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Endovascular Treatment of Ruptured Intracranial Blister Aneurysms: A Systematic Review and Meta-analysis

 A. Scerrati,  J. Visani,  M.E. Flacco,  L. Ricciardi,  S. Trungu,  A. Raco,  F. Dones,  P. De Bonis, and  C.L. Sturiale



ABSTRACT

BACKGROUND: Endovascular treatment of blister aneurysms is a promising approach, even though they are vascular lesions challenging to treat due to their angioarchitectural characteristics.

PURPOSE: Our aim was to investigate clinical and radiologic outcomes after endovascular treatment of ruptured blister aneurysms.

DATA SOURCES: PubMed, Ovid MEDLINE, Ovid EMBASE, Scopus, and the Web of Science were screened.

STUDY SELECTION: We performed a comprehensive review of the literature from 2010 to 2019 reporting series of patients with blister aneurysms treated with an endovascular approach.

DATA ANALYSIS: Event rates were pooled across studies using a random effects meta-analysis.

DATA SYNTHESIS: A total of 32 studies reporting on 684 patients (707 aneurysms) were included. Stent placement, stent-assisted coiling, and flow diversion were the most commonly described treatments (282, 256, and 155 patients, respectively). The long-term complete occlusion rate was 76.9% (95% CI, 69.2%–83.9%). The perioperative complication rate was 8.9%, and clinical outcome at final follow-up was mRS <2 in 76.6% (95% CI, 68.2%–84.2%) of patients. The mortality rate was 4.7% (95% CI, 2.30%–7.80%). Among the different techniques, stent-assisted coiling is the one that had the higher rate of immediate occlusion (63.4%); however, the occlusion rate at the final follow-up was comparable among the different techniques.

LIMITATIONS: Different techniques were described and data were reported in a nonhomogeneous way, possibly representing a bias in the present study.

CONCLUSIONS: This study suggests that endovascular treatment of blister aneurysms is associated with good long-term occlusion rates and reasonable complication and mortality rates. There is no consensus on the best endovascular techniques in blister aneurysm management.

ABBREVIATION: HH = Hunt and Hess

Blister aneurysms are uncommon vascular anomalies, responsible for 0.5%–2% of all SAH caused by ruptured intracranial aneurysms.^{1,2} Their etiology has not been completely clarified

yet, though wall stress or shear stress of vessels has been proposed as having a role in their pathogenesis.^{3,4}

Due to their angioarchitectural characteristics, such as a fragile wall and poorly defined neck, blister aneurysm treatment is challenging with either surgical or endovascular approaches. Surgery has been associated with controversial results in terms of surgical and clinical outcomes, demonstrating a high rate of aneurysmal recurrence, subsequent hemorrhages, and complications.^{5–7} On the other hand, endovascular treatment, which has been progressively validated as effective for saccular aneurysm management, could represent a valid therapeutic alternative for blister aneurysms. Endovascular treatment options include simple coiling, stent or balloon-assisted coiling, flow-diversion stent placement, liquid embolization, and parent vessel sacrifice. However, there are scarce data on blister aneurysm management using endovascular techniques.

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This study aimed to systematically review the pertinent literature investigating clinical-radiologic outcomes and complications of the different endovascular treatments for blister aneurysms.

MATERIALS AND METHODS

Study Design

This is a systematic review of the literature, designed and conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement. The review question was formulated according to the PICO criteria, as follows: (P, patients) In the management of blister aneurysms, (I, intervention) what is the endovascular treatment, (C, comparison) that has reported the best results, (O, outcomes) in terms of clinical-radiologic outcomes?

Study Selection

PubMed, Ovid MEDLINE, Ovid EMBASE, Scopus, and the Web of Science were selected as online medical databases to conduct the present systematic review. The search terms were the following: “intracranial,” “brain,” “cerebral,” “blister,” “blood-blister,” “blisterlike,” “aneurysm,” “coiling,” “coils,” “stent,” “stent placement,” “endovascular,” “flow diverters” (Medical Subject Headings), combined using the Boolean operators.

Studies reporting data on patients treated with endovascular techniques for intracranial blister aneurysms were searched. Inclusion criteria were articles written in English and the availability of clinical and radiologic data for single patients. We excluded clinical series reporting data on <5 patients, guidelines, reviews, commentaries, and letters to the editor.

The first-round search was conducted by 2 reviewers (J.V. and A.S.) who independently screened titles and abstracts for eligibility. The selected full texts and their reference lists (forward search) were screened and evaluated for inclusion in the second round.

In the third round, articles were screened for demographics, aneurysm location and size, aneurysm rupture status, treatment modalities, occlusion rates, procedural failure, procedure-related morbidity and mortality, procedure-related complications, and clinical outcome. The article was then excluded in case of data unavailability, incomplete data, improper data reporting, or unavailability of single-patient data (exclusion with a reason). In the fourth round, data were retrieved and added to a database for pooling and statistical analysis (inclusion). Any discordance was solved by consensus with the senior author (C.L.S.).

Outcomes Measurement

For every patient we collected, we recorded blister location, morphology, rupture status, endovascular treatment technique, postoperative and last follow-up angiographic outcome (occlusion rate, rebleeding), perioperative complications (intraoperative rupture, parent artery occlusion, transient ischemic attack, vasospasm, stroke), perioperative morbidity and mortality, and last follow-up functional status. We defined treatment failure as the inability to secure the aneurysm and/or the need for a second therapeutic attempt due to rebleeding or regrowth of the aneurysm.

Clinical outcome was scored according to the mRS.

Statistical Analysis

We performed meta-analyses of proportions to estimate the pooled rates of each outcome. Proportion meta-analyses were not used when the frequency of an outcome was reported in <1% of the sample (raw proportions and 95% confidence intervals were reported in such cases), and a random effects model was adopted to account for the interstudy heterogeneity.

RESULTS

Study Selection and Characteristics

According to our search strategy, 178 articles in English were retrieved through the electronic literature search.

After 178 read the abstracts, 103 articles were primarily excluded, while 75 were assessed for eligibility and analyzed in detail because they met our inclusion criteria.

After full-text reading and a forward search from the bibliography of the selected articles, 43 articles were excluded for the following reasons: Twenty were series of <5 patients, 8 reported incomplete follow-up, 4 did not include blister aneurysms, and in 11 studies, endovascular treatment was not performed. Thirty-two articles⁸⁻³⁹ (31 retrospective and 1 prospective) published between 2010 and 2019 reporting patients who underwent endovascular treatment for blister aneurysms were finally included in this review (Figure).

The last search was launched in January 2020.

Demographic Characteristics

We collected 684 patients with 707 aneurysms. Sex was reported in 674 patients: 228 men (33.8%) and 446 women (66.2%). The mean age was 50.4 years (the SD was reported in a minority of series).

Blister Characteristics

We collected data about a total of 707 blister aneurysms: Six hundred eighty-seven (98.7%) originated from the ICA; 9, from the basilar artery; 3 (0.4%), from the MCA; 3 (0.4%), from the posterior cerebral artery; 2 (0.3%), from the vertebral artery; 2 (0.3%) from the anterior communicating artery; and 1 (0.1%), from the anterior communicating artery.

Mean size was available for 119 of 707 aneurysms (16.8%): One hundred ten aneurysms were large, up to 5 mm; and 9 were between 6 and 10 mm.

All aneurysms were ruptured. Fisher grading at the onset was available for 255 of 268 (95.1%) patients: 21 (4.8%) grade 1; 54 (17.3%) grade 2; 123 (40.1%) grade 3; 57 (19.0%) grade 4.

The Hunt and Hess (HH) grade was reported in 631 of 684 (92.3%) patients: Eighty-seven (10.7%) were HH 1; 248 (24.8%) were HH 2; 184 (20.3%) were HH 3; 88 (9.5%) were HH 4; and 24 (1.0%) were HH 5 (Online Supplemental Data).

Type of Endovascular Procedure

The type of procedure was reported in 705 of 707 blister aneurysms (99.7%). A simple coiling was used in 6 cases. A traditional stand-alone stent placement was performed in 282 procedures, whereas stent-assisted coiling was preferred in 256 procedures. Stand-alone flow diversion was the treatment of choice in 145 cases, while in 16 patients, coiling combined with flow diversion

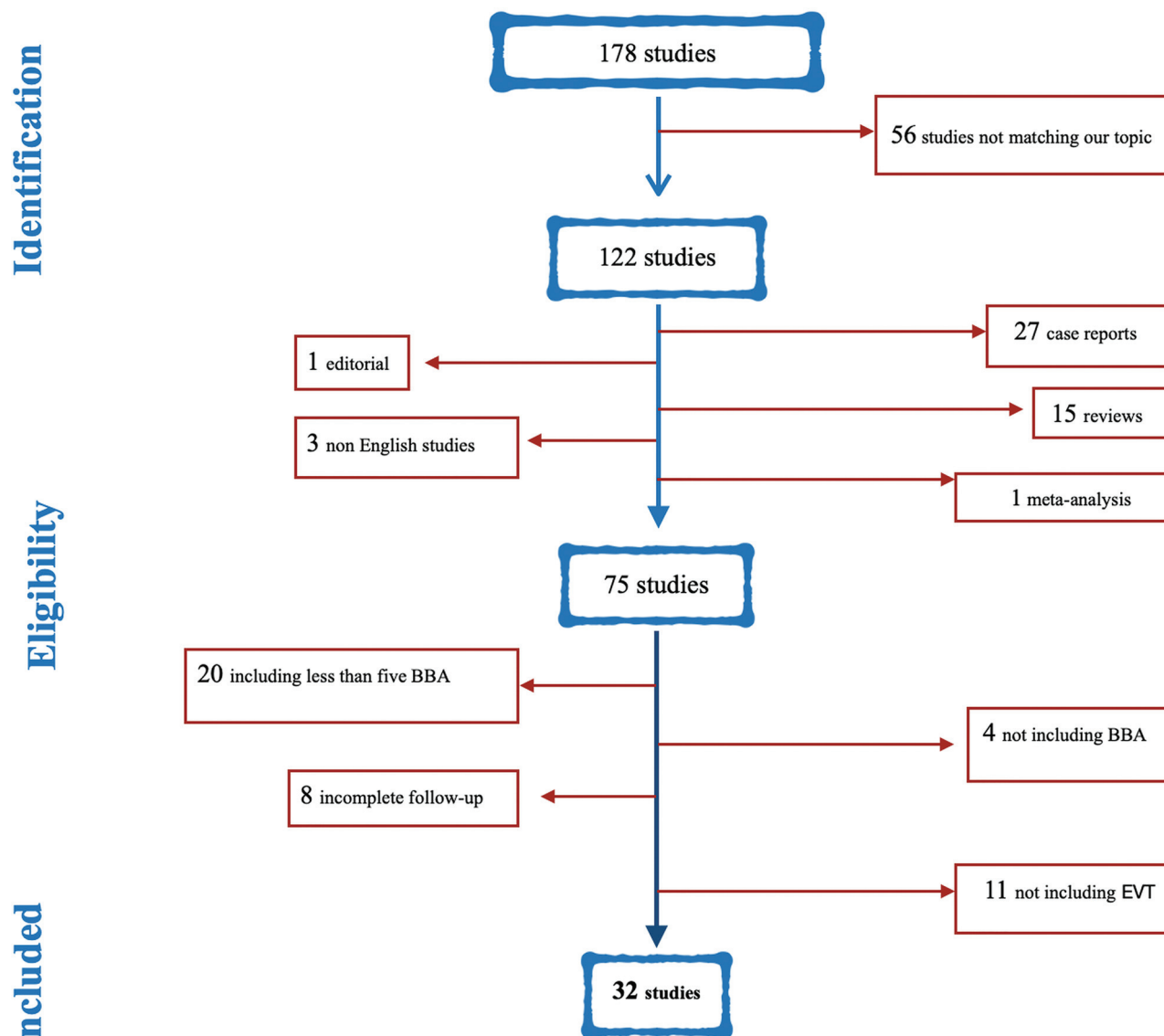


FIGURE. Search strategy. BBA indicates Blister aneurysms; EVT, endovascular treatment.

or an occlusion with glue or parent artery occlusion was performed (Online Supplemental Data).

Radiologic Outcome

Immediate radiologic outcome was reported in 498 of 684 (72.8%) patients: The complete occlusion rate was 50.6% (95% CI, 38.2%–62.9%); near-complete was 11.6% (95% CI, 5.7%–18.7%); partial was 24.4% (95% CI, 14.8%–35.2%); and failure was reported in 7 patients (0%; 95% CI, 0.0%–1.05).

Radiologic outcome at follow-up was reported in 345 of 684 (50.4%) patients: The complete occlusion rate was 76.9% (95% CI, 69.2%–83.9%); near-complete was 1.6% (95% CI, 0.17%–3.89%); partial occlusion was 1.1% (95% CI, 0.03%–2.97%); and failure was reported in 2.3% (95% CI, 0.41%–5.22%) of patients (Online Supplemental Data).

In 23 studies, the evaluation of the occlusion rate was empirically based on the author's own description on DSA.^{8,10,12-18,20,22-24,27-32,34,35,37-39} In 6 studies, authors used

the Roy-Raymond scale,^{16,19,25,26,33,36} and in 2 studies, they used the simplified Roy-Raymond scale.^{9,21} Only 1 study used the O'Kelly-Marotta and the Roy-Raymond scales.¹¹

Clinical Outcome and Complications

Details are reported in the Online Supplemental Data: Clinical outcome at discharge was reported in a minority of patients and expressed as the Glasgow Outcome Scale score. Clinical outcome at follow-up was, instead, reported in 674 of 684 (98.5%) patients: 76.6% (95% CI, 68.2%–84.2%) of patients had an mRS of less than 2; and 7.6% (95% CI, 3.09%–13.3%) of patients had an mRS > 2.

The mean follow-up time was reported in 25 of 32 included articles (406 patients) and was about 12.4 months.

Concerning complications, an intraoperative hemorrhage occurred in 27/684 procedures (1.3%; 95% CI, 0.31%–2.85%); vasospasm, in 45/684 (2.7%; 95% CI, 0.14%–7.33%); and thrombosis, in 20/684 (0.7%; 95% CI, 0.00%–2.63%), while

perioperative stroke occurred in 29/684 (1.4%; 95% CI, 0.33%–2.90%). Perioperative death occurred in 40/684 patients (2.8%; 95% CI, 0.93%–5.24%). The overall mortality rate at final follow-up was 50/684 patients (4.8%; 95% CI, 2.30%–7.80%).

Outcome Comparison among the Different Endovascular Treatments

We compared patients' clinical and radiologic outcomes according to the main different modalities of endovascular management (Online Supplemental Data). Because only a minority of cases were treated with simple coiling (0.8%) or parent artery occlusion (0.14%), we decided to compare 3 groups: stand-alone stent placement, stent-assisted coiling, and flow diversion (associated or not with coiling).

The ICA was confirmed as the most common location for blister aneurysm origin (687/707 aneurysms). Blister aneurysms were preferably treated with stand-alone stent placement in 249 cases, followed by a stent-assisted coiling in 179 and flow diverters in 135. Nevertheless, blister aneurysms originating from the anterior cerebral artery, anterior communicating artery, middle cerebral artery, and posterior cerebral artery were exclusively treated with flow diversion. In basilar artery blister aneurysms, 4 cases were treated with flow diversion, and 1, with stent-assisted coiling.

Hunt and Hess grading was not discriminating for the choice of the treatment technique, except for the flow-diverter positioning, which was more often preferred in patients with better clinical conditions on admission (26.2% of HH 1) compared with stent placement (4% of HH 1) and stent-assisted coiling (3.9% of HH 1).

Patients treated with stand-alone stent placement presented with a higher rate of good outcome (mRS 0–2) at follow-up (94.8%) compared with those treated with stent-assisted coiling (85%) and flow diverters (76.5%), as well as a lower mortality rate (1.6% versus 3.7% versus 4.4%).

Regarding the complications, vasospasm was most frequently reported with stent-assisted coiling (10.6%) compared with stent placement and flow diversion (0% and 0.1% of cases, respectively). The hemorrhage rate was, instead, very low in all groups (between 0% and 0.6%). The 3 cases of intraoperative bleeding occurred in only cases of flow-diverter positioning without associated coiling.

The perioperative death rate was >2 times higher in the flow-diverter group (5.2%) compared with stand-alone stent placement (2.1%) and stent-assisted coiling (0%) groups. Stent-assisted coiling was reported as having a higher rate of immediate complete occlusion (63.4%) compared with stand-alone stent placement (42%) and flow diverters (53.7%).

The same trend was confirmed at radiologic follow-up when stent-assisted coiling reached a rate of complete occlusion of 80.3%; stand-alone stent placement, 77.1%; and flow diverters, 75.6%. Noticeably, the rate of complete occlusion at radiologic follow-up appeared to be significantly increased in the stent placement and flow-diverter groups if compared with the immediate outcome.

Finally, the quality of each study was evaluated by the Newcastle-Ottawa grading scale (Table).

Newcastle-Ottawa grading scale for the quality of the study evaluation

Article	Selection	Comparability	Outcome
Kaschner et al ⁸	***		*
Fang et al ⁹		*	*
Kim MJ et al ¹⁰	***		**
Capocci et al ¹¹	***		**
Hellstern et al ¹²	***		*
Parthasarathy et al ¹³	***		***
Mokin et al ¹⁴	***		*
Hao et al ¹⁵	***		***
Xu et al ¹⁶	***	*	**
Ren et al ¹⁷	***	*	**
Cerejo et al ¹⁸	***		**
Yang et al ¹⁹	***		***
Ryan et al ²⁰	***		***
Zhu et al ²¹	****	**	***
Brown et al ²²	***		**
Fang et al ²³	***		**
Linfante et al ²⁴	***		**
Yu et al ²⁵	***		**
Song et al ²⁶	***		*
Ashour et al ²⁷	***		*
Chinchure et al ²⁸	***		*
Yoon et al ²⁹	***		*
Chalouhi et al ³⁰	***		*
Gonzales et al ³¹	***		*
Lim et al ³²	***		**
Walsh et al ³³	***		*
Cinar et al ³⁴	***		*
Lee et al ³⁵	***		**
Aydin et al ³⁶	***		***
Ihn et al ³⁷	**		**
Fang et al ³⁸	**		**
Fang et al ³⁹	***		*

Note:—A study can be awarded a maximum of one star for each numbered item within the Selection and Exposure categories. A maximum of two stars can be given for Comparability.

DISCUSSION

In this study, we systematically reviewed clinical and radiologic data regarding the endovascular treatment of intracranial blister aneurysms. Most of the patients reported in literature were women, and the more common clinical presentation was Hunt and Hess grade 2 or 3.

Blister aneurysms appeared in >85% of cases with small aneurysms (up to 5 mm) and in almost 99% of patients when the aneurysm originated from the internal carotid artery.

Seven different procedures are reported for treatment of blister aneurysms, highlighting the continuing technical evolution and the increasing number of new devices available for endovascular management of these challenging vascular pathologies (or lesions or anomalies). In fact, neither the pathophysiologic mechanisms at the base of blister aneurysm formation nor their optimal treatment has been established yet.

Because blister aneurysms are presumed to be a type of vascular dissection or pseudoaneurysm, their treatment should not focus solely on the aneurysm sac but should also address the reconstruction of the wall of the affected vessel.

Endovascular procedures were initially faced with skepticism because of the reported risk of incomplete aneurysm occlusion in the acute phase and rupture during traditional coiling and

rebleeding at a distance.⁴⁰ However, the endovascular treatment of blister aneurysms was completely revolutionized by the introduction of stents and, in particular, with the advent of flow diversion.

In agreement, our data showed that endovascular treatment of blister aneurysms is relatively effective and safe. The rate of immediate aneurysm occlusion/near-complete occlusion is about 62%, and the overall rate of complications is about 9%, with a perioperative mortality rate of <3%. In particular, the risk of perioperative bleeding appeared as significantly lower than after surgical techniques (1.3% vs 29%).⁴¹ At radiologic follow-up, the rate of effective occlusion was >78%, and the overall mortality rate remained below 5% (Online Supplemental Data).

The improvement of the radiologic outcome can be explained considering that most patients were treated with stent placement or a stand-alone flow diverter, which usually guarantees a long-term effect but not always immediate complete occlusion due to the specific hemodynamic modification induced.

However, the risk of prolonged use of antithrombotic medications required in stent-placement procedures needs to be carefully considered. Indeed, concerns about the use of dual-antiplatelet therapy are common.^{42,43}

A systematic review by Skukalek et al⁴⁴ suggested high-dose aspirin for >6 months to minimize permanent thrombotic complications as well as permanent and transient hemorrhagic complications and loading doses of aspirin and clopidogrel preprocedurally to potentially decrease the incidence of hemorrhagic events.

However, despite the specific type of endovascular approach, our data showed a good clinical outcome (mRS <2) at final follow-up in more than three-fourths of patients (77%). Although an overall mortality rate of 4.8% is not negligible, it mainly reflects the severity of the clinical status at admission rather than a complication of the treatment.

Coiling and Stent-Assisted Coiling

In our review, 262 patients (32.8%) underwent coiling (6 patients) or stent-assisted coiling (256 patients). The largest series have been described by Ren et al,¹⁷ Xu et al,¹⁶ Zhu et al,²¹ and Lim et al,³² who reported 58, 44, 39, and 31 patients, respectively. Major concerns about coiling included the high rate of aneurysm regrowth and of intraprocedural rupture.^{37,45-49} Indeed, the frequent lack of a real neck and the small size of the blister aneurysm often rapidly led to the use of adjuvants such as stents by most of the authors, as reported in most of the subsequent literature. However, in our study, small series for coiling alone reported a good rate of occlusion.^{17,22}

Indeed, our data showed that stent-assisted coiling was considered by most of the authors as the first-line treatment (about 32% of all cases), with 83% of complete/near-complete occlusion at final follow-up and a clinical outcome comparable with that for the other treatments. The rate of complications was also comparable except for the incidence of vasospasm, which was reported in a significantly higher percentage of cases (about 11%), though these data were not corrected for clinical status at admission. This could be partially explained by the adjunctive mechanical stimulus due to the vessel manipulation for stent and coil release.

In conclusion, pros of coiling/stent-assisted coiling are a good rate of immediate occlusion and a lower cost; the con is the higher risk of vasospasm.

Stand-alone Stent Placement

Single or multiple stand-alone stent placements were the second most common procedure performed, representing the 15.9% of the included cases. Overlapping stents were sometimes anecdotally reported with the rationale of increasing strut density and the thickness of the stent, thus remodeling and reinforcing the arterial wall.^{32,35} The larger series was described by Fang et al,⁹ including 213 patients, who reported no difference in perioperative ischemic and mortality rates among different numbers of stents delivered.

Our data showed the absence of differences in terms of the number of thrombotic or stroke events in comparison with the other types of treatment (Online Supplemental Data). Similarly, the rate of intraoperative hemorrhage was lower compared with stent-assisted coiling and flow-diverter procedures despite the need for introducing antithrombotic therapy and the delayed occlusive effect compared with procedures including coiling.

In conclusion, the advantage of stand-alone stent placement is a lower risk of intraoperative bleeding, while the disadvantages are the delayed occlusive effect and the need for long-term antithrombotic therapy for the patient.

Flow Diversion

Flow diversion was reported in 155 (27%) patients, but in only 10 patients was it associated with coiling.

Flow diverters are gaining increased attention because of the possibility of parent vessel reconstruction. They represent new effective devices for the management of complex aneurysms, but evidence of their effects on blister aneurysms has not been completely elucidated. Flow-diverter technology is, in fact, controversial for certain aspects related to its architecture and its hemodynamic effect, which expose the patient to potential complications due to the delayed occlusive effect not seen with traditional coiling. Mokin et al¹⁴ described the largest series of patients treated with flow diverters, supporting their use especially for treatment of carotid blister aneurysms.

Our data showed a good rate of occlusion at final follow-up (75.6%), but with a higher rate of perioperative death (5.2%) (Online Supplemental Data).

Overlapping flow diverters were overall reported in a limited number of cases (19 cases of 156). Cerejo et al¹⁸ reported the higher number ($n = 7$) of patients treated with overlapping stents, described in 4 cases of complete occlusion and in 3 cases of incomplete occlusion. Mokin et al,¹⁴ Ryan et al,²⁰ Yoon et al,²⁹ and Chalouhi et al³⁰ reported, instead, mixed series of patients treated with single or overlapped flow diverters without significant differences in the clinical results. On the contrary, other authors such as Parthasarathy et al,¹³ Linfante et al,²⁴ and Aydin et al³⁶ specifically preferred single-device procedures for blister aneurysm treatment.

The advantages of placing overlapping flow diverters are the minimization of the risk of postdiversion rerupture and the speed of the parent vessel endothelialization with definitive exclusion of

the lesion (Ryan et al²⁰). However, a significant reduction in post-treatment bleeding has not been demonstrated to date by placing multiple stents. On the other hand, some risks should be considered, such as cerebral ischemia due to jailing of perforating vessels, an increased risk of device thrombosis, and procedural complications related to the additional steps required for placement of multiple devices.^{29,36}

In conclusion, the advantage of flow diversion is a good final occlusion rate, with the possibility of complete vessel wall healing; the disadvantages are the higher cost of the devices, the delayed occlusion, the higher risk of perioperative death, and the need for a long-term antithrombotic therapy.

Parent Artery Occlusion

Parent artery occlusion with balloons and/or coils as rescue strategy was reported in 3 cases (0.4%) of ruptured blister aneurysms with SAH, and no complications were reported. However, ischemic complications due to important internal carotid artery side-branch occlusion (ophthalmic artery, anterior choroidal artery, and fetal presentation of the posterior communicating artery) have to be considered, even if the patient passes the balloon test occlusion.

In conclusion, the advantage of parent artery occlusion is the immediate aneurysm obliteration and the low cost; the disadvantages are the ischemic complications.

Comparison between Treatments

Our treatment subgroup analyses showed that the higher rate of immediate occlusion is obtained with the stent-assisted coiling technique (pooled percentage of 63.4%). However, at final follow-up, the different endovascular techniques show comparable results in terms of complete occlusion (Online Supplemental Data). Stand-alone stent placement presents the higher rate of good clinical outcome with 94.8% of mRS < 2 and the lower rate of complications in general.

Care must be taken for the incidence of vasospasm after stent-assisted procedures and for the non-negligible rate of perioperative death during flow diverter releasing.

Anticoagulation/Antiplatelet Treatment

Our data did not show particular complications from anticoagulation/antiplatelet therapy (hemorrhage was reported in 1.34% of patients, 0.63% in the flow-diverter group), with no statistically significant differences between groups of treatments.

In flow-diversion procedures, the timing of treatment and the antiplatelet regimen is still a dilemma; a number of differing protocols are currently available and reported.

There is uncertainty about not only the type of drug but also the timing of administration. In the study of Yoon et al,²⁹ thromboembolic complications occurred in 27% of patients despite preprocedural aspirin and clopidogrel loading (timing not specified) and monitoring of platelet inhibition. No rebleeding was reported. Lin et al⁵⁰ administered the antiplatelet loading 12 hours before the procedure. In their series of 26 patients treated with a Pipeline Embolization Device (Medtronic) for a ruptured blister aneurysm, they reported a lower number of in-stent thromboses (7.6%) and brain stem ischemia (3.8%). Still, no rebleeding was reported. Favorable outcome with no incidence of thrombo-embolism or

rebleeding was reported by Chalouhi et al³⁰ and Aydin et al³⁶ when treatment was deferred (>5 days). Antiplatelet loading was performed, respectively, 8 and 12 hours before the procedure.

Therefore, although an increased risk for bleeding theoretically exists with antiplatelet administration, from our data and the data in literature, antiplatelet drugs seem not to significantly affect the risk of intra-/postprocedural bleeding. On the other hand, the thromboembolic risk seems to be of more concern (1.81% versus 0.63% risk of hemorrhage in the flow-diverter group; Online Supplemental Data), even when preprocedural antiplatelet loading is performed.

Comparison with Previous Systematic Reviews

Compared with previous systematic reviews on this topic,^{41,51,52} our meta-analysis included a larger number of articles and patients, pooled data from different endovascular treatments, and both radiologic and clinical outcome for data analysis. Furthermore, even newer and more advanced techniques and devices involved in the endovascular treatment of blister aneurysms have been reported, fostering a current critical update of their clinical and radiologic outcomes.

Limitations

Our study has several limitations. Clinical and radiologic follow-up times were variable (6–32 months); thus, data are limited by the heterogeneity of follow-up. Most of the selected articles were observational, nonrandomized, and noncomparative studies, and data were collected retrospectively, often lacking in several details. Moreover, in patients with SAH due to blister aneurysm rupture, it is difficult to differentiate procedure-related morbidity from morbidity secondary to complications of SAH.

Also, even though aneurysm topography was reported in all cases, for a minority of patients, it was not possible to associate the location with the specific endovascular technique during the subgroup analysis.

Finally, our results could be influenced by publication bias. In fact, we could have missed some studies with worse outcomes that were performed and not published, distorting the evidence base.

However, this study provides useful data to consider when assessing the effects and risks of endovascular treatment in blister aneurysms and could represent a stepping stone for future comparative or randomized studies in this group of patients.

CONCLUSIONS

Blister aneurysms are complex vascular lesions representing a treatment challenge for cerebrovascular specialists. Currently, the endovascular approach represents a valid treatment option due to its safety and efficacy profile, reaching, at follow-up, a rate of effective occlusion of about 78%, with a relatively low incidence of complications, and an overall mortality below 5%.

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