# Fenestration of Lamina Terminalis During Anterior Circulation Aneurysm Clipping on Occurrence of Shunt-Dependent Hydrocephalus After Aneurysmal Subarachnoid Hemorrhage: Meta-Analysis

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■ BACKGROUND: **Shunt-dependent hydrocephalus (SDH) is a common complication after aneurysmal subarachnoid hemorrhage and affects its outcome significantly. Whether fenestration of the lamina terminalis (FLT) during anterior circulation aneurysm clipping for aneurysmal subarachnoid hemorrhage can decrease the occurrence of SDH is still controversial.**

■ METHODS: **Ovid and PubMed databases were retrieved by the following key words: "hydrocephalus," "subarachnoid hemorrhage," "aneurysm," "fenestration," and "lamina terminalis." The Cochran-Mantel-Haenszel test was used to compare overall incidence of SDH.**

■ RESULTS: **The literatures were searched, and 15 were included involving 2839 patients. The overall incidence of SDH in fenestrated cohort was 11.4%, compared with 15.3% in the nonfenestrated cohort ($P = 0.008$). The relative risk of SDH in fenestrated cohort was 0.67 (95% confidence interval 0.50–0.90).**

■ CONCLUSIONS: **This meta-analysis suggests that FLT during anterior circulation aneurysm clipping reduces the incidence of SDH. However, a well-designed, randomized controlled trial is necessary to prove the efficacy of FLT to reduce SDH.**

## INTRODUCTION

Aneurysmal subarachnoid hemorrhage (aSAH) is a major subset of cerebral hemorrhagic stroke with an annual incidence of 2–32 cases per 100,000 population.[1] Hydrocephalus caused by aSAH is classified as acute or chronic based on the onset time course. Acute hydrocephalus occurs within hours mainly due to blockage of cerebrospinal fluid (CSF) flow, while chronic hydrocephalus varied from weeks to months mainly due to arachnoid granulations and fibrosis of the leptomeninges caused by sSAH, which in turn leads to diminished CSF absorption. Clinically, acute hydrocephalus is often treated by external ventricular drainage and chronic hydrocephalus needed shunt to drain CSF. It is reported that shunt-dependent hydrocephalus (SDH) occurred in >20% of all aSAH patients.[2,3] Patients with SDH experienced worse short- and long-term prognosis with higher mortality, longer hospital stay, and more medical expenses. Furthermore, SDH is an independent risk factor predicting a long-term unfavorable functional outcome of aSAH.[1-3] The aneurysm can be categorized as anterior or posterior circulation considering the location.[3]

Fenestration of lamina terminalis (FLT) is a useful procedure during anterior circulation ruptured aneurysm clipping operation to decrease intracranial pressure. During operation, the lamina terminalis was exposed, which normally appears as a slightly convex light-blue membrane posterosuperior to the optic chiasm. Fenestration should be performed strictly in the midline avoid damaging the blood supply of the optic nerves and optic chiasm. The optimal fistula diameter is 5–6 mm. Once the lamina terminalis is opened posterosuperiorly to the optic chiasm, CSF flows from the third ventricle, which indicated successful fenestration.[4] However, the efficacy of FLT remains controversial. Therefore we performed this meta-analysis to determine the efficacy of FLT to reduce SDH.

## METHODS

### Literature Search Strategy

Literature from Ovid, PubMed, Cochrane Database of Systematic Reviews, and EMBASE was searched from 1950–2017 with the key

**Key words**
- Aneurysm
- Hydrocephalus
- Lamina terminalis fenestration
- Meta-analysis

**Abbreviations and Acronyms**
**aSAH**: Aneurysmal subarachnoid hemorrhage
**CSF**: Cerebrospinal fluid
**FLT**: Fenestration of the lamina terminalis
**SDH**: Shunt-dependent hydrocephalus

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words "ventriculoperitoneal shunt, hydrocephalus, subarachnoid hemorrhage, aneurysm, fenestration, and lamina terminalis" singly and in combination. The literature was limited to articles published in English, and human was specified as the study category. Two authors independently examined titles, abstracts, and references of the identified reports and resolved discrepancies through discussions with the third author. When a study was reported in more than 1 publication, the most recent or complete dataset was selected.

## Inclusion Criteria

Patients with a clear diagnosis of aneurysm were included in the study. All patients were diagnosed by digital subtraction angiography or computed tomography angiography. All studies were screened strictly, and only the studies referred to the influence of FLT on the incidence of SDH were selected in our study.

## Exclusion Criteria

Firstly, all selected original papers were scrutinized for trial design, operation procedure, patient characters, and conclusions. Next, the information in each paper was extracted and divided into 2 cohorts according to clipping with or without FLT. The information included age, sex, admission hydrocephalus, clinical grade (World Federation of Neurosurgical Societies or Hunt-Hess), Fisher grade, aneurysm location, and the incidence of SDH. Animal trials, duplicate reporting, and poor quality or lack of data in the literature were excluded. Patients treated with embolization were also excluded. Case reports, editorials, commentaries, and reviews were excluded.

## Data Analysis

Data from each cohort were combined and then compared. The total incidence of SDH between the 2 cohorts was compared with a Mantel-Haenszel test, and pooled relative risk and its corresponding 95% confidence interval were calculated. Heterogeneity in odds ratios among the studies was evaluated by the Breslow-Day test, and $P < 0.05$ was considered significant.

# RESULTS

## Study Identification

Detailed steps in the literature search are shown in Figure 1. A total of 215 published papers were selected through our initial literature retrieval. After careful scrutiny, 200 were excluded on the basis of exclusion criteria. Fifteen studies were included in this meta-analysis.[4-19]

The characters and limitations of the 15 studies are summarized in Table 1, including 7 retrospective studies[5,7-9,14,15,19] and 8 prospective studies,[1,4,6,10,13,16-18] all of which were not randomized controlled trials. The decision of FLT in all studies depended on the neurosurgeons' experience and favorites, and the criteria for shunt placement were not mentioned in any study. A total of 2839 patients with aSAH were included in this meta-analysis. Among the 15 studies, 11 had proper control groups[4,6,8,10,12,13,15-19] and 4 had historical controls.[5,7,9,14]

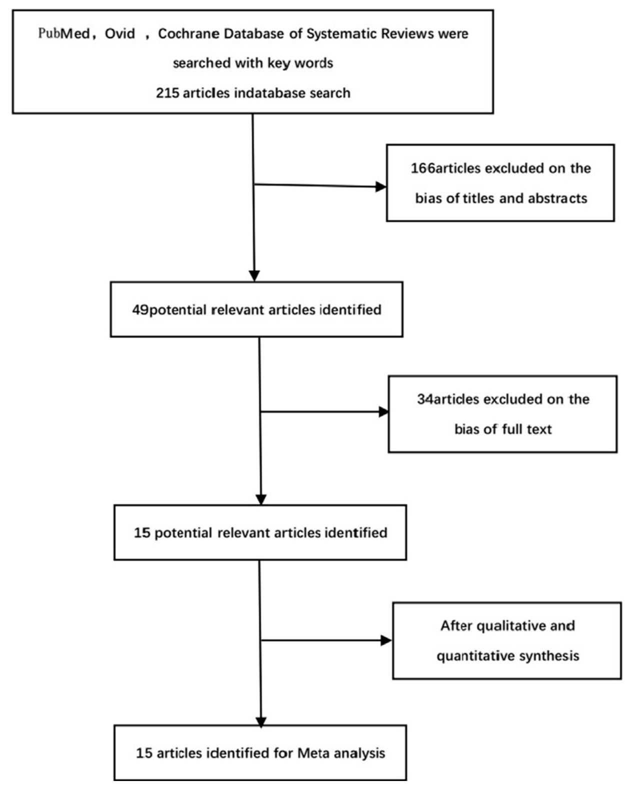


**Figure 1.** Flow chart of the articles screening and selection process for the meta-analysis.

## Heterogeneity Test

The chi-squared test showed that the occurrence of SDH had moderate heterogeneity ($chi^2 = 35.87$, $P < 0.001$, $I2 = 72\%$). The funnel plots distribution estimated the heterogeneity of this meta-analysis was moderate (Figure 2).

## Meta-Analysis of Incidence of SDH

The overall incidence of SDH was 11.4% and 15.3% in fenestrated cohort and nonfenestrated cohort, respectively (Figure 3A). The overall association between fenestration and the occurrence of SDH was statistically significant with $Z = 2.65$ ($P = 0.008$). The pooled relative risk of SDH in the fenestrated cohort was 0.67 (95% confidence interval 0.5–0.9). The Breslow-Day test revealed significant heterogeneity between studies ($P < 0.05$). A pooled analysis showed only 11 studies with a fenestrated cohort, and the other 4 studies were excluded. The overall incidence of SDH was 11.9% and 15.3% in the fenestrated cohort and nonfenestrated cohort, respectively (Figure 3B). Among the 11 studies, 6 studies supported the benefit of FLT[8,10,12,14,17,19] while 5 studies refuted the benefit of FLT.[4,7,15,16,18]

# DISCUSSION

Hydrocephalus following aSAH can be classified into acute or chronic on the basis of the time of onset. Chronic hydrocephalus is a common complication after aSAH and significantly affects

**Table 1.** Characteristics of Studies on Effect of Fenestration of Lamina Terminalis on Subdural Hematoma

| Authors and Year | Study Design | Number of Patients: DSH in FLT | FLT | DSH in No-FLT | No-FLT | Total Patients | Male/ Female | Mean Age (years) | Aneurysm Location | H&H Grade | Fisher 3-4 Degree Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sindou, 1994[4] | Pros | 11 | 71 | 14 | 126 | 197 | NA | NA | NA | 14% H&H IV-V | 34% |
| Yonekaw, 1998[5] | Retro | 13 | 150 | 0 | 0 | 150 | 104/46 | 50 | 94% ant circ | NA | 43.3% |
| Tomasello, 1999[6] | Pros | 10 | 52 | 0 | 0 | 52 | 15/37 | 55 | 100% ant circ | 100% H&H IV-V | 100% |
| Schmieder, 1999[7] | Retro | 19 | 112 | 3 | 26 | 138 | 41/97 | 51 | 93% ant circ | 33% H&H IV-V | 65% |
| Komotar , 2002[8] | Retro | 3 | 139 | 50 | 395 | 534 | 113/421 | 52 | 83% ant circ | 17% H&H IV-V | 72% |
| Andaluz , 2003[9] | Retro | 2 | 40 | 0 | 0 | 40 | 19/21 | 52 | 100% ant circ | 18% H&H IV-V | 67.5% |
| Andaluz, 2004[10] | Pros | 2 | 53 | 7 | 53 | 106 | 90/16 | 52 | 100% ant circ | 16% H&H IV-V | 100% |
| Dehdashti, 2004[12] | Pros | 25 | 180 | 12 | 65 | 245 | 133/112 | 49 | NA | 16% WFNS IV-V | 65% |
| Akyuz, 2006[13] | Pros | 7 | 71 | 0 | 0 | 71 | 30/41 | 48 | 100%ant circ | 31%H&H IV-V | 55% |
| Kim, 2006[14] | Retro | 8 | 36 | 10 | 35 | 71 | 35/36 | 52 | 100%ant circ | 54%H&H IV-V | 70% |
| Komotar, 2008[15] | Retro | 18 | 71 | 48 | 298 | 369 | 91/278 | 52 | 100%ant circ | 22%H&H IV-V | 64% |
| Lu, 2012[16] | Pros | 3 | 11 | 13 | 125 | 152 | 62/90 | 46 | | NA | NA |
| Chohan, 2013[17] | Pros | 0 | 15 | 1 | 2 | 17 | NA | NA | 100%ant circ | NA | NA |
| Hatefi, 2015[18] | Pros | 4 | 25 | 3 | 25 | 50 | 14/36 | 52 | 100%ant circ | 12.5%H&H IV-V | 50% |
| Winkler, 2017[19] | Reto | 3 | 93 | 102 | 570 | 663 | 198/465 | 54.5 | 69.5%ant circ | 59.7% H&H I-II | 76.9% |

Pros, prospective; Reto, retrospective; DSH, shunt-dependent hydrocephalus; FLT, fenestration of the lamina terminalis; NA, not Available; ant circ, anterior circulation; H&H, Hunt-Hess degree; WFNS, World Federation of Neurological Societies Scale.

outcome.[1,2,18] Development of chronic hydrocephalus after aSAH can result in neurologic deterioration, 1 of the representative complications of aSAH after occlusion of a ruptured aneurysm. During the clipping operation for a ruptured aSAH, both mechanical clot removal and lamina terminalis fenestration are possible, which might improve CSF dynamics and prevent progression of chronic hydrocephalus. FLT can be safely performed by experienced surgeons.[4-19]

Three surgical procedures—ventriculoperitoneal shunting, lumboperitoneal shunting, and ventricular fenestration—are available for patients with chronic hydrocephalus, but the complications such as infection, bleeding, and drainage tube obstruction limit their application. Opening the lamina terminalis creates an anterior third ventriculostomy, which may facilitate CSF dynamics and reduce blood in the ventricles, leptomeningeal inflammation, and subarachnoid fibrosis. The opening of the lamina terminalis during aneurysm clipping and release of third-ventricle CSF was reported to improve the prognosis in patients with aSAH.[5-10] FLT was thought to improve hydrocephalus outcome. First, lateral-ventricle and third-ventricle CSF can drain directly into the subarachnoid space. Second, CSF can be distributed from the ventricles to both cerebral hemispheres and reabsorbed after FLT. Third, FLT aids CSF circulation around the circle of Willis, improves cisternal drainage, and thus possibly prevents delayed vasospasm. FLT has been suggested to prevent SDH by promoting CSF outflow and using its pulse pressure as a force to prevent the development of occlusive membranes and clots.[20-22]

It is generally believed that chronic hydrocephalus after aSAH is communicating hydrocephalus. Fibrosis and obstruction of the subarachnoid granulation contribute to permanent malabsorption, which in turn promotes the communicating hydrocephalus.[12,14] FLT may facilitate CSF fluid dynamics in the ventricles and over the cerebral convexities with increased blood clearance, decreased leptomeningeal fibrosis, and maintenance of proper balance between CSF production and resorption.[15,17,18]

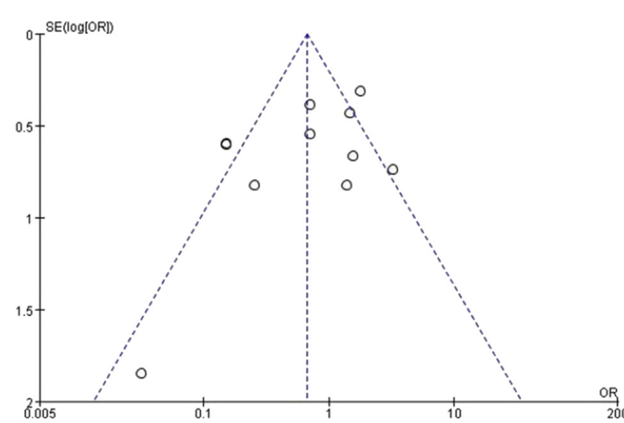


**Figure 2.** Funnel plots for heterogeneity testing.

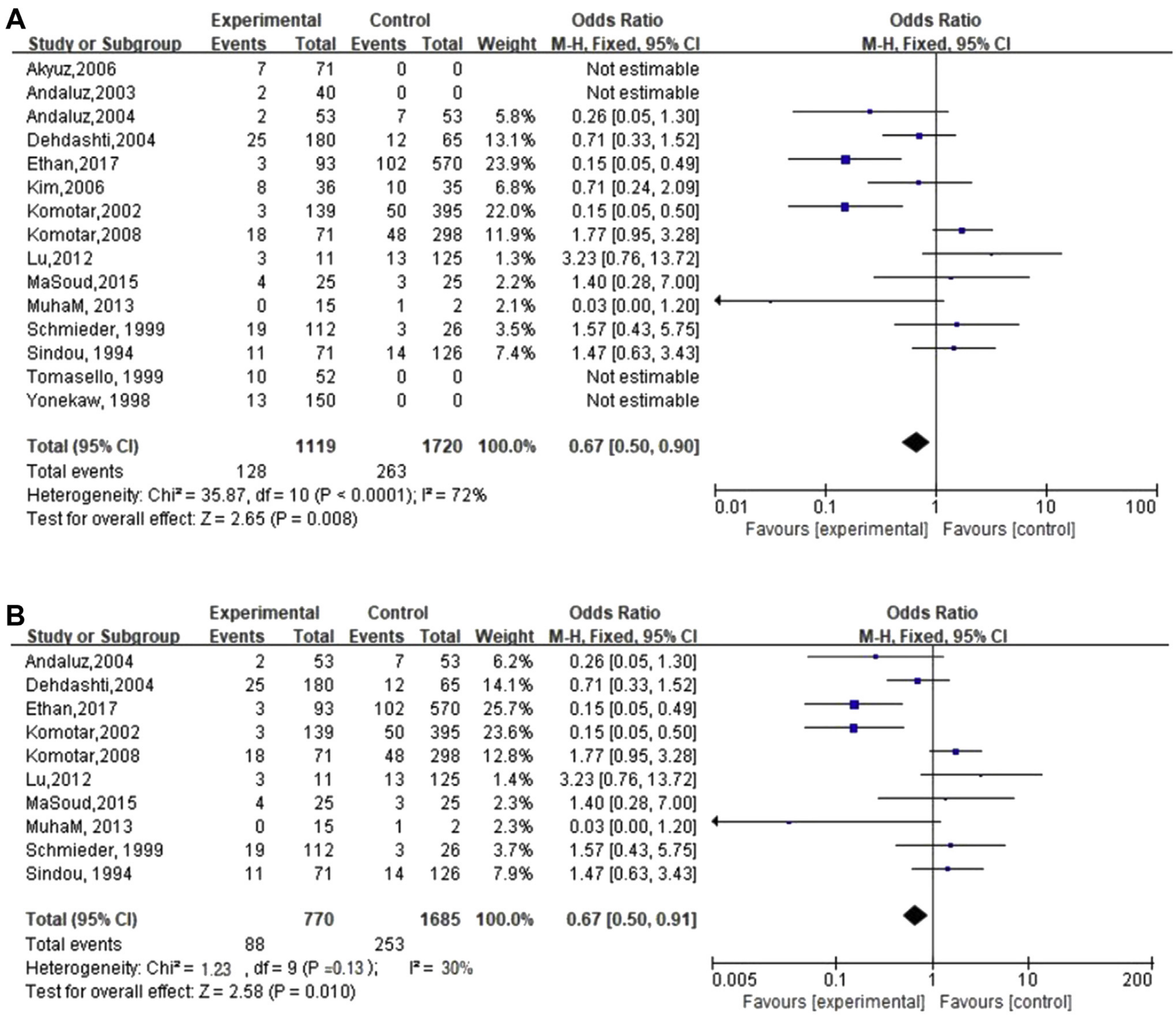


**Figure 3.** Meta-analysis on the impact of fenestration of the lamina terminalis (FLT) on the occurrence of subdural hematoma after aneurysmal subarachnoid hemorrhage. (**A**) Overall trials were included. (**B**) Trials with no FLT were excluded.

In this meta-analysis we investigated whether FLT could decrease the incidence of subsequent chronic hydrocephalus. Our results showed that FLT could reduce the development of chronic hydrocephalus compared with non-FLT with the occurrence 11.4% versus 15.3% ($P = 0.008$). However, our study has a limitation because of the bias in literature selection. Some studies were not performed by prospective randomized clinical trial and were restricted to SAH patients with ACoA aneurysms because of an easy feasibility of the LT fenestration.

Recently, Xie reported that postcirculation aneurysm was identified as risk factors of SDH.[22] A plausible explanation is that postcirculation aneurysm is close to the third ventricle and forth ventricle, where clots from a ruptured aneurysm can block CSF circulation, causing obstructive hydrocephalus. From this point of view, FLT might be beneficial to reduce occurrence of SDH. While, most postcirculation aneurysm treated by coiling, the research of FLT during postcirculation aneurysm clipping is rare. All 11 articles included in this Meta analysis were representing Anterior circulating aneurysm only. In Xie's research, AcoA aneurysm was also a risk factor for SDH.[22] So it was recommended FLT for AcoA aneurysm clipping based on our research.

In conclusion, this metaanalysis showed a significant association between FLT and reduced incidence of SDH. However, the interpretation of these results is restricted by unmatched cohort differences, as well as other inherent limitations. A large randomized, parallel-arm clinical trial (Chinese Clinical Trial Registry: ChiCTR-INR-16009249) to evaluate the efficacy of FLT in preventing SDH after acute aSAH is ongoing now to resolve this controversy.[23]

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