Retrospective comparison of craniotomy and decompressive craniectomy for surgical evacuation of nontraumatic, supratentorial intracerebral hemorrhage

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Surgical evacuation of nontraumatic, supratentorial intracerebral hemorrhage (SICH) is uncommonly performed, and outcomes are generally poor. On the basis of published experimental data and the authors' anecdotal observations, a retrospective chart review study was performed to test the hypothesis that large decompressive craniectomies (DCs), compared with craniotomies, would improve clinical outcomes after surgical evacuation of SICH. For patients with putaminal SICH, DC was associated with a statistically significant improvement in midline shift, compared with craniotomy. Decompressive craniectomies also resulted in a strong trend toward decreased likelihood of poor neurological outcome (modified Rankin Scale score > 3). For patients with lobar SICH, no associations were found between DC or craniotomy and clinical outcomes. For patients selected to undergo surgical evacuation of putaminal SICH, a DC in addition to surgical evacuation of the hematoma might improve outcome.

KEY WORDS • intracerebral hemorrhage • craniotomy • decompressive craniectomy

NONTRAUMATIC SICH represents 10%–15% of all strokes and often carries a poor prognosis.4,16,23 Although aggressive surgical intervention is recommended for patients with large or symptomatic hypertensive cerebellar hemorrhages,13 most patients with SICH are unlikely to benefit from surgical evacuation. The most widely cited and relevant study to date is the STICH, which failed to show benefit from surgical evacuation for patients with SICH, whose treating physicians were unsure whether surgery would be beneficial.10 However, the design of the STICH (only patients in “treatment equipoise” were randomized) and post hoc data analysis suggest that some patients with SICH should undergo surgery.7,10,11

After the results of the STICH were published, surgical evacuation of SICH became an uncommon procedure, reserved for a small subset of patients, at our institution (University of Miami Miller School of Medicine). In general, we consider surgical intervention for patients who are relatively young; who have a large, symptomatic SICH; who have some preservation of brainstem function; and who can undergo surgery very soon (within a few hours at most) after their initial neurological deterioration. Under these circumstances, we operate on deep basal ganglia hemorrhages and on more superficial lobar hemorrhages. Unfortunately, even among this select group of patients, clinical outcomes remain poor. Thus, the neurosurgical community continues to seek ways to improve outcomes for the subset of patients who meet the criteria for surgical evacuation.

Clinical and laboratory research has demonstrated that SICH is followed by injury to the surrounding brain; this secondary injury might result from various mechanisms including excitotoxicity, direct toxicity of the hematoma, and inflammation.12,22 These various forms of secondary injury cause cytotoxic edema, which can cause increased mass effect and tissue damage. On the basis of these studies and our own anecdotal observations of the occasional need for further surgery after evacuation of
SICH via small craniotomies, we hypothesized that surgical treatment for SICH might be optimized by larger DCs, analogous to the treatment of mass effect caused by cytotoxic edema in the setting of head trauma and ischemic stroke. To test this hypothesis, we performed a retrospective chart review to compare outcomes after evacuation of SICH with craniotomy and replacement of the bone flap and after evacuation of SICH with DC.

**Methods**

**Study Design**

After obtaining institutional review board approval for the study, we used department billing records and surgeons’ case logs to retrospectively identify study participants. We identified 51 patients at the University of Miami Miller School of Medicine with SICH who had undergone surgical decompression during 2004–2012; these dates were selected because comprehensive electronic medical records and digital radiology images were available during this period. We recognized that because of small sample size and poor clinical outcomes, the study would be underpowered to detect differences in clinically meaningful measures such as survival and neurologic outcomes. We therefore decided to also study a surrogate measure of the technical adequacy of surgical decompression, namely, the degree of midline shift. We recognized that, in clinical terms, patients with hypertensive putaminal hemorrhage represented a rather homogeneous and distinctive subgroup compared with the very heterogeneous population of patients who had lobar hemorrhage that required surgery. We therefore studied these 2 patient populations separately.

**Surgical Procedures**

For each case, the goal was evacuation of the hemorrhage, usually assisted by microscopy. Endoscopic procedures and stereotactic guided hematoma aspiration were not performed during the study period. Patients who underwent DC only, without evacuation of the hematoma, were not included in the study. At the time of the procedure, the operating surgeon decided, in a nonrandomized fashion, whether to perform a large or small craniotomy and whether to replace the bone flap or leave it off.

For all cases, putaminal hemorrhages were approached by using the operating microscope, and a large or small frontotemporal craniotomy or DC was performed as described. The small craniotomies were generally standard pterional craniotomies intended to facilitate exposure of the sylvian fissure; the DCs were generally trauma-type flaps intended to maximize decompression of the cerebral hemisphere and usually extended to the floor of the middle fossa to maximize decompression of the tentorial incisura and brainstem. In some cases, the sylvian fissure was split under the microscope to allow less traumatic access to the insula and deep hematoma; however, for most cases, the hematoma was drained by making a small corticotomy in the superior temporal gyrus or other noneloquent location. At the discretion of the operating surgeon, intraoperative ultrasonography was used for some cases.

**Data Analysis**

According to review of preoperative CT images, patients were classified as having had putaminal or lobar hemorrhage. Review of medical records and CT images provided preoperative and intraoperative clinical data and postoperative outcome data. Given the small numbers of patients, we decided to use the combined measure of death or severe disability (defined as mRS Score 4–5) as our primary clinical outcome. Secondary outcomes included death within 30 days and need for reoperation. Given the generally poor neurologic outcomes and the small size of our patient population and consequent low statistical power of our study to detect differences in meaningful clinical outcomes, we decided to also measure preoperative and postoperative midline shift. We believed that midline shift would indicate the technical success of surgery and quantify the relief of mass effect resulting from hematoma and secondary tissue injury. To determine the maximal midline shift, we reviewed radiologists’ reports; when the midline shift was not specified in a report, it was measured at the foramen of Monro by using digital measuring tools available on our viewing software. Midline shift was quantified preoperatively and immediately postoperatively; if multiple postoperative CT images were available, the maximum postoperative midline shift was also measured. Categorical variables were compared by using the 2-tailed Fisher exact test; continuous variables were compared by using the Mann-Whitney U-test.

**Results**

**Patients With Putaminal SICH**

Of the 26 patients who underwent surgery for putaminal SICH, DCs were performed in 10 and craniotomies were performed in 16 (1 patient in this latter group had a small pterional craniotomy, and the bone flap was left off at the end of the surgery because of intraoperative brain swelling). Preoperative clinical data and postoperative outcomes for patients with putaminal SICH are shown in Table 1. Patients with putaminal SICH who underwent DC were more likely than those who underwent craniotomy to have a preoperative GCS score less than 8 (p = 0.019); also among patients who underwent craniotomy, we decided to compare the technical adequacy of surgery and quantify the relief of mass effect resulting from hematoma and secondary tissue injury. To determine the maximal midline shift, we reviewed midline shift images quantified preoperatively and immediately postoperatively; if multiple postoperative CT images were available, the maximum postoperative midline shift was also measured. Categorical variables were compared by using the 2-tailed Fisher exact test; continuous variables were compared by using the Mann-Whitney U-test.
patients who underwent DC than for patients who under-
went craniotomy (p = 0.016 and p = 0.006, respectively).
In addition, the average degree of midline shift decreased
after surgery only in patients who underwent DC and not
in patients who underwent craniotomy.

Among patients in the DC group, 4 eventually under-
went cranioplasty, and 1 of these patients required a third
surgery to remove the cranioplasty because of infection.
Another patient required placement of a ventriculoperito-
near shunt for hydrocephalus.

Patients With Lobar SICH

Of the 25 patients who underwent surgery for lobar
SICH, DCs were performed in 8 and craniotomies were
performed in 17. All patients in the DC group underwent
transcortical hematoma evacuation (Table 2). The DC
and craniotomy groups were less well matched
among patients with lobar SICH than among patients with pu-
taminal SICH. Patients with lobar SICH who underwent
DC had greater preoperative midline shift (p = 0.022)
and were much more likely to have right-sided SICH (p
= 0.011) than were patients who underwent craniotomy.
Among patients in the DC group, there were trends,
although not statistically significant, toward younger age,
female sex, and larger hematoma volume. The likeli-
hoods of poor clinical outcome, death within 30 days, and
reoperation did not differ between the 2 groups, nor did
postoperative midline shift. There were no statistically
significant differences, or strong trends toward differ-
ences, in any of the clinical or radiographic outcomes be-
tween patients with lobar SICH who had undergone DC
and those who had undergone craniotomy.

Two patients required reoperation for wound infec-
tion. Postoperative hydrocephalus did not develop in ei-
ther of these patients.

Discussion

Since publication of the STICH, surgical evacuation
of SICH has become less common at many centers, in-
cluding our own. However, our own experiences, as well
as post hoc data analysis from the STICH and other pub-
ished studies, indicate that there is probably a small sub-
set of SICH patients who will benefit from surgical evac-
uation. Ongoing research, including the STICH 2, is intended to help clinicians preoperatively identify
these patients. A complementary area of research aims
to identify the optimal surgical techniques for patients
who are selected to undergo surgical evacuation of SICH.
Most of the available literature is focused on minimal ac-
cess techniques, such as stereotactic-guided hematoma
aspiration and endoscopic clot evacuation, both of which
are intended to minimize the disruption of intact brain
tissue superficial to the hematoma. We believe
that although these minimal access techniques might
have a role in treating deeper, thalamic, or even brain-
stem SICH, there are technical advantages to open surgi-
cal approaches for putaminal and lobar SICH. The use of
open techniques and a microscope allows for more rapid
clot decompression and facilitates meticulous hemostasis
at the walls of the hematoma cavity. In addition, our data
suggest that at least for deep basal ganglia hemorrhages,
open decompression with DC might optimize outcomes.

We identified only 1 other published study in the Eng-
lish language that compared craniotomy and craniectomy
among patients selected to undergo open surgical evacua-
TABLE 1: Clinical variables and outcomes among patients who underwent surgery for putaminal SICH*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Decompressive Craniectomy (n = 10)</th>
<th>Craniotomy (n = 16)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>age (yrs; mean ± SD)</td>
<td>50 ± 12</td>
<td>58 ± 11</td>
<td>0.096†</td>
</tr>
<tr>
<td>sex (M/F)</td>
<td>4:6</td>
<td>9:7</td>
<td>0.688‡</td>
</tr>
<tr>
<td>GCS Score &lt;8</td>
<td>10/10 (100)</td>
<td>7/14 (50)</td>
<td>0.019‡</td>
</tr>
<tr>
<td>surgery w/in 24 hrs</td>
<td>6/9 (67)</td>
<td>12/15 (80)</td>
<td>0.635‡</td>
</tr>
<tr>
<td>rt/lt side</td>
<td>5:2</td>
<td>3:7</td>
<td>0.051‡</td>
</tr>
<tr>
<td>hematoma volume (ml)</td>
<td>57 ± 6</td>
<td>70 ± 12</td>
<td>0.136‡</td>
</tr>
<tr>
<td>intraop brain relaxation</td>
<td>2/7 (29)</td>
<td>5/7 (71)</td>
<td>0.286‡</td>
</tr>
<tr>
<td>poor clinical outcome (death or mRS Score 4–5)</td>
<td>7/9 (78)</td>
<td>14/14 (100)</td>
<td>0.142‡</td>
</tr>
<tr>
<td>improved motor function</td>
<td>1/10 (10)</td>
<td>2/13 (15)</td>
<td>1.00‡</td>
</tr>
<tr>
<td>improved language/cognition</td>
<td>6/10 (60)</td>
<td>4/15 (27)</td>
<td>0.122‡</td>
</tr>
<tr>
<td>midline shift (mm; mean ± SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preop</td>
<td>9.5 ± 4.3</td>
<td>8.4 ± 3.5</td>
<td>0.802†</td>
</tr>
<tr>
<td>postop</td>
<td>4.1 ± 2.2</td>
<td>7.5 ± 2.8</td>
<td>0.016†</td>
</tr>
<tr>
<td>max</td>
<td>4.2 ± 2.3</td>
<td>8.4 ± 2.6</td>
<td>0.006†</td>
</tr>
<tr>
<td>reoperation</td>
<td>0/10 (0)</td>
<td>2/16 (13)</td>
<td>0.508‡</td>
</tr>
<tr>
<td>death w/in 30 days</td>
<td>3/9 (33)</td>
<td>4/15 (27)</td>
<td>1.00‡</td>
</tr>
</tbody>
</table>

* Unless otherwise indicated, data are expressed as number of patients (%).
† Mann-Whitney U-test.
‡ Fisher exact test.
tion of SICH. Shimamura et al. performed a single-center retrospective analysis of 25 patients with SICH who underwent either DC or clot removal. In contrast to our observations, they concluded that DC did not decrease midline shift, decrease hematoma volume, or improve outcome. However, that study was smaller than ours; only 5 of 25 patients were allocated to the DC group. Additionally, in the Shimamura et al. study, data from lobar and deep putaminal SICH were combined. On the basis of our observations and the post hoc data analysis from the STICH trial, we suggest that for purposes of surgical planning these SICH subtypes should be considered as 2 distinct groups. We cannot confidently explain why more aggressive decompression seems to be beneficial for putaminal SICH. It is possible that putaminal SICH causes more tissue damage as a result of involvement of the more friable deep gray matter, as opposed to lobar hemorrhages, which affect white matter to a greater degree; also, deeper hemorrhages with 360 degrees of exposure to surrounding brain might adversely affect a larger surface area, as opposed to lobar hematomas that breach the cortical surface. In addition, surgery for putaminal SICH often requires more tissue dissection than surgery for lobar SICH.

We recognize several potentially serious limitations of our study, but despite these limitations we suggest that useful clinical conclusions can be drawn from our data. The first limitation is that our study is retrospective. Treatment was determined at the time of surgery by the treating surgeon, based on entirely subjective criteria. The retrospective nature of this study is reflected in the differences in preoperative variables between the treatment groups. We recognize this limitation but point out that the preoperative differences between patients with putaminal SICH who underwent DC (worse GCS score and greater likelihood of right-sided hemorrhage compared with those who underwent craniotomy) were unlikely to affect the most important difference in outcome, namely postoperative midline shift. Despite the worse preoperative GCS scores, there was a trend toward improved outcomes among patients who underwent DC rather than craniotomy. The second limitation is that our small sample sizes and the poor prognosis associated with SICH result in low statistical power to detect differences in the most clinically significant outcome measures, such as death and poor functional status after surgery. We attempted to address this limitation in part by studying a surrogate measure of the technical outcome of surgery (postoperative midline shift), which showed a robust, statistically significant improvement in patients with putaminal SICH who underwent DC rather than craniotomy. We suggest that the trend toward improved neurologic outcomes with DC, and our limited observation that reoperation was performed only for the group of patients who underwent craniotomy, is consistent with our observations about this surrogate outcome.

Conclusions

We suggest that DC combined with hematoma evacuation improves outcomes in patients who undergo surgery for putaminal SICH and should be performed in patients selected for this uncommon surgical procedure. We propose that for patients with lobar SICH who undergo surgery, the decision whether to perform craniotomy or craniectomy should be individualized to the patient, considering factors such as the hematoma size, degree of midline shift, and intraoperative brain swelling.

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TABLE 2: Clinical variables and outcomes among patients who underwent surgery for lobar SICH*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Decompressive Craniectomy (n = 8)</th>
<th>Craniotomy (n = 17)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>age (yrs; mean ± SD)</td>
<td>46 ± 12</td>
<td>57 ± 15</td>
<td>0.091†</td>
</tr>
<tr>
<td>sex (M/F)</td>
<td>3:5</td>
<td>13:4</td>
<td>0.072‡</td>
</tr>
<tr>
<td>GCS Score &lt;8</td>
<td>6/8 (75)</td>
<td>6/15 (40)</td>
<td>0.193‡</td>
</tr>
<tr>
<td>surgery w/in 24 hrs</td>
<td>7/8 (88)</td>
<td>15/17 (88)</td>
<td>1.0‡</td>
</tr>
<tr>
<td>r/t side</td>
<td>7:1</td>
<td>5:12</td>
<td>0.011‡</td>
</tr>
<tr>
<td>hematoma volume (ml)</td>
<td>150 ± 92</td>
<td>75 ± 24</td>
<td>0.087†</td>
</tr>
<tr>
<td>intraop brain relaxation</td>
<td>4/6 (67)</td>
<td>3/5 (60)</td>
<td>1.0‡</td>
</tr>
<tr>
<td>poor clinical outcome (death or mRS Score 4–5)</td>
<td>4/8 (50)</td>
<td>8/17 (47)</td>
<td>1.0‡</td>
</tr>
<tr>
<td>improved motor function</td>
<td>6/8 (75)</td>
<td>6/13 (46)</td>
<td>0.366‡</td>
</tr>
<tr>
<td>improved language/cognition</td>
<td>6/8 (75)</td>
<td>8/15 (53)</td>
<td>0.400‡</td>
</tr>
<tr>
<td>midline shift (mm; mean ± SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preop</td>
<td>12 ± 3</td>
<td>8 ± 3</td>
<td>0.022†</td>
</tr>
<tr>
<td>postop</td>
<td>5 ± 6</td>
<td>5 ± 3</td>
<td>0.542†</td>
</tr>
<tr>
<td>max</td>
<td>5.3 ± 6.1</td>
<td>6.3 ± 5.4</td>
<td>0.327†</td>
</tr>
<tr>
<td>reoperation</td>
<td>0</td>
<td>0</td>
<td>1.0‡</td>
</tr>
<tr>
<td>death w/in 30 days</td>
<td>2/8 (25)</td>
<td>6/17 (35)</td>
<td>1.0‡</td>
</tr>
</tbody>
</table>

* Unless otherwise indicated, data are expressed as number of patients (%).
† Mann-Whitney U-test.
‡ Fisher exact test.
Craniotomy versus decompressive craniectomy for SICH

Disclosure

Dr. Aziz-Sultan is a proctor and course instructor for ev3.

Author contributions to the study and manuscript preparation include the following. Conception and design: Benveniste. Acquisition of data: all authors. Analysis and interpretation of data: Benveniste, Hayes, Morcos. Drafting the article: Hayes. Critically revising the article: Benveniste, Hayes, Morcos. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Benveniste. Study supervision: Benveniste.

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