e-ISSN: 0975-9506, p-ISSN: 2961-6093

Available online on www.ijpqa.com doi: 10.25258/ijpqa.16.3.71

International Journal of Pharmaceutical Quality Assurance 2025; 16(3); 422-428

Original Research Article

Effectiveness of Early Lumbar Cerebrospinal Fluid Drainage in Reducing Vasospasm and Improving Outcomes in Aneurysmal Subarachnoid Hemorrhage: A Multicenter Randomized Controlled Trial

Satyendra Kumar

Associate Professor and HOD, Department of Neurosurgery, Anugrah Narayan Magadh Medical College and Hospital, Gaya, Bihar, India

Received: 15-01-2025 / Revised: 13-02-2025 / Accepted: 29-03-2025

Corresponding Author: Dr. Satyendra Kumar

Conflict of interest: Nil

Abstract:

Background: Aneurysmal subarachnoid hemorrhage (SAH) remains an urgent life-threatening neurological emergency frequently complicated by cerebral vasospasm, producing delayed cerebral ischemia and poor functional outcome. Despite all the treatments, vasospasm remains a major clinical issue.

Objective: To ascertain whether early LCSFD is effective in the prevention of vasospasm and in determining outcome in patients with aneurysmal SAH.

Methodology: In this prospective, multicenter randomized controlled trial, 70 patients with surgically secured aneurysmal SAH were randomized into two groups: 35 had early LCSFD (Group I) and 35 had no LCSFD (Group II). The main outcomes were the incidence of vasospasm (clinical, TCD, and radiological) and Glasgow Outcome Score (GOS) at discharge, 1-month, and 3-month follow-ups. Secondary outcomes included ICU/hospital stay and perioperative complications. Statistical significance was at $p<0.05$.

Results: LCSFD reduced clinical vasospasm (28.6% vs. 62.9%, p=0.01), TCD-detected vasospasm (17.1% vs. 42.9%, p=0.02), and cerebral infarction (20% vs. 45.7%, p=0.007). GOS was improved in the LCSFD group at discharge (p=0.01), and at 1-month and 3-month follow-ups (p=0.04). Mortality and complications did not differ significantly between groups.

Conclusion: Early LCSFD is a safe, effective, and minimally invasive treatment that considerably reduces vasospasm and improves neurological outcomes in aneurysmal SAH patients.

Keywords: Aneurysmal Subarachnoid Hemorrhage, Cerebral Vasospasm, Cerebrospinal Fluid Drainage, Glasgow Outcome Score, Lumbar Drainage, Randomized Controlled Trial.

Introduction

Aneurysmal subarachnoid hemorrhage (SAH) continues to be one of the most devastating causes of stroke with substantial morbidity and mortality in spite of improvements in neurocritical care and neurosurgical treatment. Cerebral vasospasm, arguably the most difficult and mysterious complication of aneurysmal SAH, is a pathologic, prolonged narrowing of cerebral arteries usually between the 3rd and 14th days after hemorrhage. The complication is also well known to be a major cause of delayed cerebral ischemia and eventually poor neurological outcome in survivors of aneurysmal SAH.

Over the years, major efforts have been made to counteract the effect of cerebral vasospasm. One of the first treatments that gained clinical attention was triple-H therapy—hypertension, hypervolemia, and hemodilution—initially suggested in the early 1980s to correct cerebral hypoperfusion due to vasospasm [1,2]. Though symptomatic improvement was noted in some patients with this therapy, it came with complications and did not offer any disease-modifying effect on the pathophysiologic mechanisms of vasospasm. The management of cerebral vasospasm has been significantly improved with the advent of endovascular therapy.

The subsequent introduction of the calcium channel blocker nimodipine into clinical practice in 1985 represented a major breakthrough in the treatment of vasospasm. Clinical trials have shown that nimodipine therapy led to a decrease in severe vasospasm from about 30% to 20% [3]. Of interest, however, is that nimodipine has not been shown to reduce angiographic signs of vasospasm, suggesting a neuroprotective rather than a vasodilatory effect. The development of endovascular techniques in the late 1980s, including transluminal balloon angioplasty and intra-arterial infusion of vasodilators like papaverine and nimodipine, further expanded the therapeutic armamentarium [4,5]. These treatments allowed neurological salvage of patients with

established vasospasm; however, they are technically demanding, not universally available, and often used as reactive instead of as prophylactic treatments.

In spite of these improvements, cerebral vasospasm remains a major clinical problem, causing prolonged hospitalization, increased healthcare costs, and severe long-term disability in aneurysmal subarachnoid hemorrhage survivors [6]. Failure to eliminate vasospasm by existing therapeutic interventions shows the need for novel strategies directed at its pathophysiologic mechanisms.

There has been growing evidence for the theory that the presence of blood in the subarachnoid space and particularly its hemolysis breakdown products is a critical element in the cascade of events to vasospasm [7]. Hence, methods that are intended to ensure early subarachnoid blood clearance are regarded as promising in prevention as well as in lessening the severity of vasospasm. Various methods have been studied by researchers to achieve this, such as intrathecal fibrinolytics, irrigation procedures, and drainage mechanisms [8].

In such a scenario, LCSFD seems to be a simple, low-cost, and minimally invasive intervention with the potential to facilitate removal of subarachnoid blood. The scientific rationale behind LCSFD is cerebrospinal fluid (CSF) physiology; by suctioning CSF from the lumbar cistern, a pressure gradient is established that promotes flow of newly formed, clear CSF from the ventricles into the subarachnoid spaces. This can be enhanced further if arachnoidal membranes are addressed to create fenestrations, which is standard when clipping aneurysms. Such an intervention not only dilutes and clears pro-inflammatory by-products of blood degradation but also facilitates physical removal of red blood cell debris from the largest subarachnoid cistern—the lumbar cistern.

Based on such theoretic and mechanistic bases, LCSFD seems to be a potentially useful adjunction for the initial treatment of aneurysmal SAH. Despite observational study suggestions of potential utility by numerous such studies, however, high-quality evidence from large randomized controlled trials (RCTs) is limited. To close this enormous knowledge gap, we conducted a prospective, multicenter randomized controlled trial to determine whether early administration of LCSFD reduces incidence and severity of cerebral vasospasm and improves functional outcome in patients with aneurysmal SAH.

The present study thus aims to critically assess whether the early initiation of cerebrospinal fluid drainage of the lumbar region can offer substantial clinical benefits to this susceptible group of patients. In attempting to meet this aim, we attempt to advance the emergent paradigm of prevention of vasospasm by providing strong evidence for a low-risk, feasible intervention that may be integrated into international standard-of-care guidelines.

Methodology

Study Design: This study was designed as a prospective, multicenter, randomized controlled trial (RCT) conducted to assess the effectiveness of early lumbar cerebrospinal fluid drainage (LCSFD) in reducing vasospasm and improving outcomes in patients with aneurysmal subarachnoid hemorrhage (SAH).

Study Area: The trial was conducted at Department of Neurosurgery, Anugrah Narayan Magadh Medical College and Hospital, Gaya, Bihar, India.

Study Duration: The study was conducted over a period of one year, from October 2023 to September 2024.

Sample Population: Patients with aneurysmal subarachnoid hemorrhage (SAH) presenting to participating centers and meeting inclusion criteria were recruited.

Sample Size: A total of 70 patients were included in the study and were randomly allocated into two equal groups:

- **Group I (Intervention Group):** Underwent placement of lumbar CSF drain.
- **Group II (Control Group):** Did not receive lumbar CSF drainage.

Inclusion Criteria

- Age ≥18 years.
- Diagnosis of aneurysmal SAH.
- Hunt and Hess Grade II–IV.
- Symptom onset (ictus) within 10 days prior to admission.
- Aneurysm secured surgically within 3 days of admission.

Exclusion Criteria

- Evidence of raised intracranial pressure (ICP) contraindicating lumbar drain placement.
- Aneurysm not surgically secured (non-operated patients).
- Presence of intracranial mass lesions (hematoma, significant cerebral edema, midline shift).
- Meningitis or other infections precluding safe intrathecal access.
- Hunt and Hess Grade I and V at admission.
- Patients undergoing endovascular coiling.

Randomization and Blinding: Patients were randomized into either group using a computer-generated randomization chart. Due to the nature of the intervention, blinding of treating clinicians and patients was not feasible; however, outcome assessors were blinded to group allocation to minimize bias.

Data Collection: Baseline demographic and clinical data, including Hunt and Hess grade and Fisher grade on CT scan, were recorded at admission. Continuous clinical and radiological monitoring was performed throughout hospitalization. Primary and secondary outcome measures were documented during hospitalization and follow-up visits at 1 and 3 months.

Clinical Procedure: All patients were stabilized and resuscitated by the time they were admitted. The grade of neurological status was monitored according to the Hunt and Hess grading scale, while the quantity and degree of subarachnoid blood was classified using the Fisher grading scale using CT scans. All patients underwent surgical clipping of the aneurysm within 72 hours of admission. In the interventional arm group, a closed system lumbar CSF drain was placed intraoperatively via the L3–L4 inter-segmental space in an aseptic fashion after anesthesia was induced. The drain was opened intra-operatively prior to dural opening to allow for relaxation of the brain and then maintained in the open position for a minimum of 72 hours postoperatively. The drainage bag was maintained at a level with the patient's head to avoid over drainage. Post-operatively, the intervention and control groups maintained standardized perioperative care, which included intravenous antibiotics, (Cefoperazone-sulbactam, netilmicin and metronidazole), nimodipine for assymptomatic vasospasm prophylaxis, daily transcranial doppler (TCD) ultrasonography for monitoring cerebral blood flow, and treating metabolic disturbances, as indicated. Other methods and support, including: 3 H therapy (hypervolemia, hypertension, hemodilution) were instigated at the request of the patient's condition.

Outcome Measures: This study analyzed the following outcomes: the incidence of clinically evident vasospasm, vasospasm-related cerebral infarction, neurological status at discharge and Glasgow Outcome Score (GOS) at one- and three-months post discharge. Clinically evident vasospasm was defined as new neurological deterioration such as confusion disorientation, drowsiness, or focal deficits between days 4 and 14 post hemorrhage, with adequate CT imaging evidence to exclude alternative causes for the change, and with additional indications of vasospasm by serial transcranial Doppler (TCD) studies. Infarction related to vasospasm was defined as sustained (lasting greater than the post hemorrhage vasospasm risk period) neurological deficits not related to other causes, or imaging changes demonstrating an infarct in vascular territories delineated by vasospasm findings. Secondary outcomes included duration of stay in a intensive care unit (ICU) and total length of stay to allow for comparison between groups of the impact of lumbar drainage on recovery and resource use.

Statistical Analysis: Descriptive and statistical analysis were performed using SPSS version 25. Continuous variables were recorded as mean ± standard deviation or median (interquartile range) as appropriate and compared using student's t-test or Mann–Whitney U test, respectively. Categorical variables were compared using the Chi-square test or Fisher's exact test, as appropriate. Where applicable, using multivariate logistic regression analysis was used to account for potential confounding variables. $p<0.05$ was considered statistically significant.

Result

"Table 1 compares the demographic and clinical profiles of patients in the Lumbar CSF drainage group (n=35) and the Non-Lumbar CSF drainage group (n=35). The mean age was comparable between groups (48.4±10.2 vs. 47.5±11.2 years; P=0.76), with age ranges of 30–70 and 18–75 years, respectively. Gender distribution was similar (male:female = 13:22 vs. 14:21; P=0.79). The mean Glasgow Coma Scale (GCS) on admission was slightly lower in the drainage group (13.90±0.35 vs. 14.05±0.65; P=0.22), though not statistically significant. Comorbidities such as hypertension were more common in the drainage group (60% vs. 49%; P=0.49), while diabetes was equally prevalent (3% each), and isolated cases of asthma and coronary artery disease appeared in the non-drainage group. SAH grades were similarly distributed across both groups, with Grade III being most common (45.7% vs. 37.1%). Aneurysm locations also showed comparable patterns, with the anterior communicating artery (ACom) being the most frequent site in both groups (48.6% vs. 57.1%; P=0.75), followed by DACA, MCA, PCom, ICA, and AICA distributions. None of the observed differences reached statistical significance.

Table 1: Summarizing demographic profile of the two groups

Parameters analyzed	Lumbar CSF drainage group (n=35)	Non-Lumbar CSF drainage group (n=35)	P
Sex (male: female)	13:22	14:21	0.79
Age in years (mean±SD)	48.4±10.2	47.5±11.2	0.76
Range	30–70	18–75	
GCS on admission (min–max)			
Median	14 (12–15)	14 (12–15)	0.22
Mean	13.90±0.35 (12–15)	14.05±0.65 (12–15)	

Comorbid illnesses (%)			
HTN	21 (60%)	17 (49%)	0.49
DM	1 (3%)	1 (3%)	
Bronchial asthma	0	1 (3%)	
CAD	0	1 (3%)	
Valvular heart disease	0	0	
SAH grade (%)			
II	13 (37.1%)	15 (42.9%)	0.58
III	16 (45.7%)	13 (37.1%)	
IV	6 (17.1%)	7 (20%)	
Aneurysmal bleed (%)			
ACom	17 (48.6%)	20 (57.1%)	0.75
DACA	2 (5.7%)	5 (14.3%)	
MCA	3 (8.6%)	3 (8.6%)	
PCom	3 (8.6%)	1 (2.9%)	
ICA	5 (14.3%)	2 (5.7%)	
AICA	5 (14.3%)	4 (11.4%)	

Table 2 presents outcome comparisons between the Lumbar CSF drainage group and the Non-Lumbar CSF drainage group. The incidence of clinical vasospasm was significantly lower in the drainage group (28.6%) compared to the non-drainage group (62.9%, *P*=0.01). Similarly, TCD-detected vasospasm (17.1% vs. 42.9%, *P*=0.02) and radiological evidence of cerebral infarction (20% vs. 45.7%, *P*=0.007) were significantly less frequent in the drainage group. Focal neurological deficits, such as hemiparesis (20% vs. 31.4%), were more common in the non-drainage group, though not statistically significant (*P*=0.15). Analysis by SAH grade showed no significant differences in vasospasm risk. Perioperative complications were comparable across groups, with meningitis (14.3% vs. 17.1%), pneumonia (14.3% each), UTI (5.7% vs. 11.4%), septicemia, and dys-electrolytemia occurring at similar rates. Mortality was equal in both groups (5.7%). Overall, the lumbar drainage group demonstrated a statistically significant reduction in vasospasm-related complications without an increase in adverse events.

Table 2: Results are summarized in two groups

Parameters analyzed	Lumbar CSF drainage group (%)	Non-Lumbar CSF drainage group (%)	P
Clinical effect of vasospasm	10/35 (28.6%)	22/35 (62.9%)	0.01
Focal neurological deficit			
Paraparesis	0	0	1
Monoparesis	0	1 (2.9%)	1
Quadriparesis	0	1 (2.9%)	1
Hemiparesis	7 (20%)	11 (31.4%)	0.15
TCD effect of vasospasm	6 (17.1%)	15 (42.9%)	0.02
Radiological effect of vasospasm (cerebral infarct)	7 (20%)	16 (45.7%)	0.007
SAH grade and risk of vasospasm			
IV	3/5 (60%)	3/7 (42.9%)	1
III	4/14 (28.6%)	6/13 (46.2%)	0.31
II	2/11 (18.2%)	7/15 (46.7%)	0.22
Perioperative complications			
Meningitis	5 (14.3%)	6 (17.1%)	0.42
Pneumonia	5 (14.3%)	5 (14.3%)	
UTI	2 (5.7%)	4 (11.4%)	
Septicemia	1 (2.9%)	2 (5.7%)	
Dys-electrolytemia	2 (5.7%)	2 (5.7%)	
Hypoxia	0	1 (2.9%)	
Subdural/extra-dural hemorrhage	2 (5.7%)	1 (2.9%)	
Hydrocephalus	0	2 (5.7%)	
Mortality	2 (5.7%)	2 (5.7%)	1

Table 3 compares patient outcomes between the Lumbar CSF drainage and Non-Lumbar CSF drainage groups. At discharge, GCS scores were similar (mean 14.39±0.27 vs. 14.48±1.43; P=0.11), with both groups showing a median of 15. However, the drainage group had a significantly better Glasgow Outcome Score (GOS) at discharge (mean 3.93±1.02 vs. 3.27±0.80; P=0.01), with a higher median score of 4 compared to 3. ICU and hospital stays were comparable between groups (median ICU stay: 7.5 vs. 8 days, P=0.91; median hospital stay: 12 days each, P=0.74). At both 1-month and 3-month follow-ups, the drainage group maintained significantly better outcomes, with mean GOS scores of 4.44±1.07 versus 3.86±0.93 (P=0.04 for both time points), and a higher median GOS of 5 compared to 4. These findings suggest that lumbar CSF drainage was associated with improved functional recovery over time.

Table 3: Summary of the two groups' results

Parameters analyzed	Lumbar CSF drainage group	Non-Lumbar CSF drainage group	P
GCS at discharge (range)			
Median	15 (14–15)	15 (9–15)	0.11
Mean	14.39±0.27 (14–15)	14.48±1.43 (9–15)	
GOS at discharge			
Median	4 (1–5)	3 (1–5)	0.01
Mean	3.93±1.02 (1–5)	3.27±0.80 (1–5)	
Median ICU stay (days)	7.5 (3–20)	8 (3–14)	0.91
Median hospital stay (days)	12 (7–31)	12 (6–45)	0.74
GOS at 1 month follow-up			
Median	5 (1–5)	4 (1–5)	0.04
Mean	4.44±1.07 (1–5)	3.86±0.93 (1–5)	
GOS at 3 months follow-up			
Median	5 (1–5)	4 (1–5)	0.04
Mean	4.44±1.05 (1–5)	3.86±0.93 (1–5)	

Discussion

Our study proved that lumbar cerebrospinal fluid drainage (LCSFD) meaningfully reduced the incidence of clinically evident vasospasm, transcranial Doppler-detectable vasospasm, and radiologic infarcts following aneurysmal subarachnoid hemorrhage (SAH). These findings are consistent with the prevailing impression that clearance of the subarachnoid blood products that cause vasospasm pathophysiology can improve clinical outcome. Similarity of groups at baseline, by age, gender, comorbidities, and SAH grade distribution in our trial confirms the robustness of these differences in outcomes."

In concordance with earlier reports, cerebral vasospasm continues to be a significant cause of morbidity and mortality after aneurysmal SAH despite advances in surgical clipping, endovascular coiling, and pharmacotherapy like calcium channel blockers and 3H therapy [9]. Pathophysiology of vasospasm is multifactorial and includes complex mechanisms of breakdown products of blood like oxygen free radicals and endothelin, resulting in prolonged vessel constriction [10]. Our finding of significantly reduced vasospasm in the lumbar drainage group is in line with the theory that aggressive subarachnoid blood clearance prevents these vasospastic mediators, in line with earlier reports emphasizing the relationship between clot burden and risk of vasospasm [11,12].

In agreement with our results, Inagawa et al. [13] reported decreased incidence of symptomatic and angiographic vasospasm among patients with cisternal CSF drainage. Likewise, trials that combined CSF drainage with the infusion of fibrinolytic agents, such as urokinase or t-PA, have reported superb prevention of vasospasm, especially among severe Fisher Grade III SAH patients, with the added benefit of early clot removal and irrigation of the subarachnoid space. We did not employ fibrinolytic agents in our study, yet the comparable reduction in vasospasm validates therapeutic effectiveness of lumbar drainage alone as a less invasive technique of CSF clearance.

Our evidence of enhanced functional outcomes as evidenced by highly elevated Glasgow Outcome Scale scores at follow-up and discharge in the lumbar drainage group is in agreement with previous work by Klimo et al. [14] and Kwon et al., [15] who demonstrated that lumbar CSF drainage reduced the incidence of vasospasm and enhanced survival. Our observed safety profile is also in agreement with Hoekema et al., [16] who stressed that lumbar drainage, when done correctly, is a safe procedure with few neurological complications.

Relative to benefits of lumbar drainage, ventricular CSF drainage has been less effective or even

deleterious by causing stasis of blood clots in subarachnoid spaces, with potential potentiation of vasospasm. Our findings support the value of lumbar drainage in clearing spasmogenic blood products from the subarachnoid space, improving CSF dynamics, and lowering intracranial pressure.[14] This action is most likely responsible for the reduced vasospasm and ischemic complications in our lumbar drainage group.

Concerning perioperative complications, our results and the literature concur with respect to the comparable rates of meningitis, pneumonia, and other infections in groups, as continuous lumbar CSF drainage has a low but certain risk of infection [17]. While intracranial hemorrhage and cerebral herniation can be produced by over drainage, as previously reported, we did not find an increase in mortality or in important neurological deterioration, suggesting strict patient selection and monitoring must be employed.

In brief, the findings provide additional clinical proof of the effectiveness of lumbar CSF drainage as an effective adjunctive treatment of aneurysmal SAH with severe cerebral vasospasm, reduction of infarcts, and enhanced functional outcomes without additional risk. The results verify and expand the previous studies, which justify the more extensive utilization of lumbar drainage in appropriate SAH patients to improve neurological outcome.

Conclusion

The research demonstrates the efficacy of early lumbar cerebrospinal fluid (CSF) drainage in aneurysmal subarachnoid hemorrhage patients in effectively minimizing the occurrence of vasospasm, both on the basis of clinical symptoms and radiological results, in patients receiving lumbar drainage compared to those who were not receiving lumbar drainage. Moreover, the lumbar CSF drainage group also exhibited improved neurological function at discharge and follow-up, with higher Glasgow Outcome Scores and fewer long-term impairments. Notably, the intervention did not significantly increase perioperative complications and mortality, indicators that the intervention is a safe and advantageous addition in subarachnoid hemorrhage management.

References

1. Clinical vasospasm after subarachnoid hemorrhage: Response to hypervolemic hemodilution and arterial hypertension. Stroke 1987; 18:365 72.
2. Origitano TC, Wascher TM, Reichman OH, Anderson DE. Sustained increased cerebral blood flow with prophylactic hypertensive hypervolemic hemodilution (“triple-H” therapy) after subarachnoid hemorrhage. Neurosurgery 1990; 27:729 39.
3. Allen GS, Ahn HS, Preziosi TJ, Battye R, Boone SC, Boone SC, et al. Cerebral arterial spasm – A controlled trial of nimodipine in patients with subarachnoid hemorrhage. N Engl J Med 1983; 308:619-24.
4. Elliott JP, Newell DW, Lam DJ, Eskridge JM, Douville CM, Le Roux PD, et al. Comparison of balloon angioplasty and papaverine infusion for the treatment of vasospasm following aneurysmal subarachnoid hemorrhage. J Neurosurg 1998; 88:277 84.
5. Eskridge JM, McAuliffe W, Song JK, Deliganis AV, Newell DW, Lewis DH, et al. Balloon angioplasty for the treatment of vasospasm: Results of first 50 cases. Neurosurgery 1998; 42:510-6.
6. Corsten L, Raja A, Guppy K, Roitberg B, Misra M, Alp MS, et al. Contemporary management of subarachnoid hemorrhage and vasospasm: The UIC experience. Surg Neurol 2001; 56:140
7. Macdonald RL. Pathophysiology and molecular genetics of vasospasm. Acta Neurochir Suppl 2001;77:7 11.
8. Hirashima Y, Kurimoto M, Hayashi N, Umemura K, Hori E, Origasa H, et al. Duration of cerebrospinal fluid drainage in patients with aneurysmal subarachnoid hemorrhage for prevention of symptomatic vasospasm and late hydrocephalus.
9. Sasaki T, Kodama N, Kawakami M, Sato M, Asari J, Sakurai Y, et al. Urokinase cisternal irrigation therapy for prevention of symptomatic vasospasm after aneurysmal subarachnoid hemorrhage: A study of urokinase concentration and the fibrinolytic system. Stroke 2000; 31:1256 62.
10. Kwon OY, Kim YJ, Kim YJ, Cho CS, Lee SK, Cho MK. The utility and benefits of external lumbar CSF drainage after endovascular coiling on aneurysmal subarachnoid hemorrhage. J Korean Neurosurg Soc 2008; 43:281 7.
11. Hänggi D, Eicker S, Beseoglu K, Behr J, Turowski B, Steiger HJ. A multimodal concept in patients after severe aneurysmal subarachnoid hemorrhage: Results of a controlled single centre prospective randomized multimodal phase I/II trial on cerebral vasospasm. Cent Eur Neurosurg 2009; 70:61 7.
12. Fisher CM, Kistler JP, Davis JM. Relation of cerebral vasospasm to subarachnoid hemorrhage visualized by computerized tomographic scanning. Neurosurgery 1980; 6:1 9.
13. Inagawa T, Kamiya K, Matsuda Y. Effect of continuous cisternal drainage on cerebral vasospasm. Acta Neurochir (Wien) 1991; 112:28-36.
14. Klimo P Jr., Kestle JR, MacDonald JD, Schmidt RH. Marked reduction of cerebral vasospasm with lumbar drainage of cerebrospinal fluid

after subarachnoid hemorrhage. J Neurosurg 2004; 100:215-24.
15. Kawamoto S, Tsutsumi K, Yoshikawa G, Shinozaki MH, Yako K, Nagata K, et al. Effectiveness of the head-shaking method combined with cisternal irrigation with urokinase in preventing cerebral vasospasm after subarachnoid hemorrhage. J Neurosurg 2004; 100:236-43.
16. Hoekema D, Schmidt RH, Ross I. Lumbar drainage for subarachnoid hemorrhage: Technical considerations and safety analysis. Neurocrit Care 2007; 7:3 9
17. Marshman LA, Hardwidge C, Donaldson PM. Bacillus cereus meningitis complicating cerebrospinal fluid fistula repair and spinal drainage. Br J Neurosurg 2000; 14:580 2.