Boffin Access

Open Access Journal | Volume: 1.1

Journal of Neuroscience and Neurosurgery

ISSN 2517-7400

Clinical Results and Costs of Endovascular Treatment in Comparison with Surgery in Subarachnoid Aneurismatic Hemorrhage (aSAH)

Angel Horcajadas Almansa[1]*

[1]Consultant Neurosurgeon, Virgen de las Nieves University Hospital, Granada, Spain

Abstract

Background: Endovascular (EV) treatment of aSAH has increased in the last 20 years. Results of surgical (SC) and endovascular treatments are comparable, but EV has higher rates of retreatments. The cost of endovascular devices is high and makes this treatment expensive.

Object: To evaluate the results and costs of surgical treatment against endovascular in SAH.

Methods: Retrospective review of SAH patients was conducted, treated endovascularly (EV) and surgically (SC). A descriptive study of demographic, clinical and radiological aspects have been carried out. Clinical and angiographic results and economic costs have been evaluated in both globally and in each of the groups.

Results: 231 patients were reviewed (82.5% EV; 17.5% SC). A 71.2% of the patients presented favorable GOS (4-5) at 6 months (80% SC; 69, 3% EV). Mortality was 7,9% (all in SV group). The angiographic results were better in the SC group (88.6% of complete occlusion versus 50%), as well as the stability of the treatment (19.5% of retreatments versus 0%). The Average Length of Stay (ALOS) was higher in the SC group, however, overall costs after follow-up and retreatment were 12.3% higher in the EV group.

Conclusion: Clinical results are comparable. The rate of complete occlusion of the SC group was higher and the need for retreatment lower. Costs of the EV group were significantly higher than the SC group due to the follow up and the rate of retreatment. Adequate selection of candidates for endovascular coiling could improve angiographic outcomes and save costs.

Introduction

Aneurysmal Subarachnoid Haemorrhage (SAH) is an important cause of death and disability, with an incidence of 6-12/100,000 in Western world. Endovascular treatment (EV) has been gaining ground against Surgical Treatment (SC) in an exponential way, mainly as a result of the publication of the ISAT study in 2002 [1,2]. The conclusions of this study have been questioned in subsequent publications [1,3-5] and nowadays the results of both treatments could be considered similar. Retreatment rates in EV are around 20% (less than 1% in surgical ones) and re-bleeding (even the very late ones) are more frequent in this group. EV requires prolonged follow-up with imaging techniques that ensure the stability of the treatment. The current trend indicates a progressive increasing in the indications for endovascular treatment, in parallel with the development of new devices and materials of embolization. Indeed, an argument against EV could be the high cost of embolization material compared to the surgical one and in this sense, several publications try to elucidate the cost of one and another option for treatment [6-15].

The present study aims to evaluate the clinical and angiographic results as well as the costs of surgical and endovascular treatment of a series of cases with SAH treated in a unique hospital. The hypothesis is that the EV is more expensive than the SC without differences in the clinical results.

Material and Methods

The SAH diagnosed patients treated between the years 2010 and 2015 were revised. Demographic data (age and sex), clinical (Fisher grade and Hunt-Hess scale at admission), anatomical characteristics of the aneurysm (location and size) and results (GOS at 6 months) of both series of treatment were analyzed. The average length of stay (ALOS) (ICU and ward days) and costs of treatment and retreatment (number of coils, stents, guide catheters, balloons, craniotomy, clips, etc.) were recorded, as well as expenses related to the follow-up of these patients (routine arteriographies, MRI angiography). The costs of stays, procedures and materials were obtained from hospital sources (Table 1). A descriptive study of both series was carried out and compared in terms of age, sex and clinical and radiological characteristics. For the calculation of costs, patients who died and those who were not

Article Information

DOI:	10.31021/jnn.20181102
Article Type:	Research Article
Journal Type:	Open Access
Volume:	1 **Issue:** 1
Manuscript ID:	JNN-1-102
Publisher:	Boffin Access Limited
Received Date:	26 October 2017
Accepted Date:	20 November 2017
Published Date:	02 January 2018

*Corresponding author:

Angel Horcajadas Almansa
Consultant Neurosurgeon
Virgen de las Nieves University Hospital
Granada, Spain
Tel: 34653610410
E-mail: angel.horcajadas@gmail.com

Citation: Almansa AH. Clinical Results and Costs of Endovascular Treatment in Comparison with Surgery in Subarachnoid Aneurismatic Hemorrhage (aSAH). J Neurosci Neurosurg. 2018 Jan;1:102

Copyright: © 2018 Almansa AH. This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 international License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Item	Price (€)
ICU day	1.300
Ward day	650
Craniotomy *	3.600
Embolisation **	1.300
Brain angiography	700
MRI angiography	600
Surgical clip	200
Coil	900
Catheter Guide	200
Balloon	1.000
Stent	5.300
Flow diverter	11.000

Table 1: Cost guide

*Craniotomy includes costs of surgery time, human resources and materials for craniotomy, excluding clips

** Embolisation includes costs of angiography, anesthesia and human resources

adequately followed up were excluded. The follow-up of the intervened patients differed from embolized ones; generally, the SC patients under- went with a routine arteriography during the first admission, without requiring other standardized test. An arteriography at 6 months and another one at 12 months were performed in embolized patients to continue with an annual MRI angiography if the treatment was considered stable, for a period of not less than 5 years. If a recanalization was observed, patients were programmed for a new treatment, restarting the cycle of arteriographies and MRI angiography. The costs of stays, procedures and materials were obtained from hospital sources (Table 1). A descriptive study of both series was carried out and compared in terms of age, sex and clinical and radiological characteristics. For the calculation of costs, patients who died and those who were not adequately followed up were excluded. The follow-up of the intervened patients differed from embolized ones; generally, the SC patients under- went with a routine arteriography during the first admission, without requiring other standardized test. An arteriography at 6 months and another one at 12 months were performed in embolized patients to continue with an annual MRI angiography if the treatment was considered stable, for a period of not less than 5 years. If a recanalization was observed, patients were programmed for a new treatment, restarting the cycle of arteriographies and MRI angiography.

Due to the retrospective nature of this study, ethics committee approval and patient consent were not required.

In the descriptive analysis, the numerical variables were expressed as mean and standard deviation; median and percentiles in cases that did not meet the normality hypothesis. Qualitative variables were described by absolute and relative frequencies. The normality of the continuous variables was contrasted by the Kolmogorov-Smirnov test. A bivariate analysis was performed to compare possible differences between groups. For the quantitative variables, in the non-parametric cases, the Student's t test or Mann-Whitney were used; chi-square test of Pearson or Fisher were used for the qualitative ones. The significance level considered for all assays was 0.05. The software used was IBM SPSS Statistics 19.

Results

Between January 2010 and December 2015, 231 SAH patients with aneurysmal were treated. Two patients were excluded due to lack of basic data so that, 229 patients were considered finally, 189 of the EV group (82.5%) and 40 of the SC group (17.5%). Eighteen patients died before 6 months, which means a 7.9% overall mortality in the series. All deaths occurred in the endovascular treatment group (9.6% mortality). The mean follow- up of the series was 43.8 months (6-77), slightly higher in the SC group (49.5 versus 43 months).

Age range from 18 to 87 years (mean 55.6 years). About gender, there was a predominance of the female sex (74%). More than half of the patients were found in a Hunt-Hess (HH) grade of 1 or 2 (56.3%) and with a Fisher grade of IV (55%). None of these factors showed statistically significant differences between the two groups (Table 2).

The aneurysms were more frequently located in the anterior circulation (86.6%). The most common location in the global series was the Anterior Communicating Artery (AcoA). Surgery is more frequent in aneurysms located in the middle cerebral artery (MCA) and in the EV group predominate those of ACoA. About the size most of the aneurysms were smaller than 10 mms (Table 2). The mean size of the aneurysms did not differ significantly between the two groups (6.05 in SC versus 6.45 in EV) (Table 2).

With reference to clinical results at 6 months, based on GOS scale measures, 71.2% of the patients had a GOS 4-5. This percentage is slightly higher in the SC group than in the EV group (80% versus 69.3%). Patients with poor clinical status at 6 months, with GOS 2-3, constituted 20.9%, with no large differences between groups (Table 3).

Certain factors influence in the clinical outcome (Figure 1):

- Age: is inversely related to GOS at 6 months so that the older patients have the worse result. Good recovery is only 46.7% in patients over 60 years.
- Initial Hunt Hess: HH 1-2 have about 90% of good results (GOS 4-5) while HH 4 -5 have only 40% of good results. Mortality increased from 2.8% in HH1 to 29.4% in HH5.
- Fisher: Fisher's grade 1-2 have about 90% of good results compared to 58% of grade 4.

Mortality at 6 months of the series was 9.6%. All cases were concentrated in the EV group. Mortality was higher in older patients (man age 61.8 years) and higher Fisher and HH grades (94% in Fisher 4 and 50% in Hunt-Hess 4-5). The event occurred in the majority of cases (83.3%) before the 30 days, with a mean in these cases of 9.6 days, between admission and exitus. There were two cases of exitus for rebleeding after treatment (at 22 and at 44 days of initial

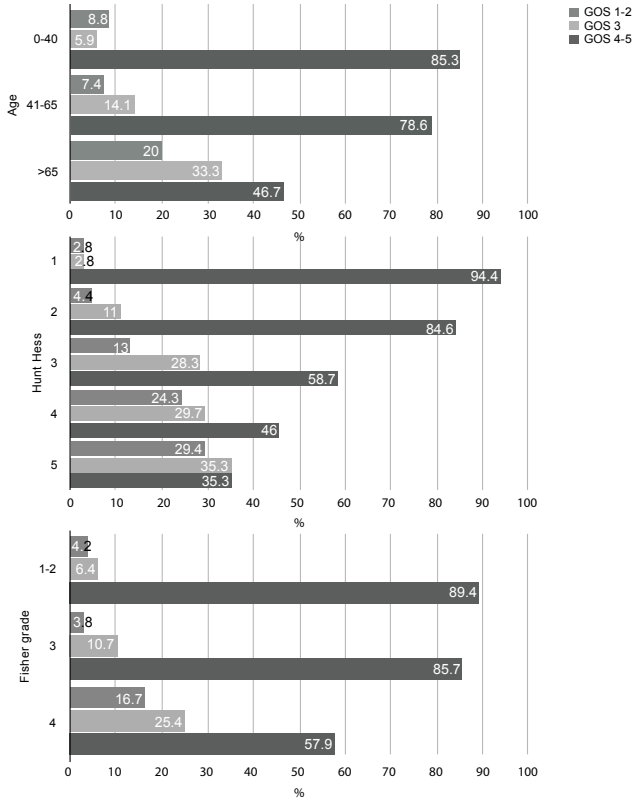

Figure 1: Influence of factors on clinical outcome. In this figure the influence of age, initial Hunt-Hess and Fisher grade on GOS at six months is represented

bleeding).

Routinely arteriography was available in 89% of cases (67% SC and 96% EV). The reason for not performing this control was a poor clinical situation in the cases of the EV or the use of intraoperative ICG (technical indocyanine green) in the SC. Complete occlusion (CO) was achieved in 56.4% of the patients, leaving a rest of neck in the others. This occlusion was superior in the SC group (88.6% versus 50%). Of the cases treated endovascularly with CO at the time of treatment, recanalization was observed in 24.9% of patients. Of these, 68% had to be retreated while the rest keeps in follow-up (Table 3). The overall rate of retreatment in the EV group was 16.9%. Most patients were retreated only once (84%), while other patients were retreated 2 to 5 times. Retreatment rates of certain aneurysms are above average (ICA, MCA, BA, PCom and PICA). The average size of the recanalized and retreated aneurysms is also higher than the mean (7.8 mm and 8.5 mm respectively versus the 6.5 mm of the mean). The mean number of coils used per patient in the first treatment was 4.6 and in the retreatments 7.15. Similarly, the use of stents and flow diverters was more frequent in retreatments.

The ALOS in patients with SAH was 30 days, of which 7.7 days corresponded to the stay in the ICU (Table 3). There are certain factors that influence in it (Figure 2):

- Type of treatment: the ALOS of the EV group was 5.6 days higher in the SC group. This difference is statistically significant.
- Age: it is related to the ALOS in the way that patients younger than 50 years had an ALOS of 7.2 days less than patients over 50 years. The ALOS increases withage.
- Initial Hunt-Hess: high degrees had longer stays (HH 1-2 had an ALOS of 31.3 days lower than HH 4-5). The ALOS increases with the initial Hunt-Hess grade with statistical significance.
- Grade of Fisher: has a positive correlation with the ALOS, which is greater with a greater Fisher grade (24.5 days more in Fisher 4 than in Fisher 1-2).

Follow-up and cost calculations exclude deceased patients [16] and those who were not adequately followed up [2], so that the calculations were performed with 209 patients (169 EV and 40 SC).

The total expenditure generated by these patients was 7,718,550€, of which 83% corresponds to the EV group. This represents an expense of 1,286,425€ per year. Of this expenditure, 68.1% corresponds to the hospitalization of the patient, 24.6% to the different interventions performed to treat ruptured aneurysm and 7.3% to follow-up. These percentages differ from the EV to the SC group. In this way, hospitalization costs are higher in the SC group and treatment and follow-up are higher in the EV group (Figure 3).

Considering only the first admission, surgical treatment is 6.7% more expensive than the endovascular one, due to the longer ALOS. When the follow-ups are added, the overall expenditure in the EV group exceeds the SC by 1.2%. When the retreatments are included, the mean expenditure per patient in the EV group is significantly higher than in the SC group (12.3% more expensive).

The average expenditure of embolization in the EV group was 6,585€, increasing to 10,500€ when retreatments were included. The total expenditure on embolization material reached 1,195,900€ (an average higher than 7,000€ per patient). In the SC group, the average cost per intervention was 3,810€ (this group did not require retreatments). Considering only the intervention to ensure the aneurysm, the endovascular treatment is 176% more expensive than the surgical one (Figure 4).

Discussion

The controversy regarding the treatment of brain aneurysms has been and still is, a major point in Neurosurgery. The EV treatment has gained acceptance and nowadays most of the aneurysms are treated by endovascular procedures. This treatment is less aggressive and easier to perform than the surgical, but it is also less stable and the material s more expensive. We hypothesize that the expenses of EV treatment are bigger than the SC and there is no difference in clinical

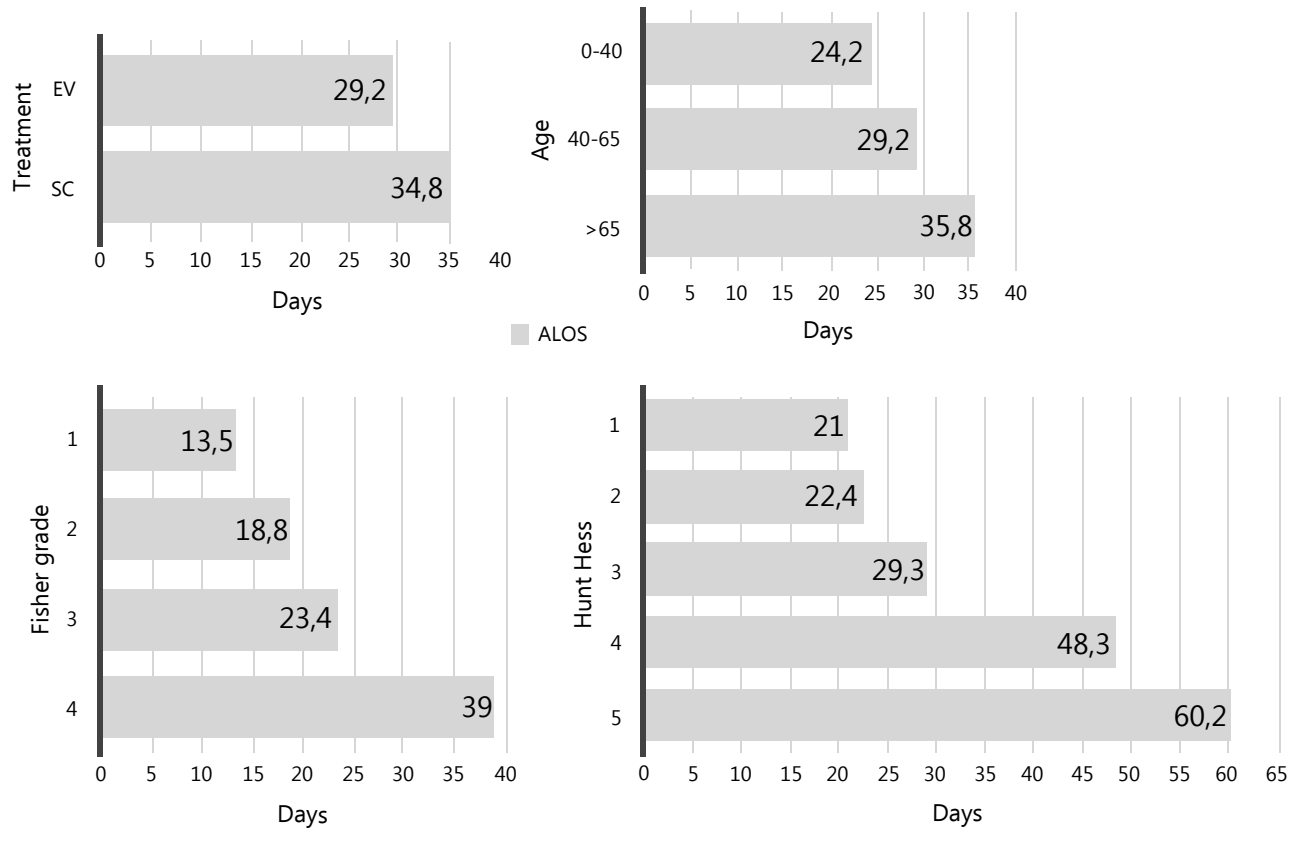

Figure 2: Influence of factors in the ALOS. In this figure the influence of modality of treatment, age, initial Hunt-Hess and Fisher grade in CT scan on the ALOS is represented

		Total	EV	SC
Age		55.6 (18-87)	56.5 (18-87)	51.5 (25-81)
Gender (F:M)		2.2	2.3	2.1
Follow Up (Months)		44 (7-78)	43.4 (7-77)	55 (25-78)
Hunt-Hess	1	16.6%	16.8%	17%
	2	39.7%	39.8%	40.2%
	3	20.1%	19.4%	19%
	4	16.2%	16.7%	16.4%
	5	7.4%	7.3%	7.4%
Fisher	1	5.7%	5.2%	5.3%
	2	14.8%	15.2%	15.4%
	3	24.5%	24.1%	24.3%
	4	55%	55.5%	55%
AneurysmLocation	Ant circ	86.6%	85.9%	90%
	Post circ	13.4%	14.1%	10%
Size	<5 mms	41.3%	40%	47.5%
	5-10 mms	47%	46.8%	47.5%
	>10 mms	11.7%	13.2%	5%

Table 2: Clinical and angiographic characteristics of the series

		TOT	EV	SC
Mean stay (days)	ICU	7.7	7.5	9
	Ward	22.3	21.6	25.8
	Total	30	29.1	34.8
GOS 6 months	1	7.9%	9.6%	0%
	2	3%	2.6%	5%
	3	17.9%	18.5%	15%
	4	19.7%	18.5%	25%
	5	51.5%	50.8%	55%
Angiography	Complete occlusion	56.4%	50%	86.6%
	Neck remnant	44.6%	50%	13.4%
	Recanalisation	24.9%	24.9%	0%
	Retreatment	16.9%	19.5%	0%

Table 3: Mean stay, clinical and angiographic results

results.

The ISAT study meant a milestone in the management of intracranial aneurysmal pathology [17]. According to those results the morbimortality of the SC versus the EV treatment advised the last one as the first treatment option. After its initial impact, subsequent studies [1,3-5,18] showed different bias in this study (selection of surgeons and cases, stratification of results) and the same group published later another study with results of this same series after 5 years in which the supposed advantage of endovascular treatment was diluted, mainly due to cases of rebleeding and retreatment of the endovascular group [5]. Rebleeding occurs sometimes in embolized aneurysms and has high morbidity and mortality with a rate around 2% [4,16,19], closely related to the degree of occlusion of the aneurysm. Rebleeding uses to appear more often in the first year after treatment, but late rebleeding is possible [20].

Nowadays, it is possible to say that the clinical results of both techniques are similar in expert hands, with the endovascular techniques in their favor the less aggressiveness of the procedure and the surgical ones their stability along time.

Incomplete occlusion is frequent in endovascular treatments, with percentages that in the best and most populated series are around 25% [19, 21-23]. Total occlusion in surgical cases is more common, around 95% [24]. Incomplete occlusion does not imply retreatment, but evolution of the neck remains unpredictable, requiring a prolonged follow-up [25, 26]. Recanalization is estimated around 15-20% of treated cases [4,16,17,22] and are described even very late in the follow up, requiring most of the times retreatment.

Lower stability of the EV makes that the follow-up of treated patients by this technique have to be more tight and prolonged, with routinely arteriographies and serial image tests over long periods of time. For costs calculation of this therapeutic modality it is necessary to include the expenses derived from this follow-up, which involve readmissions and invasive tests, in addition to those costs generated by the retreatments. To date there is no consensus about how long these patients should be followed.

In the literature there are several studies that try to elucidate which of the two treatments is the most economical in broken aneurysms. Characteristics and results of this publications are summarized in Table 4. Most of them do not take into account follow-up or retreatments when calculating costs. Some works are indirect studies based on previously published series [6,8,9,13,24] while others are based on patient series [10,11,14,18]. Most of the papers do not include the expenses of follow up and retreatment. From the literature review, it can be deduced that costs of EV are generally higher than SC and in those publications which differ, costs of follow-up and retreatment are not included, an important part of the overall expenditure per patient.

It is interesting to mention the work of Zubair et al. [26] that studied costs of both treatment including 6 months of follow-up

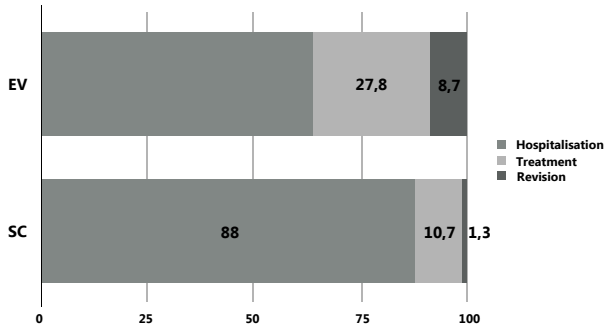

Figure 3: Distribution of expenditure. This figure represents the percentage of expenditure ofthe total costs of different items in each modality of treatment. The weight of hospital stay is more important in surgical clipped cases

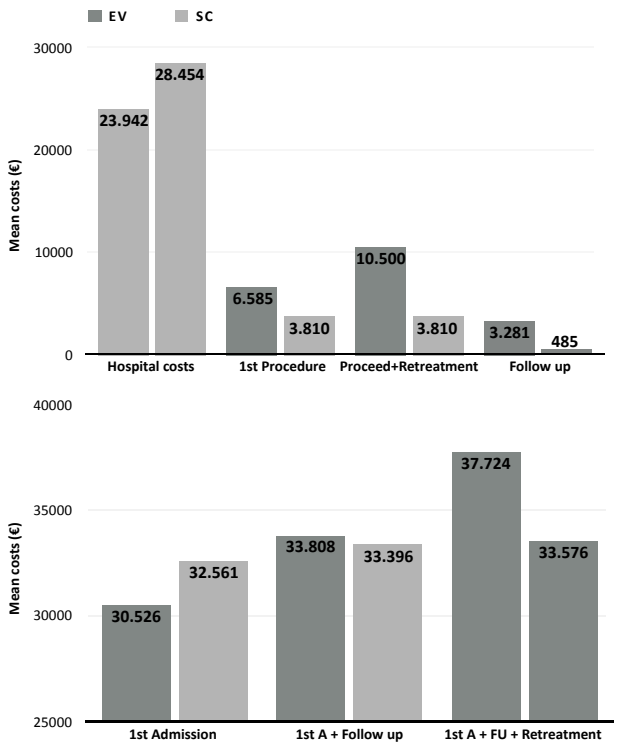

Figure 4: Mean costs. The bar chart on the left represents the mean total costs of each modality of treatment in different situations: at first admission, admission and follow up, and admission, follow up and retreatment. The right bar chart represents the mean total costs in each modality of treatment related to hospital stay and the procedure (embolisation or surgical clipping) without and with re-treatment

in 55 patients in a Pakistani hospital, concluding that EV is 62.5% more expensive than SC, without morbimortality results had favored to one or another group. It was mainly due to the fact that cost of hospitalization was relatively low, so the increase in hospital stay generated by the surgery (2 more days on average) did not impact on the final expenditure as the embolization materials. They pro- posed a decision algorithm based on the evaluation of a series of factors (patient age, Hunt-Hess, location and size of aneurysm), in order to the final recommendation taking into account risks associated with clipping and inherent costs to embolization (Figure 5).

Current series does not present clinically significant differences between the two groups in terms of age, sex, clinical status at admission or Fisher grade. Clinical results were similar in both groups, with a better result in the surgical series although the number of patients did not allow obtaining significant conclusions. Results were related to age, initial Hunt-Hess score and Fisher grade (Figure 1). Relationship of results with age has been established in other studies, such as Koffiberj et al. [14].

Complete occlusion rate of aneurysm is higher in SC group (88.6% versus 50%) as well as the stability of treatment. In EV group, a recanalization rate of around 25% and a retreatment rate of around 20% were recorded. It is interesting to highlight that both re- canalization and retreatment were more common in large aneurysms, as well as that the retreatment rate is above average in aneurysms whose surgical risk is relatively low, (MCA, PCom or CoA).

The ALOS was related to patient's age, HH and Fisher grade (Figure 2).

Regarding costs generated, results of these series indicate that EV, as a procedure, is considerably more expensive than SC (73% more expensive), a difference greater when retreatments are included (175% more expensive). This fact compensates the expenses derived from hospitalization between both modalities, which are on average 19% more expensive in SC, so that the cost of the first admission is discreetly favorable to EV (6% cheaper). However, this benefit is diluted over time because of follow-up and especially retreatments, so that the expenditure per patient including only follow-up is 1.2% higher in the EV group, a difference that is increased after including retreatment, where expenditure in the EV group is 12.4% higher (Figure 4). This difference should be higher if a correct follow up had been made.

In this series, as in others published in literature, the procedure itself constitutes a substantial part of the expenditure in endovascular group, specifically 27.8%, whereas in surgical group hospital stay generates more than 88% of expenditure (Figure 3). Price of embolization materials is mainly responsible for this high cost, which is significantly higher when, in addition to coils, stents or flow diverters are used.

It looks like evident that EV is advantageous in certain aneurysms, such as posterior circulation and especially in the vertebrobasilar segment, whereas the clinical results of surgical treatment are excellent in anterior-circulation aneurysms[6], with the advantage of its stability, therefore, generalizing and proposing surgical treatment in all aneurysms is not reasonable. Size of the aneurysm is directly related to the cost of the procedure, so Zubair et al. [26] recommended surgical treatment for those cases of large aneurysms and favorable surgery. Following the model of Zubair (Figure 5), it could be estimated the savings that would occur in current series by selecting cases for surgical or endovascular treatment based on age, clinical status and complexity and size of the aneurysm. With these parameters, surgical treatment would be indicated in 48% of the patients in this series, compared to 18.3% in those that were performed. This means that, after adjusting the average costs per patient in this series of both techniques, these new percentages gives a total expense of 7,469,516€, about 250,000€ less than the expenditure finally realized (42,000€ per year).

RISK FACTORS		Pts
AGE	<40	1
	40-60	2
	>60	3
ANEURYSM LOCATION	Simple anterior circulation	1
	Complex anterior circulation or simpleanterior circulation	2
	Complex posterior circulation	3
HUNT-HESS	Grade 1	1
	Grade 2-3	2
	Grade >3	3

ANEURYSM SIZE	POINTS		
	1-3	4-6	7-9
<5 mms	Clip	Coil	**COIL**
>5 mms	**CLIP**	Clip	Coil

Bold: strong recommendation
Normal: recommendation

Figure 5: Zubair's score system [26]. The recommendation for surgery or endovascular treatment is based on aneurysm size and location, age and Hunt Hess grade

Author Year published	Country Year study	Design (nº cases EV, SC)	Results	FU and retreatment included	Details
Bairstow 2002	Australia 1999	Hospital (12, 10)	SC > EV	No	Ruptured ISAT patients
Javadpour 2005	Canada 1998-2002	Hospital (32, 10)	SC = EV	No	Ruptured ISAT patients
Wolstenholme 2008	Reino Unido 1997-2002	National (835, 809)	SC = EV	Yes (6 months)	Ruptured ISAT patients
Maud 2009	USA 2005-2006	International (1070-1073)	SC < EV	Yes (1 year)	Ruptured ISAT patients
Hoh 2009	USA 2005-2007	Hospital (306, 259)	SC < EV	No	Ruptured and unruptured
Zubair 2009	Pakistan 2004-2007	Hospital (25, 18)	SC < EV	Yes (6 months)	Ruptured
Hoh 2010	USA 2005-2006	National (6019, 3616)	SC > EV	No	Ruptured and unruptured
Brinjikjii 2012	USA 2001-2008	National (5870, 4553)	SC > EV	No	Ruptured
Chang 2016	South Korea 2010-2014	National (21049, 24620)	SC < EV	No	Ruptured and unruptured
Ridwan 2016	Germany 2007-2009	Hospital (55, 46)	SC > EV	Yes (12 months)	Ruptured

Table 4: Summary of works published to date on treatment costs in ruptured aneurysms

Abbreviations: SC: surgical clipping; EV: endovascular; FU: follow up

The presented series has limitations. First is that it is a retrospective study and expenditure estimations have been made using various sources and sometimes indirect methods. The second is that it does not evaluate the differences that in terms of labor reincorporation rate could exist between both treatments, the so-called loss of profit, which could influence in the savings generated by one or other technique.

Conclusions

In the shown series, the morbimortality results obtained by both treatments are similar, while the angiographic results and stability of SC are superior to EV.

Although the endovascular treatment has a shorter ALOS, the total cost is significantly higher, mainly due to the price of the embolization materials, the rate of retreatment and the follow-up required. An adequate selection of patients could improve the angiographic results, the rate of retreatment and thus save costs.

References

1. Mitchell P, Kerr R, Mendelow AD, Molyneux A. Could late rebleeding overturn the superiority of cranial aneurysm coil embolization over clip ligation seen in the International Subarachnoid Aneurysm Trial? J Neurosurg. 2008 Mar;108(3):437-442.
2. Andaluz N, Zuccarello M. Recent trends in the treatment of cerebral aneurysms: analysis of a nationwide inpatient database. J Neurosurg. 2008 Jun;108(6):1163-1169.
3. Bakker NA, Metzemaekers JD, Groen RJ, Mooij JJ, Van Dijk JM. International subarachnoid aneurysm trial 2009: endovascular coiling of ruptured intracranial aneurysms has no significant advantage over neurosurgical clipping. Neurosurgery. 2010 May;66(5):961-962.
4. Molyneux AJ, Kerr RS, Birks J, Ramzi N, Yarnold J, et al. Risk of recurrent subarachnoid haemorrhage, death, or dependence and standardised mortality ratios after clipping or coiling of an intracranial aneurysm in the International Subarachnoid Aneurysm Trial (ISAT): long-term follow-up. Lancet Neurol. 2009 May;8(5):427-433.
5. Spetzler RF, Mc Dougall CG, Zabramski JM, Nakaji P, Wallace RC. The Barrow Ruptured Aneurysm Trial: 6-year results. J Neurosurg. 2015 Sep;123(3):609-617.
6. Brinjikji W, Kallmes DF, Lanzino G, Cloft HJ. Hospitalization costs for endovascular and surgical treatment of ruptured aneurysms in the United States are substantially higher than Medicare payments. AJNR Am J Neuroradiol. 2012 Jan;33(1):49-51.
7. Halkes PH, Wermer MJ, Rinkel GJ, Buskens E. Direct costs of surgical clipping and endovascular coiling of unruptured intracranial aneurysms. Cerebrovasc Dis. 2006 Sep;11(2):86-91.
8. Chang HW, Shin SH, Suh SH, Kim BS, Rho MH. Cost-Effectiveness Analysis of Endovascular Coiling versus Neurosurgical Clipping for Intracranial Aneurysms in Republic of Korea. Neurointervention. 2016 Sep;11(2):86-91.
9. Hoh BL, Chi YY, Dermott MA, Lipori PJ, Lewis SB. The effect of coiling versus clipping of ruptured and unruptured cerebral aneurysms on length of stay, hospital cost, hospital reimbursement and surgeon reimbursement at the university of Florida. Neurosurgery. 2009 Apr;64(4):614-619.
10. Hoh BL, Chi YY, Lawson MA, MoccoF, Barker FJ. Length of stay and total hospital charges of clipping versus coiling for ruptured and unruptured adult cerebral aneurysms in the Nationwide Inpatient Sample database 2002 to 2006. Stroke.2010 Feb;41(2):337-342.
11. Javadpour M, Jain H, Wallace MC, Willinsky RA, Brugge T, et al. Analysis of cost related to clinical and angiographic outcomes of aneurysm patients enrolled in the international subarachnoid aneurysm trial in a North American setting. Neurosurgery. 2015 May;56: 886-894.
12. Koffijberg H, Buskens E, Rinkel GJ. Aneurysm occlusion in elderly patients with aneurysmal subarachnoid haemorrhage: a cost-utility analysis. J Neurol Neurosurg Psychiatry. 2011 Jul;82:718-727.
13. Maud A, Lakshminarayan K, Suri MF, Vazquez G, Lanzino G, et al. Cost-effectiveness analysis of endovascular versus neurosurgical treatment for ruptured intracranial aneurysms in the United States. J Neurol Neurosurg Psychiatry. 2011 Jul;82(7):727.
14. Zubair Tahir M, Enam SA, Pervez Ali R, Bhatti A, Ul Haq T . Cost-effectiveness of clip- ping vs coiling of intracranial aneurysms after subarachnoid hemorrhage in a developing country--a prospective study. Surg Neurol. 2009 Oct;72(4):355-360.

15. Wolstenholme J, Rivero-Arias O, Gray A, Molyneux AJ, Kerr RS, et al. Treatment pathways, resource use and costs of endovascular coiling versus surgical clipping after aSAH. Stroke. 2008 Jan;39:1171-1179.
16. CARAT Investigators. Rates of delayed rebleeding from intracranial aneurysms are low after surgical and endovascular treatment. Stroke. 2006 Jun;37:1437-1442.
17. Molyneux A1, Kerr R, Stratton I, Sandercock P, Clarke M, et al. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised trial. Lancet. 2002 Oct; 26;360(9342):1267-1274.
18. Bairstow P, Dodgson A, Linto J, Khangure M. Comparison of cost and outcome of endovascular and neurosurgical procedures in the treatment of ruptured intracranial aneurysms. Australas Radiol. 2002 Sep; 46:249-251.
19. Johnston SC, Dowd CF, Higashida RT, Lawton MT, Duckwiler GR, et al. Predictors of rehemorrhage after treatment of ruptured intracranial aneurysms: the Cerebral Aneurysm Rerupture After Treatment (CARAT) study. Stroke. 2008 Jan;39:120-125.
20. Sluzewski M, Van Rooj WJ, Beute GN, Nijssen PC. Latere bleeding of ruptured intra- cranial aneurysms treated with detachable coils. AJNR Am J Neuroradiol. 2005 Nov-Dec;26:2542-2549.
21. Murayama Y, Nien YL, Duckwiler G, Gobin YP, Jahan R, et al. Guglielmi detachable coil embolization of cerebral aneurysms: 11 years' experience. J Neurosurg. 2003 May;98:959-966.
22. Gallas S, Pasco A, Cottier JP, Gabrillargues J, Drouineau J, et al. A multicenter study of 705 ruptured intracranial aneurysms treated with Guglielmi detachable coils. AJNR Am J Neuroradiol. 2005 Aug;26(7):1723-1731.
23. Plowman RS, Clarke A, Clarke M, Byrne JV. Sixteen-year single-surgeon experience with coil embolization for ruptured intracranial aneurysms: recurrence rates and incidence of late rebleeding. Clinical article. J Neurosurg. 2011 Mar;114(3):863-874.
24. Thornton J, Debrun GM, AletichVA, Bashir Q, Charbel FT, et al. Follow-up angiography of intracranial aneurysms treated with endovascular placement of Guglielmi detachable coils. Neurosurgery. 2002 Feb;50(2):249-250.
25. Byrne JV, Sohn MJ, Molyneux AJ, Chir B. Five-year experience in using coil embolization for ruptured intracranial aneurysms: outcomes and incidence of late rebleeding. J Neurosurg. 1999;90:656-663.
26. Campi A, Ramzi N, Molyneux AJ, Summers PE, Kerr RS, etal. Retreatment of ruptured cerebral aneurysms in patients randomized by coiling or clipping in the International Subarachnoid Aneurysm Trial (ISAT). Stroke. 2007;38:1538-1544.