ANGIOGRAPHIC OUTCOMES OF EMBOLIZATION IN PATIENTS WITH INTRACRANIAL ANEURYSMS WITH COIL- ASSISTED LASER CUT STENT VERSUS BRAIDED STENTS

Abstract

Introduction: Intracranial aneurysms are a focal dilatation of the vessel wall, the rupture of these, causes subarachnoid hemorrhage. Until now, endovascular management is the ideal treatment, providing the interventionist a range of options among which the stent and coils embolization stands out because of its occlusion rate. This study presents the results of a retrospective cohort comparing the effectiveness, morbidity, and mortality of IA treatment with laser-cut stent-assisted coils versus braided stents.

Methodology: Retrospective cohort of patients diagnosed with unruptured intracranial aneurysms treated with coil-assisted laser-cut stents or braided stents.

Results: 138 patients with 147 intracranial aneurysms were analyzed, with the main antecedent of arterial hypertension (48.55%), the most used stents group were the laser cut stents, the most used among these was the solitaire (54.95%). Hydrocoils were used in 66.89% of the patients and in-stent angioplasty was performed in 6.12%.

Conclusion: Treatment of patients with intracranial aneurysms with laser-cut stents or braided stents and coils is just as safe and effective

Introduction

Intracranial aneurysms (IA) are a focal dilatation of the vessel wall (1). The rupture of an IA causes a subarachnoid hemorrhage (in some cases associated with a parenchymal hematoma), which has a high morbidity and mortality that varies between 27 and 44% (2).

It is currently estimated that the incidence of intracranial aneurysms in the general population is approximately 3.2%, and their rupture represents the main cause of non-traumatic subarachnoid hemorrhage (82%) (2).

Until now, endovascular management is the treatment of choice for intracranial aneurysms; since it has shown lower morbidity, shorter hospital stay, and short recovery time compared to other treatment techniques (2,3). This has evolved from coil embolization, balloon-assisted coil embolization, and stent-assisted coil embolization (2).

The treatment of aneurysms with stents and coils has shown a complete occlusion rate at 6 months of 83.9% of patients with 6.3% of complications. Stents are divided into two groups, laser-cut stents, and braided stents. Laser-cut stents are more stable and may cause fewer thromboembolic effects in collateral vessels (4). Braided stents have a larger metallic surface and therefore generate a greater flow-diverting effect that promotes aneurysm occlusion. (4.5)

Currently, despite the increase in endovascular treatment for the management of intracranial aneurysms, there is little evidence that compares the efficacy and safety of the different endovascular techniques. Therefore, this study presents the results of a retrospective cohort in which the effectiveness, morbidity, and mortality of IA treatment with laser-cut stent-assisted coils versus braided stents were evaluated.

Methodology

The present study is a retrospective cohort of patients diagnosed with unruptured intracranial aneurysms treated with coil-assisted laser-cut stents or braided stents. The study received approval from the institutional medical ethics committee. The data analyzed were obtained from an anonymized database of the institution's Interventional Radiology service.

Patient cohort

The cohort included patients 18 years of age and older with a diagnosis of intracranial aneurysms treated endovascularly with coils assisted with laser-cut stents or braided stents between January 2014 and December 2021 at the FOSCAL Clinic and FOSCAL International. Patients with ruptured intracranial aneurysms were excluded.

The variables analyzed include demographic information of the patients, characteristics of the IA and endovascular treatment, antiplatelet protocol, complications associated with the perioperative treatment, and the one-year follow-up. The modified Rankin scale (mRs), findings on angiotomography or subtraction angiography, mortality, and cause of death were also included in the one-year follow-up.

Technique of the Procedure

Under general anesthesia, with the patient in the supine position, using Doppler ultrasound guidance, the femoral artery was punctured with an 18G Boston femoral puncture needle, 5Fr introducer, using a diagnostic catheter (JB-2 or Simmons) and a 0.035"x150cm guide.

The guide catheter is raised over the exchange guide until it is positioned in the common carotid artery. Subsequently, the intermediate catheter is raised until it is positioned in the infrapetrous segment of the carotid artery. Cerebral panangiography is performed, with a 3D acquisition, and working projections are selected. A microcatheter mounted on a microguide is advanced to catheterize the distal artery and another microcatheter is mounted on a microguide for catheterization of the aneurysm.

Subsequently, coil embolization and stent angioplasty were performed using the Jialing technique. Angiographic control is performed to assess the occlusion of the aneurysm and adequate patency of the intracranial vasculature. The femoral artery defect was closed with the Perclose ProGlide 6Fr percutaneous closure system.

Antiplatelet Protocol:

The antiplatelet and anticoagulation therapies were performed according to the dual antiplatelet therapy (DAPT) institucional protocol. The patients received daily dosages of 100mg of oral aspirin and 75mg of oral clopidogrel for the seven days preceding the procedure. The VerifyNow® test was performed before the surgery, and PRU values between 60 and 200 were considered as normal responses. Patients with antiplatelet hyporesponsive (i.e., PRU>200) were given ticagrelor at a loading dose of 180 mg orally of the day before the procedure and continued at 90 mg every 12 hours for six months. Patients with high antiplatelet responses (i.e., PRU<60) received maintenance doses of 75mg of oral clopidogrel every 48 hours or 72 hours or daily doses of 37.5mg, instead of the daily 75mg dosage. A second VerifyNow® test was performed seven days following the procedure in these high-responder patients. Fifty IU/kg of unfractionated heparin was administrated during the endovascular procedure for anticoagulation, and subsequently an activated coagulation time test was performed to guided the anticoagulation during treatment.

Statistical analysis:

The qualitative variables were described with absolute and relative frequencies including confidence intervals. The quantitative variables were described by means and standard deviation. In the bivariate analysis between groups, it was related using the T-Test and ANOVA test for quantitative variables and Chi Squared test for qualitative variables. A p value of statistical significance less than 0.05 was considered. The information was collected and cleaned in Microsoft Excel® (version 16.39). Stata/SE v 14.0 software (2003-5 Stata corp. College Station, Texas, release 9.0) was used for database validation, variable processing and analysis.

Results:

One hundred thirty-eight patients with 147 intracranial aneurysms were included in the analysis. Our evaluation excluded 7 patients of which 6 patients were treated with stenting alone and one with an aneurysm in the cervical segment of the internal carotid artery. The mean age of the patients was 61.78 years, with a minimum age of 19 years and a maximum of 83 years. The majority of patients were women (79.71%). 61.90% of the IAs were treated with laser-cut stents while 38.10% were with braided stents. Arterial hypertension was the main antecedent (48.55%), followed by previous SAH (23.91%) and smoking (14.49%).

Characteristics of the aneurysm:

Most IAs were diagnosed incidentally (82.31%). The largest diameter of the aneurysms had a mean of 5.83 mm, with the shortest diameter being 1.3 mm and the longest being 22 mm. 45.58% of the patients presented a single IA, 34.69% had two aneurysms and 19.73% more than two aneurysms. Most of the aneurysms had a regular wall (79.05%) and saccular morphology (98.65%). The most frequent location was in the middle cerebral artery (MCA,38.78%), followed by the anterior communicating artery (Acom,19.73%) and the anterior cerebral artery (ACA) 13.61%. In our cohort, 28.57% of the aneurysms had undergone prior treatment, of which 12.24% were previously treated with coils and 10.88% with stent-assisted coils. (Table 1)

Endovascular treatment:

According to the institution's protocol, the most widely used antiplatelet regimen was clopidogrel + aspirin (87.07%). The VerifyNowTM test report was obtained from 65 patients, of whom 31.29% had an adequate response, 6.12% hyper response, and 6.12% hyporesponse to clopidogrel. In 95.95% of the patients, only 1 stent was used and in 4.05% two were used. The most used stent was the solitaire (34.01%) followed by Leo Baby (28.57%) and Neuroforms Atlas (26.53%). Hydrocoils were used in 66.89% of the patients and in-stent angioplasty was performed in 6.12%. (Table 1)

Table 1. Demographic and clinical characteristics of patients diagnosed with unruptured intracranial aneurysm treated with laser-cut and braided stents.

	Laser-cut Stent, n(%)	**Braided, n(%)**	***p value***
Gender			0.915
Female	68 (80)	42 (79.25)	
Male	17 (20)	11 (20.75)	
Mean Age (years)	62	60	0.059
Hypertension	35 (41.18)	32 (60.38)	**0.028**
Diabetes Mellitus	9 (10.59)	4 (7.55)	0.552
Smoking	12 (14.12)	8 (15.09)	0.874
Ruptured Aneurysm	7 (8.24)	12 (22.64)	**0.017**
SAH Antecedent	19 (22.35)	14 (26.42)	0.586
Family history of Intracranial Aneurysm	6 (7.06)	12 (22.64)	**0.008**
Family history of autoimmune disease or vasculitis	3 (3.53)	3 (5.66)	0.550
Diagnosis			
Incidental	76 (83.52)	45 (80.36)	0.838
Symptomatic	13 (14.29)	10 (17.86)	
Family Screening	2 (2.20)	1 (1.79)	
Mean Diameter of IA (mm)	6.17	5.27	
Location			

MCA	33 (36.26)	24 (42.86)	
Acom	17 (18.68)	12 (21.43)	
ACA	9 (9.89)	11 (19.64)	
ICA Ophthalmic Segment	12 (13.19)	4 (7.14)	
T Carotid	6 (6.59)	1 (1.79)	
ICA Communicating Segment	5 (5.49)	1 (1.79)	0.384
Basilar Artery	4 (4.40)	2 (3.57)	
ICA Choroidal Segment	3 (3.30)	0	
PCA	1 (1.10)	1 (1.79)	
Cerebellar Arteries	1 (1.10)	0	
Morphology			
Sacular	90 (98.9)	56 (100)	0.431
Desiccant	1 (1.1)	0	
Wall			
Regular	74 (81.32)	42 (75)	0.362
Irregular	17 (18.68)	14 (25)	
Single or Multiple Aneurysm			
1	44 (48.35)	23 (41.07)	
2	32 (35.16)	19 (33.93)	0.429
>2	15 (16.48)	14 (25)	
History of			

previous treatment			
Without prior treatment	73 (80.22)	32 (57.14)	
Coils	10 (10.99)	8 (14.29)	
Coils+stent	5 (5.49)	11 (19.64)	0.018
Coils+Ball	3 (3.3)	4 (7.14)	
Surgery	0	1 (1.79)	
Stent Name			
Solitaire	50 (54.95)	N/A	
Neuroform Atlas	39 (42.86)	N/A	
Neuroform	2 (2.2)	N/A	
Leo Baby	N/A	42 (75)	N/A
Lvis Evo	N/A	8 (14.29)	
Leo	N/A	6 (10.71)	
Number of stents			
1	89 (97.8)	53 (94.64)	0.305
2	2 (2.2)	3 (5.36)	
Coil Type			
Hidrocoils	63 (69.23)	36 (64.29)	0.535
Platinum	28 (30.77)	20 (35.71)	
In-Stent Angioplasty	6 (6.59)	3 (5.36)	0.761
Antiaggregation Scheme			

Clopidogrel+Aspirina	79 (86.81)	49 (87.50)	0.904
Ticagrelor+Aspirin	12 (13.19)	7 (12.5)	
Anticoagulation	87 (95.6)	51 (92.73)	0.459
Verifynow Classification			
N/A	60 (65.93)	23 (41.07)	0.002
Normal (60-200)	18 (19.78)	28 (50)	
Hiper-responsive (<60 PRU)	7 (7.69)	2 (3.57)	
Hipo-responsive (>200 PRU)	6 (6.59)	3 (5.36)	

ACA: Anterior cerebral artery
Acom: Anterior communicating artery
ICA: Internal carotid artery
MCA: Middle cerebral artery
SAH: Subarachnoid hemorrhage
PCA: Posterior cerebral artery

Angiographic result

Of the 147 cases of aneurysms included, only 135 could be followed up 12 months after the intervention. The angiographic occlusion rate was classified using the Raymond Roy scale (RRO). In the immediate angiographic control, an RRO I was obtained in 86.81% of the patients with laser-cut stents and 87.50% of the patients with braided stents. 13.19% and 10.71% of patients with laser-cut and braided stents had an RRO II, respectively. In our cohort, there were no patients with immediate RRO IIB or III. (Table 2)

In the angiographic follow-up at 12 months, an RRO I occlusion rate of 85.19% was reported in both groups. The RRO II rate was 12.35% and 11.11% in patients with laser-cut and braided stents, respectively. (Table 2)

Table 2. Angiographic results of patients with a diagnosis of unruptured intracranial aneurysm treated with laser-cut and braided stents.

Outcomes	Laser-cut Stent	Braided	p value
Number of patients			
During the procedure	91	56	N/A
In the following 12 months	81	54	N/A
Immediate Occlusion Rate, n(%)			0.407
Raymond Roy I	79 (86.81)	49 (87.50)	
Raymond Roy II	12 (13.19)	6 (10.71)	
Raymond Roy IIIa	0 (0)	1 (1.79)	
Occlusion rate at 12 months, n(%)			
Raymond Roy I	69 (85.19)	46 (85.19)	
Raymond Roy II	10 (12.35)	6 (11.11)	
Raymond Roy IIIa	1 (1.23)	1 (1.85)	
Raymond Roy IIIb	1 (1.23)	1 (1.85)	

Complications

In our study, a total of 28 perioperative complications were observed in 25 patients, of which 16 occurred in patients treated with laser-cut stents and 12 in patients treated with braided stents. (Table 3)

Periprocedural thromboembolic complications

Eight patients presented thromboembolic complications only, of which 3 were in the laser-cut stent group and 5 in the braided stent group. Regarding the patients with laser-cut stents, the first patient presented perioperative in-stent thrombosis of the Acom, which required the use of tirofiban, achieving complete repatency with subsequent recovery without complications.

The second patient developed an occlusion of the left pericallosal artery secondary to in-stent thrombosis without presenting complications and without requiring additional treatment due to the adequate network of leptomeningeal collaterals. The third patient debuted with a slight motor deficit at the level of the left upper limb after the procedure. He was taken to an MRI where a filling defect was evidenced at the origin of the M1 segment of the right MCA, for which a tirofiban infusion was performed with subsequent resolution of the condition. Of the five patients in the braided stent group, the first patient presented a distal filling defect of the left precentral artery secondary to thrombus migration, for which tirofiban infusion was started for successful recanalization and thrombolysis. The second patient presented 100% occlusion of the anterior cerebral artery and Heubner's recurrent artery secondary to the migration of a thrombus, for which intravenous and intra-arterial infusion of tirofiban was started with subsequent recanalization. The third patient presented an ischemic stroke 30 minutes after the procedure with progressive deterioration of language and movement of the right hemibody. The patient underwent cerebral panangiography, which revealed occlusion of the left ACA secondary to in-stent thrombosis, for which thrombolysis was performed with tirofiban with subsequent adequate recanalization. The fourth patient presented dysarthria and loss of strength in the upper limbs, symptoms that disappeared spontaneously; however, a brain MRI was performed, which did not show signs of ischemia or hypoperfusion. The fifth patient presented strangulation of the stent with thrombosis of the upper trunk of the right middle cerebral artery with subsequent formation of a new intra-stent thrombus, for which thrombolysis was started with tirofiban with subsequent resolution of the condition. (Table 3)

Periprocedural bleeding complications

Fourteen patients had periprocedural bleeding complications, 9 of whom were in the laser-cut stent group and 5 in the braided stent group. In the group of patients treated with laser-cut stents, 5 patients presented hematoma at the puncture site, one of these associated with a retroperitoneal hematoma. Another patient presented a pseudoaneurysm at the puncture site that required endovascular stenting.

The sixth patient presented with moderate bleeding secondary to the removal of the central venous catheter. The seventh patient had a hematoma after a central venous catheter puncture. The eighth patient presented a rupture of the aneurysm dome, which was controlled with coil embolization without complications. The last patient presented neurological deterioration with aphasia and right hemiplegia 1 day after the procedure. A CT scan was performed, showing evidence of left frontoparietal intraparenchymal hemorrhage, with a mass effect and subfalcine herniation, for which he was taken to surgical drainage with subsequent recovery. This complication was probably associated with antiplatelet therapy. (Table 3)

Regarding the five patients treated with braided stents who presented bleeding complications, 3 patients presented a hematoma at the puncture site and two patients presented self-limiting hematemesis and scant epistaxis.

Multiple periprocedural complications

In our study, we found 3 patients who presented 2 or more complications, both bleeding and ischemic. Two of these patients were treated with laser-cut stents, and 1 with a braided stent. The first patient treated with a laser-cut stent presented a rupture of the right internal carotid artery in the ACoP segment related to the opening of the stent. This patient underwent surgical repair of the artery and decompressive craniectomy. After a 1-month hospital stay, he presented refractory neurogenic shock with multiple organ dysfunction and subsequent death. During the procedure, the second patient presented acute thrombosis of the temporal branch of the middle cerebral artery secondary to post-subarachnoid hemorrhage spasm, requiring mechanical thrombectomy with aspiration and chemical thrombolysis with tirofiban with improvement for a TICI III result and subsequent recovery of the patient.

One patient treated with a braided stent presented in-stent thrombosis during the procedure, which required mechanical thrombectomy and pharmacological thrombolysis. Additionally, he presented a hematoma at the puncture site with subsequent resolution. (Table 3)

Bleeding complications at 12-month follow-up

Three patients presented bleeding complications during the 12-month follow-up, of which 2 correspond to patients treated with braided stents and one with a laser-cut stent. Regarding the patients treated with braided stents, it was found that one patient had hematochezia of 8 days of evolution with severe anemia (Hb: 6.2), for which he required a transfusion of 2 UGRE with subsequent resolution of the condition. The second patient presented fecal occult blood without hemodynamic changes. The patient treated with laser-cut stents presented multiple spontaneous ecchymoses probably related to hyperresponse to clopidogrel, for which the drug dose was adjusted with the subsequent disappearance of symptoms. (Table 3)

Thromboembolic complications at 12-month follow-up

During follow-up, no patient with thromboembolic complications was reported 12 months after the procedure. (Table 3)

Table 3. Periprocedural complications and 12-month follow-up of patients diagnosed with unruptured intracranial aneurysm treated with laser-cut and braided stents.

Outcomes	Laser-cut Stent, n(%)	Braided, n(%)	p value
Perioperative Hemorrhage complications	11 (12.09)	6 (10.71)	0.800
Perioperative thromboembolic complications	5 (5.49)	6 (10.71)	0.243
Hemorrhage complications at 12 month follow-up	1 (1.23)	2 (3.64)	0.349
Thromboembolic complications at 12 month follow-up	0	0	N/A

Modified Rankin scale

To assess the degree of disability at 12-month follow-up, the mRs was used, which was divided into three groups. The first group was patients with an mRs of 0-2 where 84.62% of the patients with laser-cut stents and 94.65% of the patients with braided stents were present. In the second group, patients with mRs of 3-5 were grouped, where 4.4% of the patients were treated with laser-cut stents and 3.58% of patients with braided stents. The patient with mRs of 6 was previously described. Nine of the patients treated with laser-cut stents and one of the patients with braided stents could not be followed up and mRs were classified at 12 months due to non-attendance at a follow-up appointment. (Table 4)

Table 4. Modified Rankin scale at 12-month follow-up of patients diagnosed with unruptured intracranial aneurysm treated with laser-cut and braided stents.

mRs At 12 Months	Laser-cut Stent, n(%)	Braided, n(%)	p value
0-2	77 (84.62)	53 (94.65)	0.465
3-5	4 (4.4)	2 (3.58)	
6	1 (1.1)	0	
N/A	9 (9.89)	1 (1.79)	

Discussion

This study presents a clinical and angiographic comparison of 138 patients with 147 intracranial aneurysms treated with coils and laser-cut or braided stents, showing favorable results in both groups.

The laser-cut stents in our study were the Solitaire, Neuroform Atlas, and Neuroform, which are characterized by high radial force, good flexibility, and stability (6). The braided stents used were LEO baby, LVIS Evo, and LEO. These stents have a larger metallic surface that provides a diverting effect, which can promote intra-aneurysmal occlusion (6).

In our study, the group of patients treated with braided stents presented a statistically greater difference in terms of the history of hypertension, presence of aneurysm rupture, family history of intracranial aneurysms, and history of prior aneurysm treatment. However, although these differences could be taken into account with respect to the study results, they are independent variables of both groups related to the characteristics of each cohort.

Regarding the specific differences in each group of stents, previous studies have found disparities in terms of these; Su Hee Cho et al, studied in 2017 the differences between 2 types of laser-cut stents compared to 2 braided nitinol stents in terms of stent size, pore density, metallic surface, the force needed to load, push, and deploy the stent, radial force on deployment, surface roughness, and corrosion resistance. (7) Finding that the size of braided stents decreases significantly compared to post-delivery laser-cut stents; Likewise, the braided stents had a higher pore density than the laser-cut stents, as well as a larger metallic surface, as well as a greater load, push, and deployment force compared to the laser-cut ones. (7) These differences are comparable to those found by Benjamin Mine et al. in 2018 (8), who further suggests that the clinical implications of these findings may be that laser-cut stents are too loose to provide sufficient support when small-diameter coils are released, and, on the other hand, the higher density of the pores and the greater metallic coverage surface can increase the frequency of occlusion of the vessel originating from the neck of the aneurysm (7,8).

In our study, no statistically significant differences were found in terms of the occlusion rate in both groups (86.81% and 87.5% immediate Raymond I in laser-cut and braided stents, respectively); superior findings but similar in terms of no difference to those found by Jeong Wook Lim et al. in 2020 (5) (53.6% and 54.7% for successful occlusion in the laser-cut and braided stent group, respectively), and Longhui Zhang et al. in 2021 (6) (62.57% and 63.28% immediate Raymond I in laser-cut and braided stents, respectively). In the same way, complications, the rate of functional independence and mortality did not differ between the groups analyzed.

Regarding complications, we could see that despite not finding a statistically significant difference between the two groups, we could see that patients treated with braided stents presented almost twice as many periprocedural thromboembolic complications (10.71% vs 5.49% p, 0.243). However, the main advantage of braided stents is that they can be retrievable even before full delivery.

The main limitations of this study are based on the fact that all the patients analyzed belong to a single center, and therefore factors such as the skill of the interventionists may have biased the results. However, few previous studies on this subject have included the Latin American population in their analyses, for which this study is relevant.

Conclusion:

Treatment of patients with intracranial aneurysms with laser-cut stents or braided stents and coils is just as safe and effective

References:

1. Keun-Hwa Jund, MD, PhD. New Pathophysiological Considerations on Cerebral Aneurysms. Neurointervention. 2018. Doi: 10.5469/neuroint.2018.01011
2. Laurrent Pierot, MD, PhD; Ajay K. Wakhloo, MD, PhD. Endovascular Treatment of Intracranial Aneurysms. 2013. STROKE. AHA Journals. Doi: 10.1161/STROKEAHA.113.000733
3. Texakalidis P, Bekelis K, Atallah E, Tjoumakaris S, Rosenwasser RH, Jabbour P. Flow diversion with the pipeline embolization device for patients with intracranial aneurysms and antiplatelet therapy: a systematic literature review. Clin Neurol Neurosurg. 2017;161:78-87.
4. Longhui Zhang, Xiheng Chen, Linggen Dong, Peng Liu, Luqiong Jia, Yisen Zhang, Ming Lv. Clínical and Angiographics Outcomes After Stent-Assited Coiling of Cerebral Aneurysms With Laser-Cut and Braided Stents: A Comparative Analysis of the Literatures. Frontiers in Neurology. 2021. Doi: 10.3389/fneur.2021.666481
5. Lim J, Cho YD, Hong N, Lee J, Yoo DH, Kang HS. Follow-up outcomes of intracranial aneurysms treated using braided or laser-cut stents with closed-cell design: a propensity score-matched case-controlled comparison. J Neurointerv Surg. (2020) 13:434–7. doi: 10.1136/neurintsurg 2020-016165
6. Zhang L, Chen X, Dong L, Liu P, Jia L, Zhang Y et al. Clinical and Angiographic Outcomes After Stent-Assisted Coiling of Cerebral Aneurysms With Laser-Cut and Braided Stents: A Comparative Analysis of the Literatures. Frontiers in Neurology. 2021;12.
7. Cho S, Jo W, Jo Y, Yang K, Park J, Lee D. Bench-top Comparison of Physical Properties of 4 Commercially-Available Self-Expanding Intracranial Stents. Neurointervention. 2017;12(1):31-39.
8. Mine, B., Bonnet, T., Vazquez-Suarez, J. C., Iosif, C., & Lubicz, B. (2018). Comparison of stents used for endovascular treatment of intracranial aneurysms. Expert Review of Medical Devices. doi:10.1080/17434440.2018.15387