

Characteristics of Intracranial Aneurysms Associated with Moyamoya Disease A Review of 111 Cases

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Summary

A retrospective analysis of 111 patients with aneurysms associated with Moyamoya disease is presented. The subjects comprised of our 12 cases and 99 other well-documented cases. These 111 cases had 131 aneurysms. There were 48 males and 63 females. The average age was 40.3 years. The clinical manifestations were intracranial haemorrhage in 99 cases (89%), and ischaemic events in 9 cases (8%), but no mention was made of these in the last three cases (2%). The Hunt and Kosnik grades were grade 1 in 8%, grade 2 in 23%, grade 3 in 31%, grade 4 in 35%, and grade 5 in 3%. Of the 131 aneurysms, 73 (56%) were found distributed around the circle of Willis, 24 (18%) in the basal ganglia, 29 (22%) on collateral vessels, and 5 (4%) on other vessels. Forty-six percent of the cases were treated surgically, 51% conservatively, and 3% by endovascular procedures. The surgical procedures for the aneurysms were; neck clipping in 49%, aneurysmectomy in 18%, wrapping of the aneurysm in 11%, coating or cautery of the aneurysm in 7%, and revascularization only in 11%. The outcomes were Glasgow Outcome Scale 1 in 30%, 2 in 22%, 3 in 11%, 4 in 1%, and 5 in 25%. The main reasons for the unfavourable outcome were initial poor clinical grade and rebleeding. Follow-up angiography of 25 aneurysms demonstrated that all aneurysms in the basal ganglia or on the collateral vessels disappeared. We recommend surgical intervention for aneurysms associated with Moyamoya disease to prevent rupture or rebleeding, especially for aneurysms around the circle of Willis. However, direct surgery is not recommended for aneurysms found in the basal ganglia or on the collateral vessels.

Keywords: Aneurysm; Moyamoya disease; treatment.

Introduction

Moyamoya disease is a chronic cerebrovascular disorder of slow progressive occlusion of the major trunks of the intracerebral arteries; occlusion begins at the carotid artery in the cavernous sinus [39]. In children, the usual clinical manifestations are ischaemic events, such as recurrent transient ischaemic attacks or complete strokes. In adults, intracranial haemorrhage is the most common clinical manifesta-

tion [39]. In these cases, haemorrhages were revealed from the rupture of the aneurysms associated with Moyamoya disease. Clinically these associated aneurysms are quite different from the ordinary saccular ones [15–17, 40]. However, aneurysms associated with Moyamoya disease are uncommon, and studies from a single institution will not yield enough information for analysing the various aspects of these aneurysms. For the purpose of establishing the best management for aneurysms associated with Moyamoya disease, we investigated their clinical characteristics, treatment and outcome by analysing the data of our own institutions until June, 1994 and by doing a comprehensive review of the literature until May, 1995.

Patients and Methods

Eighty-one patients with Moyamoya disease were treated at Nara Medical University Hospital and its affiliated hospitals from January, 1983 to June, 1994. The angiographic findings of all cases were compatible with the diagnostic guidelines for Moyamoya disease proposed by the Ministry of Health and Welfare of Japan [26]. In 12 (15%) of the 81 cases, one or more aneurysms were found. These 12 cases of Moyamoya disease with 1 or more aneurysms in our present study are shown in Table 1. Ninety-nine well-documented cases of Moyamoya disease with aneurysm were picked from our literature search up to May, 1995. Of these cases, 75 (76%) showed Moyamoya vessels on carotid angiograms of both sides. The other 24 cases (24%) showed Moyamoya-like disease and had Moyamoya vessels on only one side. We reviewed and analysed our own 12 cases and 101 cases from the literature [2, 3, 5–25, 27–32, 34–38, 40, 44–46]. The outcome was evaluated by the Glasgow Outcome Scale (GOS) at discharge from the hospital or at 3 months from the surgery or onset; GOS 1 for good recovery, GOS 2 for moderately disabled, GOS 3 for severely disabled, GOS 4 for persistent vegetative stage, and GOS 5 for dead. The outcome was classified as favourable for cases with a GOS 1, 2 or 3, and as unfavourable for cases with GOS 4 or 5.

Table 1. Summary of Our Own 12 Cases

Case no.	Sex/Age (yrs)	H & K grade	Location of aneurysm	Surgical procedures for aneurysms, ICH and IVH (operative day)	Surgical procedure for future stroke (operative day)	GOS at 3 months
1	F, 49	3	BA top post. chor.	clipping (day 30)	bilateral STA-MCA with EMS (day 30, 58)	1
2	F, 60	1	BA-SCA	clipping (day 75)	–	3
3	M, 48	4	A-com	clipping (day 0)	–	5
4	M, 43	3	A-com	clipping (day 48)	STA-MCA with EMS (day 48)	1
5	M, 42	2	BA top	coating (day 23)	bilateral STA-MCA with EMS (day 23, 56)	1
6	M, 34	2	BA top	clipping (day 7)	–	1
7	F, 53	4	basal ganglia	aneurysmectomy (day 0)	–	5
8	F, 57	4	BA-SCA	clipping (day 50)	–	3
9	F, 57	3	basal ganglia	aneurysmectomy (day 0)	–	3
10	F, 51	2	IC-PC	clipping (day 20)	–	1
11	F, 49	3	BA-top	coating (day 18)	–	3
12	M, 52	2	post. chor.	VD (day 0)	bilateral STA-MCA with EMS (day 43, 72)	2

A-com anterior communicating artery, *BA* basilar artery, *EMS* encephalomyosynangiosis, *GOS* Glasgow outcome scale, *H & K grade* Hunt and Kosnik grade, *ICH* intracerebral haemorrhage, *IC-PC* internal carotid – posterior communicating artery, *IVH* intraventricular haemorrhage, *post. chor.* posterior choroïdal artery, *SCA* superior cerebellar artery, *STA-MCA* superficial temporal artery to middle cerebral artery anastomosis, *VD* ventricular drainage.

Results

Age and Sex

Of the 111 patients, 48 (43%) were male and 63 (57%) female. Their age ranged from 7 months to 68 years (mean age: 40.3 years). Patients in their fifties accounted for the majority (Fig. 1). The number of cases less than twenty years of age was 12 (11%).

Clinical Manifestations

Clinical manifestations were intracranial haemorrhage in 99 cases (89%) and ischaemic events in 9 (8%). No mention was made of these in the last three cases (3%). In the 99 haemorrhagic cases, the type of intracranial haemorrhage was mentioned. Subarachnoid haemorrhage (SAH) was seen in 73 cases (74%), intracerebral haemorrhage (ICH) in 33 (34%), and intraventricular haemorrhage (IVH) in 28 (29%). Some cases had more than one type of haemorrhage. In 86 haemorrhagic cases, the clinical onset and condition were stated in detail. The Hunt and Kosnik (H&K) grade of these 84 cases were grade 0 in 10 cases (12%), grade 1 in 7 cases (8%), grade 2 in 20 (24%), grade 3 in 27 (32%), grade 4 in 29 (35%), and grade 5 in 3 (4%).

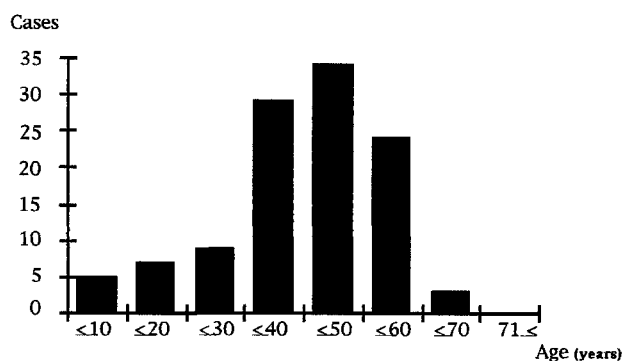


Fig. 1. Age distribution of the 111 cases having an aneurysm associated with Moyamoya disease

Number and Distribution of Aneurysms

One-hundred and eleven cases had 131 aneurysms. The mean number of aneurysms was 1.18 per patient. Ninety-five cases (86%) had one aneurysm, while the other 16 cases (14%) had two or more aneurysms. The distribution of the aneurysms was usually divided into three groups; around the circle of Willis, in the basal ganglia, and on the collateral vessels. Distribution of the 131 aneurysms was: 73 (56%) around the circle of Willis, 24 (18%) in the basal ganglia, 29 (22%) on the collateral vessels, and 5 (4%) on other

Table 2. *Distribution of the 131 Aneurysms in 111 Cases*

Around the circle of Willis	73 aneurysms (56%)
Internal carotid artery	16 aneurysms
Anterior communicating artery	7 aneurysms
Anterior cerebral artery	5 aneurysms
Middle cerebral artery	2 aneurysms
Basilar-bifurcation	25 aneurysms
Basilar-superior cerebellar artery	8 aneurysms
Posterior cerebral artery	10 aneurysms
In the basal ganglia	24 aneurysms (18%)
On the collateral vessels	29 aneurysms (22%)
Anterior choroidal artery	15 aneurysms
Posterior choroidal artery	14 aneurysms
On the other vessels	5 aneurysms (4%)

vessels (Table 2). Incidence of ruptured aneurysms was 66% in the group of aneurysms around the circle of Willis, 96% in the group of aneurysms in the basal ganglia, 90% in the group of aneurysms on collateral vessels, and 80% in the group of aneurysms on other vessels. Among the cases without intracranial haemorrhage, most of the aneurysms (93%) were located around the circle of Willis, while the others (7%) were seen on the posterior choroidal artery. Among the cases with intracranial haemorrhage, 60 aneurysms (54%) were around the circle of Willis, 28 (25%) on the collateral vessels, and 24 (21%) in the basal ganglia.

Treatment

In 100 cases, the mode of treatment was mentioned. Forty-five cases (45%) were treated surgically, 52 (52%) conservatively, and 3 (3%) by endovascular procedures. Of the 120 aneurysms mentioned, 64 (53%) were conservatively managed, while 56 (47%) were surgically managed. The surgical procedures for the aneurysms were: neck clipping in 28, aneurysmectomy in 10, wrapping of the aneurysm in 6, coating or cautery of the aneurysm in 4, revascularization only in 6, and endovascular embolization in 3. Of the 30 aneurysms found around the anterior circle of Willis ring, only 13 (44%) were treated by direct surgery. Of the 43 aneurysms around the posterior circle of Willis ring, direct surgery for the aneurysm was done in 22 (51%). Six aneurysms (20%) on the collateral vessels were treated by direct surgery, while the other 5 (17%) were treated by revascularization alone. Sixteen aneurysms (67%) in the basal ganglia were managed conservatively (Table 3).

Outcome

Ninety cases including ours were mentioned of each outcome. The outcomes were GOS 1 (good recovery) in 38 cases (43%), 2 (moderately disabled) in 20 (21%), 3 (severe disabled) in 10 (11%), 4 (persistent vegetative stage) in 1 (1%), and 5 (dead) in 22 (24%). Eighty-seven percent of the cases whose initial Hunt and Kosnik grade were 1, 2, or 3 showed favourable outcomes. On the other hand, 56% of H&K grade 4 and 5 cases had an unfavourable prognosis (Table 4). No marked difference in outcome was

Table 3. *Treatment of Each Aneurysm*

Location of aneurysms	No. of aneurysms (%)							Total
	Neck clipping	Aneurysmectomy	Coating, wrapping or cautery	Revascularization only	Endovascular approach	Non-surgical	Unknown	
Anterior circle of Willis	11 (37)	0 (0)	2 (7)	1 (3)	0 (0)	16 (53)	0 (0)	30
Posterior circle of Willis	14 (33)	1 (2)	7 (16)	0 (0)	3 (7)	16 (37)	2 (5)	43
Basal ganglia	0 (0)	3 (13)	0 (0)	1 (4)	0 (0)	16 (67)	4 (17)	24
Collateral vessels	1 (3)	5 (17)	0 (0)	5 (17)	0 (0)	14 (48)	4 (14)	29
Other vessels	0 (0)	1 (20)	1 (20)	0 (0)	0 (0)	2 (40)	1 (20)	5
Total	26 (20)	10 (8)	10 (8)	7 (5)	3 (2)	64 (49)	11 (8)	131

Table 4. Outcome of 84 Cases According to Each H&K Grade

H&K grade	No. of cases (%)						Total (n = 84)
	0 (n = 10)	1 (n = 7)	2 (n = 18)	3 (n = 22)	4 (n = 25)	5 (n = 2)	
GOS 1	4 (40)	5 (71)	12 (66)	9 (40)	7 (28)	0 (0)	37 (44)
GOS 2	2 (20)	0 (0)	3 (17)	7 (32)	3 (12)	0 (0)	15 (18)
GOS 3	2 (20)	2 (29)	1 (6)	2 (9)	2 (8)	0 (0)	9 (11)
GOS 4	0 (0)	0 (0)	0 (0)	1 (5)	0 (0)	0 (0)	1 (1)
GOS 5	2 (20)	0 (0)	2 (11)	3 (14)	13 (52)	2 (100)	22 (26)

GOS Glasgow outcome scale, H&K grade Hunt and Kosnik grade.

Table 5. Outcome of 90 Cases According to Each Aneurysm Location

Location of aneurysms	No. of cases (%)					Total (n = 90)
	Anterior circle of Willis (n = 18)	Posterior circle of Willis (n = 28)	Collateral vessels (n = 22)	Basal ganglia (n = 18)	Other vessels (n = 4)	
GOS 1	10 (55)	14 (50)	8 (36)	5 (28)	1 (25)	38 (43)
GOS 2	1 (6)	3 (11)	7 (32)	6 (33)	2 (50)	19 (21)
GOS 3	1 (6)	5 (18)	3 (14)	1 (6)	0 (0)	10 (11)
GOS 4	0 (0)	0 (0)	0 (0)	0 (0)	1 (25)	1 (1)
GOS 5	6 (33)	6 (21)	4 (18)	6 (33)	0 (0)	22 (24)

GOS Glasgow outcome scale.

Table 6. Outcome of 90 Cases According to Management

Management	No. of cases (%)			Total (n = 90)
	Direct surgery (n = 32)	Revascularization (n = 7)	Conservative (n = 51)	
GOS 1	15 (46)	3 (42)	20 (39)	38 (43)
GOS 2	6 (19)	2 (29)	11 (22)	19 (21)
GOS 3	6 (19)	2 (29)	2 (4)	10 (11)
GOS 4	0 (0)	0 (0)	1 (2)	1 (1)
GOS 5	5 (16)	0 (0)	17 (33)	22 (24)

GOS Glasgow outcome scale.

seen between groups with regard to the aneurysmal location (Table 5). Among the 51 cases with conservative treatment, 33 (65%) had a favourable outcome. Twenty-seven cases (84%) with direct surgical manoeuvre had a favourable outcome, and 5 cases (71%) with revascularization also had a favourable outcome (Table 6).

Follow-up Study

Following up angiography was done on 21 (25 aneurysms) of the 111 cases. Sixteen cases (18 aneu-

rysms) were treated conservatively, and the other 5 cases (7 aneurysms) were treated surgically (revascularization in 3 cases, direct surgery for aneurysm in 1 case, and direct surgery with revascularization in 1 case). Follow-up angiography was done between 0.4 and 60 months (mean: 7.1 months) from the onset or from surgery. The follow-up angiography demonstrated that 19 aneurysms (76%) disappeared, one (4%) showed reduction in size, 3 (12%) showed no change in size, and two (8%) showed enlargement of the aneurysm. One new aneurysm was seen on the follow-up angiogram. All aneurysms in the basal gan-

glia or on the collateral vessels had disappeared on the follow-up angiography, whether or not surgery was performed. In the 16 cases with 18 aneurysms treated conservatively, there were two enlarged aneurysms on the posterior circle of Willis.

Discussion

In Moyamoya disease, intracerebral haemorrhage was the most common and fatal complication [42]. The source of this haemorrhage was thought to be a thin walled collateral vessel [1] or aneurysm [6]. Cerebral aneurysm associated with Moyamoya disease was first reported in 1967 by Pool [32]. Generally, these aneurysms are known to occur around the circle of Willis, in the basal ganglia (so called Moyamoya vessels), and on the collateral vessels (anterior or posterior choroidal artery). In our review, the distribution was 3:1:1 (around the circle of Willis : in the

basal ganglia : on the collateral vessels). The aneurysms around the circle of Willis were often seen on the posterior circle of Willis. Many cases of the aneurysms associated with Moyamoya disease showed a poor initial clinical condition. The relationship between the initial clinical condition and the location of the aneurysms was that cases with aneurysms on the collateral vessels or in the basal ganglia tended to have poorer clinical grades compared with cases with aneurysms around the circle of Willis.

The overall outcome of the aneurysms associated with Moyamoya disease was not good compared to ordinary aneurysms [43] (Table 4). The relationship between the initial clinical grade and outcome was that cases with an initially good clinical grade had a favourable outcome and cases with an initially poor clinical grade had an unfavourable outcome. There were 22 deaths in this review (Table 7). Of these fif-

Table 7. Summary of the Reported Dead 22 Cases

Reference (year)	Age/ Sex	H&K grade	Management (interval)	Location of the aneurysm	Survival time from surgery or onset (days)	Main cause of death
<i>Cases with direct surgery for aneurysm or haematoma</i>						
1 Yuasa <i>et al.</i> (1982) [46]	51/F	4	aneurysmectomy (1)	BG	3 months	infection
2 Yamashita <i>et al.</i> Case 2 (1983) [42]	48/M	4	removal of haematoma(0)	MCA	10	brain oedema
3 Kasamo <i>et al.</i> (1984) [13]	55/F	2	clipping for all onset (45)	ACH, A-com(X2)	7	infection
4 Hanakita <i>et al.</i> Case 3 (1988) [8]	54/F	5	clipping (9)	BA-SCA	14	brain oedema
5 Kawaguchi <i>et al.</i> Case 3 (1996)	48/M	4	clipping (0)	A-com	5	brain oedema
6 Kawaguchi <i>et al.</i> Case 7 (1996)	53/F	4	aneurysmectomy (0)	BG	4	brain oedema
<i>Cases without direct surgery</i>						
7 Ohno <i>et al.</i> (1975) [28]	36/M	4	none	BG	9	brain oedema
8 Pilz <i>et al.</i> (1976) [31]	16/M	0	none	PCA, pericallosal artery	14	brain oedema
9 Tanaka <i>et al.</i> Case 3 (1978) [36]	57/F	3	VD	ACh	20	brain oedema
10 Adams <i>et al.</i> Case 4 (1979) [1]	32/F	5	none	BA-top	55	sepsis
11 Mauro <i>et al.</i> (1980) [20]	43/M	3	none	thalamo perforator	9	infection
12 Muraki <i>et al.</i> Case 9 [24]	22/F	4	none	BG	1	lung oedema
13 Yamashita <i>et al.</i> Case 1 (1983) [42]	16/F	4	none	ACA	20	brain oedema
14 Nomura <i>et al.</i> (1983) [27]	35/M	4	none	BA-top	5	rebleeding
15 Murakami <i>et al.</i> (1984) [23]	33/F	4	VD	BG (X2)	15	rebleeding
16 Sato <i>et al.</i> Case 1 (1984) [34]	38/M	4	VD	ACh	2	
17 Konishi <i>et al.</i> Case 3 (1985) [15]	57/F	4	none	ACh	20	
18 Konishi <i>et al.</i> Case 5 (1985) [15]	34/F	4	VD	ACh	10	
19 Konishi <i>et al.</i> (1985) [15]	48/F	4	none	A-com	29	
20 Ando <i>et al.</i> Case 6 (1988) [2]	59/F	3	none	BA-top	15	spasm
21 Onda <i>et al.</i> Case 2 (1988) [30]	43/F	2	none	ICA	18	rebleeding
22 Massoud <i>et al.</i> Case 2 (1994) [19]	34/M	0	endovascular	BA-top	30	infection

ACA anterior cerebral artery, ACh anterior choroidal artery, A-com anterior communicating artery, BA basilar artery, BG basal ganglia, H & K grade Hunt and Kosnik grade, ICA internal carotid artery, MCA middle cerebral artery, PCA posterior cerebellar artery, SCA superior cerebellar artery, VD ventricular drainage.

teen cases (68%) were in H&K grade 4 or 5 initially. In eighteen cases the main cause of death was given as: brain oedema in 8, rebleeding in 3, infection in 5, and other causes in 2. Three cases (cases 7, 11, 20) had a previous history of haemorrhage. Therefore, the initial clinical grade, brain oedema and rebleeding were important factors for the poor prognosis. These results support the radical management for aneurysms associated with Moyamoya disease.

Direct surgery for aneurysms associated with Moyamoya disease located on the circle of Willis should be considered to prevent rerupture and enlargement of aneurysms [2, 5, 7, 25, 30]. Posterior circulation aneurysms associated with Moyamoya disease form and grow as a result of haemodynamic stress due to the obstruction of the internal carotid artery [41]. The surgical indications for aneurysms associated with Moyamoya disease are: a) saccular aneurysm; b) scant transdural cerebral anastomoses; and c) scant collaterals around the aneurysm [41]. However, it is difficult to perform radical surgery on aneurysms around the circle of Willis associated with Moyamoya disease due to the following reasons. The interruption of anastomotic channels (collateral vessels) and manipulation of the brain during surgery may be a significant factor in the operative management of these patients [1, 2]. Because, in Moyamoya disease, tolerance to retraction and ischaemia is poor and the reserve capacity of haemodynamics is also poor [8, 12]. Due to recent developments made in brain protection techniques by drug agents or surgical technique, there has been an increase in the number of cases treated by direct surgery for aneurysms around the circle of the Willis. Adams *et al.* stated that an STA-MCA bypass should be done before clipping an aneurysm [1]. However, bypass surgery for Moyamoya disease with haemorrhage is angiographically far less successful compared with ischaemia [4]. Moreover, a bypass could not reduce the above risks. On follow up angiography, all aneurysms in the basal ganglia or on the collateral vessels disappeared completely. Therefore, surgical treatment for such aneurysms is not recommended. The mechanism of this phenomenon was increase of blood flow through the external carotid system [40]. Generally, direct surgery for most aneurysms located in the basal ganglia or on the collateral vessels is difficult because of the severe invasiveness [2] and the danger of damaging vital collateral vessels [7]. However, if the aneurysm is located near the ventricle wall, it could be surgically treated by a transventricular approach with invasiveness

comparable to usual aneurysm surgery and without compromising the collateral circulation [33].

Conclusion

The factors for the poor outcome of ruptured aneurysms associated with Moyamoya disease were an initial poor clinical condition and rebleeding. The overall outcome of patients with surgical procedures was good. We recommend surgical intervention for aneurysms associated with Moyamoya disease to prevent rupture or rebleeding especially for aneurysms around the circle of Willis. However, direct surgery is not recommended for aneurysms found in the basal ganglia or on the collateral vessels. Unfortunately, we do not have enough information about the natural history of these aneurysms. In the future, we should study the natural history of this type of aneurysm.

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Comment

The article by Kawaguchi *et al.* "Characteristics of intracranial aneurysms associated with moyamoya disease. A review of 111 cases" contains considerable scientific and clinical importance.

The authors treated a relatively large number of patients with moyamoya disease and 1 or more aneurysms in their own hospital and in addition to that they collected 99 well documented cases from the literature. The cases are nicely presented and the conclusions drawn from these clinical studies are very sensible.

The advice of the authors not to treat aneurysms in the basal ganglia or on the collateral vessels surgically is well taken as is the advice for radical surgical management of aneurysms in patients with moyamoya disease, that are located on the circle of Willis.

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