Online January 13, 2024
Journal of Neuroendovascular Therapy 2024; 18: 29–36
DOI: 10.5797/jnet.oa.2023-0069

Original Article

Efficacy and Safety of Lumbar Drainage before Endovascular Treatment for Ruptured Intracranial Aneurysms

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Objective: Intraoperative rebleeding during endovascular treatment for ruptured intracranial aneurysms is associated with poor prognosis. Lumbar drainage is performed preoperatively to control intracranial pressure; however, it is associated with a risk of brain herniation or rebleeding because intracranial pressure may change rapidly. Therefore, this study aimed to examine the efficacy and safety of preoperative lumbar drainage.

Methods: This retrospective study enrolled 375 patients who underwent endovascular treatment of ruptured intracranial aneurysms at our institution between April 2013 and March 2018. The incidence of rebleeding and clinical outcomes were compared between patients who did and did not undergo preoperative lumbar drainage.

Results: Among the 375 patients with ruptured intracranial aneurysms, 324 (86.0%) and 51 (14.0%) patients did and did not undergo lumbar drainage, respectively. The incidence of rebleeding was 11/324 (3.4%) and 2/51 (3.9%) in lumbar drainage and nonlumbar drainage groups, respectively, with no statistical differences (p = 0.98). Of the rebleeding cases, 9/11 (81%) and 2/2 (100%) in lumbar drainage and nonlumbar drainage groups, respectively, were due to intraoperative bleeding, and 2/11 (19%) in the lumbar drainage group, the causes of the rebleeding were undetermined. The incidence of symptomatic vasospasm did not differ significantly between the groups (13.2% vs. 11.8%, P = 0.776), while the incidence of hydrocephalus (24.6% vs. 11.8%, P = 0.043) and meningitis (15.2% vs. 5.9%, P = 0.075) were slightly higher in the lumbar drainage group. Favorable clinical outcomes (modified Rankin Scale score <2) at discharge were less frequent in the lumbar drainage group (55.3% vs. 70.0%, P = 0.051). No significant differences were observed in the propensity score-matched analysis.

Conclusion: Lumbar drainage before endovascular treatment for ruptured intracranial aneurysms is a safe procedure that does not increase the incidence of rebleeding.

Keywords cerebrospinal fluid, drainage, subarachnoid hemorrhage, endovascular procedures

Introduction

There are many reports on the use of lumber drainage during the perioperative period of endovascular treatment of ruptured intracranial aneurysms. Many of these studies have reported that lumbar drainage after aneurysm treatment reduces delayed vasospasm and cerebral infarction.[1–5] Nowadays, there is a consensus on lumbar drainage management after ruptured intracranial aneurysm treatment. However, although intraoperative rebleeding is

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Received: October 2, 2023; Accepted: December 11, 2023
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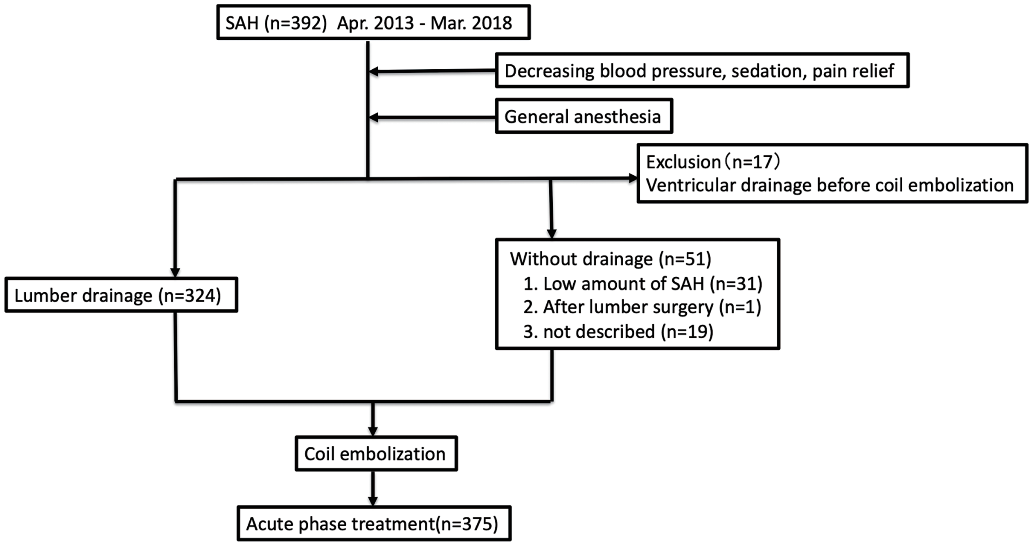

Fig. 1 Patient inclusion flowchart. SAH: subarachnoid hemorrhage

rare in this disease (5.0%–7.7%), 63% of intraoperative rebleeding cases have poor outcomes.[6,7] The sudden increase in intracranial pressure caused by an aneurysm rupture is associated with poor outcomes. Lumbar drainage in the preoperative period has been shown to control intracranial pressure rapidly and may also decrease secondary brain damage.[8] However, rebleeding or brain herniation may occur during insertion of a lumbar drainage catheter,[9–12] though the effectiveness and safety of lumbar drainage before endovascular treatment of ruptured intracranial aneurysms remain unclear. We hypothesize that lumbar drainage before endovascular treatment would not increase perioperative rebleeding and would reduce intracranial pressure in the event of intraoperative rebleeding, preventing poor functional outcomes. Therefore, the present study examined the effectiveness and safety of preoperative lumbar drainage during the endovascular treatment of ruptured cerebral aneurysms.

Materials and Methods

Study design and patients

This retrospective study was approved by the Institutional Review Committee of the Neuroendovascular and Surgical Management from Multicenter Observation to build a PHILosophical Approach (NEMMOPHILA) study (Reference number: H30-137) and was conducted according to the tenets of the Declaration of Helsinki. This retrospective observational study was conducted using the opt-out method on our department's website.

Three hundred and seventy-five patients who underwent endovascular treatment for ruptured intracranial aneurysms between April 2013 and March 2018 at five associated institutions were included (**Fig. 1**). Patients with acute hydrocephalus that required ventricular drainage were excluded.

Endovascular technique and perioperative management

Endovascular treatment of ruptured intracranial aneurysms was performed within 48 hours of onset. All patients with a longer treatment duration were re-evaluated using head CT scans. Lumbar drainage was basically performed on patients who underwent endovascular treatment, but the final decision was left to the surgeon. Reasons for not performing lumbar drainage included low hematoma volume and postoperative lumbar surgery (**Fig. 1**). A lumbar drainage catheter was inserted after general anesthesia, and cerebrospinal fluid (CSF) was continuously drained during the procedure. Systemic heparinization (80 IU/kg) was performed prior to insertion of the guiding catheter, and antiplatelet drugs were not administered. However, dual antiplatelet therapy loading doses were administered in cases that required stent placement. Head CT scans were performed within 24 hours after the treatment to evaluate complications. When rebleeding occurred, the blood pressure was decreased as soon as possible. In cases of intraoperative rebleeding, bleeding was stopped with a balloon catheter or coil. After endovascular treatment, the drain rate was set at 5 to 10 mL/hour. Drainage was continued until the hematoma resolved on head CT, if an adverse event occurred, or at 7 days postoperatively. Fasudil and ozagrel sodium were administered intravenously for the prevention of vasospasm. Treatment-resistant vasospasm was managed with intra-arterial fasudil or percutaneous transluminal angioplasty.

Data collection

The following data were collected: age, sex, aneurysm location, aneurysm size (largest dimension of the aneurysm), bleb, pretreatment World Federation of Neurological Surgeons (WFNS) grade; Fisher's group as determined using the first head CT, treatment methods, adverse events associated with lumbar drainage (e.g., brain herniation due to excessive drainage, and a piece of the drainage catheter remained in the patient at the time of its removal, which required additional treatment), perioperative rebleeding, symptomatic vasospasm, hydrocephalus requiring shunt surgery, meningitis, and the modified Rankin Scale (mRS) score at discharge. Fisher's group was determined as follows: Group 1, with no blood detected; Group 2, with diffuse deposition or a thin layer with all vertical layers of blood <1 mm in thickness; Group 3, with localized clots and/or a vertical layer of blood ≥1 mm in thickness; Group 4, with diffuse or no subarachnoid blood but with intracerebral or intraventricular clots.

Study endpoints

A comparative study was conducted both with and without lumbar drainage. Lumbar drainage insertion was defined as LD (+), and noninsertion was defined as LD (−). The primary endpoint was the frequency of favorable clinical outcomes at discharge, defined as an mRS score <2. The secondary endpoints were the frequency of perioperative rebleeding, symptomatic vasospasm, hydrocephalus, and meningitis. Perioperative rebleeding was defined as bleeding that occurred up to the time of the postoperative CT. Therefore, bleeding during lumbar drainage insertion, intraoperative bleeding, and enlarged subarachnoid hemorrhage (SAH) on postoperative CT were included.[7] Symptomatic vasospasm was defined using the following criteria: (1) newly developed neurological deficit; (2) no explanation for neurological deficits, such as hyponatremia, infection, hypoxia, and epilepsy; and (3) evidence of vasospasm on magnetic resonance imaging, CT angiography, and transcranial Doppler. Hydrocephalus was defined as the need for shunt surgery. Meningitis was defined as increased cell count and hypoglycorrhachia in the CSF with fever.

Statistical analysis

Data were compared between patients who did and did not undergo preoperative lumbar drainage. Continuous data were expressed as the mean ± standard deviation and categorical data were presented as the counts and percentages. Between-group differences were assessed using Fisher's exact test for discrete data and two-sample Student's t-test for continuous data. The propensity score was calculated using a multivariable logistic regression model with the two groups as dependent variables and sex, WFNS score, Fisher's group, rebleeding, symptomatic vasospasm, hydrocephalus, meningitis, and mRS at discharge as independent variables. The inverse probability of treatment weighting (IPTW) was determined using propensity score-matched analysis. Briefly, IPTW uses weights based on the propensity score to create a synthetic sample in which the distribution of measured covariates is independent of the treatment assignment. All statistical analyses were performed using SPSS statistics software (version 25.0; IBM, Armonk, NY, USA). Statistical significance was set at P <0.05.

Results

Of the 375 patients with ruptured intracranial aneurysms, 324 (86.0%) and 51 (14.0%) did and did not undergo lumbar drainage. There were no significant between-group differences in age, sex, aneurysm location, and aneurysm size. The WFNS grade was significantly lower in the LD (−) group (P = 0.013). Fisher group was lower in the LD (−) group (P <0.001), and aneurysms with blebs were more frequent in the LD (+) group (65.7% vs. 46.0%, P = 0.007). A double catheter or balloon-assisted technique was used more frequently in the LD (+) group (P = 0.034) (**Table 1**).

The frequency of an mRS ranging between 0–2 at discharge was lower in the LD (+) group than in the LD (−) group (55.3% vs. 70.0%, P = 0.051), but there were no significant differences in rebleeding (4.0% vs. 3.9%, P = 0.975). Furthermore, symptomatic vasospasm did not differ significantly between the LD (+) and LD (−) groups (13.2% vs. 11.8%, P = 0.776). The incidences of hydrocephalus (24.6% vs. 11.8%, P = 0.043) and meningitis (15.2% vs. 5.9%, P = 0.075) were slightly higher in the LD (+) group (**Table 2**).

The characteristics of the patients with rebleeding are summarized in **Table 3**. Re-bleeding occurred in 13 patients in the LD (+) group, and intraoperative rebleeding in 11 of these patients was perforated by a coil,

Table 1 Patient characteristics and adverse events

Patients	Drainage (+)	Drainage (–)	P value
	324	51	
Age (years)	63.0 ± 14.4	60.3 ± 14.5	0.211
Male	98 (30.2)	13 (25.5)	0.489
WFNS grade	324	50	0.013
1	69 (21.3)	18/50 (36.0)	
2	96 (29.6)	15/50 (30.0)	
3	42 (13.0)	5/50 (10.0)	
4	80 (24.7)	3/50 (6.0)	
5	37 (11.4)	9/50 (18.0)	
Fisher's grade	324	49	<0.001
1	3 (0.9)	5/49 (10.2)	
2	78 (24.1)	18/49 (36.7)	
3	160 (49.4)	15/49 (30.6)	
4	83 (25.6)	11/49 (22.4)	
Aneurysm location	323	51	0.176
ICA proximal	15 (4.6)	5 (9.8)	
ICA distal	97 (30.0)	9 (17.6)	
AcomA	77 (23.8)	11 (21.6)	
MCA	23 (7.1)	4 (7.8)	
VA	59 (18.3)	8 (15.7)	
BA apex	36 (11.1)	8 (15.7)	
Others	16 (5.0)	6 (11.8)	
Fusiform	37 (11.4)	1 (2.0)	0.037
Size	6.45 ± 3.25	6.62 ± 4.98	0.75
Bleb	205/312 (65.7)	23/50 (46.0)	0.007
Treatment method	305	47	0.034
Simple catheter	115 (57.4)	30 (58.8)	
Double catheter	22 (7.2)	0 (0.0)	
Balloon assist	145 (47.5)	18 (38.3)	
Stent assist	23 (7.5)	2 (4.3)	

Data are presented as the mean ± standard deviation or n (%). AcomA: anterior communicating artery; BA: basilar artery; ICA: internal carotid artery; MCA: middle cerebral artery; VA: vertebral artery; WFNS: World Federation of Neurological Surgeons

Table 2 Clinical outcomes

	Drainage (+) (n = 324)	Drainage (–) (n = 51)	P value
Primary endpoint			
Modified Rankin Scale score 0–2	176/318 (55.3)	35/50 (70.0)	0.051
Secondary endpoint			
Rebleeding	13 (4.0)	2 (3.9)	0.975
Symptomatic vasospasm	42/318 (13.2)	6 (11.8)	0.776
Hydrocephalus	78/317 (24.6)	6 (11.8)	0.043
Meningitis	48/316 (15.2)	3 (5.9)	0.075

microcatheter, or microguidewire. In the remaining 2 patients, no adverse events occurred during the intraoperative period; however, postoperative CT revealed an enlarged SAH. No rebleeding occurred between the lumbar drainage procedure and the endovascular treatment. In contrast, rebleeding occurred in two patients in the LD (−) group during the intraoperative period. The adverse events that occurred in 2 patients (1.0%) who underwent lumbar drainage included brain herniation due to excessive drainage and a piece of the drainage catheter that remained in the patient at the time of its removal, which required additional surgery.

Given that patient characteristics differed between the LD (+) and LD (−) groups, we matched 42 patients in both groups and compared the rebleeding and outcomes at discharge (**Table 4**). There was no significant difference between the LD (+) and LD (−). The odds ratio of good outcomes at discharge were 1.378 (95% confidence interval [CI]: 0.555–3.421; P = 0.489) by propensity score matching and 1.824 (95% CI: 0.546–6.094; P = 0.329) with IPTW for the LD (+) group relative to the LD (−) group. The odds ratio of rebleeding was 1.00 (95% CI: 0.134–7.451; P = 1.000) by propensity score matching and 1.089 (95% CI: 0.210–5.652; P = 0.919) with IPTW (**Tables 5** and **6**). Preoperative lumbar drainage was not associated with intraoperative rebleeding or poor neurological outcome.

Discussion

Perioperative lumbar drainage is commonly performed during endovascular treatment to prevent cerebral vasospasms. The volume of SAH was previously shown to be associated with cerebral vasospasm.[13] The drainage of SAH from ruptured aneurysms is important for preventing cerebral vasospasm. Lumbar drainage is known to reduce SAH more rapidly than ventricular drainage.[3] Previous studies showed that 17%–29% of symptomatic vasospasm cases occurred with lumbar drainage, whereas 27%–45% occurred without lumbar drainage.[2,4,5,14,15] However, some studies have reported occasional rebleeding and herniation associated with lumbar drainage.[9,10] The most critical complication of endovascular treatment of ruptured cerebral aneurysms is intraoperative rebleeding. Previous studies reported an intraoperative rebleeding rate of 5.0%–7.7%, which is lower than surgical clipping.[6,7,16] Intraoperative

Table 3 Summary of characteristics of patients with rebleeding

	Lumbar drainage	Age (years)	Sex	Location	WFNS	Fisher's grade	Details of rebleeding	Symptomatic vasospasm	Hydrocephalus	mRS at discharge
1	+	83	F	AcomA	2	4	Intraoperative	–	+	4
2	+	60	F	IC-PC	5	3	Intraoperative	–	–	1
3	+	67	F	MCA	3	2	Intraoperative	Dead (day 9)		6
4	+	72	M	IC-PC	4	3	Intraoperative	Dead (day 3)		6
5	+	60	F	MCA	4	3	Intraoperative	–	–	3
6	+	62	F	VA	4	3	SAH increased at postoperative CT	–	–	3
7	+	63	F	IC-PC	1	2	Intraoperative	–	–	0
8	+	41	F	IC-PC	1	2	Intraoperative	–	–	1
9	+	80	F	ACA	1	3	Intraoperative	–	+	5
10	+	92	F	IC-PC	2	3	Intraoperative	–	–	3
11	+	84	M	VA	1	2	Intraoperative	–	–	2
12	+	59	F	IC-PC	2	2	Intraoperative	–	+	2
13	+	47	F	AcomA	1	3	SAH increased at postoperative CT	Dead (day 8)		6
14	–	56	F	ICA	1	3	Intraoperative	–	–	0
15	–	80	F	AcomA	2	3	Intraoperative	–	+	5

ACA: anterior cerebral artery; AcomA: anterior communicating artery; ICA: internal carotid artery; IC-PC: internal carotid-posterior communicating artery; MCA: middle cerebral artery; SAH: subarachnoid hemorrhage; VA: vertebral artery; WFNS: World Federation of Neurological Surgeons

rebleeding during surgical clipping does not yield a poor outcome because a sudden increase in intracranial pressure is prevented by craniotomy and the cessation of bleeding as soon as possible.[17,18] Meanwhile, intraoperative rebleeding during endovascular treatment is associated with poor outcomes due to a sudden increase in intracranial pressure because craniotomy is not performed.[6,7] A previous study showed that lumbar drainage after SAH effectively controlled intracranial pressure and may contribute to preventing secondary brain damage.[8] If the risk of rebleeding or complications associated with the insertion of a lumbar drainage catheter in the preoperative period is low, it may contribute to controlling intracranial pressure during the acute phase and preventing a sudden increase in intracranial pressure due to rebleeding.

In the present study, the rebleeding rate was 5.8% in the LD (+) group, which is consistent with previous findings (5.0%–7.7%).[6,7] Moreover, the rebleeding rate associated with lumbar drainage was 0.6% (2/324 patients). In the propensity score-matched analysis to adjust for patient backgrounds between the LD (+) and LD (−) groups, the findings confirmed that lumbar drainage before endovascular treatment did not contribute to aneurysm rebleeding. Connolly et al. previously reported a series of 314 patients who underwent lumbar drainage before surgical clipping for ruptured aneurysms.[19] Rebleeding due to lumbar drainage occurred in only 1 patient (0.3%). In the study by Ochiai et al., although no patient had rebleeding associated with lumbar drainage among the 31 patients, 1 (9.1%) had rebleeding while awaiting treatment.[20] Furthermore, Ruijs et al. showed that, in 11 patients with SAH who underwent lumbar drainage during the acute phase, rebleeding occurred in 5 patients (45.4%) while waiting for treatment (several hours to 6 days).[21] These findings support that rebleeding associated with a lumbar drainage catheter insertion is extremely low. However, the risk of rebleeding is high while awaiting treatment after the insertion of a lumbar drainage catheter. Ruptured aneurysms need to be treated early when a lumbar drainage catheter is inserted.

Most patients in this study underwent lumbar drainage under general anesthesia. Lumbar drainage was safely performed with pain relief and strict blood pressure control. Endovascular treatment was administered immediately after lumbar drainage. If the aneurysm is treated soon after lumber drainage, the risk of rebleeding is extremely low, and lumbar drainage before endovascular treatment is considered a safe procedure. Lumbar drainage prior to endovascular treatment has an additional advantage. If a lumbar

Table 4 Propensity score matching between the lumbar drainage and no lumbar drainage groups

Patients	Drainage (+)	Drainage (–)	P value
	42	42	
Age (years)	59.7 ± 14.0	61.6 ± 15.0	0.554
Male	15 (35.7)	11 (26.2)	0.345
WFNS grade			0.871
1	14 (33.3)	15 (35.7)	
2	13 (31.0)	12 (28.6)	
3	3 (7.1)	5 (11.9)	
4	4 (9.5)	2 (4.8)	
5	8 (19.0)	8 (19.0)	
Fisher's grade			0.616
1	2 (4.8)	3 (7.1)	
2	12 (28.6)	17 (40.5)	
3	17 (40.5)	13 (31.0)	
4	11 (26.2)	9 (21.4)	
Aneurysm location			0.673
ICA proximal	4 (9.5)	3 (7.1)	
ICA distal	9 (21.4)	8 (19.0)	
AcomA	14 (33.3)	11 (26.2)	
MCA	6 (14.3)	4 (9.5)	
VA	5 (11.9)	5 (11.9)	
BA apex	2 (4.8)	8 (19.0)	
Others	2 (4.8)	3 (7.1)	
Fusiform	0 (0.0)	0 (0.0)	–
Size	5.79 ± 3.32	6.30 ± 4.93	0.585
Bleb	18 (42.9)	20 (47.6)	0.661
Treatment method			0.801
Simple catheter	28 (66.7)	26 (61.9)	
Double catheter	0 (0.0)	0 (0.0)	
Balloon assist	13 (31.0)	14 (33.3)	
Stent assist	1 (2.4)	2 (4.8)	

Data are presented as the mean ± standard deviation or n (%). AcomA: anterior communicating artery; BA: basilar artery; ICA: internal carotid artery; MCA: middle cerebral artery; WFNS: World Federation of Neurological Surgeon; VA: vertebral artery

Table 5 Clinical outcomes and odds ratio of adverse events by propensity score matching and inverse probability of treatment weighting

Patients	Drainage (+)	Drainage (–)	P value
	42	42	
Primary endpoint			
Modified Rankin Scale Score 0–2	25 (59.5)	28 (66.7)	0.488
Secondary endpoint			
Rebleeding	2 (4.8)	2 (4.8)	1.000
Symptomatic vasospasm	5 (11.9)	5 (11.9)	1.000
Hydrocephalus	10 (23.8)	6 (14.3)	0.243
Meningitis	8 (19.0)	3 (7.1)	0.097

drainage catheter is inserted before endovascular treatment when antithrombotic therapy is administered during the perioperative period, hemorrhagic complications associated with its insertion may be prevented.

We suspected that lumbar drainage during intraoperative rebleeding may prevent the deterioration of patient outcomes. However, lumbar drainage did not affect patient outcomes in the propensity score-matched or ITPW analyses in this study. The sample size of patients with rebleeding in the LD (−) group was considered too small to prove its effects on the clinical outcomes.

Incidences of meningitis and hydrocephalus were slightly higher in the LD (+) group than in the LD (−) group before propensity score matching. One reason for this was the more severe SAH grade in the LD (+) group than in the LD (−) group. Long-term lumbar drainage was needed to wash out thick SAH. However, lumbar drainage for more than four days increased the risk of meningitis.[22] Moreover, meningitis is associated with an increased risk of hydrocephalus (odds ratio: 5.90).[23] Therefore, the duration of lumbar drainage warrants careful consideration, and the drainage catheter needs to be removed as soon as the hemorrhage is washed out.

The present study has several limitations. This was a nonrandomized retrospective study, and the clinical backgrounds of the two groups were different. Therefore, further randomized controlled trials involving a larger number of patients are required to confirm the safety of lumbar drainage. Furthermore, the LD (−) group included only 14% (51/375) of all patients, and the decision to perform spinal drain insertion was completely based on individual judgment; thus, statistical analyses may have been inadequate because there were too few patients in this group. It remains unknown whether lumbar drainage controls intracranial pressure in rebleeding cases because it was not calculated during treatment. Spinal drainage may promote bleeding when an intraoperative rebleeding occurs. However, massive bleeding did not occur in most cases, and we considered this to indicate that spinal drainage controlled the intracranial pressure until the bleeding stopped. The reason for not inserting the lumbar drainage catheter was not described in 19 patients in the LD (−) group. Patients who had rebleeding between lumbar drainage and endovascular

Table 6 Odds ratio of adverse events by propensity score matching and inverse probability of treatment weighting

	Propensity matched score		IPTW	
	OR (95% CI)	P value	OR (95% CI)	P value
Modified Rankin Scale 0–2 at discharge	1.378 (0.555–3.421)	0.489	1.824 (0.546–6.094)	0.329
Rebleeding	1.000 (0.134–7.451)	1.000	1.089 (0.210–5.652)	0.919
Symptomatic vasospasm	1.028 (0.274–3.854)	0.968	1.545 (0.457–5.217)	0.484
Hydrocephalus	1.935 (0.631–5.934)	0.248	1.267 (0.314–5.122)	0.740
Meningitis	3.152 (0.773-12.851)	0.109	3.560 (0.898–14.113)	0.071

IPTW: inverse probability of treatment weighting; OR: odds ratio

treatment were not suitable for endovascular treatment, and thus, they were not enrolled in the present study. Further randomized controlled trials involving a larger number of patients are required to confirm the safety of lumbar drainage.

Conclusion

Lumbar drainage before endovascular treatment for ruptured intracranial aneurysms is a safe procedure that does not increase the incidence of rebleeding.

Acknowledgments

The authors thank Editage (www.editage.jp) for editing the English language.

Funding

This work was supported by JSPS KAKENHI Grant Number JP20242763.

Author Contributions

TT (1st), YI, MS, MH, and YM contributed to the study conception and design. TT (1st) and YI, KH, MS, TT (5th), AM, MH, WT, NK, YN, KS, YM, and EI acquired the data. TT (1st) and YI analyzed and interpreted the data. TT (1st) and YI drafted the manuscript. KH, MS, TT (5th), AM, MH, WT, NK, YN, and KS revised and edited the manuscript.

Disclosure Statement

The authors declare no potential conflicts of interest with respect to the research, authorship, or publication of this article.

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