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Surgical Treatment of Multiple Intracranial Aneurysms

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Summary

A retrospective review of 126 patients with multiple aneurysms seen over a 10 year period was undertaken. They had a total of 302 aneurysms. Thirty-seven percent of the patients were males, and 63% were females. Direct operations were performed on 97 cases. Both the ruptured and unruptured aneurysms were treated in 71% (69 of the 97 cases), and only the ruptured aneurysms were treated in 29% (28). In 69 cases in whom both ruptured and unruptured aneurysms were treated, one-stage operations were used for 48 cases, and two-stage operations were used for 21 cases. Thirty-four of the 48 cases, who were treated in one-stage operations, were operated on by day 4 after subarachnoid haemorrhage. In 12 cases, a total of 13 small unruptured aneurysms, which had not been found by preoperative angiograms, were discovered during surgery, and 9 of the 13 were discovered while removing blood clots to reduce cerebral vasospasm. Regardless of the operative method selected and the timing of operations, the surgical outcome of patients with multiple aneurysms was comparable to that of the 228 cases with single aneurysms treated during the same period at the same hospital.

The analysis of this study suggests that surgical results for multiple aneurysms are satisfactory, even for early operations. Further, the actual incidence of multiple aneurysms may be higher than has been reported to date because small unruptured aneurysms which have been discovered during clot removal may not have been reported.

Keywords: Multiple intracranial aneurysms; early operation; unruptured aneurysm; surgical outcome.

Introduction

While there are different opinions regarding the appropriateness of direct surgery on incidental unruptured aneurysms in patients with multiple aneurysms, surgery for such aneurysms is gradually becoming the accepted practice as the result of improved operative, anaesthetic, and management techniques. Recent papers on surgical treatment of unruptured asymptomatic aneurysms have demonstrated excellent surgical results; i.e., several series have reported operative mortalities of zero or only a few percent[8, 24, 25, 34, 36, 44].

Opinions regarding surgical indication for multiple aneurysms have changed. McKiossock *et al.*[21] in 1964, and Paterson and Bond[31] in 1973 thought that operations for unruptured aneurysms were not indicated. Heiskanen and Marttila[9] in 1970 advocated that only those unruptured aneurysms which could be reached through the same approach as the ruptured aneurysms should be operated on, and that a second operation would not be indicated. Hamby[6] in 1959, Poppen and Fager[32] in 1959, Moyes[27] in 1971, Mount and Brisman[24, 26] in 1971 and in 1977, and Samson *et al.*[36] in 1977 recommended that if conditions were satisfactory, all surgically accessible unruptured aneurysms should be operated on. Suzuki and Sakurai[37] in 1979, and Salazar[34, 35] in 1980 and in 1983 insisted that all of the multiple aneurysms should be considered for operation, even if a second operation were necessary to clip the unruptured aneurysms.

The main objectives of this study were to assess the surgical results for patients with multiple intracranial aneurysms, especially those who were operated on in the early stages after subarachnoid haemorrhage (SAH).

Material and Methods

During the 10 year period from 1979 to 1988, 478 patients who had suffered aneurysmal SAH were admitted to the Department of Neurosurgery of Shimane Prefectural Central Hospital. The subjects of the present study are 435 consecutive patients in whom the exact location of the ruptured aneurysm could be confirmed. With the calendar day of initial SAH considered as day 0, 59% (258) of the patients were admitted on day 0 and 88% (381) were admitted by day 7 (Fig. 1). Of the total 435 patients, 29% (126) had multiple aneurysms, and 71% (309) had single aneurysms. Of the 126 patients with multiple aneurysms, 37% (46) were males, and 63% (80) were females. The mean age was 60 years for the 126 patients, 53 years for males, and 64 years for females. The 126 patients with multiple aneurysms had 302 aneurysms. Ninety-one patients had 2 aneurysms,

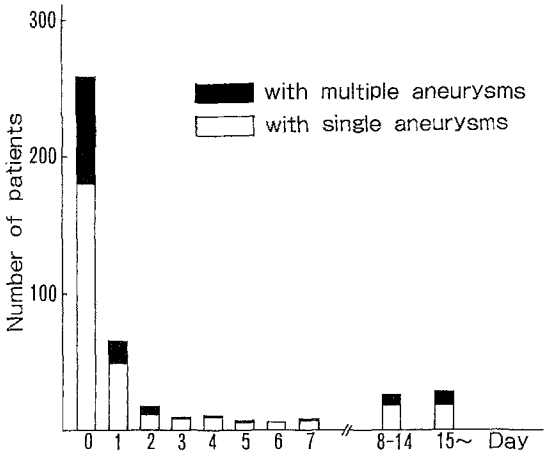

Fig. 1. Day of admission in relation to the initial subarachnoid haemorrhage, with the day of haemorrhage considered as day 0

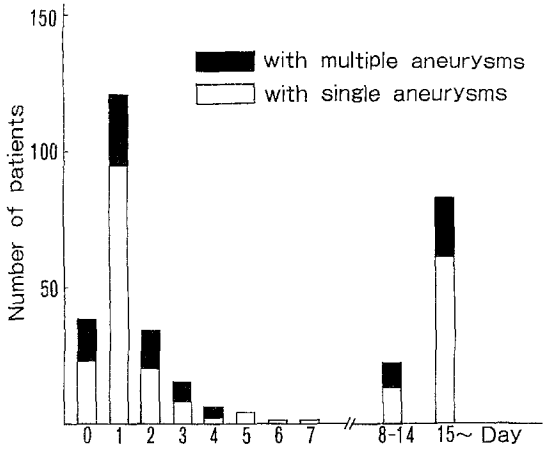

Fig. 2. Timing of first operation in relation to the initial subarachnoid haemorrhage, with the day of haemorrhage considered as day 0

24 had 3 aneurysms, 8 had 4 aneurysms, 2 had 5 aneurysms and 1 had 6 aneurysms. The percentage of the patients with 3 or more aneurysms were 28% for both males and females (13 of 46 patients and 22 of 80 patients). Of the 309 patients with single aneurysms, 45% (139) were males and 55% (170) were females. The mean age was 59 years for the 309 patients, 55 years for males, and 61 years for females.

In accordance with a policy of early operation for ruptured intracranial aneurysms of the anterior circle[11, 12, 15, 16], direct operations were performed on 75% of the 435 patients (325). This included 77% of 126 cases with multiple aneurysms (97) and 74% of 309 cases with single aneurysms (228). Figure 2 shows the interval between the initial SAH and the first surgery. Of the 325 surgical patients, 66% (214) were operated on by day 4 after the initial SAH. Each patient's preoperative clinical condition was graded according to Hunt and Hess[10] without modification. The 97 patients with multiple aneurysms, who were operated upon, were classified into three groups. Group 1 comprised 48 patients whose ruptured and unruptured aneurysms were treated by one-stage operations. Group 2 included 21 patients whose multiple aneurysms were treated by two-stage operations, i.e., initially, the ruptured aneurysms were operated upon, and then the unruptured aneurysms were treated by a second operation. Group 3 included 28 patients in whom only the ruptured aneurysms were operated upon. Group 1 patients were subdivided into three subgroups: (group 1-A) had unruptured aneurysms which were discovered fortuitously during surgery and treated; (group 1-B) had unruptured aneurysms which were discovered by preoperative angiograms, and were treated by the same approach as used for the ruptured aneurysms; and (group 1-C) had unruptured aneurysms which were discovered by preoperative angiograms, and treated by a different approach to that used for the ruptured aneurysms.

A study was made of the following two points: (1) relationships of the site of ruptured aneurysms to the site of unruptured aneurysms in groups 1 to 3, and (2) outcome at 1 year after the initial SAH.

The outcome was classified according to the Glasgow Outcome Scale[18]. Statistical analyses were done using the chi-square test.

Results

Table 1 shows the age distribution of patients with multiple or single aneurysms who were operated upon. The mean age was higher in group 3 than in the other groups; that is, 56 years for group 1, 59 years for group 2, 64 years for group 3, and 57 years for the patients with single aneurysms. Further, the rate of elderly patients aged 70 years or older was higher in group 3 than in the other groups. There were no significant differences between these groups in the preoperative clinical grades (Table 2).

1. Relationships of Site of Ruptured Aneurysms to Site of Unruptured Aneurysms in Groups 1 to 3

Tables 3 and 4 shows the relationships of the site of ruptured aneurysms to the site of unruptured aneurysms in groups 1 to 3.

In the 12 cases in group 1-A, 13 unruptured aneurysms were discovered during surgery. Most of these were tiny aneurysms a few mm in diameter on main trunks of the cerebral arteries. Therefore, while it was possible to clip 5 of the aneurysms, 8 of them were too small to clip and were wrapped or coated instead. Nine of the 13 aneurysms were discovered while removing clots during operations done by day 3 after SAH. In one case, after clipping a ruptured right internal carotid-posterior communicating artery aneurysm, a left unruptured internal carotid-ophthalmic artery aneurysm was discovered during the clot removal and then clipped; i.e., the unruptured aneurysm was clipped by a contralateral pterional approach[28]. In group 1-B, 19 of 28 cases were operated on by day 4 after SAH. In this group, there was a case in which a ruptured anterior communicating artery aneurysm and an unruptured basilar artery aneurysm were clipped by the same pterional approach. In group 1-C, 6 of the 9 cases were

Table 1. *Age Distribution in Surgical Patients*

With multiple or single aneurysms	Group	Age (years)			Total
		⩽59	60–69	⩾70	
Multiple	Group 1	29 (21) 60% (62%)	16 (12) 33% (35%)	3 (1) 6% (3%)	48 (34)
	Group 2	12 (8) 57% (57%)	6 (4) 29% (29%)	3 (2) 14% (14%)	21 (14)
	Group 3*	12 (5) 43% (28%)	5 (3) 18% (17%)	11 (10) 39% (55%)	28 (18)
Single		133 (89) 58% (60%)	63 (39) 28% (26%)	32 (20) 14% (14%)	228 (148)
Total		186 (123) 57% (57%)	90 (58) 28% (27%)	49 (33) 15% (15%)	325 (214)

Group 1: ruptured and unruptured aneurysms were treated by one-stage operations.
Group 2: multiple aneurysms were treated by two-stage operations.
Group 3: only the ruptured aneurysms were operated on.
Numbers in parentheses indicate patients who were operated on by day 4 after subarachnoid haemorrhage.
* The number of elderly patients aged 70 years or older is significantly higher in group 3 than in groups 1 and 2 and in patients with single aneurysms ($\chi^2 = 12{,}894$ and 11,377, both $p < 0.01$).

Table 2. *Preoperative Clinical Grades*

With multiple or single aneurysms	Group	Clinical grade*			Total
		I, II	III	IV, V	
Multiple	Group 1	30 (20) 63% (59%)	12 (8) 25% (24%)	6 (6) 13% (18%)	48 (34)
	Group 2	10 (6) 48% (43%)	8 (5) 38% (36%)	3 (3) 14% (21%)	21 (14)
	Group 3	13 (7) 46% (39%)	10 (6) 36% (33%)	5 (5) 18% (28%)	28 (18)
Single		131 (80) 57% (54%)	63 (41) 28% (28%)	34 (27) 15% (18%)	228 (148)
Total		184 (113) 57% (53%)	93 (60) 29% (28%)	48 (41) 15% (19%)	325 (214)

Group 1: ruptured and unruptured aneurysms were treated by one-stage operations.
Group 2: multiple aneurysms were treated by two-stage operations.
Group 3: only the ruptured aneurysms were operated on.
Numbers in parentheses indicate patients who were operated on by day 4 after subarachnoid haemorrhage.
* Hunt and Hess grades[10] without modification.
There are no significant differences.

operated on by day 4 after SAH, and in 3 of these cases, extensive clot removal was performed.

In the 21 cases of group 2, 6 unruptured aneurysms were located on vertebrobasilar arteries. In group 3, 61% of 33 unruptured aneurysms (20) were located on the internal carotid artery. Of the 20, 8 were on the C3 portion and 1 was on the C4 portion of the internal carotid artery, as named by Fischer[5]. The average max-

Table 3. *Relationship of Site of Ruptured Aneurysms to Site of Unruptured Aneurysms in Group 1*

Group	Site of ruptured aneurysms [No. of aneurysms]		Site of unruptured aneurysms				
			AComA	ACA	ICA	MCA	BA
Group 1-A	AComA	[1 (1)]				1 (1)	
	ACA	[2 (2)]	2 (2)				
	ICA	[8 (5)]		1	5 (4)	3 (1)	
	MCA	[1 (1)]	1 (1)				
Group 1-B	AComA	[10 (7)]		1 (1)	2 (1)	6 (4)	1 (1)
	ACA	[2 (1)]		2 (1)			
	ICA	[4 (4)]	2 (2)		2 (2)	1 (1)	
	MCA	[11 (7)]	5 (4)		2	4 (3)	
	BA	[1]				1	
Group 1-C	AComA	[4 (3)]			1 (1)	3 (2)	
	ICA	[3 (1)]		1		2 (1)	
	MCA	[2 (2)]		2 (2)		1 (1)	

Group 1: ruptured and unruptured aneurysms were treated by one-stage operations.
Group 1-A: unruptured aneurysms were discovered fortuitously during surgery, and then treated.
Group 1-B: unruptured aneurysms were discovered preoperatively and treated by the same approach as the ruptured aneurysms
Group 1-C: unruptured aneurysms were discovered preoperatively, and treated by a different approach as the ruptured aneurysms.
One case is classified into both groups 1-B and 1-C. Number in parentheses indicates number of patients who were operated on by day 4 after subarachnoid haemorrhage.
AComA anterior communicating artery; ACA anterior cerebral artery; ICA internal carotid artery; MCA middle cerebral artery; BA basilar artery.

Table 4. *Relationship of Site of Ruptured Aneurysms to Site of Unruptured Aneurysms in Groups 2 and 3*

Group	Site of ruptured aneurysms [No. of aneurysms]		Site of unruptured aneurysms				
			AComA	Distal ACA	ICA	MCA	VBA
Group 2	AComA	[6 (3)]		1	1	1	3
	ACA	[1 (1)]			1		
	ICA	[8 (4)]	1	3	3	6	2
	MCA	[6 (6)]		1	1	3	1
Group 3	AComA	[9 (4)]			6	3	
	ACA	[3 (3)]	1		2		1
	ICA	[4 (4)]			2	1	1
	MCA	[11 (7)]	1	1	10	3	
	VBA	[1]	1				

Group 2: multiple aneurysms were treated by two-stage operations.
Group 3: only the ruptured aneurysms were operated on.
Number in parentheses indicates number of patients who were operated on by day 4 after subarachnoid haemorrhage.
AComA anterior communicating artery; ACA anterior cerebral artery; ICA internal carotid artery; MCA middle cerebral artery; VBA vertebrobasilar artery.

imal dimension of these 9 unruptured internal carotid artery aneurysms was 3.7 mm, with a range of 2 to 7 mm.

2. *Outcome at 1 Year After Initial SAH*

The outcome was assessed at 1 year from the time of initial SAH in all of the 435 patients of this series.

Table 5 shows the surgical outcome in 325 patients with ruptured aneurysms. The operative mortalities in patients with multiple aneurysms were 10% in group 1, 0% in group 2 and 14% in group 3. Of the 228 patients with single aneurysms, 12% died. The surgical results in group 1 with multiple aneurysms was comparable to the results of patients with single aneurysms.

Table 5. *Surgical Outcome at 1 Year after Initial SAH*

With multiple or single aneurysms	Group	Outcome* at 1 year after initial SAH					Total
		GR	MD	SD	VS	Dead	
Multiple	Group 1	30 (22) 63% (65%)	3 (2) 6% (6%)	8 (4) 17% (12%)	2 (2) 4% (6%)	5 (4) 10% (12%)	48 (34)
	Group 2	16 (10) 76% (71%)	4 (3) 19% (21%)	1 (1) 5% (7%)	0 (0) 0% (0%)	0 (0) 0% (0%)	21 (14)
	Group 3	19 (12) 68% (67%)	3 (2) 11% (11%)	1 (0) 4% (0%)	1 (1) 4% (6%)	4 (3) 14% (17%)	28 (18)
Single		150 (92) 66% (62%)	25 (15) 11% (10%)	20 (16) 9% (11%)	6 (3) 3% (2%)	27 (22) 12% (15%)	228 (148)
Total		215 (136) 66% (64%)	35 (22) 11% (10%)	30 (21) 9% (10%)	9 (6) 3% (3%)	36 (29) 11% (14%)	325 (214)

Group 1: ruptured and unruptured aneurysms were treated by one-stage operations.
Group 2: multiple aneurysms were treated by two-stage operations.
Group 3: only the ruptured aneurysms were operated on.
Numbers in parentheses indicate patients who were operated on by day 4 after subarachnoid haemorrhage.
* Outcome measured by the Glasgow Outcome Scale[18].
There are no significant differences.
SAH subarachnoid haemorrhage; GR good recovery; MD moderate disability; SD severe disability; VS vegetative state.

Table 6. *Reasons for Nonoperative Treatment*

Reason	With multiple or single aneurysms		Total
	Multiple	Single	
Poor condition	10	47	57
Rebleeding	4	14	18
Vasospasm	1	3	4
Medical complication	8	6	14
Advanced age	4	5	9
Refusal	1	2	3
Other	1	4	5
Total	29	81	110

Also, of those patients who were operated on by day 4 after SAH, there were no major differences in the surgical results between the patients with multiple aneurysms and those with single aneurysms.

The reasons for nonoperative treatment are shown in Table 6. In both the patients with multiple and single aneurysms, the primary reason for nonoperation was the patient's poor condition due to the direct effect of aneurysmal rupture itself. The ultimate outcome of the inoperable patients was very poor regardless of the number of aneurysms (Table 7). Eighty-three percent of inoperable patients with multiple aneurysms and 88% of those with single aneurysm died within 1 year after the initial SAH.

The causes of death within 1 year after initial SAH are shown in Table 8. There were no patients who died from bleeding of unruptured aneurysms.

Discussion

The natural history of unruptured aneurysms, especially the risk of rupture, is not precisely known[3, 7, 17, 40, 41, 43]. Jane *et al.*[17] and Winn *et al.*[43] speculated that the annual risk of rupture of an unruptured asymptomatic aneurysm was similar to the natural history of the healed ruptured aneurysm. In patients with multiple aneurysms, the risk of bleeding from a previously unruptured aneurysm has been described as 10% to 17%[4, 7, 9, 24–27]. According to Heiskanen[7] and Winn *et al.*[42], in patients with multiple aneurysms, the annual risk of rupture of an intact aneurysm is approximately 1% per year, and the mortality rate is said to be 4% over a 5 year period[2, 26].

The incidence of diagnosed multiple aneurysms ranges from 5% to 33.5%, depending primarily on the completeness of the diagnostic procedures[12, 14, 21, 22, 29, 30, 32, 34, 35, 37, 39]. In general, the incidence of multiple aneurysms is a little higher in autopsy series than in

Table 7. *Outcome at 1 Year After Initial SAH in Non-Surgical Patients*

With multiple or single aneurysms	Outcome* at 1 year after initial SAH					Total
	GR	MD	SD	VS	Dead	
Multiple	2 7%	0 0%	2 7%	1 3%	24 83%	29
Single	7 9%	0 0%	1 1%	2 2%	71 88%	81
Total	9 8%	0 0%	3 3%	3 3%	95 86%	110

* Outcome measured by the Glasgow Outcome Scale[18].
There are no significant differences.
SAH subarachnoid haemorrhage; GR good recovery; MD moderate disability; SD severe disability; VS vegetative state.

Table 8. *Cause of Death Within 1 Year After Initial SAH in 126 Patients*

Cause of death	Operated		Unoperated	
	Multiple An	Single An	Multiple An	Single An
Direct effect	1	4	11	43
Rebleeding	1	2	6	16
Vasospasm	4	12	4	4
Medical complication	3	4	3	8
Surgical complication	0	1	0	0
Unrelated illness	0	2	0	0
Other	0	2	0	0

SAH subarachnoid haemorrhage; An aneurysm.

angiographic studies[2, 14, 21]. Furthermore, as clarified in this study, unruptured aneurysms of a few millimeters in diameter are sometimes encountered during operations, especially during clot removal in the acute stage. These tiny aneurysms are usually missed by preoperative angiograms. Even in autopsy examinations, they may be overlooked because the size of unruptured aneurysms in autopsy material decreases to about one half to three-fourths of their previous size when the patients were alive[20]. Therefore, the actual incidence of multiple aneurysms may be higher than those reported so far.

In group 1-A of this study, 13 tiny unruptured aneurysms were discovered fortuitously and treated. This suggests that surgeons should be mindful of the probability of the co-existence of unruptured aneurysms which cannot be discovered pre-operatively but can be found by surgeons as they remove clots during the acute stage after SAH. There were several combinations of aneurysms in group 1-B, including multiple aneurysms of the same artery, unilateral internal carotid artery combined with middle cerebral artery aneurysms, and an anterior communicating artery aneurysm in combination with a distal anterior cerebral artery aneurysm. One-stage operations in groups 1-A and 1-B are generally accepted as standard procedure. There were some combinations in group 1-C also: including bilateral internal carotid artery aneurysms, bilateral middle cerebral artery aneurysms, and a distal anterior cerebral artery aneurysm in combination with an internal carotid artery aneurysm or a middle cerebral artery aneurysm. In cases with bilateral internal carotid artery or middle cerebral artery aneurysms, bilateral craniotomy is necessary.

The surgical outcome in group 1 with multiple aneurysms was not statistically different from that for patients with single aneurysms, even for those patients whose operations were performed by day 4 after SAH. Recently, early operations for ruptured aneurysms have been attempted, usually within a few days after SAH,

not only to prevent rebleeding but also to remove subarachnoid blood clots to alleviate vasospasm[1, 11, 15, 23, 33, 38]. Furthermore, one-stage operations for multiple aneurysms in the acute stage after SAH have been attempted by some neurosurgeons[22, 37, 39]. Mizoi *et al.*[22] reported that the results of early one-stage operations in patients with multiple aneurysms were comparable to the results in patients with single aneurysms. To remove subarachnoid clots, extensive craniotomy is sometimes required[11, 15]. Furthermore, in patients with multiple aneurysms, whose unruptured aneurysms are small and are readily accessible, the risk of dissection or clipping of unruptured aneurysms seems to be basically similar to that as for the removal of blood clots surrounding the arteries. Therefore, when extensive clot removal is intended and unruptured aneurysms are situated in cisterns containing severe clots, the clipping of unruptured aneurysms seems to be indicated. When extensive clot removal is not intended, individual cases must be evaluated case by case.

In the 21 patients of group 2, there were no surgical deaths. Several authors have reported also that there was no operative mortality in patients with unruptured asymptomatic aneurysms treated by elective surgery[24, 25, 34, 36, 44]. There is no question that second operations can be performed with a very low mortality for morbidity on patients with multiple aneurysms when their ruptured aneurysms have already been clipped.

In the 28 patients of group 3, the main reasons why only the ruptured aneurysms were operated on and the unruptured aneurysms were not operated on are as follows. First, 39% of group 3 patients (11 of 28) were 70 years or older, and therefore at high risk. Second, 9 of 33 unruptured aneurysms in group 3 were relatively small and physically inaccessible, arising from the C3 or C4 portion of the internal carotid artery. Wiebers *et al.*[40, 41], in a clinical study, reported that unruptured saccular aneurysms of less than 10 mm in diameter have a very low probability of subsequent rupture. On the contrary, Kassel and Torner[19] stressed that unruptured aneurysms of less than 10 mm in diameter could not be considered innocuous, and that operation should be considered for lesions of more than 5 mm in diameter. Consequently, although the surgical risk of direct operations for multiple aneurysms seems to be similar to that of operations for single aneurysms, several factors, such as the patient's clinical condition and age[12, 16], and the site[12, 29, 39] and size[13, 14, 19, 40, 41] of the unruptured aneurysms should be taken into consideration before operating on the aneurysms.

Because of the introduction of contemporary microsurgical and anaesthetic techniques, the operative mortality and morbidity rates for unruptured asymptomatic aneurysms have been reduced progressively to near zero percent[8, 24, 25, 34, 36, 44]. In this study also, surgical results for multiple aneurysms are satisfactory, even for early operations by day 4 after SAH. Nevertheless, surgical indications for unruptured aneurysms should be considered carefully. In the future, with further advances in diagnostic techniques, unruptured asymptomatic aneurysms, which can be found now only in autopsy materials or during surgery, may become discoverable preoperatively. Furthermore, patients whose unruptured asymptomatic aneurysms are not likely to rupture, especially elderly patients with small aneurysms, may not need to be operated on. To evaluate the risks and benefits of operations upon unruptured asymptomatic aneurysms, continuing investigation is essential to know what kind of unruptured aneurysms are likely to rupture[12].

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