Decompressive hemicraniectomy without clot evacuation in dominant-sided intracerebral hemorrhage with ICP crisis


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Object. Large intracerebral hemorrhage (ICH), compounded by perihematomal edema, can produce severe elevations of intracranial pressure (ICP). Decompressive hemicraniectomy (DHC) with or without clot evacuation has been considered a part of the armamentarium of treatment options for these patients. The authors sought to assess the preliminary utility of DHC without evacuation for ICH in patients with supratentorial, dominant-sided lesions.

Methods. From September 2009 to May 2012, patients with ICH who were admitted to the neurological ICU at Columbia University Medical Center were prospectively enrolled in that institution's ICH Outcomes Project (ICHOP). Five patients with spontaneous supratentorial dominant-sided ICH underwent DHC without clot evacuation for recalcitrant elevated ICP. Data pertaining to the patients' characteristics and outcomes of treatment were prospectively collected.

Results. The patients' median age was 43 years (range 30–55 years) and the ICH etiology was hypertension in 4 of 5 patients, and systemic lupus erythematosus vasculitis in 1 patient. On admission, the median Glasgow Coma Scale (GCS) score was 7 (range 5–9). The median ICH volume was 53 cm³ (range 28–79 cm³), and the median midline shift was 7.6 mm (range 3.0–11.3 mm). One day after surgery, the median decrease in midline shift was 2.7 mm (range 1.5–4.0 mm), and the median change in GCS score was +1 (range −3 to +5). At discharge, all patients were still alive, and the median GCS score was 10 (range 9–11), the median modified Rankin Scale (mRS) score was 5 (range 5–5), and the median NIHSS (National Institutes of Health Stroke Scale) score was 22 (range 17–27). Six months after hemorrhage, 1 patient had died, 2 were functionally dependent (mRS Score 4–5), and 2 were functionally independent (mRS Score 0–3). Outcomes for the patients treated with DHC were good compared with 1) outcomes for all patients with spontaneous supratentorial ICH admitted during the same period (n = 144) and 2) outcomes for matched patients (dominant ICH, GCS Score 5–9, ICH volume 28–79 cm³, age < 60 years) whose cases were managed nonoperatively (n = 5).

Conclusions. Decompressive hemicraniectomy without clot evacuation appears feasible in patients with large ICH and deserves further investigation, preferably in a randomized controlled setting.

(1) key words • intracerebral hemorrhage • decompressive hemicraniectomy • clot evacuation • intracranial pressure

Abbreviations used in this paper: CUMC = Columbia University Medical Center; DHC = decompressive hemicraniectomy; GCS = Glasgow Coma Scale; GOS = Glasgow Outcome Scale; ICH = intracerebral hemorrhage; ICHOP = Intracerebral Hemorrhage Outcomes Project; ICP = intracranial pressure; mRS = modified Rankin Scale; NIHSS = National Institutes of Health Stroke Scale; STICH = Surgical Treatment for Ischemic Heart Failure.

Intracerebral hemorrhage is a devastating stroke subtype accounting for 10%–15% of all strokes,9 with 30-day mortality rates ranging from 23% to 52%. Large ICHs have particularly poor outcomes; 30-day mortality rates for patients with ICH volumes greater than 50–60 cm³ range from 81% to 91%,18 and poor functional outcome rates of 96%–97% have been reported for those with ICH volumes greater than 40–45 cm³.12,33 The primary etiological mechanism for injury following large ICH is intracranial hypertension and resultant herniation.

Decompressive craniectomy is a surgical technique designed to provide instantaneous and definitive relief of elevated ICP. Although some regard DHC as a last-ditch effort—only to be used when more conservative ICP treatment measures have failed—evidence suggests that decompression may play an important role in the optimal care of patients with elevated ICP.5,9 While the evidence for decompressive craniectomy in ICH is relatively poor, it has proven to be beneficial in analogous conditions, including traumatic brain injury, poor grade subarachnoid hemorrhage, and malignant ischemic stroke.2,6,8,16,17,19,31

Results of decompressive craniectomy combined with clot evacuation in a total of 138 ICH patients have been retrospectively reported in the literature. On average...
these patients had a mortality of 29%, with a follow-up period ranging from discharge to 2 years.10,24,25,30

We present a preliminary series of 5 cases in which clot evacuation was not attempted due to the fact that all clots were deep and in the dominant hemisphere. We hope these data will help isolate the effect of DHC without clot evacuation.

**Methods**

Between September 2009 and May 2012, patients admitted to the neurological ICU at Columbia University Medical Center (CUMC) with ICH were prospectively enrolled in our Intracerebral Hemorrhage Outcomes Project (ICHOP). The particular ICHOP study characteristics have been outlined in detail in previous reports.3,35 The study was approved by the CUMC Institutional Review Board, and written consent was obtained prior to enrollment in the study, either from the patient or from the appropriate surrogate representative when the patient lacked decision-making capacity. Patients with infratentorial ICH or ICH due to arteriovenous malformation or aneurysm were excluded from our current analysis. Management was in accordance with the most recent American Heart Association guidelines for the treatment of ICH.18,29 Midline shift was measured at the level of the foramina of Monro.

The decision to pursue DHC was based on the collective judgment of the treating neurointensivists and attending neurosurgeon and patient/family preferences. Some guiding principles included the family’s decision to proceed with tracheostomy, gastrostomy, and skilled nursing home placement as well as aggressive medical management regardless of the degree of residual neurological deficit.

Signs and symptoms of increasing ICP despite optimal conservative management underpinned the decision for DHC. Younger patients (<60 years) with good baseline functionality, large ICH volume, and dominant hemorrhage are generally considered potential candidates for DHC at our institution, as they likely represent a population that have the most to lose from competing surgical strategies and have some chance for an outcome deemed acceptable by their families.

**Results**

During the study period, 5 patients (<2%) were treated with DHC without clot evacuation for spontaneous supratentorial dominant ICH. Their median age was 43 years (range 30–55 years), and 4 of the 5 patients were female. The hemorrhage lateralized to the left in all patients, and each patient was right-handed. The ICH was mainly cortical in 2 of the 5 patients and originated from the deep gray matter (basal ganglia) in the other 3 patients. The etiology of the hemorrhage was adjudicated to hypertension in 4 of 5 patients, and systemic lupus erythematosus vasculitis in 1 patient.

On admission, the median GCS score was 7 (range 5–9), and the median ICH score was 2 (1–3). The median ICH volume was 53 cm³ (range 28–79 cm³), with 3 of 5 patients having a hemorrhage greater than 50 cm³, the median midline shift was 7.6 mm (range 3.0–11.3 mm), and 2 of 5 ICHs extended into the ventricles. Surgery took place within 24 hours after admission in 2 of 5 cases, between 24 and 48 hours after admission in 1 case, and between 2 and 7 days after admission in the final 2 cases (Table 1). One day after surgery, the median GCS change was +1 (range −3 to +5), and the median decrease in midline shift was 2.7 mm (range 1.5–4.6 mm) (see Figs. 1 and 2). In the one case in which the patient’s condition was worse postoperatively (Case 4), the patient’s condition eventually improved during hospitalization and was ultimately better on discharge than preoperatively (GCS +2).

At discharge, all patients were still alive. The median GCS score was 10 (range 9–11), the median mRS score was 5 (range 5–5), and the median NIHSS score was 22 (range 17–27). All patients’ GCS scores improved by at least 2 points. Four of the 5 patients were discharged to an appropriate rehabilitation facility; the remaining patient was transferred to the hospital of initial admission.

Six months following the insult, 1 patient had died, and 2 patients were functionally dependent (mRS Score
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4–5). The first of the 2 functionally dependent patients (Case 1) suffered low verbal output, as well as headache caused by hydrocephalus. The headache improved after spinal drainage. The second patient (Case 2) was bedridden, required full-time home health aid, had low verbal output, and suffered some prosopagnosia. The final 2 patients (Cases 3 and 5) were functionally independent (mRS Score 0–3).

During the study period, 266 patients with ICH were admitted and enrolled in the same prospective ICHOP database (including patients who were treated with surgery). After exclusion of patients with ICH due to arteriovenous malformations or aneurysms, patients with infratentorial ICH, patients lost to follow-up at 6 months, and patients treated with DHC without clot evacuation, 144 patients with spontaneous ICH remained. Of the 144 patients, 2 had DHC with clot evacuation and 6 underwent craniotomy for evacuation only. The median admission GCS score of this group was 9 (range 3–15) and the median ICH volume was 17 cm³ (range 0.5–120 cm³). At 6 months after hemorrhage, the mortality rate was 47%, and 24% of the patients were functionally independent.

Of all patients whose cases were managed nonoperatively, 5 had characteristics similar to the patients in the DHC group (dominant ICH, admission GCS Score 5–9, ICH volume 28–79 cm³, age < 60 years). In this group the median admission GCS score was 7 (range 5–9), the median ICH volume was 46 cm³ (range 40–52 cm³), and the median age was 47 years (range 42–57 years). At 6 months posthemorrhage, 60% of the patients in this group had died and 20% were functionally independent (Table 2).

Discussion

We report the results of a prospective series of cases
TABLE 2: Presenting characteristics and outcomes in patients treated with DHC without clot evacuation (DHC cases) in comparison to selected controls and to all other cases of spontaneous, supratentorial ICH*

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Other Cases (n = 144)</th>
<th>Selected Controls† (n = 5)</th>
<th>DHC Cases (n = 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Value</td>
<td>p Value</td>
<td>Value</td>
</tr>
<tr>
<td>male sex</td>
<td>58%</td>
<td>0.17</td>
<td>80%</td>
</tr>
<tr>
<td>age (yrs)</td>
<td>median</td>
<td>68.5</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>IQR</td>
<td>56–81</td>
<td>43–55</td>
</tr>
<tr>
<td>HTN etiology</td>
<td>65%</td>
<td>0.66</td>
<td>60%</td>
</tr>
<tr>
<td>scores on admission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICH</td>
<td>median</td>
<td>2</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>IQR</td>
<td>1–3</td>
<td>3–3</td>
</tr>
<tr>
<td>GCS</td>
<td>median</td>
<td>7</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>IQR</td>
<td>7–8</td>
<td>6–7</td>
</tr>
<tr>
<td>hematoma characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICH volume (cm³)‡</td>
<td>median</td>
<td>17</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>IQR</td>
<td>6–43</td>
<td>43–49</td>
</tr>
<tr>
<td>midline shift (mm)</td>
<td>median</td>
<td>2.4</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>IQR</td>
<td>0–5</td>
<td>3–8</td>
</tr>
<tr>
<td>lobar location</td>
<td>median</td>
<td>35%</td>
<td>1</td>
</tr>
<tr>
<td>IVH</td>
<td>56%</td>
<td>0.65</td>
<td>60%</td>
</tr>
<tr>
<td>6-mo follow-up</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mortality</td>
<td>47%</td>
<td>0.37</td>
<td>60%</td>
</tr>
<tr>
<td>mRS score</td>
<td>median</td>
<td>5</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>IQR</td>
<td>4–6</td>
<td>4–6</td>
</tr>
<tr>
<td>good outcome</td>
<td>24%</td>
<td>0.60</td>
<td>20%</td>
</tr>
</tbody>
</table>

* All statistical comparisons were made with the hemicraniectomy group. The Wilcoxon rank-sum test was used for continuous variables, and the Fisher exact test was used for categorical variables. Good outcome was defined as mRS Score 0–3.
† Nonoperatively managed cases similar to the DHC cases.
‡ Does not include IVH volume.

In which patients with dominant ICH and persisting ICP elevation despite optimal nonoperative management were treated with DHC without clot evacuation. At discharge all patients were still alive. At 6 months after surgery, 1 patient had died, and of the remaining 4 patients, 50% were functionally dependent (mRS Score 4–5), and 50% were functionally independent (mRS Score 0–3).

Intracerebral hemorrhage incites ICP elevation by several distinct mechanisms. Initially, the hematoma volume itself, which can expand for up to 24 hours after the ictus,7,12,13,22,23,33 impacts the intracranial volume buffer capacity. Subsequently, osmotically active proteins in the hematoma cause edema formation in the surrounding tissue, with approximately 75% of patients experiencing an increase in perihematomal edema within the first 24 hours.15,36 Rather counterintuitively, surgical clot evacuation may in some cases also contribute to ICP elevation, as it bears the potential to induce endema formation through tissue manipulation and/or venous interruption.10,11,20,21,25,32

Although the topic of clot evacuation in ICH has gained increased attention in recent years4,21,27 following a relatively silent period after the 1961 landmark paper by McKissock et al.,26 the role of decompressive craniectomy in large ICHs has only scarcely been explored. The majority of the reports on decompressive craniectomy following ICH involve a combination of decompression with concurrent clot evacuation. The mortality rates for patients undergoing such intervention in these studies were considerably better than the natural history, as the mortality of the latter approaches 86%.6,18 Moreover, the results for concurrent DHC and clot evacuation were favorable compared with results for patients managed with craniotomy and clot evacuation alone, suggesting a therapeutic effect of decompression.10,24,25,30
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Clinical outcomes for decompressive craniectomy with clot evacuation have been reported for a total of 138 patients in the literature, rendering an overall 29% mortality rate and 51% favorable outcome rate, with follow-up duration ranging from discharge to 2 years (Table 3).

In light of the negative conclusions of the STICH trial and studies implicating an exacerbation of tissue damage from clot evacuation, decompression alone, without attempts at concurrent hematoma removal, may prove a better option than others for the management of medically refractory large ICH. Ramnarayan et al. were the first to explore the impact of DHC without clot evacuation and reported on a series of 23 patients with putamen ICH. At 3-month follow-up, 56% had a favorable outcome and only 13% had died. Of 7 patients with an ICH volume greater than 60 cm³ in their cohort, 2 patients attained functional independence by 3 months, while 5 patients had poor outcome (GOS Score 1–4). The mortality rate was not reported. Fung et al. likewise reported results of DHC without clot evacuation and reported on a series of 23 patients with putamen ICH. At 3-month follow-up, 56% had a favorable outcome and only 13% had died. Of 7 patients with an ICH volume greater than 60 cm³ in their cohort, 2 patients attained functional independence by 3 months, while 5 patients had poor outcome (GOS Score 1–4). The mortality rate was not reported. Fung et al. likewise reported results of DHC without clot evacuation in ICH. Of their 12 patients, of whom half had an ICH volume greater than 60 cm³, 25% died and 50% gained functional independence at 6 months. A summary of the literature on DHC without clot evacuation in ICH, including the results of the present study, yields 40 cases, with an 18% mortality rate and 53% good outcome rate after a follow-up ranging from 3 to 6 months (Table 3). In this overview it seems that dominant ICH as well as large ICH volume are accompanied by worse outcome.

Another promising field of research in ICH management involves minimally invasive techniques, including stereotactic catheter placement and endoscopic evacuation. Although none of these procedures were performed at our institution during the study period, we consider their potential in ICH promising and look forward to the results of the MISTIE-ICES trial (Minimally Invasive Surgery plus T-PA for Intracerebral Hemorrhage Evacuation–Intraoperative CT-guided Endoscopic Surgery) at Johns Hopkins as well as the specific ICH catheters that are currently being developed by the EKOS Corporation.

Comparison of the 6-month results of the patients in the DHC group to the results of spontaneous ICH patients with similar characteristics (dominant ICH, GCS Score 5–9, ICH volume 28–79 cm³; age < 60 years; n = 5) whose cases were nonoperatively managed suggests a beneficial role for DHC. Decompressive hemicraniectomy rendered a 20% mortality rate compared with 60% in their conservatively managed counterparts. Moreover, 40% of patients in the DHC group attained functional independence compared with 20% in the nonoperatively managed group. The reasons for lack of surgical intervention are unknown, but family preferences likely played a role and may also have contributed to differences in outcome due to differences in the aggressiveness of medical therapy.

As to the negative conclusions of the STICH trial, our data appear to confirm the lack of benefit from clot evacuation in spontaneous ICH. In our total cohort, 6 patients received clot evacuation by nondecompressive craniotomy for spontaneous supratentorial ICH. The median GCS score in this group was 9 (range 4–15) and the median ICH volume was 55 cm³ (range 8–117 cm³). Moreover, the rate of coma was 50% in these patients compared with 80% in the DHC group, yet despite these more favorable characteristics, 6-month outcomes were favorable for the DHC group (clot evacuation vs DHC: mortality 33% vs 20%, good outcome 17% vs 40%). This finding suggests that the harm caused by the surgery outweighs the benefit of the clot removal and that decompression with preservation of brain integrity may prove a better therapeutic technique in ICH. Future endeavors should be directed at further investigation of the potential benefits of decompressive craniectomy in ICH.

The small sample size of this study as well as its nonrandomized design are substantial limitations. Our goal in presenting our cases and analysis, however, is to contribute data to the growing literature on this treatment modality for ICH. The presented data, combined with data from the literature, suggest that DHC is feasible in patients with large ICH. Nonetheless many additional factors are involved in driving outcome following ICH.

TABLE 3: Summary of literature on decompressive craniectomy and DHC in ICH

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Cases</th>
<th>Dominant Side</th>
<th>&gt;50/60 cm³</th>
<th>Mortality</th>
<th>Term</th>
<th>Good Outcome</th>
<th>Term</th>
<th>Definition of Good Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>decompressive craniectomy w/ clot evacuation</td>
<td>Dierssen et al., 1983</td>
<td>73</td>
<td>53%</td>
<td>unknown</td>
<td>33%</td>
<td>2 yrs</td>
<td>45%</td>
<td>2 yrs</td>
</tr>
<tr>
<td>Ma et al., 2010</td>
<td>38</td>
<td>unknown</td>
<td>unknown</td>
<td>32%</td>
<td>1 mo</td>
<td>55%</td>
<td>6 mos</td>
<td>GOS 3–5</td>
</tr>
<tr>
<td>Maira et al., 2002</td>
<td>15</td>
<td>unknown</td>
<td>unknown</td>
<td>20%</td>
<td>1 yr</td>
<td>73%</td>
<td>1 yr</td>
<td>GOS 4–5</td>
</tr>
<tr>
<td>Murthy et al., 2005</td>
<td>12</td>
<td>8%</td>
<td>67%</td>
<td>8%</td>
<td>discharge</td>
<td>50%</td>
<td>17 mos*</td>
<td>mRS 0–3</td>
</tr>
<tr>
<td>total</td>
<td>138</td>
<td>29%</td>
<td></td>
<td></td>
<td></td>
<td>51%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DHC w/out clot evacuation</td>
<td>Ramnarayan et al., 2009</td>
<td>23</td>
<td>43%</td>
<td>30%</td>
<td>13%</td>
<td>3 mos</td>
<td>56%</td>
<td>3 mos</td>
</tr>
<tr>
<td>Fung et al., 2012</td>
<td>12</td>
<td>58%</td>
<td>50%</td>
<td>25%</td>
<td>6 mos</td>
<td>50%</td>
<td>6 mos</td>
<td>mRS 0–3</td>
</tr>
<tr>
<td>present series</td>
<td>5</td>
<td>100%</td>
<td>60%</td>
<td>20%</td>
<td>6 mos</td>
<td>40%</td>
<td>6 mos</td>
<td>mRS 0–3</td>
</tr>
<tr>
<td>total</td>
<td>40</td>
<td>18%</td>
<td></td>
<td></td>
<td></td>
<td>53%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Mean value.
and therefore large, multicenter, randomized trials are needed to accurately assess the role of DHC in optimal ICH management. In this light we are looking forward to the results of the ongoing trial comparing decompressive craniectomy with clot evacuation to clot evacuation only, the results of the ongoing trial comparing decompressive ICH management. In this light we are looking forward to investigate the therapeutic value of DHC in ICH.

Conclusions

Our data indicate that DHC with preservation of brain integrity in patients with spontaneous dominant ICH and medically refractory ICP elevation is feasible. Large randomized controlled trials are needed to further investigate the therapeutic value of DHC in ICH.

Disclosure

Michael McDowell and Eric Sussman are recipients of a clinical research fellowship from the Doris Duke Charitable Foundation. Author contributions to the study and manuscript preparation include the following. Conception and design: Connolly. Acquisition of data: Kellner. Analysis and interpretation of data: Heuts. Drafting the article: Heuts. Critically revising the article: Connolly, Zacharia, Hickman, Kellner, Sussman, McDowell. Statistical analysis: SS Bruce. Administrative/technical/material support: RA Bruce. Study supervision: Connolly.

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