and double-catheter coil embolization (DCE) are three methods utilized in medical procedures.

4. Discussion

The consequences of intracranial aneurysm rupture are of utmost gravity. Consequently, numerous studies have been conducted over the past decades with the aim of predicting aneurysm rupture. It was previously held that aneurysms with a diameter of less than 7 mm posed a low risk of rupture, and those exhibiting irregular morphology or containing a sac warranted more aggressive management. [11] [12] Nevertheless, as research has progressed, it has been proposed that the indications for treating small, unruptured aneurysms should be appropriately expanded. A morphological analysis conducted at our center, involving 467 ruptured intracranial aneurysms, revealed that the average maximum diameter of aneurysms at each site ranged from 3.70 to 5.81 mm, which falls within the category of small aneurysms and is significantly smaller than the "recommended treatment range" of 7 mm. Furthermore, only 3.9% of all aneurysms were found to be associated with a sac.

It is noteworthy that a limited number of models for predicting aneurysm rupture incorporate indicators related to the aneurysm site. [13] In a comprehensive epidemiological examination of intracranial aneurysms, it was determined that the presence of aneurysms located within the posterior communication and anterior circulation areas emerges as a critical factor in influencing their potential for rupture. The impact of the anatomical site exceeds that of an individual's smoking history as a contributing element. [14] Within the scope of our analysis involving aneurysms that have undergone rupture, we observe that more than fifty percent of the occurrences were centered within the anterior and posterior communicating arteries. Therefore, we postulate that the surveillance or treatment protocols for unruptured aneurysms found within these arteries may warrant heightened scrutiny and perhaps more assertive therapeutic intervention.

The mortality and disability rates subsequent to posterior circulation aneurysm rupture are notably elevated. Notably, in our dataset, individuals with this specific type of aneurysm exhibited the lowest preoperative Hunt-Hess scores, potentially owing to the fact that patients of a higher severity had either succumbed to the condition prior to admission or experienced deterioration during transportation to the hospital.

The acute stage of hemorrhage represents a relative contraindication for antiplatelet therapy administration. In addressing acute aneurysmal subarachnoid hemorrhage, the majority of medical guidelines advocate against the intraoperative deployment of stents, as this may elevate the risk of subsequent cerebral hemorrhage when antiplatelet therapy is initiated. Nevertheless, the overall occlusion rate for wide-necked aneurysms, when treated with coil embolization or balloon-assisted coil embolization, falls below 30%, ultimately rendering these approaches insufficient in achieving the objective of emergency interventional surgical hemostasis. [3] The double catheter embolization technique is inapplicable as a sole solution for treating all types of ruptured aneurysms, as reported by previous literature. [4] Additionally, comprehensive studies indicate that there is no substantial elevation of the risk for intracranial hemorrhage among individuals diagnosed with ruptured aneurysms and undergoing stent-assisted embolization subsequent to dual antiplatelet therapy administration. [2]

In the framework of our ongoing clinical investigations, approximately fifty percent (50%) of cases featuring patients suffering from ruptured aneurysms characterized by broad neck structures and exhibiting low Hunt-Hess scores underwent a form of treatment consisting of stent-assisted coil embolization. On the contrary, there are a number of patients afflicted by ruptured aneurysms possessing large necks alongside higher Hunt-Hess scores that necessitated the implementation of the dual-catheter coil embolization procedure for effectual therapeutic intervention.

Despite a marginal elevation in the risk of perioperative bleeding and infarction associated with stent utilization, no statistically significant difference was observed in comparison to the coil embolization cohort. Conversely, the implementation of stents enhances the immediate cure rate of wide-necked aneurysms, achieving a level commensurate with that of narrow-necked saccular aneurysms, and assumes a pivotal role in averting recurrent aneurysm ruptures.

Adhering to the principle of immediate curative embolization for ruptured aneurysms, the employment of stent-assisted embolization techniques for low preoperative Hunt-Hess score wide-necked ruptured aneurysms did not appreciably elevate the risk of perioperative bleeding or infarction.

Limitation of the Study

The current article acknowledges a significant limitation in its scope, which is the absence of long-term follow-up data pertaining to patients diagnosed with ruptured aneurysms. Despite the inclusion of case records involving diverse stent types, a notable preponderance of the aforementioned cases utilized Enterprise stents. Consequently, the insufficient volume of alternative stent types did not furnish a robust dataset capable of supporting statistically sound scientific analyses.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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