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Original Research Article

Impact of Decompressive Craniectomy Size and Volume on Deep Spontaneous Intracerebral Hemorrhage Outcomes

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Abstract

Background: One of the most life-threatening types of stroke is spontaneous intracerebral hemorrhage (SICH), which has a 30–40% death rate. In patients with supratentorial capsuloganglionic bleeding who received a decompressive craniectomy (DC) at our facility, we sought to assess the impact of craniotomy size and decompression volume on surgical outcome, complications, mortality, and morbidity.

Methods: The study was conducted prospectively at MMCH, Madhubani, Bihar between April 2024 and March 2026. The study included all patients with capsuloganglionic bleeding who underwent DC and hematoma evacuation.

Results: During the study period, 55 patients at our hospital had DC for SICH. The bone flap's mean anteroposterior (AP) diameter was 12.42 cm. In our study, a greater AP diameter was linked to a higher incidence of hydrocephalus, but the volume of decompression had no effect on mortality or morbidity. Midline shift (MLS) was less reduced after a smaller craniectomy with an AP diameter of less than 12 cm. Mortality was significantly impacted by persistent postoperative MLS, and the magnitude of the craniectomy affected its decrease (p=–0.037).

Conclusion: In terms of MLS reduction, DC with an AP diameter of 12 to 13 cm yields the best results. A larger DC volume need careful monitoring since it increases the risk of hydrocephalus.

Keywords: decompressive craniectomy, spontaneous intracerebral hemorrhage, stroke, mRs, surgical outcome.

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Introduction

One of the most life-threatening types of stroke is spontaneous intracerebral hemorrhage (SICH), which has a 30–40% death rate.[1] Interest in surgery for SICH decreased after the STICH trials [2], and there is still no class 1 evidence regarding the best way to treat SICH with refractory elevated intracranial pressure (ICP). However, when compared to conservative treatment and traditional surgical evacuation method, there is growing evidence in the literature that minimally invasive surgery is linked to much better outcomes.

Over the past several years, there has also been a resurgence of interest in decompressive craniectomy (DC), as multiple major studies and meta-analyses have demonstrated DC's superiority in reducing mortality from intracerebral hemorrhage (ICH). In fact, DC with or without hematoma evacuation may lower mortality for patients with supratentorial ICH who are in a coma, have large hematomas with significant midline shift (MLS), or have elevated ICP resistant to medical treatment, according to the most recent American Heart Association guidelines on SICH (class 2b; level of evidence C).[2] The Monro-Kellie doctrine serves as the foundation for DC's reasoning, and Kocher and Cushing initially outlined the process in the early 1900s. [3] By restoring perimesencephalic cisterns, DC seeks to increase intracranial volume and space, lower MLS, enhance cerebral compliance, and lower ICP.[5] It is still unclear what the ideal craniectomy size is to achieve maximum decompression without raising the risk of complications. For ischemic stroke and traumatic brain injury (TBI), the size and volume of DC have been thoroughly investigated.[7]

The impact of craniectomy size in SICH, however, has not been investigated. Anteroposterior (AP) diameter of at least 8 cm [9] is sufficient, according to some research, while at least 15 cm is required. However, there is no level 1 evidence establishing the optimal size of DC [8].[10] Hematoma evacuation in SICH patients results in considerable brain tissue collapse, which is observed intraoperatively, in contrast to patients with trauma and ischemic stroke, when the main insult generates extensive cerebral edema. DC typically has a therapeutic role in preventing such secondary deteriorations, but perihematomal edema, rebleed, or residual bleed may cause delayed deterioration.

Our investigation was predicated on the idea that, unlike in situations of trauma or ischemic stroke, a big DC might not be necessary in patients with significant SICH because brain tissue tends to collapse after hematoma evacuation. Large DC may also be dangerous because intraoperative brain collapse can result in problems such bridging vein shearing. In patients with supratentorial capsuloganglionic bleeds who had DC at our facility, we sought to assess the impact of craniotomy size and decompression volume on surgical outcome, complications, mortality, and morbidity.

Material and Methods

The study was conducted prospectively at Madhubani Medical College and Hospital, Madhubani, Bihar between April 2024 and March 2026. The study included all patients with capsuloganglionic bleeding who underwent DC and hematoma evacuation for unilateral spontaneous capsuloganglionic hemorrhage.

As per our hospital protocol, patients who had two of the following features were taken up for DC: hematoma volume greater than 60 mL, MLS > 10 mm, Glasgow Coma Score (GCS) < 8, and pupillary asymmetry. Patients with lobar hemorrhage were excluded in this study.

Patient demographic data, that is, age, sex, comorbidities, GCS at admission, were collected. All the patients underwent no enhanced computed tomography (CT) of the brain on admission and the images were analyzed. On admission, all the patients were intubated given the poor GCS. Blood pressure reduction was performed in all cases with a target of < 140 mmHg as per INTERACT II.[11] Brain-specific antiedema measures were initiated in all patients. Hematoma volume was calculated from the CT brain done before surgery using the formula ABC/2, where A and B are the perpendicular maximal diameters of the lesion and C is the total length in the vertical plane.

Descriptive statistics were reported for continuous variables. Continuous variables were analyzed using independent Student's t-test and one-way analysis of variance for normally distributed data while Welch–Satterthwaite t-test was used for variables with unequal variances. Categorical variables were analyzed with the chi-squared test. Univariate Spearman's correlations were performed between all the independent variables and mRS at follow-up. Mann–Whitney U test was used to analyze nonparametric data. A 5% α error and 80% β error along with a corrected p-value of < 0.05 were considered as statistically significant. The analysis was performed using IBM SPSS version 24 for Windows.

Results

55 of the 63 patients who had DC throughout the study period were part of the study group. With a male majority (47:8), the mean age was 50.73 ± 11.51 years. At admission, the mean systolic and diastolic blood pressure readings were 186.47±29.53 mmHg and 104.69±17.7 mmHg, respectively. With a hematoma volume of 49.39 ± 23.33 mL, the median GCS was 8 at presentation and 7 prior to surgery. Ten patients exhibited hydrocephalus on the presenting MRI, and twenty-three had an intraventricular extension of a hematoma. The average duration to surgery was 18.47 hours, the average preoperative MLS was 1.05 ± 0.32, and the average hospital stay was 15 ± 8.12 days.(Table 1)

Table 1: Demographic and radiological data, and outcome of our cases

Parameter	No. of cases (n=55)
Age(y)	50.73±11.51
Male(n)	47
Female(n)	8
Side(n): Right	33
Left	22
Volume of hematoma	49.39±23.33mL
Preoperative mid line shift	1.05±28.262cm
Postoperative midline shift	0.39±0.27cm
Anteroposterior diameter	12.42±0.90cm
Height	9.88±0.81cm
½ ABC(cm^3)	126.67±34.78
Patients with craniectomy to base (n)	28
Complications (n)	10
mRSat 3 months (median)	4
Mortality at 3 months (n)	14

In our study, the DC bone flap's mean AP diameter was 12.42 cm (10.9–14.7 cm). The patient's morbidity and mortality were not statistically significantly affected by the AP diameter (p = 0.4 and 0.8, respectively). Patients who experienced postoperative hydrocephalus had a greater mean AP diameter than those who did not (12.8 and 12.1 cm, respectively; p = 0.036). The development of postoperative hygroma did not show a comparable connection (p = 0.49).

The DC flap's average height was 9.88 ± 0.8 cm. Patients with higher flap heights fared better. DC's mean height was 10 cm as opposed to 9.2 cm (p = 0.021) in individuals with favorable outcomes. Of the 55 patients, 27 did not have a craniotomy flush with the temporal base, while 28 did. The amount of temporal bone that remained from the base in these patients varied from 4 to 20 mm. Compared to the residual temporal bone group, which had a 3-month mortality rate of 33%, patients who had a craniotomy up to the temporal base had a 3-month mortality rate of 21% (p = 0.227). Patients who lived at three months had a mean distance from the midline to the craniotomy of 2.3 cm, whereas those who did not had a mean distance of 2 cm. However, neither the overall mortality nor the result were found to be statistically significant.

The formula ½ ABC was used to estimate the volume obtained by decompression. 126.67 ± 34.78 mm^3 was the average volume. Patients who survived had a mean craniotomy volume of 123.87 ± 33.90 mm^3, while those who died had a mean volume of 132.75 ± 37.30 mm3 (p = 0.317). In our sample, neither mortality nor outcome were affected by the volume of decompression (Table 2 and 3).

Table 2: Relationship between surgical parameters and mortality

Parameter	Alive(41)	Dead(14)	p-Value
AP(cm)	12.47±0.85	12.27±1.05	0.529
Diameter (cm)	1.99±0.46	2.25±0.52	0.116
Height(cm)	9.93±0.82	9.71±0.80	0.378
ABC/2(mm3)	123.87±33.90	132.75±37.30	0.346
Distance from midline(cm)	2.14±0.49	2.08±0.69	0.76
Postoperative MLS(cm)	0.34±0.24	0.55±0.27	0.011

***AP=anteroposterior; MLS=midline shift.**

Table 3: Relationship between surgical parameters and outcome

Parameter	mRS0–3	mRS4–6	p-Value
AP(cm)	12.47±0.85	12.47±0.86	0.981
Diameter (cm)	2.17±0.45	1.93±0.45	0.16
Height(cm)	9.35±0.70	10.12±0.77	0.009
ABC/2(mm3)	127.10±30.21	122.83±35.42	0.714
Distance from midline(cm)	2.09±0.50	2.16±0.49	0.701
Postoperative MLS(cm)	0.23±0.22	0.37±0.24	0.075

***AP =anteroposterior; MLS=midline shift; mRS=Modified Rankin Scale.**

After hematoma evacuation and DC, the two groups' persistent postoperative MLS was measured; patients with good outcomes had an MLS of 0.34 ± 0.24 cm, whereas those with poor outcomes had an MLS of 0.55 ± 0.27 cm (p = 0.001). 53% of patients with persistent MLS larger than 5 mm passed away during the first three months (p = 0.001). However, the postoperative reduction in MLS was considerably lower in patients with an AP diameter of less than 12 cm (14/55) (p-value: -0.037).

Overall mortality in the study group at 3 months was 14. Mean GCS and mRS on discharge were 10.34 and 4.85, respectively. Mean mRS at 90 days was 4.85. Ten patients had a good outcome and 45 had a poor outcome at 3 months. Every patient underwent a follow-up scan at six weeks. Hydrocephalus (Evans index > 0.3) was present in 25 cases. Additionally, hydrocephalus was noted in 68% of patients with an AP diameter greater than 13 cm and 35.6% of patients with an AP diameter less than 13 cm (p = 0.025; Table 4). Eight of them underwent a permanent CSF diversion operation after their lumbar CSF drainage improved. Six of these patients had a subdural hygroma along the ipsilateral convexities. Neither hydrocephalus nor hygroma were correlated with the volume of the craniotomy or the distance from the midline (p > 0.05).

Due to their protracted need for ventilators, sixteen patients underwent tracheostomies. Out of all the patients, four experienced ventilator-assisted pneumonia, one experienced a wound complication with a CSF leak, and five experienced postoperative meningitis. The size of the craniectomy did not correlate with problems.

Table 4: Anteroposterior diameter and mortality, and postoperative outcome

Parameter	AP diameter		p-Value
	>13 cm	<13 cm	
Mortality	10(25.6%)	4(25%)	0.96
Outcome (mRS<3)	17.9%	18.8%	0.94
Mean reduction in MLS	0.52cm	0.7cm	0.53
Hydrocephalus	35.9%	68%	0.025

Discussion

Over the past few decades, surgery for ICH has been a hotly disputed topic, with numerous studies contrasting conservative versus surgical approaches. According to the findings of the STICH 1 and 2 studies, patients with spontaneous superficial ICH who do not have intraventricular hemorrhage may benefit slightly but clinically from early surgery.[13] According to some recent research, surgery increased survival when compared to long-term medical care.[14] Many hospitals are now turning back to surgery for SICH, although neurosurgeons have struggled to determine what kind of surgery will yield the best results. DC has been shown to enhance mortality and morbidity outcomes in multiple series, despite the fact that minimally invasive methods are at the forefront of surgery for SICH.[14, 15] DC successfully decreased mortality in patients with SICH, according to a recent meta-analysis of seven high-quality studies comparing DC with craniotomy for spontaneous intracerebral bleeding.[14] It has never been determined what the appropriate decompression size is and how DC problems relate to volume, dimensions, the requirement for a craniectomy up to the base of the middle cerebral fossa, and the ideal distance from the midline.

Tanrikulu et al. found that a craniectomy of 12 to 18 cm was equally effective as complete hemispheric exposure (i.e., AP diameter >18 cm) in reducing intracranial hypertension in a cohort that included both TBI and SICH. Furthermore, the risk of secondary problems such parenchymal shear stress, bleeding, and swelling is not increased by a less comprehensive treatment.[16] The idea that a larger craniotomy would result in a better outcome was disproved in a comparable study with 526 patients undergoing DC with 21% SICH patients. The size of the bone flap did not correlate with either survival or outcome.

The AP diameter of the bone flap and outcome or mortality were not found to be directly correlated in our study. Mortality and prognosis were found to be significantly impacted by incomplete hematoma evacuation and the persistence of MLS, which is a marker of elevated ICP [17] in the postoperative scans following DC. We found that the necessary decrease in MLS may be achieved with a diameter of 12 to 13 cm. Complications are linked to any further growth in size. Patients with TBI and extensive cerebral infarcts have been shown to have better outcomes when DC is extended up to the temporal base. Few authors think that the size of the craniectomy flap is more crucial than this surgical step.[18] Patients with DC up to the temporal base in our study had superior survival rates (mortality 21 and 33%, respectively; p = 0.157), indicating that even in cases when the brain is slack after hematoma evacuation, extension up to the temporal base is a beneficial addition.

In order to lower refractory elevated ICP, the magnitude of the therapeutic DC is crucial.19. The volume of decompression can be analyzed using a variety of techniques, the most popular being computer-assisted volumetric analysis.[12] Our study's mean volume acquired with DC was 126.64 ± 34.78 cm3, which was consistent with other earlier research that employed 3D volumetric analysis.[3] In clinical practice, it has long been believed that "go big or go home" is beneficial in DC, meaning that the greater the volume of decompression, the better the result.[16] This was not the case in our investigation since no meaningful conclusion could be drawn to demonstrate the advantages of a bigger volume of craniectomy.

According to De Bonis et al., an excessively near DC margin to the midline increases venous outflow to the sinus and decreases the external force applied to the bridging vein. The brain parenchyma's volume is reduced as a result of the increased extracellular fluid absorption, which also causes ventricular enlargement. Patients who get a craniectomy with a superior limit that is too near to the midline may be at risk for hydrocephalus. Therefore, wide DCs with a superior limit of > 25 mm from the midline are advised.[20] Our investigation was unable to demonstrate the relationship between hydrocephalus and distance from midline.

Our investigation revealed an intriguing finding: patients with an AP diameter greater than 13 cm were substantially more likely to develop hydrocephalus (p = 0.03). Due to the transmission of a pressure pulse out through the cranial lesion, significant DC likely played a "flattening" effect in the typically dicrotic CSF pulse wave in patients. The pressure differential between the draining venous supply and the subarachnoid space determines the function of arachnoid granulation. Therefore, hydrocephalus may develop from reduced CSF outflow and absorption due to disturbance of pulsatile ICP dynamics caused by opening the cranial defect.[21]

Conclusion

In the case of SICH, the widely held notion that a greater craniectomy results in a better outcome has not been validated. To have the best results with the fewest difficulties, the DC's AP diameter should be between 12 and 13 cm. Hydrocephalus was more common in people with larger AP diameters. Better survival results are obtained by extension to the temporal base.

Following full hematoma evacuation, patients with persisting MLS of > 5 mm in the initial postoperative scan had a much worse prognosis and a higher death rate.

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