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Mortality and Morbidity of Aneurysmal Neck Clipping during the Learning Curve

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Objective : Young neurosurgeons need to focus on the mortality and morbidity of aneurysmal neck clipping to develop a personal experience with an initial series.
Methods : Total 88 aneurysms from 75 patients who underwent neck clipping by the same operator from 2001 to 2004 were reviewed. Patients were divided into three groups : first year (Group I), second year (Group II), and third year (Group III) in each group. Location of aneurysm, age, Fisher grade, Hunter-Hess grade (H-H grade), postoperative Glasgow outcome scale (GOS), and complications related to surgical procedures were evaluated with Chi-square and logistic regression analyses.
Results : Fourteen patients had complications related to surgery (18.7%). The major causes of mortality and morbidity related to surgery were cerebral infarction, hemorrhage and brain swelling due to intraoperative rupture, brain retraction and vasospasm. Among the 4 cases of mortality were 2 patients in Group I, 1 patient in Group II and 1 patient in Group III, and location of aneurysms were 2 internal carotid artery(ICA) and 2 posterior communicating artery(PCoA) aneurysms. There were 4 morbidity and new neurological deficits in Group I, 4 in Group II and 2 in Group III. Although mortality and morbidity during the learning curve had a statistical significance in H-H grade, age (>60 years old), and aneurysm location (especially ICA aneurysm) as variables, mortality mainly occurred in ICA and PCoA aneurysms.
Conclusion : Experienced supervision or endovascular approach should be considered for the treatment of ICA and PCoA aneurysms during the learning curve.

KEY WORDS : Aneurysmal neck clipping · Learning curve · Mortality · Morbidity.

Introduction

Despite the great evolution in diagnostic tools, critical care, and advances in microanatomy and microneurosurgery, ruptured intracranial aneurysms are still a major cause of death and disability in neurosurgical practice. Some of the well-known predictors of clinical outcomes in patients with ruptured aneurysms are preoperative clinical condition and the amount of subarachnoid blood[1,2,4,10,33,34]. Intraoperative aneurysm rupture(IAR) is a severe postoperative complication that has been associated with increased neurological deficits and increased mortality during the learning curve[1,15,29,34]. An important factor in decreasing IAR is individual surgical skill and experience[29,34]. Those neurosurgeons who started learning microsurgical techniques for cerebral aneurysms may retire from the field in the future because the surgical experience of cerebrovascular surgeons has been tempered by endovascular influences. As a result of these trends, even master neurosurgeons have had little opportunity to train their fellows and residents with posterior circulation[18]. Young neurosurgeons who are trained as endovascular surgeons or as hybrids who can practice both disciplines think that the mortality and morbidity during the learning curve can be used to measure the influence of surgical experience on the outcome of aneurysm surgery[9,13,18].

The mortality and morbidity related to surgery during the learning curve will be helpful in selecting the modalities of treatment and provide a shortcut to proficiency, which can be as demanding mentally as it is technically, although endovascular therapy for cerebral aneurysm also has a learning curve[7,8].

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Materials and Methods

Patients' selection

From January 2001 to March 2004, total 88 aneurysms from 75 patients underwent direct clipping by the same neurosurgeon who had experienced a few cases during his residency around 10 years before. Patient medical records were reviewed retrospectively. The authors divided the treated patients into the three groups : first, second and third-year group (Group I, II, III) respectively. Patients' demographic data, location, age, sex, presenting grade of subarachnoid hemorrhage(SAH) were also documented and assessed according to the clinical status of the three groups including H-H grade, Fisher grade, and postoperative GOS. We focused mainly on complications related to surgery, which resulted in mortality and morbidity with new neurological deficits. Postoperative follow-up duration ranged from 9 to 48 months, and mean postoperative follow-up duration is 24.8 months (Table 1).

Statistical analysis

For the statistical comparison, we performed a Chi-square test, logistic regression analysis using SPSS 12.0 for window. In all cases, differences in p values of less than 0.05 were considered to be statistically significant.

Results

There were 4 cases of morbidity with new neurological deficits in Group I (16.7%), 4 cases in Group II (16%) and 2 cases in Group III (7.7%). There were 6 cases of IARs in Group I, 4 in Group II and 3 in Group III, but there was no significant difference statistically (p=0.2593). There were 2 cases of mortality related to surgery in Group I, 1 in Group II, and 1 in Group III (Table 1).

The old aged group (AGE≥60) had a higher prevalence of IAR and hydrocephalus than the young aged group (AGE<60), but there were no statistically significant differences ($p>0.05$). However, GOS of the old aged group was poor and it was statistically significant ($p<0.05$) (Table 2).

On location, size, and other variable factors of the aneurysms, there

Table 1. Patient clinical characteristics of the three groups

	*Group I (n=24)	Group II (n=25)	Group III (n=26)
Mean Age	52.3	59.3	53.1
H-H grade	2.9	2.9	2.9
Fisher Grade	3.1	3.0	2.8
GOS(Post-operation)	3.9	3.0	3.7
Morbidity	4(16.7%)	4(16%)	2(7.7%)
Mortality	2(8.3%)	1(4%)	1(3.8%)
Aneurysm Size (mm)			
<6	6	13	18
6-15	20	14	12
>15	3	1	1
Location			
ACoA/ACA	12	9	17
MCA	6	8	8
PCoA	7	5	2
ICA	3	5	3
Posterior circulation	1	1	1
Rebleeding			
Pre-operation	2(8.3%)	2(8%)	3(11.5%)
Intra-operation	6(25%)	4(16%)	3(11.5%)
Post-operation	3(12.5%)	2(8%)	0(0%)
Hydrocephalus	6(25%)	4(16%)	3(11.5%)
Vasospasm	8(33.3%)	6(24%)	7(26.9%)
Infarction	7(29.1%)	8(32%)	6(23.1%)
Mean Follow-Up (month)	35.2	22.0	18.0

*Group I=first year, Group II=second year, Group III=third year. ACoA : Anterior Communicating Artery, ACA : Anterior Cerebral Artery, MCA : Middle Cerebral Artery, PCoA : Posterior Communicating Artery, ICA : Internal Carotid Artery

Table 2. Age comparison of the three groups

	Age < 60				Age ≥ 60			
	Total (n=51)	Group I (n=18)	Group II (n=14)	Group III (n=19)	Total (n=24)	Group I (n=6)	Group II (n=11)	Group III (n=7)
Mean Age	49.0	48.5	49.9	48.9	67.2	63.3	71.1	64.2
H-H grade	2.7	2.8	2.4	2.8	2.7	2.3	3.1	2.4
GOS (Post-operation)*	3.9	4.0	3.6	4.0	2.7	3.3	2.4	2.7
Morbidity (%)	11.1	20	0	28.5	16	0	33.3	0
Mortality (%)	3.7	5	7	0	8	16.7	0	14.2
Fischer Grade	2.9	3.2	2.8	2.8	3.0	3.2	3.2	2.7
Hydrocephalus	8	5	1	2	5	1	3	1
Vasospasm	11	1	4	6	3	0	2	1
Infarction	15	6	4	5	6	1	4	1

* $p<0.05$

Table 3. Location of aneurysms correlated with other factors

		H-H grade	GOS (postop)	Rebleeding			Vasospasm	Hydrocephalus	Infarction
				Pre-op	Intra-op	Post-op			
ACoA/ ACA	Total (n=29)	2.7	4.0	2	3	0	7	5	9
MCA	Total (n=17)	2.7	3.6	2	3	2	1	0	2
PCoA	Total (n=10)	2.6	2.7	1	4	1	2	2	3
ICA	Total (n=6)	3.3	*2.0	2	2	1	1	1	2
Multiple	Total (n=10)	2.4	3.8	0	2	1	2	3	4
Posterior circulation	Total (n=3)	3	2.7	0	1	0	1	2	2

* $p<0.05$

Table 4. Distribution of aneurysmal size between each group

	Small (<6mm)	Medium (6~15mm)	Large (>15mm)
	Total (n=37)	Total (n=46)	Total (n=5)
GOS (Post-operation)	3.4	3.7	2.8
Fisher Grade	3.0	3.0	3.2
Rebleeding			
Pre-operation	3	3	0
Intra-Operation	5	7	1
Post-operation	2	2	1
Hydrocephalus	4	6	1
Vasospasm	6	8	0
Infarction	9	12	0

* p>0.05

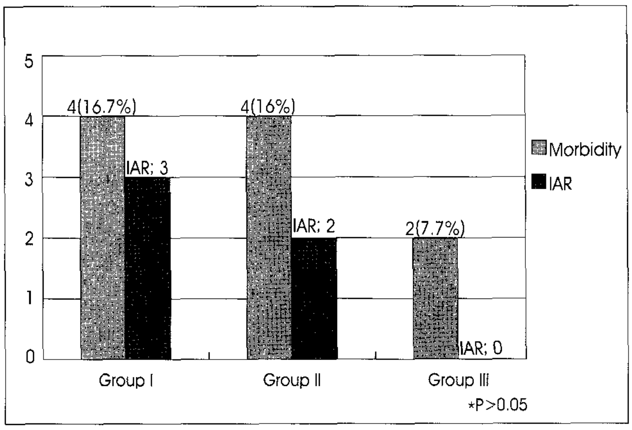

Fig. 1. Morbidity* with new neurological deficits and IAR in each group.

were no significant differences between Group I, II, and III. The aneurysm was located on the anterior communicating artery (ACoA), anterior cerebral artery(ACA) in 29 cases, the middle cerebral artery (MCA) in 17, posterior communicating artery (PCoA) in 10, ICA in 6, multiple sites in 10, and the posterior circulation in 3. The rates of IAR were 40% among PCoA, 33.3% in ICA, 11.7% in MCA, and 10.3% in ACoA/ACA aneurysms and there was no statistical difference. However, ICA was significantly related statistically to postoperative GOS (Table 3).

Thirty-seven aneurysms (42.0%) were small (<6mm), 46 (52.3%) were medium (6~15mm), and 5 (5.7%) were large (>15mm). There was no statistical significance between the size and postoperative GOS, complications, and IAR etc (Table 4).

Table 6. The outcome of ICA and PCoA aneurysms

	Favorable(n=13)	Morbidity(n=4)	Mortality(n=4)
Mean Age	57.7	58	56.3
H-H grade	2.6	2.3	3.3
GOS (Post-operation)	4.1	3.3	1
Aneurysm Size (mm)			
<6	6	2	1
6-15	7	3	4
>15	2	0	0
Aneurysm Location			
PCoA	9	2	3
ICA	6	3	2
Fisher Grade	3.0	3.0	3.5
Rebleeding			
Pre-operation	1	0	1
Intra-operation*	0	2	2
Post-operation	2	1	0
Hydrocephalus	2	1	0
Vasospasm	1	1	1
Infarction	5	2	0

* p<0.05

Table 7. Prognostic factors related to postoperative GOS

Factors	P value
Age≥60 versus <60*	0.0128
H-H grade1,2,3 versus 4,5*	0.0372
Fisher Grade 3 versus 1,2,4	0.0644
Intraoperative bleeding	0.2800
Postoperative bleeding	0.3523
Aneurysm location	
PCoA	0.0731
ICA*	0.0076
Hydrocephalus	0.2419
Vasospasm	0.3323
Infarction	0.2519

* p<0.05

There were 4 cases (16.7%) of morbidity with new neurological deficits in Group I, 4 (16%) in Group II and 2 (7.7%) in Group III, There was no statistical difference between all the variables of each group on logistic regression analysis (Fig. 1).

Among the 17 patients who had died after surgery, 9 had initial poor Glasgow Coma Scales with brain swelling, 3 had sepsis and 1 had disseminated viral pneumonitis with herpes simplex esophagitis. However, among the four patients who had mortalities related to surgery, 3 were caused by IARs and 1 by vasospasm. Two patients were in Group I, 1 in Group II, and 1 in Group III, and there were 2 ICA and 2 PCoA aneurysms (Table 5).

IAR related to the outcome of ICA and PCoA aneurysms had a

Table 5. Mortality related to surgery

		Age	H-H grade	Aneurysm Size (mm)	Fisher Grade	Aneurysm Location	Rebleeding
Group I	CASE 1	64	2	Medium	4	PCoA Left	Intra-operation
	CASE 2	47	4	Medium	3	PCoA Right, PCoA Left	Pre -operation & Intra-operation
Group II	CASE 3	49	3	Medium	3	ICA Left	Vasospasm
Group III	CASE 4	65	4	Small	4	ICA Right	Intra-operation

significant difference on univariate analysis but did not have any multivariate significance (Table 6).

Postoperative GOS during the learning curve was statistically influenced by ICA aneurysm, age and H-H grade (Table 7).

Discussion

The management of aneurysms requires difficult clinical, personal, and ethical decisions. For inexperienced neurosurgeons that are just beginning in medical practice, the difficulty of these decisions is compounded. The recent controversy between microsurgical clipping and endovascular coiling will likely remain unresolved for many years, even after completion of randomized prospective clinical trials, including the 2005 International Subarachnoid Aneurysm Trial(ISAT). Despite advances in coil technology and methodology, many aneurysms cannot be coiled simply[19,20,28,31]. These uncoilable aneurysms that are unsuitable to endovascular procedure continue to be treated with microsurgery.

In order to perform aneurysm surgery, a surgeon should be technically competent and inevitably overcome personal learning curves of skill and experience, but it is difficult to document gains in proficiency. Furthermore, surgical experience and skill with unestimated personal talent are not the sole factors in the clinical results[18,34].

According to a review of some literature, even hydrocephalus after aneurysmal rupture was influenced by several factors. Graff-Radford et al.[5] found the following were significantly related to clinical hydrocephalus : increasing age, intraventricular hemorrhage, level of consciousness at admission, subarachnoid blood noted on CT scan, and posterior circulation aneurysm site. In our study, the old aged group also had a higher incidence of hydrocephalus and the rate of hydrocephalus decreased from 25% in the first year to 11.5% in the third year during the learning curve, although there was no statistical significance[5,21,25,26,35]. Hwang et al.[14] considered that opening the lamina terminalis is an effective method for preventing the development of hydrocephalus after aneurysmal spontaneous SAH. The author had never done the fenestration of the lamina terminalis in the first year but did it among cases of acute hydrocephalus as well as some parts of poor graded patients in the second and third year.

Actually, we could have obtained lesser brain retraction and easy access of the target through the orbital or orbitozygomatic osteotomy during the first year on previous study[12,16,24,30]. We therefore thought that this approach might play a role in providing the same rate of morbidities between Group I (16.7%), Group II (16%), and even higher than in Group III (7.7%).

According to some literature, IAR occurs during aneurysm surgery in 7 to 40% of cases and was influenced by previous rupture but was not related with approach, size, hydrocephalus, operation time, and multiple aneurysms[1,3,4,15,33,34]. Our data showed that IAR was 17.3% did not have a statistically significant relationship to other variable factors including aneurysm size, Fisher grade, GOS, age, and hydrocephalus. Our study showed a higher incidence of IAR at PCoA and posterior circulation aneurysms (40%) and ICA (33.3%) than other sites, but in the study by van Lindert et al.[34], and other authors[3,29] basilar artery and anterior communicating artery aneurysms were especially prone to intraoperative rupture.

Sundt et al.[33] reported that aneurysm location is not uniformly recognized as a risk factor. It may be related to other intraoperative complications too, for example, inadvertent clipping or occluding of arteries and direct injury of neural structure like excessive brain retraction and surgical routes[4,30,34]. We also experienced direct optic nerve damage in Group III and postoperative intracerebral hematomas in all groups.

Our data showed that surgical experience and annual caseload inversely correlated with intraoperative rupture related to new neurological deficits. Especially, the mortality related to surgery had mainly developed at the location of ICA and PCoA, although the rate of IAR during the learning curve had decreased from 14% to 8% among ICA and PCoA aneurysms.

Hoh et al.[11] reported that poor outcome factors were age $\geq$50 years, Fisher Grade 3, H-H Grades 4 and 5, and symptomatic vasospasm. Lagares et al.[17] considered those factors showing a significant relationship with outcome in analysis (level of consciousness, age, Fisher grade of the first CT scan and size of the aneurysm). In our study, prognostic factors which were statistically significant on multivariate logistic regression test were old age (AGE$\geq$60), H-H grade and ICA aneurysm. However, on univariate test (Chi-square test), Fisher grade, IAR and the PCoA/posterior circulation aneurysms also had statistical significances, but on multivariate test they had no statistical significance. Our study showed that ICA, PCoA and posterior circulation aneurysms had relatively poor outcomes.

The only way to evaluate patient safety while progressing along the learning curve is to compare one's initial results with those of established neurosurgeons, If possible, during the leaning curve, one should be willing to stop an operation and consider the endovascular procedure for ICA and PCoA aneurysms in order to avoid the mortality related to direct clipping[6,10,11,27]. In the 2002 ISAT, most participating centers considered endovascular treatment as the favored option for posterior circulation aneurysms, particularly aneurysms arising from the basilar artery because of the high surgical risk[22]. According to the 2005 ISAT, endovascular treatment seems beneficial for all aneurysm locations, and is especially suitable for

ICA and posterior circulation aneurysms[23].

Lawton[18] stated that the learning curve is characterized by increased temporary clipping, better perforator dissection, and more sophiscated permanent clipping technique, and the path to proficiency can be as demanding mentally as it is technically. Otherwise, results from unruptured aneurysm treatment provide more direct information about the procedural risk because patients with this condition have minimal aneurysm-related impairment prior to treatment[32]. The few unruptured patients made us not attempt to compare direct procedural risk in our study. Furthermore, the true impact of surgical skill and the independence of the personal learning curve on the results of aneurysm surgery can only be established by a prospective randomized study with a large numbers of patients with comparable characteristics. Such a study is seldom to be feasible to us.

Conclusion

Although proficiency might be the object of young neurosurgeons, we suggest that coiling can be considered for better outcomes of ICA and PCoA aneurysms during the learning curve. We agree that the learning curve is characterized by increased temporary clipping, better perforator and neck dissection, and more sophiscated permanent clipping technique. The path to proficiency can be as demanding mentally as it is technically. Finally, we expect to compare the learning curve between surgery and endovascular procedure in the near future.

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Commentary

The author described a three-year personal experience in clipping of cerebral aneurysm as a young neurosurgeon. He divided the patients into 3 groups (1st year, 2nd year, 3rd year), and evaluated postoperative Glasgow outcome scale (GOS) and surgical complications. According to his analysis, the surgical mortality and morbidity was relatively higher in Group I, and ICA aneurysms. He concluded that supervision by an experienced neurosurgeon or endovascular treatment should be considered for the treatment of ICA aneurysms during the period of learning curve.

According to the role of endovascular treatment for aneurysm repair is growing, young neurosurgeons have less opportunity of microsurgical clipping of posterior circulation and ICA paraclinoid aneurysm especially. Like author's experiences microsurgical aneurysm clipping of posterior circulation or ICA aneurysms during the period of learning curve will result because of deep location and difficulties in handling of premature rupture.

The safety and early efficacy of endovascular treatment for aneurysm is well-known, but it has some pitfalls in the management of ICA aneurysms such as intra-procedural rupture, incomplete packing and recanalization though. We have several experiences that incomplete packing and recanalization are relative high in large/giant-sized aneurysms. Stent-assisted coiling is feasible, but physicians should be concerned about embolic complication and stenosis of parent artery.

Our first treatment option for ICA aneurysm is microsurgical clipping. Posterior communicating or anterior choroidal artery can be safely preserved under direct vision. Intraoperative aneurysmal rupture is the most fearful situation to young neurosurgeon. Suction decompression technique is helpful to avoid perforator injuries in case of large/giant ICA aneurysms. For successful dealing with the premature rupture, I'd like to recommend the internal carotid exposure in the neck before brain lobe retraction or anterior clinoidectomy. Improving better knowledge on cerebrovascular anatomy and various surgical tactics including atraumatic sylvian fissure dissection, gentle brain retraction, safe perforator dissection, more sophisticated permanent clipping, skull base techniques, and revascularization procedures is also necessary for better surgical outcomes.

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