Shunt-dependent hydrocephalus after rupture of intracranial aneurysms: a prospective study of the influence of treatment modality

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Object. This study was designed to determine whether the frequency of shunt-dependent hydrocephalus in patients suffering from aneurysmal subarachnoid hemorrhage (SAH) differs when comparing surgical clip application with endovascular obliteration of ruptured aneurysms.

Methods. In this prospective nonrandomized study, 245 patients with aneurysmal SAH treated using either surgical clip application or endovascular coil embolization were studied at our institution between September 1997 and March 2003. One hundred eighty patients underwent clip application and 65 had coil embolization. In those patients who underwent clip application of anterior circulation aneurysms, the lamina terminalis was systematically fenestrated.

The occurrence of acute, asymptomatic, and shunt-dependent hydrocephalus was analyzed in both treatment groups. A subgroup analysis of patients with good clinical grade (World Federation of Neurosurgical Societies [WFNS] Grades I–III) and better Fisher Grade (1–3) and of patients with Fisher Grade 4 hemorrhage was performed.

Acute hydrocephalus was observed in 19% of surgical cases and 46% of endovascular ones. The occurrence of asymptomatic hydrocephalus was similar in both treatment groups (p = 0.4). Shunt-dependent hydrocephalus occurred in 14% of surgical cases and 19% of endovascular cases. This difference did not reach statistical significance (p = 0.53). Logistic regression models controlling for patient age, WFNS grade, Fisher grade, and acute hydrocephalus in patients with good clinical grade and better Fisher grade revealed no significant difference in the rate of shunt-dependent hydrocephalus in both therapy groups (odds ratio [OR] 0.8, 95% confidence interval [CI] 0.2–2.65). Results of similar models indicated that among patients with intraventricular hemorrhage (IVH), surgical clip application carried a lower risk of shunt-dependent hydrocephalus (OR 0.32, 95% CI 0.14–0.75) compared with that for endovascular embolization.

Conclusions. Shunt-dependent hydrocephalus was comparable in the two treatment groups, even in patients with better clinical and radiological grades on admission. Only patients in the endovascular therapy group who had experienced IVH showed a higher likelihood of shunt-dependent hydrocephalus.

Key Words • shunt • hydrocephalus • subarachnoid hemorrhage • endovascular therapy • aneurysm • clip application

The incidence of hydrocephalus, a well-known sequela of aneurysmal SAH, has been reported to range from 6 to 67%. Hydrocephalus may occur through obstructive mechanisms when blood products or adhesions block CSF circulation within the ventricular system or may result from problems attributable to impaired CSF absorption at the arachnoid granulations. Furthermore, hydrocephalus may cause poorer neurological outcomes and cognitive and memory deficits among patients suffering from aneurysmal SAH.

With the advances in endovascular procedures, it is important to compare the rate of shunt-dependent hydrocephalus in patients treated using surgical techniques with those undergoing endovascular obliteration of ruptured aneurysms. Previous studies are limited and offer conflicting results. In one study, data demonstrated fewer occurrences of shunt-dependent hydrocephalus in the surgical treatment group; in another, data revealed no difference between the therapy groups. Despite potential referral biases, a systematic assessment of the experience at a single institution can provide valuable information. In the present study, we analyze the results in 245 patients treated at our institution for ruptured intracranial aneurysms.

Clinical Material and Methods

Patient Population

This study was conducted in a prospective nonrandomized, nonblinded manner. Between September 1997 and March 2003, 273 patients were admitted to the Department of Neurosurgery, Geneva University Hospital, for aneurysmal SAH. Patient symptoms were classified according to the WFNS and Fisher scales. Those patients in very bad clinical condition (WFNS Grade IV or V) who died early after the hemorrhagic insult (< 7 days) were excluded from the study, leaving 245 consecutive patients for analysis. All

Abbreviations used in this paper: CI = confidence interval; CSF = cerebrospinal fluid; CT = computerized tomography; EVD = external ventricular drainage; IPH = intraparenchymal hemorrhage; IVH = intraventricular hemorrhage; OR = odds ratio; SAH = subarachnoid hemorrhage; VP = ventriculoperitoneal; WFNS = World Federation of Neurosurgical Societies.
Shunt-dependent hydrocephalus

TABLE 1
Distribution of admission WFNS clinical and Fisher radiological grades in 245 patients with aneurysmal SAH

<table>
<thead>
<tr>
<th>Grade</th>
<th>Surgical Group</th>
<th>Endovascular Group</th>
<th>% Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>WFNS scale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>1</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>54</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>18</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>6</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>10</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Fisher scale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>11</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>26</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>39</td>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>

Patients underwent CT angiography or cerebral angiography before a diagnosis was rendered. Each case was evaluated by a vascular neurosurgeon as well as an interventional neuroradiologist, and the decision to treat the aneurysm via surgical or endovascular approach was based on the angiography of the aneurysm, the location of the aneurysm, and the presence or absence of intracerebral hematoma with mass effect. Patient ages ranged from 18 to 78 years, with a mean age of 49 years for those in the surgical treatment group and 52 years in the endovascular treatment group. The female/male ratio was 1.3:1.

Patients selected for surgical treatment (180 patients) underwent pterional or posterior fossa craniotomy with wide opening of the cisterns, hematoma evacuation, if necessary, and clip occlusion of the aneurysm. Routinely, the sylvian fissure was opened widely, according to the technique of Yaşargil, and the lamina terminalis was systematically fenestrated in all cases of pterional craniotomy.

The endovascular procedure was performed in 65 patients by using Guglielmi Detachable Coil embolization of the ruptured aneurysms.

External Ventricular Drainage

Patients who demonstrated WFNS Grade II or greater SAH, alteration of consciousness, and radiological evidence of acute hydrocephalus underwent preoperative EVD. The EVD drip chamber was positioned 10 cm from the foramen of Monroe. In other patients who had undergone craniotomy and clip application, a lumbar drain was inserted preoperatively and removed immediately after the operation.

All patients with EVD underwent drainage during the 1st postoperative week and progressive elevation of the drip chamber 7 to 10 days after SAH. Prior to removal of the external drain, control CT scanning studies were performed. Note that this protocol did not differ between the two treatment groups. If progressive elevation of the drip chamber resulted in neurological deterioration or if the control CT results demonstrated deterioration of hydrocephalus, patients underwent VP shunt insertion.

Patients who did not require EVD were evaluated during the hospital stay and were followed up for at least 3 months thereafter. In cases of neurological deterioration unexplained by other causes (rebleeding, vasospasm, electrolyte disturbances, seizure, or hypoxia) and documented hydrocephalus, VP shunt placement was performed, and patients in these cases were considered shunt dependent. If CT scans revealed hydrocephalus with no related neurological sign and the patient did not have a shunt, the hydrocephalus was considered asymptomatic.

Clinical and Radiological Conditions in Patients

The treatment groups were compared based on clinical conditions, according to the WFNS grading scale, and the amount of subarachnoid blood, according to the Fisher scale (Table 1). Baseline information for patients in both therapy groups is featured in Table 2. Note that both groups were comparable in terms of age, sex, and clinical and radiological grades.

In this study, we determined the rate of acute hydrocephalus requiring EVD placement. The occurrence of asymptomatic and shunt-dependent hydrocephalus was also evaluated in both treatment groups. A subgroup analysis was performed in patients with better clinical and radiological conditions (that is, WFNS Grades I–III and Fisher Grades 1–3) to diminish statistical bias because patients in poor condition are more likely to undergo embolization and to have or develop hydrocephalus.

Patients with Fisher Grade 4 hemorrhage were divided into two smaller groups: those with IVH and those without (that is, those with IPH only). The risk of shunt-dependent hydrocephalus was compared in each subgroup.

Statistical Analysis

A comparison between therapy groups was made using the Mann–Whitney U-test and chi-square test of independence. These tests were two-sided, and a probability value of 0.05 or less was regarded as statistically significant. To assess treatment effects, a logistic regression model was fit using the response variables listed in Table 3. In these models, we controlled for risk factors by including them in the models: patient age, WFNS grade on admission (WFNS Grades I–III compared with Grade IV or V), Fisher grade (Grades 1–4), and presence of acute hydrocephalus. Patient age, WFNS grade, and Fisher grade were included in the models because these factors are known to influence the risk of shunt-dependent hydrocephalus.

Note that this protocol did not differ between the two treatment groups. If progressive elevation of the drip chamber resulted in neurological deterioration or if the control CT results demonstrated deterioration of hydrocephalus, patients underwent VP shunt insertion.

TABLE 2
Baseline information in 245 patients with acute aneurysmal SAH treated using clip application or endovascular embolization

<table>
<thead>
<tr>
<th>Variable</th>
<th>Surgical Group</th>
<th>Endovascular Group</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of patients</td>
<td>180</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>age (yrs)</td>
<td>49</td>
<td>52</td>
<td>0.066</td>
</tr>
<tr>
<td>% younger than 50 yrs</td>
<td>57</td>
<td>31</td>
<td>0.04</td>
</tr>
<tr>
<td>female (%)</td>
<td>62</td>
<td>69</td>
<td>0.64</td>
</tr>
<tr>
<td>acute hydrocephalus (%)</td>
<td>19</td>
<td>46</td>
<td>0.05</td>
</tr>
<tr>
<td>no. of patients w/ shunt-dependent hydrocephalus (%)</td>
<td>25 (14)</td>
<td>13 (19)</td>
<td>0.53</td>
</tr>
<tr>
<td>no. of patients w/ asymptomatic hydrocephalus (%)</td>
<td>7 (4)</td>
<td>5 (8)</td>
<td>0.40</td>
</tr>
</tbody>
</table>
younger patients—that is, those younger than 50 years—
was significantly different in both treatment groups (p = 0.04). The presence of acute hydrocephalus was included because this particular variable was found to be signifi-
cantly different between therapy groups (p = 0.05). To test
whether the treatment effect was dependent on patient age,
WFNS grade, Fisher grade, and presence of acute hydro-
cephalus, we tested for interactions between treatment and
these variables at the 0.05 level of probability. When we
noted a significant interaction, the variable was included in
the logistic regression model. Because there were two pos-
sible outcomes for shunt dependency (yes or no), we ap-
plied an ordinal logistic regression model. We found that the
proportional odds model fit these data adequately. In these
particular ordinal logistic regression models, the OR for the
treatment effect is interpreted as the relative odds for shunt
dependency in patients treated with surgery rather than
endovascular embolization. Consequently, an OR signifi-
cantly lower than 1 would indicate that shunt-dependent
hydrocephalus was less likely to occur after surgery, where-
as an OR significantly greater than 1 would indicate that
shunt-dependent hydrocephalus was less likely to occur af-
fter endovascular treatment.

Results

The overall mortality rate in the entire group was 6.5% 
(16 patients). Acute hydrocephalus with EVD placement
was observed in 34 (19%) of 180 patients in the surgical
therapy group and 30 (46%) of 65 patients in the endovas-
cular group. The mean delay between hemorrhage onset
and treatment intervention for the surgical clip application
was 1 day (range 0–14 days) and for the endovascular
embozation group it was 2 days (range 0–12 days).

In patients who survived the initial SAH, the rate of shunt
dependency resulting from chronic posthemorrhagic hydro-
cephalus was 15.5% (38 of 245 patients). Eleven of 38 pa-
ients developed delayed clinical hydrocephalus and under-
went shunt placement after discharge. Definitive VP shunt
insertion was performed 36 ± 25 days after SAH.

The occurrence of shunt-dependent hydrocephalus was posi-
tively correlated with the WFNS and Fisher grades (Table 4).

Treatment Method

Thirty-eight patients (15.5% of the total study popula-
tion) underwent definitive shunt placement for the treat-
ment of chronic hydrocephalus. Based on univariate
analysis, the rate of shunt dependency was 14% (25 of 180
patients) for patients in the surgical therapy group and 19% 
(13 of 65 patients) for patients in the endovascular therapy

TABLE 3
Response-dependent variables used in the logistic regression model

<table>
<thead>
<tr>
<th>Model</th>
<th>Response-Dependent Variable</th>
<th>Response Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>asymptomatic hydrocephalus</td>
<td>yes no</td>
</tr>
<tr>
<td>2</td>
<td>shunt-dependent hydrocephalus</td>
<td>yes no</td>
</tr>
</tbody>
</table>

group. This difference did not reach statistical significance 
(p = 0.53).

Results of univariate analysis indicated that the rate of shunt dependency in patients with better clinical and radi-
ological grades was similar (11% [12 patients] in the surgical therapy group compared with 6% [three patients] in the endovascular therapy group; p = 1; Table 2).

Among patients with Fisher Grade 4, 11 (16%) of 70 pa-

tients in the surgical group and seven (47%) of 15 patients
in the endovascular group presented with shunt-dependent
hydrocephalus (p = 0.04). The patients with Fisher Grade 4
were divided into those with IVH and those with IPH only.

Thirty-eight patients in the surgical treatment group and
13 in the endovascular therapy group had IVH. Among the
former patients with IVH, 36 underwent perional cranio-
tomy and fenestration of the lamina terminalis. In the re-
main ing two patients a posterior fossa craniotomy was per-
formed. Thirty-two patients in the surgical group and two in
the endovascular group had IPH.

Results of logistic regression analysis controlling for pa-

tient age, WFNS score, Fisher grade, and presence of acute
hydrocephalus are featured in Table 5. Overall, treatment
modality does not affect the rate of shunt-dependent hydro-
cephalus. Even patients with better clinical and radiological
grades (WFNS Grades I–III and Fisher Grades 1–4) had similar rates of shunt dependency, regardless of treatment 
(OR 0.8, 95% CI 0.2–2.65).

In contrast, surgical clip application was associated with
a lower risk of shunt dependency in patients with Fisher
Grade 4 who had IVH (eight [21%] of 38 patients in the sur-
gical group and seven [53%] of 13 patients in the endovas-
cular group; OR 0.32, 95% CI 0.14–0.75).

Among patients in the surgical group with IVH, one of two
who had undergone posterior fossa craniotomy present-
ed with shunt-dependent hydrocephalus. This group was
too small to be compared statistically with the remaining 36

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TABLE 5
Results of logistic regression analyses*

<table>
<thead>
<tr>
<th>Response</th>
<th>Patients Studied</th>
<th>Risk OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>asymptomatic hydrocephalus</td>
<td>w/ WFNS Grades I–III &amp; Fisher Grades 1–3</td>
<td>0.97 (0.29–3.31)</td>
</tr>
<tr>
<td></td>
<td>w/ WFNS Grade IV or V</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>w/ Fisher Grade 4 (w/ IPH)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>w/ Fisher Grade 4 (w/ IVH)</td>
<td>0.95 (0.55–2.90)</td>
</tr>
<tr>
<td>shunt-dependent hydrocephalus</td>
<td>w/ WFNS Grades I–III &amp; Fisher Grades 1–3</td>
<td>0.80 (0.20–2.65)</td>
</tr>
<tr>
<td></td>
<td>w/ WFNS Grade IV or V</td>
<td>1.39 (0.54–4.59)</td>
</tr>
<tr>
<td></td>
<td>w/ Fisher Grade 4 (w/ IPH)</td>
<td>0.97 (0.29–3.31)</td>
</tr>
<tr>
<td></td>
<td>w/ Fisher Grade 4 (w/ IVH)</td>
<td>0.32 (0.14–0.75)</td>
</tr>
</tbody>
</table>

* The table features the ORs for the different populations under study in a comparison between surgical clip placement and endovascular embolization. The results were controlled for patient age, WFNS grade, Fisher grade, and acute hydrocephalus. Abbreviation: — = no patients in this group.

In our series, 40% of patients who underwent definitive shunt placement also had IVH. Some authors assert that the presence of blood clots and high CSF viscosity can lead to an obstructive form of hydrocephalus and early CSF disturbances. In one study, investigators noted no relationship between the development of hydrocephalus and the number of erythrocytes in the CSF, thus indicating that flow disturbances also play an important role in acute hydrocephalus. The most important and novel finding in the present study is in the subgroup of patients with IVH who could probably benefit from surgical fenestration of lamina terminalis. The protective effect of lamina terminalis fenestration against shunt dependency has been demonstrated in several studies; however, in the series conducted by Dorai, et al., this effect is not significant. One can assume that this is the only possible way that surgical clip application could have decreased the risk of shunt dependence in this subset of patients. Nevertheless, whether the benefit of lamina terminalis fenestration for the prevention of hydrocephalus outweighs the risk of surgical therapy in patients with Fisher Grade 4 and IVH would need to be evaluated in a comprehensive outcome analysis.

Increased patient age has been correlated with the development of shunt-dependent hydrocephalus by data from many studies. Both of our treatment groups were comparable with respect to mean age in general, but were not comparable with respect to patients younger than 50 years old. This element was controlled by the logistic regression model and not found to be a potential confounder variable.

Intracranial pressure correlates with the rate of CSF production and outflow. Kosteljanetz attributed 90% of the intracranial pressure increase following SAH to an increase in outflow resistance. Fuhrmeister, et al., reported CSF outflow resistance to be elevated threefold in patients with SAH. Although CSF hydrodynamics become normalized in the majority of patients, physiological CSF outflow resistance may not occur until 40 to 50 days post-SAH. In cases of arachnoid scarring and blockage of arachnoid granulations, CSF outflow resistance can remain elevated and a
state of chronic hydrocephalus may develop. In the present series, definitive shunt insertion was performed a mean of 36 days after SAH, that is, at a time when CSF hydrodynamics should have been normalized.

Limitations of Our Study

The patients in this series were treated using craniotomy and clip application or an endovascular approach, based on a consensus reached by a vascular neurosurgeon and an interventional neuroradiologist in each individual case. Although patients in both treatment groups were comparable on admission data, only random allocation of patients to the treatment arms could have ensured control for unrecognized risk factors for shunt dependency. Note that the only two available randomized studies in which investigators compare the outcome of patients treated using the surgical or endovascular approach do not address this issue selectively.

The treatment groups in the present study were different in terms of the number of patients. This discrepancy is due to the fact that the majority of ruptured aneurysms are still being treated using surgery and clip application at our institution.

There was a significant trend toward EVD placement among patients who underwent endovascular therapy because the rate of acute hydrocephalus was higher in this group (41% compared with 19% in the surgical treatment group). Although the presence of acute hydrocephalus does not always lead to the development of shunt dependency, it can be a predictor, as shown in the present study and in previous series.

Aneurysm location was not selectively evaluated in the present study, but many investigators have examined the association between aneurysm location and hydrocephalus. The conclusions are rather confounding, with some researchers asserting that posterior circulation aneurysms are more frequently associated with shunt dependency and others showing a clear correlation between the anterior communicating aneurysms and the development of shunt-dependent hydrocephalus. In the study by Gruber, et al., there was no relationship between aneurysm location and the development of shunt-dependent hydrocephalus.

Conclusions

The particular treatment method used in the patients in this study had grossly no influence on the rate of shunt-dependent hydrocephalus, even in patients with better clinical and radiological grades. Only those patients in the endovascular therapy group who had presented with IVH had a significantly higher rate of shunt dependency. Surgical fenestration of the lamina terminalis might be a determinant factor in this issue. These findings should be considered in the management of aneurysmal SAH.

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References


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