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Endovascular treatments, predictors and outcomes of cerebral aneurysm. A systematic review

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Keywords
aneurysm, endovascular, vasospasm, surgical techniques, therapy, coils, clips

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ABSTRACT

Background: Recent studies in surgical techniques have significantly transformed therapeutic approaches, leading to substantial decreases in morbidity and mortality rates. Differential diagnosis plays a pivotal role in determining the most suitable surgical strategies for addressing aneurysms. Historically, clipping has been considered a longstanding tradition in the vascular field between 1937 and 1975, pioneered by Microneurosurgery pioneers Yasargil and Fox.

Methods: This study followed the PRISMA (Preferred Reporting Items for Systematic Reviews), and the statistical analysis was performed using IBM SPSS Statistics for Windows, Version 26.0 (released 2020; IBM Corp., Armonk, New York, United States). And EXCEL: A comprehensive review of neurosurgical care for cerebral aneurysms in controlling subarachnoid haemorrhage through endovascular clipping and coiling was conducted by the followers' methods used on aneurysm patients. Databases like Science Direct and PubMed were utilized, and articles were searched from the earliest available dates up to January 2024. Tables 1-2-3 are shown. The search focused primarily on publications in English, adhering to PRISMA guidelines. The search process for scientific papers, including meta-analysis, centred on PubMed and Science Direct.

Results: A total of 45,223.00 patients with aneurysms who underwent endovascular procedures or surgical methods involving clipping or colling are displayed in Table 1. Of these, 2769 patients had ruptured aneurysms associated with subarachnoid haemorrhage, while 985.00 patients did not rupture. In Table 2, 6090.14 patients with

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aneurysms are evaluated, and in Table 3, 36,251.00 patients with coils 31,502.00 and clips 28,803.00 were assessed.

Conclusion: From the synthesis of various reviewed studies, effective management strategies involve early detection of bleeding using diagnostic tests like MRI or CT angiography, considering neurological functioning levels assessed through scales such as the Fisher scale or the Hunt and Hess scale for subarachnoid haemorrhage or potential stroke.

Introduction

Recent studies in surgical techniques have significantly transformed therapeutic approaches, leading to substantial decreases in morbidity and mortality rates [1]. Differential diagnosis plays a pivotal role in determining the most suitable surgical strategies for addressing aneurysms. Historically, clipping has been considered a longstanding tradition in the vascular field between 1937 and 1975, pioneered by Microneurosurgery Pioneers Yasargil and Fox [1]. Yasargil and Fox's introduction of the microscope paved the way for today's recognized safe and effective exposure of the polygon of Willis. The primary objective of clipping was to achieve direct access to the aneurysm through an open craniotomy and isolate it from the surrounding parenchyma. [2]. The aneurysm development process begins within the first week of induction and progresses through mastoid cell activation in the fourth week, ultimately leading to rupture. Surgical intervention aims to minimize infiltration and inflammation, although its impact on aneurysm formation is limited [3]. Cerebral strokes (MI) exhibit a significant frequency of 282.9 per 100,000 individuals, with 106-110 thousand cases occurring annually, predominantly affecting working-age adults (35.5%) [4]. Aneurysms and vascular abnormalities contribute substantially to brain hemorrhages, encompassing approximately 30 different aneurysm types and nearly a dozen types of vascular abnormalities. Their etiology, pathophysiology, clinical symptoms, diagnosis, therapy, and prognosis vary significantly, necessitating further investigation. [5]. Aneurysm accounts for 70–85% of non-traumatic subarachnoid hemorrhages (SAH), playing a substantial role in hemorrhagic stroke etiology. Treatment objectives focus on complete occlusion of the AMs while preserving blood flow in maternal, branching, and perforating veins. Table 1 illustrates the short frequency of aneurysm rupture or unruptured. [6].

The objectives of this study are to evaluate and demonstrate the significance and advantages of managing aneurysms in controlling subarachnoid hemorrhages, as well as compare the effectiveness of clipping and coiling through endovascular therapy.

Materials and methods

Literature search strategy

This study followed the PRISMA (Preferred Reporting Items for Systematic Reviews). The statistical analysis was performed using IBM SPSS Statistics for Windows, Version 26.0 (released 2020; IBM Corp., Armonk, New York, United States). And EXCEL: A comprehensive review of neurosurgical care for cerebral aneurysms in controlling subarachnoid hemorrhage through endovascular clipping and coiling was conducted by the followers' methods used on aneurysm patients. Databases like Science Direct and PubMed were utilized, searching from the earliest available articles up to January 2024. Tables 1-2-3 are shown. The search focused primarily on publications in English, adhering to PRISMA guidelines. The search process for scientific papers, including meta-analysis, centered on PubMed and Science Direct. (refer to Fig. 1).

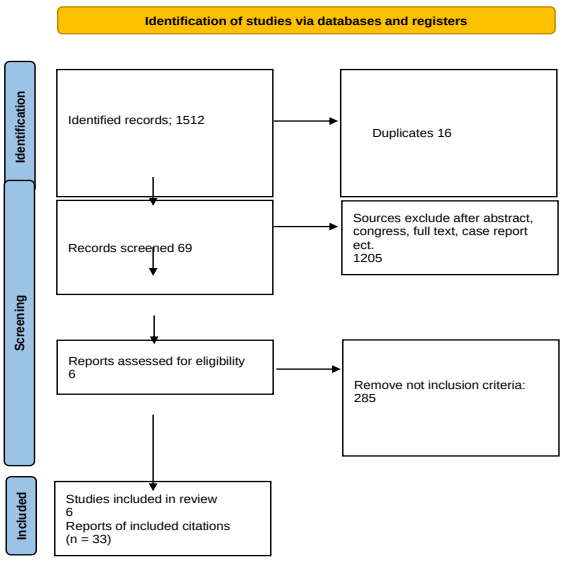

Figure 1. Flowchart systematic review.

Search strategy development

Comprehensive search strategy keywords

The comprehensive search strategy incorporated the following MeSH terms:

(("Intracranial Aneurysm/classification"[Mesh] OR "Intracranial Aneurysm/complications"[Mesh] OR "Intracranial Aneurysm/diagnosis"[Mesh] OR "Intracranial Aneurysm/diagnostic imaging"[Mesh] OR "Intracranial Aneurysm/epidemiology"[Mesh] OR "Intracranial Aneurysm/etiology"[Mesh] OR "Intracranial Aneurysm/genetics"[Mesh] OR "Intracranial Aneurysm/immunology"[Mesh] OR "Intracranial Aneurysm/mortality"[Mesh] OR "Intracranial Aneurysm/pathology"[Mesh] OR "Intracranial Aneurysm/physiopathology"[Mesh] OR "Intracranial Aneurysm/prevention and control"[Mesh] OR "Intracranial Aneurysm/rehabilitation"[Mesh] OR "Intracranial Aneurysm/surgery"[Mesh] OR "Intracranial Aneurysm/therapy"[Mesh])) AND ("Intracranial Aneurysm/blood"[Mesh] OR "Intracranial Aneurysm/embryology"[Mesh] OR "Intracranial Aneurysm/enzymology"[Mesh] OR)

Study inclusion criteria

The studies considered needed to meet specific inclusion criteria, including the development of both ruptured and unruptured cerebral aneurysms, involvement of the adult population by clipping and coiling, utilization of pterional craniotomy, middle meningeal artery involvement, subarachnoid and epidural hemorrhage, pre- and post-clipping risk factors, calcification and epileptic mechanisms, and risks associated with vasospasm.

Study exclusion criteria

Studies involving pediatric populations found cases of patients not receiving timely treatment on time, resulting in death due to ruptured aneurysms, sudden death cases with unknown bleeding, and recurring bleeding and instant mortality.

Data extraction

Data extraction from studies that met the inclusion criteria involved the use of standardized search systems. This included demographic data, intervention and control details, and methodologies relevant to the study's scope, focusing on cerebrovascular diseases such as intracranial aneurysms.

Potential bias

Every report was evaluated for bias and applicability using Kaplan's survival approach and the paths for endovascular or surgical therapy of aneurysms. In order to ascertain whether the data sets under examination included aneurysms that are typical of the adult population, published research data were obtained. The evaluation was centered on the term "aneurysm treatments and outcomes" and was founded on widely acknowledged practices for therapeutic therapy, diagnosis, and prognosis.

Statistical analysis

Summary statistics such as mean differences and odds ratios (OR) were employed for relevant occurrences. The weighted mean difference and 95% confidence interval (CI) defined the outcomes of interest. A random effects model estimated outcome measures using individual data from included studies. The statistical analysis was performed using Review Manager Rayyan software version 5.3, Excel, with statistical significance set at a P value of 0.05.

Results

A total of 45,223.00 patients with aneurysms who underwent endovascular procedures or surgical methods involving clipping or colling are displayed in Table 1. Of these, 2769 patients had ruptured aneurysms associated with subarachnoid hemorrhage, while 985.00 patients did not rupture.

Table 1. The most common major lesions associated with subarachnoid hemorrhages were observed around the meningeal artery in several investigations that examined aneurysms with and without rupture.

Year	Patients	Rupture Aneurysm-SAH	Unrupture
2014 Backes et al. [63].	124	88	36
2018 2021 van der Kamp et al. [64].	312	25	226
2022 Yamanouchi et al. [65].	113	10	18
2020 Rinaldo et al. [66].	568	157	411
2015 Hishikawa et al. [67].	1577	8	182
2020 Tanioka et al. [68].	188	112	112

In Table 2, 6090.14 patients with aneurysms are evaluated, and in Table 3, 36,251.00 patients with coils 31,502.00 and clips 28,803.00 were assessed. From 2004 to 2014, a total of 79,600 patients with intracranial aneurysms underwent endovascular coiling, whereas 42,256 patients received surgical interventions in America. Surgical and endovascular methods were used on aneurysm patients,[2]. The evolution of treatment options for specific disorders was considered, and in 2005, vascular patency intraoperatively was initially assessed.

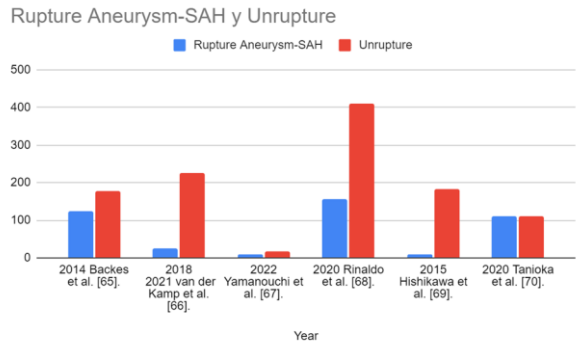

Figure 2. Diagram showing the study group's intervention for both ruptured and unruptured aneurysms.

Early studies by Raabe et al. involving 114 patients demonstrated the efficiency of Indocyanine Green Videoangiography (ICGVA), displaying feedback [9]. However, this approach poses a risk of ischemia in vascular beds supplied by the proximal artery, warranting caution with occlusion time typically limited to 10-20 minutes [7]. In severe cases, multiple bouts of occlusion with 15-minute reperfusions have been deemed safe and effective [9]. A study on intraoperative hypothermia for aneurysm surgery concluded that neuroprotective hypothermia during surgery did not improve neurological outcomes after craniotomy in patients with SAH of WFNS grade 1-3 [2]. Advancements in microinstrument designs and clamp techniques have refined original microsurgical techniques, ranging from modified skull base approaches to minimally invasive and endoscopic surgeries. These advancements are associated with increased neuroprotection and innovative approaches for managing complex lesions intraoperatively [7].

Various endovascular approaches for proximal control, including intraluminal balloons, have been developed, resulting in more precise techniques and better outcomes [5–13]. The International Trial of Ruptured Intracranial Subarachnoid Aneurysms (ISAT) in 2002 demonstrated better survival outcomes for aneurysms treated with endovascular coils than those treated with surgical clipping, leading to a significant increase in endovascular-treated aneurysms. [15].

While clipping is an invasive procedure, coiling, being minimally invasive, has shown reduced vasospasm and rebleeding after subarachnoid hemorrhage control. The role of intra-to-intra shunting in aneurysm surgery has gained attention, with discussions on its benefits [15]. Shunting approaches involving revascularization and anastomosis of distal efferent branches have been considered more technically challenging but potentially associated with higher rates of aneurysm obliteration and shunt patency [8]. Shown in figure 4.

Table 2. Patients' endovascular management of endovascular clipping vs coiling.

Authors/ Year	Study type	No. Patients	SAH Patients intervention	Procedure	Predictor of rupture	95% CI	P-value
Molyneux A. et al. 2013. [14]	RCS	1644	81%	Endovascular coiling group 674 (83%) Neurosurgical clipping group 657 (79%).	Endovascular group, 504/657 (77%)	1·35, 95% CI 1·06-1·73	< 0.002
Molyneux A. et al. 2009 [15]	RCT	2143	11%	Endovascular coiling 83% Neurosurgical clipping 82%	coiling vs clipping group (relative risk 0.61-0.98;	0.77, 95% CI 0.61-0.98	< 0.0001
Dorhout Mees S. et al. 2012. [16].	RCT	2,143	99.6%	DCI 2 months 98.8% Clipped /8.7%	Clipping vs coiling: OR 1.01–1.5	(95% CI 1.01-1.51)	< 0.005

Darsaut T. at al. 2017 [17].	RCT	260	22.2%	The 1-year surgical surgical clipping 104 patients 5/48 (10.4%/4.5%/22.2%).	surgical clipping, 10/56	OR: 0.54 (0.13-1.90	< 0.0001
Laiwalla A. et al. 2017. [18]	CCT	21	8.6% vs. 47.5%	clipping vs coiling,	19.7%	OR: 5.17; 95% CI: 1.21–25.02	< 0.05
Darsaut T et al. 2022. [19].	RCT	1010	82%	18/60	18%	89%, 95% CI 82%–93%	< 0.003
Raymond J. et al. 2023 [20].	RCT	1010	116	pre Embolization 84%	70%	15 (14%, 95% CI 8%-22%	< 0.05

Table 3. According to various study variations, intracranial aneurysms are found in the vicinity of the following anatomical structures: the posterior communicating artery (25–35%), the anterior communicating artery (30–35%), the middle cerebral artery bifurcation (20%), the basilar artery (5%), the posterior wall or the terminal of the internal carotid artery (ICA), the superior cerebellar artery (SCA), and the posteroinferior cerebellar artery (PICA). [66].

Author	Kind of study	year	No. Patients	Coil	Clip	Follow up	Mortality	P-value
Zanaty et al. [23].	RCT	2016	1	182	70	180 days	13.2%	0.001
Berro et al. [24].	RCT	2019	187	88	90	N/A	N/A	0.04
Choi et al. [25].	RCT	2016	178	8	30	4–12 months	3	0.001
Darsaut et al. [26].	RCT	2019	103	48	55	1 year	N/A	N/A
Ayling et al. [27].	RCT	2015	212	212	181	3 months	N/A	0.0024
Kelly et al. [28].	Retrospective	2010	2342	778	2342	N/A	N/A	0.04
Bekelis et al. [29].	Retrospective	2016	3210	2004	1206	1-year	Clipping 36.3% Coiling 41.0%	0.03
McDonald et al. [30].	Retrospective	2014	5229	1227	1227	1-year	Clipping 23.5%- 30.9% Coiling 22%	0001
Zhao et al. [31].	Prospective	2016	262	133	129	12 months	N/A	.030
Yu et al. [32].	Retrospective	2007	169	80	89	6 and 18 months	coiling group (12/80 clipping group (30/89, 34%	0.004
Shen et al. [33].	Retrospective	2019	94	29	65	3-month and 6-month	coiling group (38% vs. 15%,	0.015
Heit et al. [34].	Retrospective	2017	100	50	50	3 months.	Clipping 3 (6.0) Coiling 7 (14.0)	03
Koh et al. [35].	Retrospective	2013	133	23	33	3-month and 6-month	16 (18.0%) ruptured intracranial aneurysms.	0.01
Scheller et al. [36].	RCT	2018	99	45	54	N/A	N/A	0.001
Li et al. [37].	Retrospective	2017	162	77	85	2 Months to one year	25%–30%	N/A
Varelas et al. [38].	Retrospective	2006	188	48	135	N/A	N/A	0.5
Deutsch et al. [41].	Retrospective	2018	6555	15350	6555	1-year	2.96 vs. 2.44	0.0001
Lusseveld et al. [40].	Retrospective	2002	44	44	44	N/A	N/A	0.28
Ryttlefors et al. [41].	Retrospective	2008	278	138	140	1-year	N/A	0.001

Zhang et al. [42].	Retrospective	2012	198	76	122	N/A	N/A	N/A
Wadd et al. [43].	Retrospective	2015	140	70	70	1-year	clipping (n=3, 4.3% coiling (n=1, 1.4%	0.310
Liao et al. [44].	Retrospective	2013	100	56	44	12 Month	32.0% and 27.0%	0.202
Hoh et al. [45].	Retrospective	2010	9635	3564	5783	N/A	N/A	0.0001
Klompenhouwer et al. [46].	Retrospective	2011	403	230	173	33.9 months	N/A	084
Zhao et al. [47].	Retrospective	2019	111	46	65	N/A	N/A	0.028
Taweesomboonyat et al. [48].	Retrospective	2019	189	84	105	6 Months	28% and 31%	0.734
Brunken et al. [49].	Retrospective	2009	598	145	370	1 year	clip: 51.1/13.8 % coil: 45.5 / 10.3 % non-rupt. A: 88.2/0 % coil: 88.5/1.3 %	< 0.01
Kim et al. [50].	Retrospective	2008	73	37	35	4-72 months	N/A	.05
Hoh et al. [51].	Retrospective	2011	10 899	4306	6593	N/A	N/A	.001
Zaidat et al. [52].	Retrospective	2009	216	98	118	N/A	N/A	.03
Li et al. [53].	Retrospective	2012	186 /192	94	92	12 months	13.33%	0.05
Rabinstein et al. [54].	Retrospective	2003	415	76	339	6 months	N/A	0.001
Liu et al. [55].	Retrospective	2013	642	281	361	642	N/A	0.01
Niskanen et al. [56].	Retrospective	2004	171	68	103	12-month	N/A	N/A
Koivisto et al. [57].	RCT	2000	109	52	57	12 months	Hunt and Hess grades I–II (1716 days; 95% CI 1600 to 1832 days) ONE patients died.	0.025
Gross et al. [58].	Retrospective	2014	258	52	203	N/A	N/A	0.01
Molyneux et al 59].	RCT	2005	2143	1073	1070	1 year	243 of 793 (30.6%)	0.0019
Suzuki et al. [60].	Prospective	2013	579	297	282	N/A	N/A	N/A
McDougall et al. [61].	Retrospective	2012	725	233	238	One year	1.24%	0.02

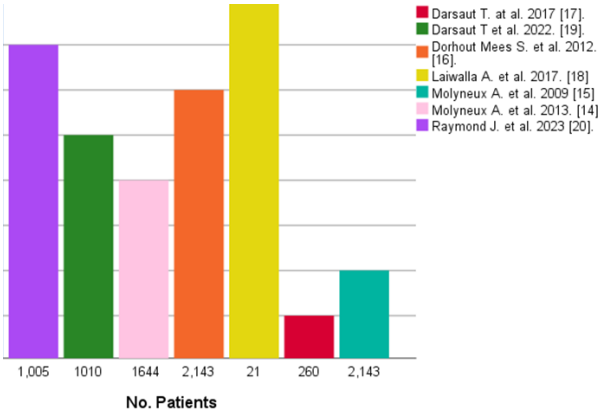

Figure 3. Graphic representation of Patients with Aneurysm and SAH Treated by Clipping and coiling.

Discussion

45,223.00 patients with aneurysms who underwent endovascular procedures or surgical methods involving clipping or colling are displayed in Table 1. Of these, 2769 patients had ruptured aneurysms associated with subarachnoid hemorrhage, and 1,127.00 patients did not rupture.

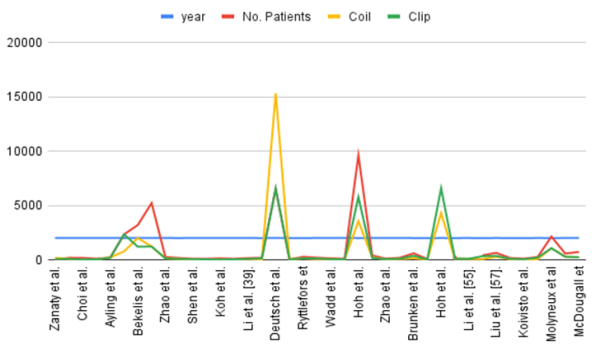

Figure 4. Endovascular and surgical techniques applied to aneurysm.

In Table 2, 6090.14 patients with aneurysms are evaluated, and in Table 3, 36,251.00 patients with coils 31,502.00 and clips 28,803.00 were assessed. Advancements in neuromonitoring play a pivotal role in enhancing surgical safety within the field of neurosurgery. Indocyanine Green Infrared Videoangiography (ICGVA) has gained attention for its recent development as a quality control adjunct. However, concerns have been raised regarding its exclusive use as the sole technique for intraoperative assessment during aneurysm clipping, as highlighted in studies by Cekirge H. et al. [5].

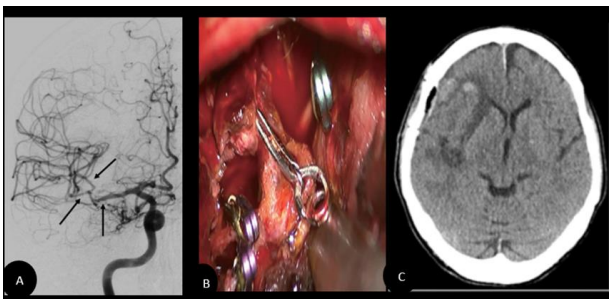

Figure 5. a) Intraoperative clip of the aneurysm with recurrence, **b)** postoperative with images of the M1-M2 and MCA segments, with active vasospasm, **c)** Post operatory computed tomography example after treated the patient.

In cerebrovascular neurosurgery, the use of extracranial-intracranial (EC-IC) or intracranial-intracranial (IC-IC) shunt methods has distinct clinical indications and technical approaches. For instance, Crowell-/Yasargil (EC-IC) first-shunting involves anastomosing the extracranial artery to the intracranial artery's distal branch carrying the aneurysm, aiding in the safe closure of the aneurysm's originating artery and subsequent obliteration in challenging clipping cases. The (EC-IC) bypass can be categorized into low-flow and high-flow bypass techniques [4, 11]. The low-flow shunt, connecting the superficial temporal artery (TSA) to the intracranial artery, is favored due to its smaller and gradual increase in inflow rate, reducing the risk of hyperperfusion injury compared to high-flow shunting [4].

Studies by Darflinge J. et al. [6] emphasize the safety of using EC-IC shunting for massive or complex aneurysms, particularly giant aneurysms, which often necessitate surgical removal to alleviate symptoms caused by their bulk effect. Recent research has linked increased usage of bypass procedures to improved patient outcomes, with lower surgical mortality rates and high graft patency in bypasses, even among patients with giant aneurysms [1, 4]. The surgical goal primarily aims for total lesion excision, although partial resections are sometimes employed for functional, cosmetic, or safety reasons [3].

Research comprising 138 individuals (19.6%) found a correlation between severe spasms and a bad prognosis based on cerebral retardation or late ischemia. As a result, in cases of vasospasm, C-reactive protein levels were higher, and in grade IV hemorrhage, the D dimers coincided with those of Fisher, a study that focused on the first 24 hours following the hemorrhage. over a span of six years. [69]. The risk of perforation was significantly higher in ruptured aneurysms compared to ruptured aneurysms, from 4.1% to 0.5% with a $p = 0.5\%$, $P < 0.001$, 38% for ruptured aneurysms, and 29% for unruptured ones, according to a study based on 17 reports on aneurysm perforations that complicated therapy with detachable aneurysms. demonstrating a similarity with 39% of spinal cord perforations and 33% of microcatheter perforations, as well as a morbidity and mortality. [70]..

Limitations

In certain measures, the use of intraoperative hypothermia for surgical intervention of aneurysms under neuroprotective hypothermia had no effect or improved postoperative neurological outcomes after the use of craniotomy in patients with subarachnoid hemorrhage. While in a report of 17 studies about aneurysm perforations during surgery as complications in detachable aneurysms with a 39% similarity in spinal cord perforations and microcatheter perforations increasing the mortality rate.

Conclusions

From the synthesis of various reviewed studies, effective management strategies involve early detection of bleeding using diagnostic tests like MRI or CT angiography, considering neurological functioning levels assessed through scales such as the Fisher scale or the Hunt and Hess scale for subarachnoid hemorrhage or potential stroke. Prompt actions can prevent adverse neurological outcomes such as aneurysm rupture, subarachnoid

hemorrhage, hemiparesis, or cerebral decortication following brain herniation. The evolution of these approaches over time indicates a synergistic relationship between microsurgery and endovascular therapies, which are now integrated with state-of-the-art equipment. Based on the insights from the reviewed studies, the following recommendations are suggested:

- Mini-pterional or open Craniotomy Pterional Clips are recommended for MCA reconstruction.
- Sealing off aneurysms using a flexible wire and catheter is advised.
- In cases of massive right MCA calcified aneurysms, consider employing an interposition shunt from the saphenous vein.
- Post-clipping, a decrease in vasospasm levels is beneficial in preventing bleeding and potential new subarachnoid hemorrhages, thereby improving the overall survival rate.

Future suggestions align with the evolving new materials, techniques, and advancements in the field, emphasizing the importance of tailored and swift intervention strategies in mitigating the risks associated with aneurysms and subarachnoid hemorrhages. Continued research and modern, nuanced strategies aim to further enhance patient outcomes and minimize associated neurological complications.

Abbreviations

ISAT: International subarachnoid aneurysm trial
ICGVA: Videoangiography
AVMs: Arteriovenous malformation
MCA: Middle cerebral artery
SAH: Subarachnoid hemorrhage
WFNS: World Federation of Neurological Surgeons
EC-IC: Extracranial-intracranial Superficial temporal artery
MRI: Magnetic resonance imaging
CT: Computed tomography

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