의학석사 학위논문

Long-term outcomes after indirect bypass for 629 children with moyamoya disease: cross-sectional and longitudinal analysis

629 명 소아 모야모야병 환자의 간접우회술 후 장기 추적 결과 분석: 종적, 횡적 분석

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하 은 진

Abstract

Long-term outcomes after indirect bypass for 629 children with moyamoya disease: cross-sectional and longitudinal analysis

Eun Jin Ha

Department of Translational Medicine

The Graduate School

Seoul National University

Objective: In pediatric Moyamoya disease (MMD), there are few reports on the efficacy of surgical intervention for stroke prevention. We evaluated the long-term outcomes of indirect bypass surgery on a relatively large number of children with MMD in a single centre.

Materials and methods: From August 1988 to December 2012, 772 children with

MMD underwent indirect bypass surgery. This study included 629 patients who were followed up for more than 5 years, excluding patients with moyamoya syndrome. The mean clinical follow-up duration was 12 years (range, 5-29 years). Cross-sectional analysis was performed based on either Karnofsky performance scale (KPS) or Lansky play performance scale (LPS) to evaluate overall clinical outcomes and factors associated with unfavorable outcomes. To analyze the longitudinal effect of surgery, the annual risk of symptomatic infarction or hemorrhage on the operated hemisphere after indirect bypass surgery was calculated with a person-year method, and the event-free survival rate was evaluated using the Kaplan–Meier method.

Results: The overall clinical outcome was favorable in 95% of the patients. The annual risks of symptomatic infarction and hemorrhage on the operated hemispheres were 0.08% and 0.04%, respectively. Furthermore, the 10-year event-free survival rates for symptomatic infarction and hemorrhage were 99.2 % and 99.8%.

Conclusions: Indirect bypass surgery resulted in satisfactory long-term improvement in overall clinical outcome and prevention of recurrent stroke in children with MMD.

Key words: pediatric, moyamoya disease, indirect bypass, stroke prevention, stroke-free survival, long term outcome

Student number: 2011-23784

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List of abbreviations and symbols

MMD: Moyamoya disease

ICA: Internal carotid artery

ACA: Anterior cerebral artery

TIA: Transient ischaemic attack

EDAS: Encephaloduroarteriosynangiosis

STA: Superficial temporal artery

EG(P)S: Encephalogaleo-(periosteal)-synangiosis

PCA: Posterior cerebral artery

LPS: Lansky Play Performance Scale

KPS: Karnofsky performance scale

IRB: Institutional review board

ICH: Intracerebral haemorrhage

SD: Standard deviation

OR: Odds ratio

CI: Confidence interval

IVH: Intraventricular haemorrhage

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Introduction

Moyamoya disease (MMD) is a cerebrovascular disorder characterized by progressive occlusion of both the internal carotid artery (ICA), including the proximal anterior cerebral artery (ACA) and the middle cerebral artery (MCA), and the arterial collateral vessels at the base of the brain. (1) The clinical presentation of MMD usually includes repeated transient ischemic attacks (TIA) or infarctions in children and intracranial hemorrhages in adults. (2) The benefit of surgery for the ischemic type of MMD has been well established. (3–8) However, only a few studies have been conducted on post-operative stroke events in padiatric MMD patients after a considerable period in a large population. Therefore, it remains necessary to investigate the preventive effect of indirect bypass surgery for late onset stroke. We previously reported surgical outcomes of MMD in 410 children. (3) Here, we report our assessment of the long-term outcomes in a larger group of children with MMD who underwent similar pre-surgical evaluation and relatively uniform surgical procedures at a single institute.

We conducted multivariate analysis to provide more details of the clinical characteristics and the independent prognostic factors for overall clinical outcome following indirect bypass surgery and survival analysis to evaluate its longitudinal stroke prevention effect.

Methods

Study population

We reviewed all medical records of children who were operated on using indirect bypass surgery between August 1988 and December 2012. During the study period, we performed 1548 indirect bypass surgeries on 772 patients. MMD was confirmed through cerebral angiography. Patients under 18 years of age at the time of surgery and who were followed up for more than 5 years post-operatively were enrolled. Patients associated with other conditions such as Down syndrome, systemic vasculitis, neurofibromatosis or prior skull-base radiation therapy (moyamoya syndrome) were excluded from this study (15 patients). Finally, a total of 629 patients were included (Figure 1), with 1283 surgeries performed. Overall clinical outcome and stroke event were analyzed base on the records of the most recent outpatient visits, imaging studies and telephone interview.

Of the 629 patients, 219 patients visited the outpatient clinic since January 2018 and 173 patients responded telephone interview. Therefore, we confirmed the current status of 392 patients. In the remaining patients, the clinical status and stroke event of the patients were analyzed based on the records of the last visits. The mean follow-up duration was 12 years (range, 5–29 years). Patient consent was omitted under IRB approval (No. 1808-050-964) for this minimal risk study.

Operative Technique

Surgery was performed in two stages (N= 556 patients), except for patients with unilateral MMD (N=73 patients), which is usually in the symptomatic and the more hemodynamically affected hemisphere first, followed by the other side. Encephaloduroarteriosynangiosis (EDAS) using the superficial temporal artery (STA) was performed to obtain collateral formation of the MCA area, in most cases. For ACA territories (N=522 patients), bifrontal encephalogaleo-(periosteal)-synangiosis (EG(P)S) or multiple burr hole surgery was performed and combined with STA EDAS. (9–11) To obtain the collateral formation in the posterior cerebral artery (PCA) territory (N= unilateral 109 operations, bilateral 49 operations), EDAS using the occipital artery or multiple burr hole surgery was performed.

Peri-operative infarctions included an obviously increased extent of a previous infarction or a new-onset infarction accompanying new neurological symptoms. Peri-operative adverse events were defined as infarctions or hemorrhages that occurred within 2 weeks after the operation.

Cross-sectional analysis: Overall clinical outcome

Karnofsky performance scale (KPS) or Lansky Play Performance Scale (LPS) for young age patients (under the age of 10) were used for evaluating functional outcome. These scales allow patients to be classified as to their functional impairment. This can be used to compare effectiveness of different therapies and to assess the prognosis in individual patients. They score range from 0 to 100. The lower the score, the worse their functional status. It is also known that both scales have the same score rule and correlate well with each other. The

favorable outcome was defined that KPS or LPS is 80 or more. The definition of KPS 80 is that the patients can do normal activity with efforts. LPS 80 means that the patients have restriction of strenuous play and tires more easily, otherwise active.

Cross-sectional analysis: Factors associated with unfavourable outcome

We analyzed whether there was a difference between the unfavorable outcome group and favorable outcome group in the ratio of girl, the mean age at operation, the rate of initial stroke, the mean pre-operative KPS or LPS, the mean incidence of peri-operative complications, Suzuki stage, pre-operative perfusion status. Among the factors that represent a significant difference between the two groups, a univariate and multivariate logistic regression was performed to identify the factors associated with the unfavorable outcome.

Longitudinal analysis: Newly developed stroke event and stroke-free survival rate

A newly developed stroke event was defined as all ischemic and hemorrhagic strokes with neurological symptoms occurring more than 30 days after surgery. This is the same definition used in previous large studies. (13,14)

Statistical analysis

Continuous variables were presented as the mean ± SD. Paired t-tests were performed to compare clinical states in patients who had consecutive follow-

ups pre-operatively and post-operatively. Pearson correlation tests were used to identify correlations between clinical features and poor functional outcomes. The annual risk of symptomatic infarction or hemorrhage in the ipsilateral hemispheres after indirect bypass surgery was calculated with a person-year method, and the event-free survival rate was evaluated using the Kaplan–Meier method. The end-points were the occurrence of stroke and last follow-up (censored). A value of $p < 0.05$ was considered statistically significant. All statistical analyses were performed using SPSS 23.0 software (IBM SPSS Inc., Chicago, IL).

Results

Demographics and Clinical Presentation (Table 1)

A total of 629 pediatric patients were included, consisting of 326 girls and 303 boys. The ratio of girls to boys was 1.1:1. The mean age at operation was 7.7 (0.6 to 17) years. Most of the initial presenting type was ischemia (98%). Among these, 44% patients had infarctions confirmed by pre-operative magnetic resonance imaging (MRI). MCA, ACA, PCA territorial or larger infarctions beyond the arterial territory occurred in 160 patients (25%). Hemorrhage (2%) was rare.

Surgical outcomes (Table 1).

A total of 1283 operations were conducted on 629 patients; average operation per person was 2.0 (1-4, ±0.5). The overall peri-operative adverse event rate was 8% per operation. Infarctions were the dominating complication, occurring in 74 cases (12% per patient; 6% per operation). Seizures tended to occur in patients preceding the infarction, and status epilepticus occurred in one patient (0.2%). The other complications are epidural and subdural hematoma requiring surgical removal (2%), intracerebral hemorrhage (ICH, 0.2%). Notably, of 104 patients with peri-operative complications, 88 patients recovered normal neurological function during long-term follow-up.

Cross-sectional analysis: Overall clinical outcome

The overall clinical outcome was favourable in 95% of patients based on their final KPS or LPS (80 or more). Final Functional status (the mean KPS or LPS:

93.6) showed significant improvement over its initial functional status (final KPS or LPS – initial KPS or LPS, mean: 8.2, $p < 0.001$, Figure 2A). Even patients whose KPS or LPS was initially low (<80) also showed significant improvement in their final follow-up. The mean of difference between final KPS or LPS and initial KPS or LPS of these patients was 28.4 ($p < 0.001$, Figure 2B).

Cross-sectional analysis: Factors associated with unfavorable outcome

When comparing the unfavorable outcome group and favorable outcome group, there was a significant difference in the mean age at operation, the presence of initial symptomatic stroke, the mean pre-operative KPS or LPS, and the rate of peri-operative complications associated with surgery. On the other hand, there were no differences in sex, Suzuki stage or perfusion status.

Univariate logistic regression analysis showed that age younger than 3 years (odds ratio [OR], 3.7; 95% confidence interval [CI], 1.7–8.3; $p = 0.001$), initial symptomatic stroke (OR, 8.6; 95% CI, 4.4–16.6; $p < 0.001$), pre-operative poor KPS or LPS (OR, 6.8; 95% CI, 3.6–13.0; $p < 0.001$) and peri-operative complications (OR, 4.3; 95% CI, 2.2-8.4; $p < 0.001$) were associated with unfavorable clinical outcomes (Table 2). Multivariate logistic regression analysis revealed that age (OR, 1.1; 95% CI, 0.4–2.6; $p = 0.972$) was not associated with unfavorable outcome. Initial symptomatic stroke (OR, 4.9; 95% CI, 2.2–10.8; $p < 0.001$) remained most strongly associated with unfavorable outcome (Table 2)

Longitudinal analysis: Newly developed stroke events during follow-up

During the follow-up period, a total of 17 infarctions occurred (Table 3). There were three untreated hemispheric infarctions while waiting for the second stage surgery. Patient ages were 3, 4 and 6 years old. The interval between the first operation and the second operation was longer than that of the other patients by 6 to 11 months due to various reasons. Excluding them, a total of 14 infarctions occurred on the operated hemisphere. There were 8 silent infarctions (i.e., infarction on regular follow-up images without neurological symptoms). One was a posterior border zone infarction that occurred after PCA progression. The others (7 patients of 8 silent infarction) were small infarctions within the operated area.

Symptomatic infarction occurred in 6 patients. Of these, 2 were PCA territory infarctions due to progressive occlusion of the PCA (one at 6 years, and the other at 17 years). One of these two infarctions due to PCA progression was occur 17 years after the surgery. The remaining four cases were cerebral infarctions on the operated territory. Of these 4 cases, three revealed strokes within six months (one at 4 months and two at 6 months), and the latest one at 2 years after surgery. Among new-onset infarcted patients, two patients were under 3 years of age. Their infarctions were distant from the previous infarction site. By contrast, the other 2 patients showed increased extent of previous infarctions. On their follow-up imaging, increased tissue defects were documented.

According to initial presentation, all patients who showed symptomatic new-onset infarction after operation were initially presented as ischemic type without exceptions. Among them, three patients presented with symptomatic infarctions.

New hemorrhage after surgery was also very rare. A total of 3 cases of

hemorrhage occurred. However, unlike infarction, they tended to occur after considerable time after surgery. All hemorrhagic events occurred 5 years after surgery. In our cohort, hemorrhage occurred at 9 years, 16 years, and 24 years after surgery, respectively. All patients experienced hemorrhage in their 20s and 30s, not during adolescence. One had pure intraventricular hemorrhage (IVH) of the 3rd and 4th ventricles. Her perfusion images during follow-up showed preserved vascular reserve and improved cerebral blood flow after surgery. Cerebral angiography was performed to evaluate the vascular cause. There were no suspected findings on angiography. The patient had long-term uncontrolled renovascular hypertension. The other 2 cases were ICH combined with IVH. One ICH was in the splenium, classified as posterior hemorrhage.15,16 On angiography, there were no demonstrable collaterals causing such hemorrhage. The patient had been diagnosed with hypertension in her adolescence. The other ICH was in the frontal lobe and putamen, which was called anterior hemorrhage. (16) She does not have any comorbidity.

All late - onset hemorrhages occurred in patients who had not initially presented with hemorrhage at disease onset. Two presented with ischemic symptoms without symptomatic infarction; one had presented with large infarctions at the MCA territory and anterior, posterior border zone.

During the entire follow up period, overall newly developed stroke occurred in 20 cases (3.2%) including 17 cases of infarctions (8 silent, 6 symptomatic infarctions on the operated hemisphere, 3 contralateral side to operated hemisphere) and 3 hemorrhagic cases (0.47%).

The annual symptomatic stroke rate on the operated hemisphere was 0.12%. The annual symptomatic infarction and hemorrhage rates were 0.08% and 0.04% per person-year, respectively. The 10-year event-free survival rates for symptomatic infarction on the operated hemispheres were 99.2% (Figure 3). The 10-year event-free survival rates for symptomatic hemorrhage were 99.8%, higher than that of infarction, though it decreased to 99.2% for 20-year and 95.8% for 25-year rates (Figure 4).

Illustrative Cases

Case 1. Late ischemic stroke

A 1-year-old boy underwent bilateral EDAS and bifrontal EGPS after presenting with symptomatic infarction on bilateral hemisphere. He suffered from perioperative infarction, but his symptoms were improved 6 months after the surgery. During follow-up, he showed relatively normal development. When he became 3 years old, after 13 days of high fever and dehydration, his ability to learn words was reduced, and he was not good at naming things. And he became difficult to speak fluently. On the MRI for regular follow-up, newly appeared tissue defect due to infarction at left temporal lobe were identified. (Figure 5)

Case 2. Late hemorrhagic stroke

A 6-year-old girl presented with TIA and underwent bilateral indirect bypass surgery. After the operation, she had no difficulties in daily life, had no problems in learning, entered a university, and was good at grades. Sixteen years

after surgery, severe headache and sudden loss of consciousness was occurred. Computed tomography (CT) scan showed IVH with ICH on the splenium. (Figure 6) Angiograms obtained at that time revealed good revascularization, without prominent collateral vessels. Some posterior choroidal artery collaterals from PCA remained. After treatment with external ventricular drainage, she recovered to normal status. She had been diagnosed with hypertension, when she was in adolescence.

Discussion

As a retrospective study, it is inevitable to have an underestimation of the adverse events associated with follow up losses. However, this study is meaningful because it is the largest long-term data analysis performed under the same surgical method and well-managed protocol. Given that there is no effective treatment for moyamoya disease other than surgery, it may impossible to do a control study. Pediatric patients are vulnerable groups, therefore randomized controlled trials are very difficult. Multicenter studies also have difficulties because of differences in surgical procedures, protocols, and surgical skills.

Overall clinical outcome

Most of our patients showed favorable functional outcome (95%). Postoperative KPS or LPS improved in 84% of patients compared to preoperative KPS or LPS. As children grow, scores can naturally improve. Therefore, the improvement of score is not purely the effect of surgery. However, considering the natural history of the conservatively treated group, it would have been difficult to catch up with functional status if they were exposed to repeated stroke without surgery.

Factors associated with Unfavorable Outcome

Initial symptomatic strokes (OR, 4.9) were found to be the most powerful factors associated with adverse results and age had no effect. Pre-operative poor

KPS or LPS may be the result of a symptomatic infarction prior to surgery. Moreover, it is known that the probability of surgical complications is high when pre-operative infarction is present.3 Therefore, current findings strongly suggest that early diagnosis and intervention prior to symptomatic infarction can reduce stroke rates and improve clinical results.

Among peri-operative complications, surgery-related infarctions were the most common complications and they were closely related to an unfavorable outcome. Therefore, careful attention should be paid to maintaining adequate hemodynamic status during the peri-operative period. (17)

Stroke preventive effect of indirect bypass surgery

Whether direct or indirect, the benefits of surgery have been well-establish in pediatric MMD with ischemic symptoms. The natural history of untreated MMD varies from intermittent slow progression to rapid neurological and cognitive decline, with an overall mortality rate of 4.3% in the Japanese literature. (13) The long-term outcome of the disease is not good because this decline is inevitable in most patients, and symptoms progress up to 66% after 5 years of diagnosis. (18) In post-operative follow-up studies of pediatric MMD, recurrence of ischemic stroke was also rare; only a small proportion (0–0.8%) of patients experienced late ischemic stroke. (Table 4) (4,5,7,8,13,14,19,20)

The incidence of late - onset ischemic stroke in our cohort was as low as 0.08% per year. The incidence of late - onset ischemic stroke in our cohort was as low as 0.08% per year. After six months of surgery, there were few symptomatic

infarctions on the operated hemisphere. After stabilization of indirect bypass, it appears that a patient can live without fear of infarction. The exceptionally late infarction on the operated territory, which occurred 2 years after surgery was related to 14 days of high fever and dehydration. These results suggest that indirect bypass surgery might be a very effective long-term safeguard against cerebral infarction in children with MMD.

However, if PCA stenosis progresses, a late onset symptomatic infarction can occur. In many cases, additional surgery for PCA territory (OA EDAS or OA multiple burr hole) is required. Early detection of PCA insufficiency through periodic follow-up and active surgical prevention is important to prevent infarction.

On the other hand, the surgical preventive effect for hemorrhage is controversial. There has been too little experience with hemorrhagic cases of pediatric MMD to form any conclusions regarding the efficacy of bypass surgery. Our group has previously reported the implicit effect of indirect surgery on hemorrhage. (21) However, another group insisted that indirect bypass was insufficient to prevent recurrence of hemorrhage based on their retrospective data. (22) In 2014, a Japan group published the results of the only randomized clinical trial to evaluate the preventive effect of direct bypass surgery for rebleeding in adult patients with MMD presenting with hemorrhage (Japan Adult Moyamoya [JAM] trial). (23) They concluded that bilateral direct surgery prevents rebleeding. Among our patients, recurrent bleeding was not observed in patients with hemorrhagic MMD after surgery. In addition, the incidence of new-onset hemorrhage was estimated at 0.04% per year after surgery. This is quite low compared with the

hemorrhage rate in asymptomatic adult patients (2–3% per year). (22,24) Indirect surgery in childhood is probably beneficial for primary prevention of hemorrhage. Nevertheless, the possibility of new - onset hemorrhage should not be overlooked. Sudden bleeding can occur even though the patient had been without symptoms for a considerable time. Some retrospective reports agree with our findings. New - onset hemorrhage might increase at age 20 or later, even more than 10 years after bypass surgery. (6,14,25)

The mechanism of new - onset hemorrhage remains obscure. In our cases, the patients had lived well with good performance status before hemorrhagic events occurred. There were no characteristic angiographic findings such as pseudoaneurysm, prominent collaterals. Hypertension may have contributed to new-onset hemorrhage. Even though they were in their 20s and 30s, two of the three patients were diagnosed with hypertension. Patients with MMD may have high blood pressure at a young age. As with one of our patients, 5-8% of moyamoya patients have renal artery stenosis. (26) Therefore, life-long regular follow-up and risk factor control is requested even for the patients with excellent long-term surgical outcome.

Limitations

This study has limitations as a retrospective study. It is quit long term follow-up study, but it might be insufficient when we consider the patient's overall life expectancy. More long-term tracking data needs to be accumulated to clarify the clinical course of surgically treated children with MMD.

CONCLUSIONS

Our long-term survey revealed that indirect bypass surgery for children with MMD could achieve favorable clinical outcomes. Surgical management is expected to provide excellent protection for both ischemic and hemorrhagic stroke. Nevertheless, a few new - onset hemorrhagic events and ischemic events due to PCA progression were observed a considerable time after the initial surgery. Therefore, careful and long traces should be made for the remainder of life, even though the course has been good for several years after surgery.

Figure. 1 Study participant selection

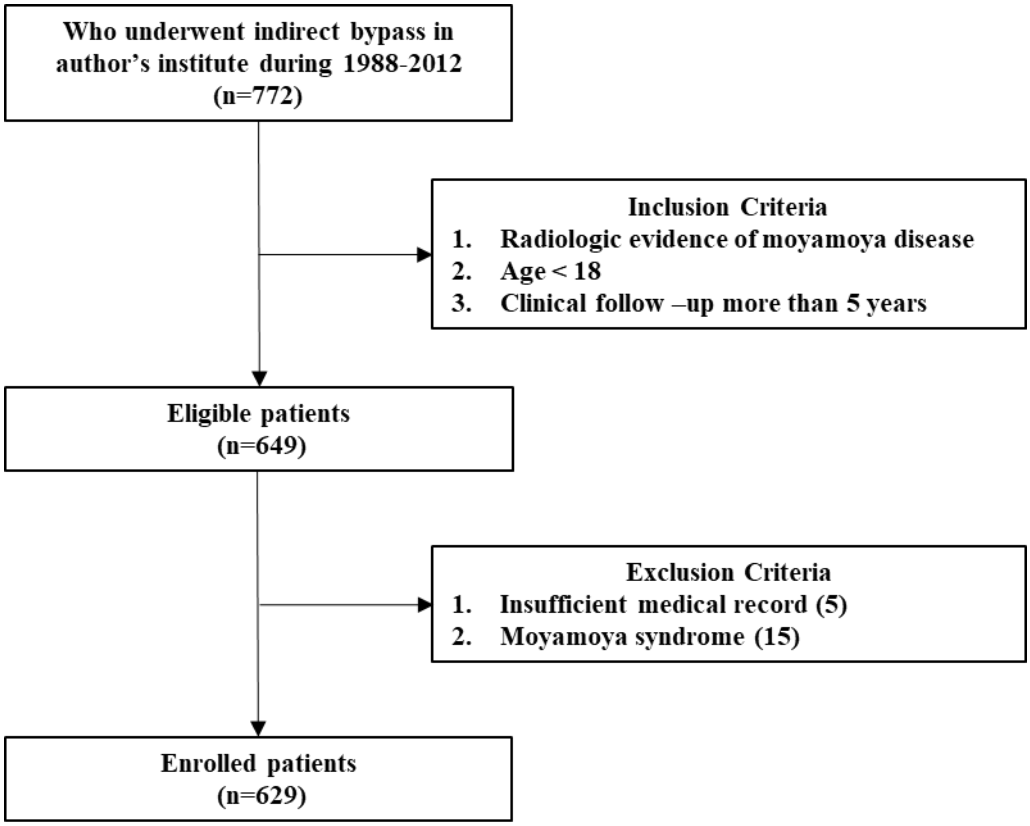
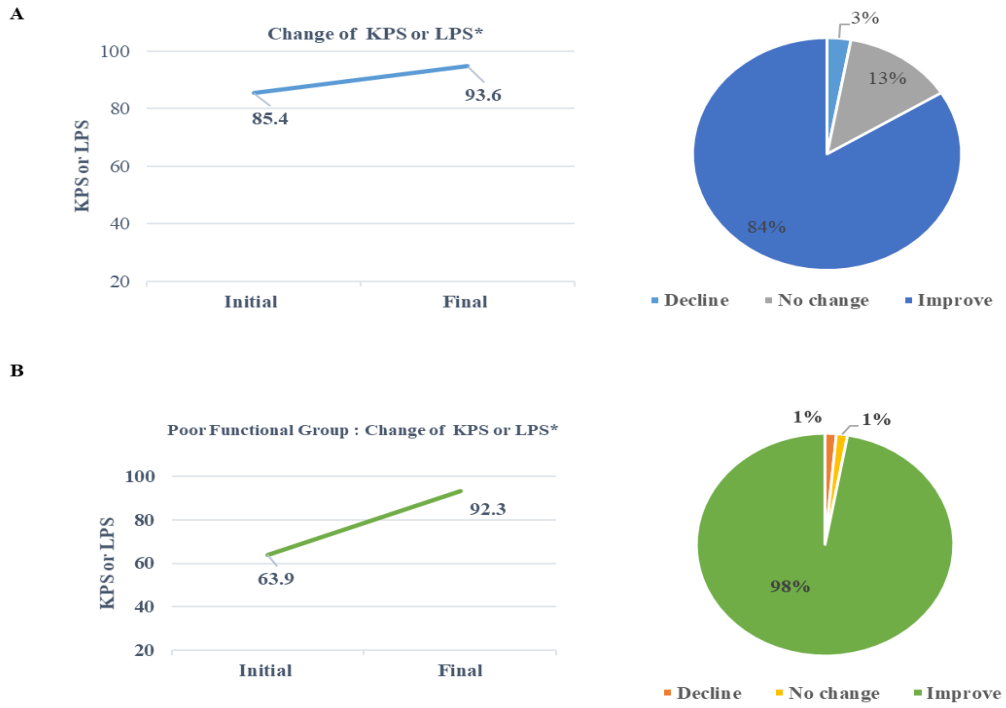


Figure. 2 Change of Functional status.

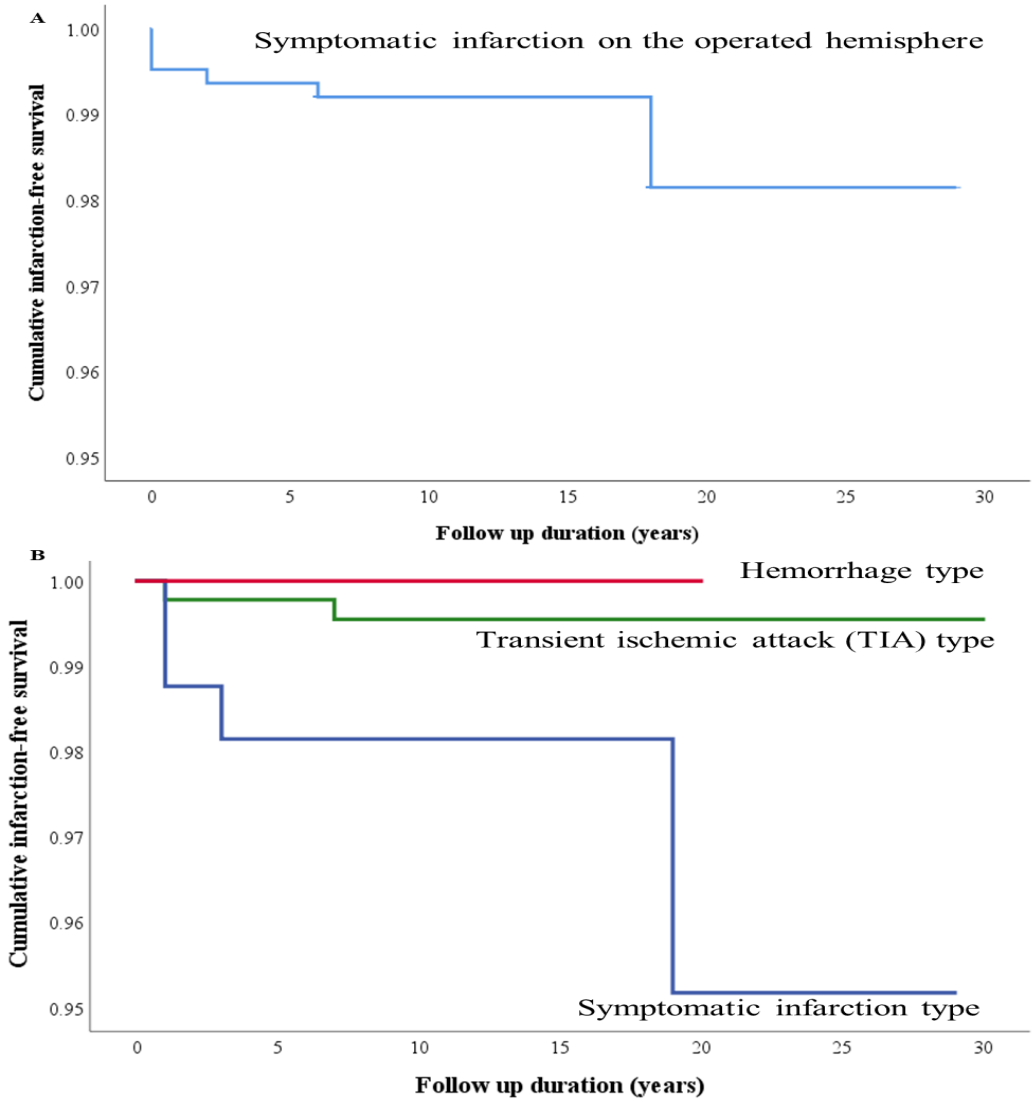


(A) Final KPS or LPS showed significant improvement over its initial KPS or LPS ([(final KPS or LPS– initial KPS or LPS]) mean: 8.2, $p<0.001$) and only 3% of patients showed a decrease in KPS or LPS.

(B) Patients whose KPS or LPS was initially low (≤70) also showed significant improvement in their final follow-up. ([(final KPS or LPS – initial KPS or LPS]) mean: 28.4, $p<0.001$). Ninety-eight percent of patients showed improvement in KPS or LPS.

* Lansky Play Performance Scale (LPS), Karnofsky Performance Scale (KPS)

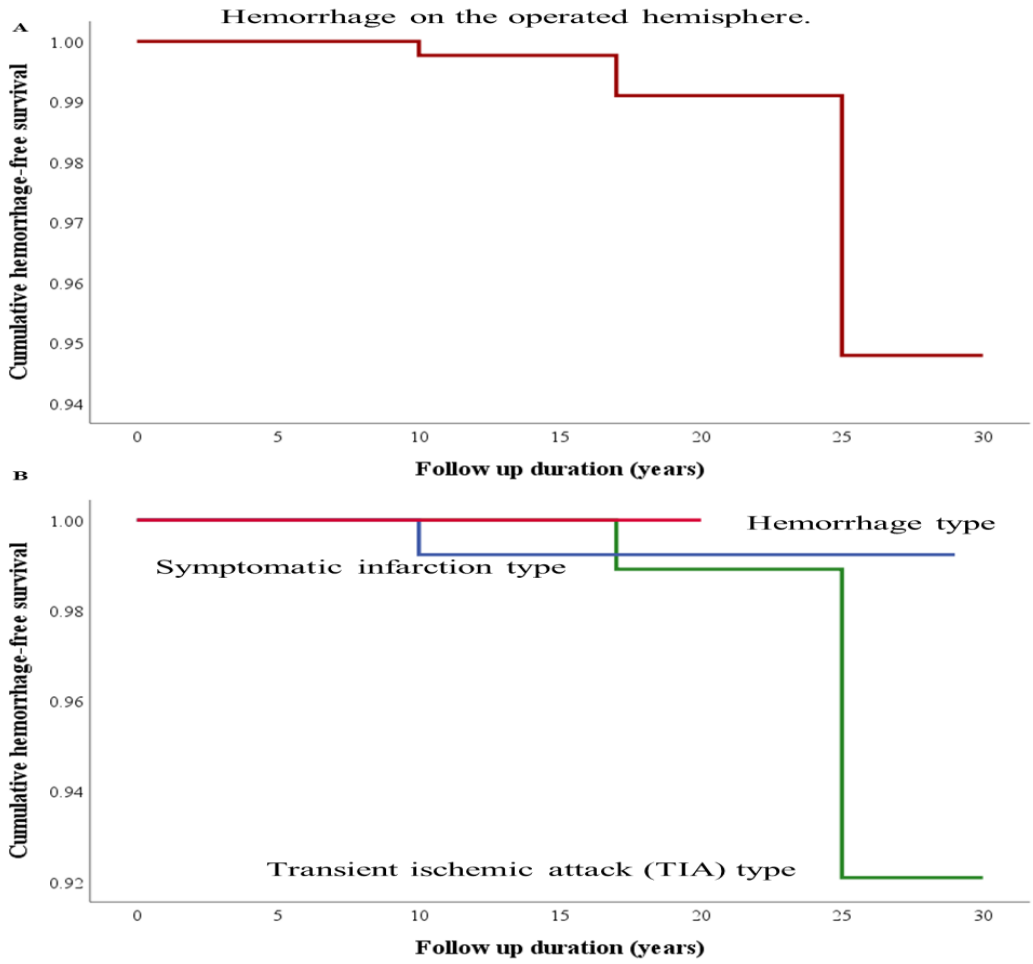
Figure. 3 The Kaplan–Meier survival curves of infarction.



(A) Symptomatic infarction on the operated hemisphere.

(B) Symptomatic infarction on the operated territory, according to the initial presentation, significant infarction type (blue line), transient ischemic attack (TIA) type (green line), hemorrhage (red line, log-rank test, p = 0.959)

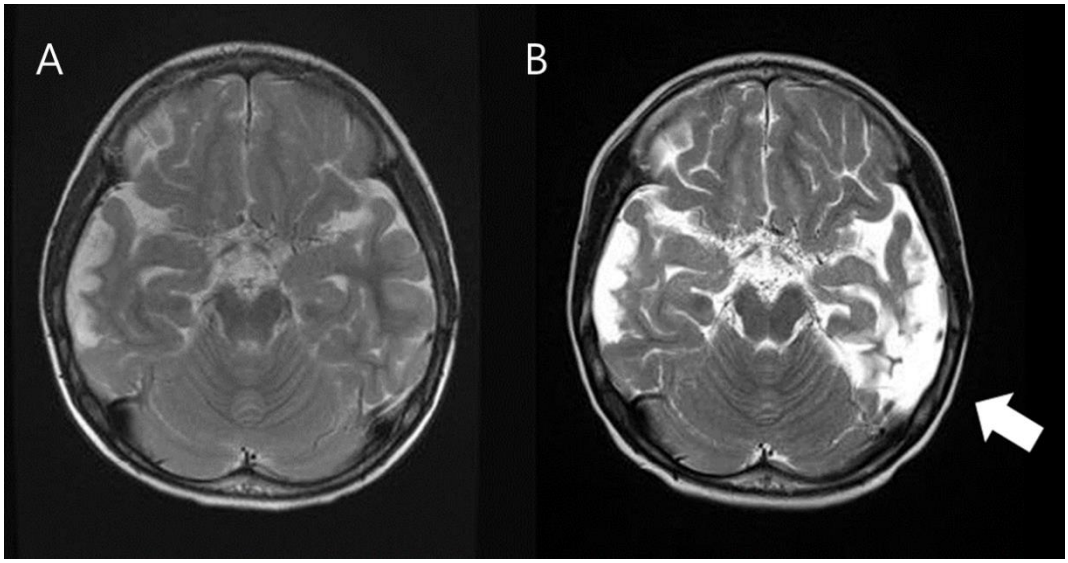
Figure. 4 Kaplan–Meier survival curves of hemorrhage.



(A) Hemorrhage on the operated hemisphere.

(B) Hemorrhage according to the initial presentation, significant infarction type (blue line), transient ischemic type (TIA) type (green line), hemorrhage (red line, log-rank test, p = 0.959)

Figure. 5 Late-onset infarction case.



(A) Pre-operative MRI (T2)

(B) On the follow-up MRI (2 years after operation), newly appeared tissue defect (white arrow) due to infarction at left temporal lobe were identified.

Figure. 6 Late-onset hemorrhage case.

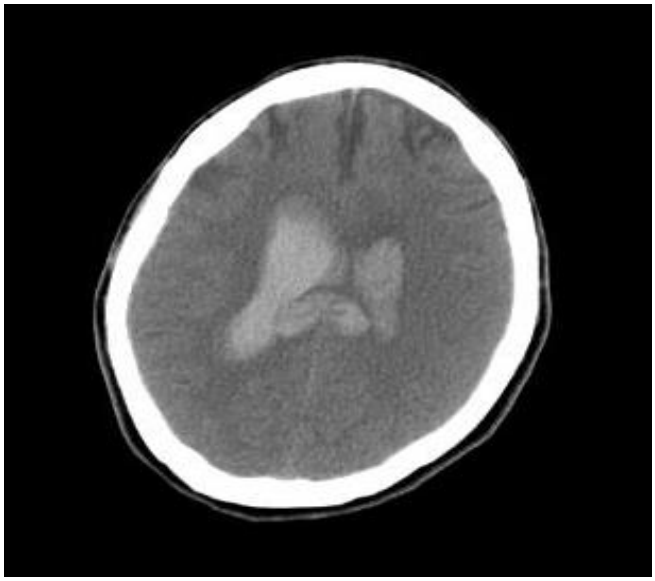


Table. 1 Summary of Demographics, Clinical Presentation and Perioperative Complication.

Baseline characteristics		Number of cases or value
Sex	Girls : Boys	326:303 (1.1:1)
Age		7.7 (0.6-17, ±3.5)
Initial Presentation		
	Ischemia	617 (98%)
	TIA	338 (54%)
	Infarction	279 (44%)
	Symptomatic infarction	160 (25%)[a]
	Hemorrhage	12 (2%)
Total Operation		1283
Average operation per person		2.0 (1-4, ±0.5)
Perioperative adverse event		104 (8%)
	Infarction[b]	74 (12% per person, 6% per operation)
	Intracranial extraaxial hemorrhage	29 (2%)
	Intracerebral hemorrhage	2 (0.2%)
	Status epilepticus	1 (0.2%)

TIA= transient ischemic attack

[a] 2 with intracranial hemorrhage

[b] Infarctions per site were 39 cases in superficial temporal artery encephaloduroarteriosynangiosis, 31 case in frontal lobe, 3 in occipital lobe, one in contralateral hemisphere.

Table 2. Univariate and Multivariate Logistic Regression Analyses of Risk Factors for Unfavorable Outcome (KPS or LPS<80)

Univariate analysis Characteristics	Parameters	OR	95%CI	p-value
Age at the operation	<3	3.7	1.7-8.3	0.001
Initial Presentation with Symptomatic stroke	Present	8.6	4.4-16.6	<0.001
Pre-operative KPS or LPS	<80	6.8	3.6-13.0	<0.001
Perioperative complications	Present	4.3	2.2-8.4	<0.001
Multivariate analysis Characteristics	Parameters	OR	95%CI	p-value
Age at the operation	<3	1.1	0.4-2.6	0.972
Initial Presentation with Symptomatic stroke	Present	4.9	2.2-10.8	<0.001
Pre-operative KPS or LPS	<80	2.5	1.1-5.5	0.027
Perioperative complications	Present	3.1	1.5-6.4	0.002

KPS=Karnofsky performance scale, LPS= Lansky Play Performance Scale (under the age of 10), OR=odds ratio, CI=confidence interval

Table 3. Summary of Longitudinal Surgical Outcome

Parameters	Number of Cases or Percentages
Follow up period	12 y (5-29 y)
Newly developed stroke event (≥30 days after op)	20
Infarction	17
Contralateral to operated hemisphere	3
Operated hemisphere	14
Silent infarction	8
Symptomatic infarction	6
Hemorrhage	3 (9 y, 16 y, 24 y)
Annual symptomatic stroke rate in operated hemisphere	0.12%
Infarction	0.08%
Hemorrhage	0.04%

y=years after indirect bypass surgery

Table 4. Literature Review of Long-term Stroke Events after Bypass surgery

Authors	Year	Number of patient	Late post-operative stroke (Haemorrhage)	Follow-up duration (months)	Annual stroke rate (%)
Indirect bypass surgery for children					
Goda et al.	2004	23	0	144	0.0
Scott et al.	2004	126	4(0)	62	0.6
Mukawa et al.	2012	172	9(6)	172	0.36
Imai et al.	2015	29	0	90	0.0
Bao et al.	2015	288	10(2)	52	0.8
Sum		635	23(8)		0.6
Present study		629	9(3)	144	0.12
Direct bypass surgery for children					
Karasawa et al.	1992	104	2(0)	115	0.2
Kuroda et al.	2010	28	0	73	0.0
Funaki et al.	2014	58	4(3)	217	0.4
Fujimura et al.	2016	23	0	77	0.0
Sum		213	6(3)		0.15

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국 문 초 록

목적: 소아 모야모야병에 있어 뇌졸중 예방을 위한 수술의 장기적 효능에 대한 연구는 거의 없다. 이에 우리는 단일 센터에서 가장 많은 수의 소아 모야모야병 환자에 대해 간접 우회 수술을 시행하고 장기 추적 결과를 분석하였다.

방법: 임상 추적 기간은 12 년 (범위, 5-29 년)이었다. 횡단면 분석은 Karnofsky 기능 척도 (Karnofsky performance scale, KPS) 또는 Lansky 놀이 기능 척도 (Lansky play performance scale, LPS)를 기반으로 수행되어 전반적인 임상 결과 및 불리한 결과와 관련된 요인을 평가했습니다. 수술의 종단 효과를 분석하기 위해 간접 우회 수술을 시행한 반구의 증상성 경색 또는 출혈의 연간 위험도를 person-year 방법으로 계산하고 무 발생 생존율을 Kaplan-Meier 방법을 사용하여 평가했다.

결과: 전반적인 임상 결과는 환자의 95 %에서 양호했다. 수술한 반구의 증상을 동반한 경색 및 출혈의 연간 위험은 각각 0.08 % 및 0.04 %였다. 또한, 경색 및 출혈의 10 년 무발생 생존율은 99.2 % 및 99.8 %였다.

결론: 간접 우회 수술은 모야모야병 소아에서 전반적인 임상 결과의 장기적인 개선과 뇌졸중의 재발 예방에 효과적 방법이다.

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주요어: 소아 모야모야병, 간접우회술, 뇌졸중 예방, 뇌졸중 무발생 생존률, 장기 예후

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