Decompressive hemicraniectomy for spontaneous intracerebral hemorrhage

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Intracerebral hemorrhage (ICH) is devastating, with high mortality rates, but its optimum management has not been fully established. Decompressive hemicraniectomy is a surgical procedure used to relieve the malignant elevation of intracranial pressure. The application of decompressive hemicraniectomy in patients with hemispheric ICH has been much less common, although several studies have shown the usefulness of this procedure for large hemispheric ICH. In this review, the present knowledge of the safety and efficacy of this procedure are evaluated. The authors conclude that decompressive hemicraniectomy with hematoma evacuation for large ICH might be a safe and effective procedure in patients with severely disturbed consciousness and large hematoma volume.
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KEY WORDS • decompressive hemicraniectomy • surgery • intracerebral hemorrhage

HYPERTENSIVE ICH accounts for 10%–20% of strokes.⁴ Intracerebral hemorrhage can be devastating; mortality rates are high, ranging from 30% to 50% at 30 days,^{2,6,12} and many survivors remain severely disabled. The International Surgical Trial in Intracerebral Hemorrhage (STICH), a landmark trial involving over 1000 ICH patients, showed that emergent surgical hematoma evacuation via craniotomy within 72 hours of onset failed to improve outcome compared with a policy of initial medical management.²³ The STICH II study is currently enrolling patients to establish whether earlier hematoma evacuation in selected patients will improve outcome compared with conservative initial treatment.²⁴ To date, the optimal management of ICH has not been definitively established.

Decompressive hemicraniectomy is a surgical procedure to relieve malignant elevation of ICP. It involves opening the skull and removing a bone flap to allow the edematous brain to swell outward, thus preventing in-

tracranial tissue shifts and life-threatening downward herniation. The procedure also has beneficial effects in reducing ICP and can contribute to improvements in cerebral compliance, cerebral oxygen supply, cerebral blood perfusion, and various abnormal CT signs.^{1,19,30} Decompressive hemicraniectomy has been used mainly for the treatment of severe traumatic brain injury,^{1,5,9,34,38} high-grade aneurysmal subarachnoid hemorrhage,^{8,14,27,31} and hemispheric cerebral infarction.^{3,15,17,35–37} The use of DHC to treat patients with hemispheric ICH has been much less common. However, DHC can improve outcome after experimental ICH in rats,²² and several clinical studies have demonstrated that this procedure is useful for large hemispheric ICHs.^{10,11,18,20,21,26,29,32,33}

The present review summarizes our knowledge about DHC for the treatment of hemispheric ICH and discusses the safety and efficacy of this procedure.

Methods

A PubMed search for studies in the English language was performed using the key words “craniectomy” or “hemicraniectomy” in several combinations with the key words “hemorrhagic stroke” and “intracerebral hemorrhage.” Series about cerebellar hemorrhage, hemorrhagic cerebral infarction, subarachnoid hemorrhage, and

Abbreviations used in this paper: DHC = decompressive hemicraniectomy; GCS = Glasgow Coma Scale; GOS = Glasgow Outcome Scale; ICH = intracerebral hemorrhage; ICP = intracranial pressure; IVH = intraventricular hemorrhage; mRS = modified Rankin Scale; STICH = International Surgical Trial in Intracerebral Hemorrhage.

hemorrhage from known etiology (tumor, arteriovenous malformation, cavernoma, or cerebral sinus thrombosis) other than hypertension were excluded. We also decided to limit the analysis to series containing at least 5 cases treated surgically reported in papers that provided data about the outcomes. Favorable outcome was defined for purposes of this review as mRS scores of 0–2 or the GOS categories good recovery or moderate disability. Poor outcome was defined as mRS scores of 3–6 or the GOS categories severe disability, vegetative state, or dead.

Results

A total of 9 studies were identified, reporting 226 cases in which DHC was performed for spontaneous hemispheric ICH.^{10,11,18,20,21,26,29,32,33} Seven of these studies reported 191 cases in which patients were treated with DHC with hematoma evacuation,^{10,18,20,21,26,32,33} and the other 2 studies reported 35 cases in which patients were treated with DHC without hematoma evacuation.^{11,29} Tables 1 and 2 summarize these studies.

Decompressive Hemicraniectomy With Hematoma Evacuation

The mean or median patient ages were reported in the range of 40–60 years. Preoperative consciousness was severely disturbed in many patients. Four studies reported frequencies of preoperative GCS scores of 8 or less (≥ 8 or < 8), and in these studies, at least 83% of patients (62 of 75) had a preoperative GCS score of 8 or less.^{18,21,26,33} Four studies reported hematoma location in 147 patients.^{10,20,26,33} Hematoma location was the lobar region in 79 (54%) of these 147 patients and the basal ganglia/thalamus in 69 patients (47%). Four studies discussed IVH in 147 patients.^{10,20,26,33} Intraventricular hemorrhage was associated with ICH in 78 (53%) of these 147 patients. Four studies measured hematoma volume in 79 patients.^{20,26,32,33} Mean or median hematoma volume was relatively large (> 60 ml). All 7 studies reported the interval between hemorrhage onset and surgery, and 3 studies reported that the mean interval ranged from 8.3 to 22 hours.^{18,20,32} Four studies reported that 83 (67%) of 124 patients underwent surgery within 24 hours after onset.^{10,21,26,33}

Three studies reported the occurrence of complications in 86 patients, including hydrocephalus in 16 patients (19%), intracranial hemorrhage in 3 patients (3%), and infection in 3 patients (3%).^{18,20,33} Clinical outcomes were assessed in various ways in all 7 studies. Two studies used the mRS,^{26,32} and 5 studies used the GOS.^{10,18,20,21,33} However, 1 study of 5 patients reported only median mRS,³² and 1 patient left our previous study within the 1st month after DHC.³³ Therefore, the outcomes of 185 cases were available for further analysis. Outcome was favorable in 75 (41%) of 185 cases. Fifty-two (28%) of the 185 patients died during various follow-up periods. In addition, 4 studies were case-control studies.^{10,20,21,32} Three of these studies reported significant improvement in functional outcome or mortality compared with the control group (only hematoma evacuation),^{10,20,21} but one study reported no significant differences in outcome.³²

Decompressive Hemicraniectomy Without Hematoma Evacuation

A total of 23 patients (age range 31–68 years) underwent only DHC for putamen hemorrhage.²⁹ The GCS score was 8 or less in 7 patients (30%). Intraventricular hemorrhage was observed in 6 patients. The hematoma volume was 30–60 ml in 13 patients (57%) and more than 60 ml in 7 (30%). Three patients underwent DHC within 6 hours after hemorrhage onset. Outcome was favorable in 15 patients (good recovery in 13 and moderate disability in 2). Three patients (13%) died within 1 month of surgery.

Twelve patients (median age 48 years) underwent only DHC for hemorrhage in the basal ganglia (5 patients) or lobar (7 patients) region.¹¹ The median GCS score was 8. The median hematoma volume was 61 ml. The median interval between hemorrhage onset and surgery was 12 hours. Complications after DHC included intracranial hemorrhage in 2 patients (17%) and infection in 1 (8%). Outcome at 6 months was favorable in 4 patients (33%). Three patients (25%) died within 6 months of surgery. In addition, this study reported significant improvement in the functional outcome compared with the control group (only medical treatment).

Discussion

The optimum treatment for patients with spontaneous hemispheric ICH remains controversial. Outcomes have been disappointing for patients with large ICH. Hematoma evacuation has been the most studied intervention for the surgical management of ICH, but hematoma evacuation alone may not be adequate to relieve intracranial hypertension.^{21,28} Hemorrhage triggers a series of negative pathogenic mechanisms soon after its onset, and this can result in the loss of cerebral autoregulation.^{21,28} Consequently, the ICP can increase again and reach pathological values within a few hours after hematoma evacuation.^{21,28} Decompressive hemicraniectomy has been considered as an option to resolve this problem.

Decompressive Hemicraniectomy With Hematoma Evacuation

This review identified a substantial cohort of patients who underwent DHC for spontaneous hemispheric ICH. Overall, we found that DHC was performed mainly in patients with GCS scores of 8 or less and large hematomas with a volume greater than 60 ml.

Among several postoperative complications, hydrocephalus was most frequent; it was observed in approximately 20% of patients undergoing DHC with hematoma evacuation. In addition, hemorrhagic or infectious complications occurred in 3% of patients who underwent DHC with hematoma evacuation. These findings were consistent with those in patients undergoing DHC for severe traumatic brain injury.^{9,18,38} The development of hydrocephalus as a result of DHC has been well reported, whereas only one study has examined the risk factors for hydrocephalus after DHC with hematoma evacuation. We previously reported that the presence of IVH, the superior limit of the DHC,

TABLE 1: Summary of studies of decompressive hemicraniectomy with hematoma evacuation for spontaneous hemispheric intracranial hemorrhage*

Authors & Year	Study Design	No. of Pts†	Mean Age (yrs)	Preop Consciousness (N)	Hematoma Location (N)	No. of IVHs	Mean Hematoma Volume (ml)	Surgical Procedure‡	Complication (N)	Outcome (N)
Dierssen et al., 1983	case-control study	73	52	coma/deep coma (36)	basal ganglia/thalamus (6), lobar (56), cerebellum (11)	24	NA	DHC w/ HE (w/in 24 hrs in 33 cases)	NA	GOS (FU duration NA): GR/MD (33), SD/VS (16), D (24); statistically significant improvement in mortality compared w/ only HE
Maira et al., 2002	case-control study	15	NA	GCS ≤ 8 (15)	NA	NA	NA	DHC w/ HE (w/in 24 hrs)	NA	GOS at 1 yr: GR/MD (11), SD/VS (1), D (3); in pts w/ GCS 4–5, statistically significant improvement in functional outcome compared w/ only HE
Murphy et al., 2005	case series	12	49.8	GCS ≤ 8 (12)	basal ganglia + lobar (12)	12	71	DHC w/ HE (w/in 24 hrs)	NA	mRS at last FU (mean FU duration 17 mos): Scores 0–2 (5), Scores 3–5 (6), Score 6 (1)
Kim et al., 2009	case series	24	56.2	GCS < 8 (19)	NA	NA	NA	DHC w/ HE (mean, 8.3 hrs)	hydrocephalus (6)	GOS at 6 mos: GR/MD (12), SD/VS (6), D (6)
Ma et al., 2010	case-control study	38	52	mean GCS 7.4	basal ganglia (38)	28	62	DHC w/ HE (mean, 22 hrs)	rebleeding (3)	GOS at 6 mos: MD (8), SD/VS (16), D (14); statistically significant improvement in functional outcome & mortality compared w/ only HE
Shimamura et al., 2011	case-control study	5	43	median GCS 7	NA	NA	97.8	DHC w/ HE (mean, 15.7 hrs)	NA	mRS at 3 mos: median mRS Score 5; no improvement in functional outcome compared w/ only HE
Takeuchi et al., 2013	case series	24§	57.1	GCS ≤ 8 (16), mean GCS 6.8	basal ganglia (13), lobar (11)	14	72.8	DHC w/ HE (w/in 24 hrs in 23 cases)	hydrocephalus (10), meningitis (3)	GOS at last FU (mean, 135 days): GR/MD (6), SD/VS (13), D (4)

* D = dead; FU = follow-up; GR = good recovery; HE = hematoma evacuation; MD = moderate disability; NA = not available; pts = patients; SD = severe disability; VS = vegetative state.

† Number of patients who underwent decompressive hemicraniectomy with hematoma evacuation (not including control group).

‡ Values in parentheses indicate the interval between hemorrhage onset and surgery.

§ Our previous study was performed to investigate the prevalence of hydrocephalus after DHC and excluded 1 patient who left the study and 2 patients who died within the 1st month after DHC. In this table, data except for outcome are given for 24 patients, including these 3 patients. Outcome data are given for 23 patients who were followed up for more than 1 month.

TABLE 2: Summary of studies of only decompressive hemicraniectomy for spontaneous hemispheric intracranial hemorrhage*

Authors & Year	Study Design	No. of Pts	Age (yrs)	Preop Consciousness (N)	Hematoma Location (N)	No. of IVHs	Hematoma Volume	Surgical Procedure†	Complication (N)	Outcome
Ramnarayan et al., 2009	case series	23	31–68	GCS ≤ 8 (7)	basal ganglia (23)	6	>60 ml in 7 cases	DHC (<6 hrs in 3 cases, >6 hrs in 20 cases)	NA	GOS at 1 mo: GR/MD (15), VS/SD (5), D (3)
Fung et al., 2012	case-control study	12	median 48	median GCS 8	basal ganglia (5), lobar (7)	NA	median 61.25 ml	DHC (median 12 hrs)	remote hemorrhage (1), SDH (1), subdural empyema (1)	mRS at 6 mos: Scores 0–2 (4), Scores 3–5 (5), Score 6 (3); statistically significant improvement in functional outcome compared w/ only medical treatment

* SDH = subdural hematoma.

† Values in parentheses indicate the interval between hemorrhage onset and surgery.

and the presence of meningitis might be causative factors for hydrocephalus after DHC,³³ which is consistent with the findings in cases of DHC for traumatic brain injury.^{5,9,16}

Preoperative consciousness and hematoma volume are the main predictive factors for outcome in ICH. In the study by Broderick et al.,⁷ which included 142 patients with deep or lobar ICH, among whom 16% underwent hematoma evacuation, the patients with GCS scores of 8 or less and hematoma volume greater than 60 ml had a mortality rate of 91%. A meta-analysis by Gregson et al.¹³ found favorable outcomes in only 5% of patients with GCS scores of 8 or less and only 7% of patients with hematoma volumes of 80 ml or greater. Although the present review found most patients had GCS scores of 8 or less and large hematoma volumes, a favorable outcome was achieved in 41% of cases and the overall mortality rate was 28%, which indicates that DHC with hematoma evacuation might improve the outcomes of patients with such severe conditions. In fact, 3 of 4 case-control studies reported significant improvement in functional outcome or mortality compared with the control group (only hematoma evacuation),^{10,20,21} supporting this speculation. In addition, 42% of patients included in the STICH had associated IVH, and further detailed analysis of STICH revealed that the prognosis for patients with IVH is much worse than that for patients with only ICH.^{23,24} In the current review, 53% of patients who underwent DHC with hematoma evacuation had associated IVH, indicating that DHC with hematoma evacuation might have some benefit even for patients with associated IVH.

In the STICH, the median time between hemorrhage onset and surgery was 30 hours in the early surgery group.²³ Recent meta-analysis confirms that earlier surgery can be beneficial for ICH.¹³ In the present review, 67% of patients underwent DHC with hematoma evacuation within 24 hours after the hemorrhage onset, so early timing of surgery might have been one of the factors in the improvement of outcome. However, data on the timing of the procedure were not available for a large number of patients, so further studies are needed on this factor.

Minimally invasive surgery, including endoscopic surgery and stereotactic aspiration, have been used in the treatment of patients with ICH, with positive results suggesting the safety and efficacy of such techniques.³⁹ The Minimally Invasive Surgery Plus Recombinant Tissue-Type Plasminogen Activator for ICH Evacuation (MISTIE) Phase II trial (NCT00224770) has recently reported significant reduction in perihematoma edema in patients who underwent successful hematoma evacuation after the MISTIE procedure.²⁵ The Intraoperative Stereotactic CT-Guided Endoscopic Surgery (ICES) arm of the trial is also in progress to determine the safety, feasibility, and effectiveness of endoscopic surgery.

However, meta-analysis of experiences with minimally invasive surgery has found that the candidates most likely to benefit from surgery have a GCS score of 9 or greater and hematoma volume between 25 and 40 ml,³⁹ conclusions that differ from those of our review. Therefore, whether minimally invasive surgery can have benefits for patients in even more severe condition remains debatable. We will reevaluate these results only after the

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ongoing trials are completed, but we presently consider that minimally invasive surgery has beneficial effects on outcome in patients with relatively mild disturbance of consciousness and small hematoma volume.

In addition to these limitations, the present review has some other limitations. We could not access detailed data on the size of the DHC, ICP, and extent of perihematoma edema. In addition, data on hematoma volume were not available for a large number of patients. Further studies are also needed on these factors.

Despite these limitations, the present findings suggest that DHC with hematoma evacuation is safe for the treatment of ICH and may reduce the mortality and improve the functional outcome, especially in patients with severely disturbed consciousness and large hematoma volume.

Decompressive Hemicraniectomy Without Hematoma Evacuation

Experimental DHC without hematoma evacuation in the rat ICH model can improve outcome, with earlier intervention of greater benefit,²² but whether DHC without hematoma evacuation is superior to hematoma evacuation without DHC or DHC with hematoma evacuation remains unclear.

In the series reported by Ramnarayan et al.,²⁹ only 30% of patients had GCS scores of 8 or less, and hematoma volumes were relatively small. Therefore, the resultant high rate of favorable outcomes (65%) and low mortality rate (13%) might be due to the relatively mild disease severity. On the other hand, in the recent series of Fung et al.,¹¹ most patients had severe preoperative conditions and relatively large ICH. Hemorrhagic or infectious complications occurred in 17% of patients and infection in 8%, whereas relatively favorable outcome was obtained in 33%, and the mortality rate was 25%. However, the small sample does not allow us to analyze these complication rates and outcomes.

Conclusions

Decompressive hemicraniectomy with hematoma evacuation might be safe and effective for the treatment of large hemispheric ICH in selected patients. Further investigations including a prospective randomized trial are needed to confirm the safety and efficacy of DHC with hematoma evacuation for treatment of large ICH. The application of only DHC (DHC without hematoma evacuation) for ICH remains inconclusive because of the small number of reported patients. We suggest that selection of the optimal treatment protocol, including conservative therapy, minimally invasive surgery, conventional hematoma evacuation via craniotomy, and DHC with/without hematoma evacuation, should be based on the severity of the disease in individual patients.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation

include the following. Conception and design: Takeuchi. Acquisition of data: Takeuchi, Nagatani. Analysis and interpretation of data: Takeuchi. Drafting the article: Takeuchi. Critically revising the article: all authors. Study supervision: Mori.

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