Original research

Surgical and endovascular treatment for ruptured anterior circulation cerebral aneurysms: A comparison of outcomes — A single centre study from Taiwan

Chen-Chieh Liao, Yu-Hua Huang, Peng-Hsiang Fang, Tao-Chen Lee*

Department of Neurosurgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan

ARTICLE INFO

ABSTRACT

The purpose of this 2-year retrospective study is to compare the outcomes of patients with either surgical clipping or endovascular coiling treatment for ruptured anterior circulation cerebral aneurysms. We enrolled 100 patients with spontaneous subarachnoid hemorrhage resulting from ruptured anterior circulation cerebral aneurysms. We reviewed the demographic information, operative details, and image examinations including computed tomography (CT), digital subtraction angiography, and magnetic resonance imaging of brains. The patients were subdivided into two groups on the basis of treatment modalities: surgical clipping ($N = 44$) or endovascular coiling ($N = 56$). The modified Rankin's scale (mRS) was used as an outcome measures. Unfavorable outcome was defined by a mRS score of $1-3$. The mean age of 100 patients, comprising 35 men and 65 women, was 57.48 ± 12.68 years. The follow-up period was 18.91 ± 13.05 months in average. The differences between the clipping and coiling groups in terms of admission Glasgow Coma Scale, Hunt and Hess grade, World Federation of Neurosurgical Societies grade, and Fisher's grade by CT scans were not statistically significant. There was no intergroup difference in the following results: symptomatic or radiographic vasospasm, post-treat rebleeding, and recurrence of aneurysms. Although the incidences of unfavorable outcome at the end of follow-up were 32.0% and 27.0% in the clipping and coiling group respectively, it revealed no significant difference ($p = 0.202$). In dealing with the patients with ruptured anterior circulation cerebral aneurysms, our results provide helpful information when discussing projected outcome before surgical or endovascular treatment.

© 2013 Surgical Associates Ltd. Published by Elsevier Ltd. All rights reserved.

1. Introduction

Acutely-ruptured cerebral aneurysms are a devastating disease because of the high morbidity and mortality rates. The 30-day death rate among all patients who suffered subarachnoid hemorrhage (SAH) was up to 45%, with the majority of deaths occurring in the first days after hemorrhage.[1] At present time, there is significant progression in dealing with acutely-ruptured aneurysms, especially using the endovascular modality. In the recent literature, the endovascular treatment seems to have more benefit in selected patient groups, and is becoming as a favorable option.[2,3] Several studies conclude that endovascular treatment for ruptured cerebral aneurysms have better functional outcomes.[4–6] Historically, the surgical clipping is a standard procedure for anterior circulation cerebral aneurysms. Whether the role of surgery had been replaced by the endovascular modality remains uncertain. Moreover there is wide variability among cerebrovascular centers in the proportional use of these 2 methods for the treatment of ruptured aneurysms. Therapeutic outcomes may vary with respect to the available methods, and evaluation of clinical results should be individualized in each medical institute.

Consequently, in this study, we retrospectively collected clinical details and compared the outcomes between patients undergoing surgical clipping and endovascular coiling for acutely-ruptured anterior circulation aneurysms at our institute.

2. Materials and methods

From January 2008 to December 2009, 182 patients were diagnosed as spontaneous SAH resulting from ruptured cerebral aneurysms at Kaohsiung Chang Gung Memorial Hospital, a medical center in southern Taiwan. We included patients with anterior circulation cerebral aneurysms only, and exclude patients without

* Corresponding author. Department of Neurosurgery, Kaohsiung Chang Gung Memorial Hospital, 123 Ta Pei Road, Niao Sung District, Kaohsiung City, Taiwan. Tel.: +886 7 7317123x8011; fax: +886 7 7354309.

E-mail addresses: ccliao@adm.cgmh.org.tw (C.-C. Liao), newlupin2001@yahoo.com.tw (Y.-H. Huang), doctorcombine@yahoo.com.tw (P.-H. Fang), jukusei@gmail.com (T.-C. Lee).

treatment for aneurysms. Thence a total of 100 patients were enrolled for the analysis. The patients' charts were retrospectively reviewed after approval by the Institutional Review Board of our hospital. The characteristics of the patients were documented, including age, gender, Glasgow coma scale (GCS) score, Hunt and Hess grade, World Federation of Neurosurgical Societies (WFNS) grading scale, Fisher's grade by computed tomography (CT) scans.

All patients were initially admitted to the intensive care unit. The diagnosis of cerebral aneurysms was confirmed by digital subtraction angiography (DSA) or computed tomography angiography (CTA). The treatment modalities included surgical clipping or endovascular coiling of cerebral aneurysms. Suggestions regarding aneurysm treatment modality were made by a combined neurovascular team based on a combination of factors including aneurysm location, size and shape, patient age, and presence or absence of mass effect from hematoma. The patient or family made the ultimate decision for the option of treatment.

The diagnosis of symptomatic vasospasm was made on the basis of clinical judgment using the following criteria: (1) new or worsening of neurological deficit occurring between Days 4 and 14 after SAH, (2) no other identifiable cause for neurological worsening (such as hydrocephalus, bleeding, seizure, or metabolic disturbance. DSA, CTA, or magnetic resonance angiography for diagnosis of vasospasm was performed in selected patients. When there was clinical suspicion or imaging evidence for vasospasm, hypertensive hypervolemic therapy was instituted. Vasospasm management was uniform and did not differ according to the aneurysm treatment modality.

In patients who had endovascular coiling, follow-up studies consisting of skull x-ray films and either a magnetic resonance angiogram (MRA) or a DSA were obtained at 3-month, 6-month, and 1-year intervals. Skull x-ray films can show the status of coils, such as compaction or migration, that is not presented by MRA. Angiographic follow-up after surgical clipping may be not mandatory if complete aneurysm obliteration was confirmed visually during operation. Recurrence of treated aneurysms was defined as reappearance or progression of aneurysm remnant that was identified angiographically.

Neurological outcome was assessed using modified Rankin's scale (mRS), and documented from medical charts by reviewing the discharge and last clinical record made by a physician or physical therapist. For use as the dichotomous variables, unfavorable and favorable outcomes were defined by mRS of 1–3 and 4–5, respectively.

Separate statistical analyses were performed. Categorical variables were analyzed by the chi-square test or Fisher's exact test. The continuous variables were compared by the Student's t test or Wilcoxon's rank sum test. A p value of less than 0.05 was considered to be statistically significant. All statistical analyses were conducted using the Statistics Package for Social Science software, version 12.0.

3. Results

The 100 patients (35 males and 65 females) with ruptured anterior circulation cerebral aneurysms had a mean age of 57.48 ± 12.68 years. The mean duration of follow-up was 18.91 ± 13.05 months. Forty-four patients underwent surgical clipping for cerebral aneurysms and 56 patients were treated by endovascular coiling. The clinical characteristics of the clipping and coiling groups are compared as below.

Differences in the gender ($p = 0.642$) and mean age ($p = 0.704$) were not statistically significant. The incidence of the presenting symptoms in the 2 groups revealed no differences in the case of headache ($p = 1$), neck rigidity ($p = 0.052$), nausea or vomiting ($p = 0.097$), seizure ($p = 1.000$), or conscious change ($p = 0.705$). The prevalence of underlying diseases including hypertension, diabetes mellitus, or stroke was similar between the clipping and coiling subjects. As to admission GCS score, Hunt and Hess grade, or WFNS grade, there was no statistical difference.

The features of the CT scans at admission showed no significant differences for the presence of subarachnoid hemorrhage ($p = 1.000$), intraventricular hemorrhage ($p = 0.953$), intracerebral hemorrhage ($p = 0.235$), or acute hydrocephalus ($p = 0.54$). According to the Fisher's grade, the number of all patients with scores 1, 2, 3, and 4 were 7, 11, 62, and 20, respectively, and the distribution in the clipping and coiling groups was similar ($p = 0.296$). The baseline clinical features and neuro-imaging findings of the two groups are compared in Table 1.

Regarding the location of ruptured aneurysms, there were 38 anterior communicating arterial aneurysms, 24 posterior communicating arterial aneurysms, and 14 middle cerebral arterial

Table 1
Comparisons of clinical characteristics of patients undergoing clipping or coiling treatment.

	Total cases	Clipping	Coiling	P value
	N = 100	N = 44	N = 56	
Mean age (year)	57.48 ± 12.68	56.93 ± 13.75	57.91 ± 11.89	0.704
Gender				0.642
Male	35 (35%)	17 (39%)	18 (32%)	
Female	65 (65%)	27 (61%)	38 (68%)	
Medical history				
Hypertension	45 (45%)	15 (34%)	30 (54%)	0.082
Diabetes mellitus	4 (4%)	2 (5%)	2 (4%)	1
Stroke	1 (1%)	0 (0%)	1 (2%)	1
Presenting symptoms				
Headache	81 (81%)	36 (82%)	45 (80%)	1
Nausea/vomiting	20 (20%)	5 (11%)	15 (27%)	0.097
Neck rigidity	14 (14%)	10 (23%)	4 (7%)	0.052
Consciousness change	51 (51%)	21 (48%)	30 (54%)	0.705
Seizure	2 (2%)	1 (2%)	1 (2%)	1
GCS at admission				0.843
3-5	9 (9%)	5 (11%)	4 (7%)	
6-8	15 (15%)	7 (16%)	8 (14%)	
9-15	76 (76%)	32 (73%)	44 (79%)	
Hunt and Hess grade				0.661
1	23 (23%)	10 (23%)	13 (23%)	
2	42 (42%)	18 (41%)	24 (43%)	
3	22 (22%)	8 (18%)	14 (25%)	
4	9 (9%)	6 (14%)	3 (5%)	
5	4 (4%)	2 (5%)	2 (4%)	
WFNS grade				0.856
1	47 (47%)	22 (50%)	25 (45%)	
2	18 (18%)	6 (14%)	12 (21%)	
3	1 (1%)	1 (2%)	0 (0%)	
4	22 (22%)	9 (20%)	13 (23%)	
5	12 (12%)	6 (14%)	6 (11%)	
Features of CT				
Subarachnoid hemorrhage	93 (93%)	39 (89%)	54 (96%)	0.235
Intraventricular hemorrhage	20 (20%)	7 (16%)	13 (23%)	0.513
Intracerebral hemorrhage	13 (13%)	9 (20%)	4 (7%)	0.096
Hydrocephalus	32 (32%)	16 (36%)	16 (29%)	0.54
Fisher grade				0.296
1	7 (7%)	5 (11%)	2 (4%)	
2	11 (11%)	4 (9%)	7 (13%)	
3	62 (62%)	28 (64%)	34 (61%)	
4	20 (20%)	7 (16%)	13 (23%)	
Hospital stay (day)	27.00 ± 22.04	29.84 ± 23.56	24.77 ± 20.71	0.255
Follow-up duration (month)	18.91 ± 13.05	13.81 ± 11.79	23.12 ± 12.64	0

aneurysms. Two patients had anterior cerebral arterial aneurysms at A2 segment and twenty-two patients had aneurysms in the other locations of intracranial internal cerebral arteries. Multiple aneurysms (more than 2 locations) were identified in two patients. The shape of ruptured aneurysms included: ninety-two saccular, seven fusiform, and one dissecting types (Table 2).

The mean hospital stay was 29.84 ± 23.56 days for patients undergoing aneurysm clipping and 24.77 ± 20.71 days for patients undergoing aneurysm coiling ($p = 0.255$). Among 100 patients, thirty-one cases encountered neurological deterioration which was compatible with symptomatic vasospasm during the period of hospitalization. Twenty-one cases had radiographic vasospasm that was proved by the follow-up angiographs. The incidence of symptomatic or radiographic vasospasm was similar in the clipping and coiling groups. There were 11 (25%) and 12 (21%) patients with hydrocephalus requiring ventriculoperitoneal shunt insertion in the clipping and coiling groups, respectively. Rebleeding of treated aneurysms occurred in 2 patients among the clipping group and 4 patients among the coiling group ($p = 0.692$). Recurrence of treated

Table 2
Clinical data of clipped and coiled aneurysms.

	Total cases	Clipping	Coiling
	N = 100	N = 44	N = 56
Location of aneurysm			
Anterior communicating artery	38 (38%)	14 (32%)	24 (43%)
Anterior cerebral artery (A2)	2 (2%)	0 (0%)	2 (4%)
Posterior communicating artery	24 (24%)	12 (27%)	12 (21%)
Middle cerebral artery	14 (14%)	12 (27%)	2 (4%)
Internal carotid artery	22 (22%)	6 (14%)	16 (29%)
Shape of aneurysm			
Saccular	92 (92%)	40 (91%)	52 (93%)
Fusiform	7 (7%)	3 (7%)	4 (7%)
Dissecting	1 (1%)	1 (2%)	0 (0%)
Number of aneurysm detected			
Single	90 (90%)	41 (93%)	49 (88%)
Multiple	10 (10%)	3 (7%)	7 (13%)

Table 3
Comparisons of clinical outcomes of patients undergoing clipping or coiling treatment.

	Total cases	Clipping	Coiling	P value
	N = 100	N = 44	N = 56	
Radiographic vasospasm	21 (21%)	8 (18%)	13 (23%)	0.714
Symptomatic vasospasm	31 (31%)	14 (32%)	17 (30%)	1
Rebleeding of treated aneurysm	6 (6%)	2 (5%)	4 (7%)	0.692
Recurrence of treated aneurysm	8 (8%)	1 (2%)	7 (13%)	0.075
Mortality at discharge	9 (9%)	3 (7%)	6 (11%)	0.727
Mortality at the end of follow-up	10 (10%)	4 (9%)	6 (11%)	1
Unfavorable outcome at discharge	40 (40%)	18 (41%)	22 (39%)	1
Unfavorable outcome at the end of follow-up	33 (33%)	14 (32%)	15 (27%)	0.303

aneurysms was found in 1 and 7 patients undergoing clipping and coiling aneurysms respectively ($p = 0.075$). Overall mortality rate after the treatment of aneurysms was 9% at discharge and 10% at the end of follow up. There was no statistically significant inter-group difference in terms of mortality rate. The unfavorable outcome at discharge or at the end of the follow-up was not different between the clipping and coil groups (Table 3).

4. Discussion

Ruptured cerebral aneurysm with SAH is a critical condition, and poses a public health problem. Whether ruptured aneurysms should be treated surgically, or managed endovascularly is a complicated judgment. All the factors that support the treatment of an aneurysm with either clipping or coiling are important for the clinicians. In general, aneurysms in the posterior cerebral circulation are frequently more difficult to treat with surgery. Comparative observational studies have found better outcomes after coil embolization in these locations,[7,8] and endovascular method has become a widely accepted alternative treatment. However, in cases with anterior circulation aneurysms, either method may be appropriate, and the decision is influenced by difficult-to-access variables such as patient preference or operator availability or expertise. As a result, the optimal management and outcome of ruptured anterior circulation aneurysms is not easily determined.

The ISAT study demonstrated that, for the study population, endovascular treatment resulted in patients suffering fewer poor clinical outcomes at 1 year compared with patients who underwent surgical clipping.[5] The independent survival benefit of coiling continues for at least 7 years.[9] Although the study assessed 9559 patients, only 2143 patients (22.4%) underwent randomization. The high exclusion rate may have been a reflection of the fact that not all aneurysms are suitable for coiling, rather than a selection bias against coiling among participating neurosurgeons.[10] In addition, the outcome evaluation in the subgroups of patients with anterior or posterior circulation aneurysms was not shown. Thus generalizing the findings in ISAT study to all intracranial aneurysms is not adequate.

The experience of a neurosurgeon and interventional radiologist is an important factor of the outcomes of aneurysm treatment, and better outcomes are presented when a high volume of procedures is performed.[11—13] Bardach et al. also reported better outcomes with surgeons who performed more than 30 craniotomies for aneurysms per year.[14] Based on these findings, regionalization of care for intracranial aneurysms is recommended, and the outcomes should be examined individually. In this series, the unfavorable outcome was 32% and 27% in clipping and coiling groups respectively, which

is close to the percentages reported in the literature.[5] Our analysis does not demonstrate the inter-group difference in the unfavorable outcome of patients with ruptured anterior circulation aneurysms after treatments.

The low incidence of total aneurysmal occlusion and recanalization of aneurysm is one of the major limitations of endovascular coiling. Henkes et al. demonstrated 1579 patients harboring 1811 aneurysms treated with endovascular coiling.[15] Their initial occlusion percentage in the group of 90—100 was finally achieved in 88.9% of cases with ruptured aneurysms. Generally, partial occlusion (50—90%) may provide some hemodynamic effects, but occlusion rate less than 50% is insufficient for hemodynamic and bleeding protection. In the report by Murayama et al., angiographically demonstrated complete occlusion was identified in 55% of aneurysms and a neck remnant was displayed in 35.4% of lesions.[16] Their overall recanalization rate was up to 20.9%, which was related to the size of the dome and neck of the aneurysm. In this study, it is not surprising that the recurrent rate of anterior circulation aneurysms was higher in coiled (13%) than in clipped groups (2%). As a result, we suggest that follow-up angiography is mandatory after embolization of ruptured anterior circulation aneurysms. Based on the American Heart Association Council, the timing of first post-coiling angiography should be performed one to six months after intervention.[17]

Because technology improves and newer avenues of treatment are introduced, there will be a continuing impetus toward less risky treatments. However, changes in clinical practices are often the result of gradual evolution rather than dramatic revolution. At present time, surgical clipping for ruptured cerebral aneurysms still cannot be replaced. For patients accompanied with high intracranial pressure or intracerebral hemorrhage, immediate decompression with definite treatment of aneurysms is required. Smaller aneurysms have the risk of aneurysm perforation during embolization, and are better treated with surgical clipping. Furthermore, the location of aneurysm is another one of the major factors in determining the best treatment method. In this study, the results demonstrate that the same neurological outcomes can be achieved in patients with ruptured anterior circulation lesions by use of surgical or endovascular modalities. As a result, for daily clinical practice and decision making, we suggested that coiling and clipping are to be considered equivalent in this population.

This study has several potential limitations. It was a retrospective review of preexisting data and suffers from the inherent limitations of such studies. Specifically, data collection through chart and imaging reviews is less complete and accurate than is planned research. Variations in the assessment of neurological status account for the observed differences in results. From a statistical standpoint, the number of patients is still relatively small, and the study may be underpowered to detect the significance of inter-group difference. In addition, the findings reflect the experience

of a single large urban medical center. Hence, the study may not be representative of all patients with ruptured anterior circulation aneurysms in other institutes. Even with these issues in the preliminary analysis, we consider that these data are useful as clinical decision and prognostic information for clinicians and families.

5. Conclusions

Our current study finds no difference in neurological outcomes between patients undergoing clipping as compared with coiling for ruptured anterior circulation aneurysms. The results provide helpful information when discussing projected outcome before surgical or endovascular management, and consistent assessment of the therapeutic results are important to offer evolving treatment options.

Ethical approval
None.

Funding
None.

Author contribution
Mr. Chen-Chieh Liao: literature review, data collection, writing and revising of the article.
Mr. Yu-Hua Huang: data analysis, study design and final approval of the article.
Mr. Peng-Hsiang Fang: data collection, revising and drafting of the article.
Mr. Tao-Chen Lee: study design and final approval of the article.

Conflict of interest
None.

References

1. Bederson JB, Connolly Jr ES, Batjer HH, Dacey RG, Dion JE, Diringer MN, et al. Guidelines for the management of aneurysmal subarachnoid hemorrhage: a statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. *Stroke* 2009;**40**:994–1025.
2. Qureshi AI, Janardhan V, Hanel RA, Lanzino G. Comparison of endovascular and surgical treatments for intracranial aneurysms: an evidence-based review. *Lancet Neurol* 2007;**6**:816–25.
3. Vanninen R, Koivisto T, Saari T, Hernesniemi J, Vapalahti M. Ruptured intracranial aneurysms: acute endovascular treatment with electrolytically detachable coils–a prospective randomized study. *Radiology* 1999;**211**:325–36.
4. Koivisto T, Vanninen R, Hurskainen H, Saari T, Hernesniemi J, Vapalahti M. Outcomes of early endovascular versus surgical treatment of ruptured cerebral aneurysms. A prospective randomized study. *Stroke* 2000;**31**:2369–77.
5. Molyneux A, Kerr R, Stratton I, Sandercock P, Clarke M, Shrimpton J, et al. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomized trial. *Lancet* 2002;**360**:1267–74.
6. McDougall CG, Spetzler RF, Zabramski JM, Partovi S, Hills NK, Nakaji P, et al. The Barrow ruptured aneurysm trial. *J Neurosurg* 2012;**116**(1):135–44.
7. Gruber DP, Zimmerman GA, Tomsick TA, van Loveren HR, Link MJ, Tew Jr JM. A comparison between endovascular and surgical management of basilar artery apex aneurysms. *J Neurosurg* 1999;**90**:868–74.
8. Johnston SC, Wilson CB, Halbach VV, Higashida RT, Dowd CF, McDermott MW, et al. Endovascular and surgical treatment of unruptured cerebral aneurysms: comparison of risks. *Ann Neurol* 2000;**48**:11–9.
9. Molyneux AJ, Kerr RS, Yu LM, Clarke M, Sneade M, Yarnold JA, et al. International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomized comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. *Lancet* 2005;**366**:809–17.
10. Britz GW. ISAT trial: coiling or clipping for intracranial aneurysms? *Lancet* 2005;**366**(9488):783–5.
11. Barker II FG, Amin-Hanjani S, Butler WE, Ogilvy CS, Carter BS. In-hospital mortality and morbidity after surgical treatment of unruptured intracranial aneurysms in the United States, 1996-2000: the effect of hospital and surgeon volume. *Neurosurgery* 2003;**52**:995–1007.
12. Berman MF, Solomon RA, Mayer SA, Johnston SC, Yung PP. Impact of hospitalrelated factors on outcome after treatment of cerebral aneurysms. *Stroke* 2003;**34**:2200–7.
13. Johnston SC. Effect of endovascular services and hospital volume on cerebral aneurysm treatment outcomes. *Stroke* 2000;**31**:111–7.
14. Bardach NS, Zhao S, Gress DR, Lawton MT, Johnston SC. Association between subarachnoid hemorrhage outcomes and number of cases treated at California hospitals. *Stroke* 2002;**33**:1851–6.
15. Henkes H, Fischer S, Weber W, Miloslavski E, Felber S, Brew S, et al. Endovascular coil occlusion of 1811 intracranial aneurysms: early angiographic and clinical results. *Neurosurgery* 2004;**54**:268–85.
16. Murayama Y, Nien YL, Duckwiler G, Gobin YP, Jahan R, Frazee J, et al. guglielmi detachable coil embolisation of cerebral aneurysms: 11 years experience. *J Neurosurg* 2003;**98**:959–66.
17. Johnston SC, Higashida RT, Barrow DL, Caplan LR, Dion JE, Hademenos G, et al. Committee on cerebrovascular imaging of the American Heart Association Council on Cardiovascular Radiology: recommendations for the endovascular treatment of intracranial aneurysms: a statement for healthcare professionals from the committee on cerebrovascular imaging of the American Heart Association Council on Cardiovascular Radiology. *Stroke* 2002;**33**:2536–44.