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DECOMPRESSIVE CRANIECTOMY IN MALIGNANT STROKE: COMPARING OUTCOMES AND IDENTIFYING MORTALITY PREDICTORS ACROSS ISCHAEMIC, HAEMORRHAGIC, AND VENOUS AETIOLOGIES

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ABSTRACT

Background and Aims: Prospective trials and registries have established the positive benefit of decompressive craniectomy (DC) in large cohorts of acute ischaemic stroke (AIS), intracerebral haemorrhage (ICH) and cerebral venous sinus thrombosis (CVST). This study directly compares post-operative functional outcomes and identifies predictors of mortality following decompressive craniectomy across AIS, ICH, CVST in a single cohort.

Methodology: This ambispective study at a university teaching hospital included patients who underwent decompressive craniectomy from 2020 to 2024. Clinical characteristics including level of consciousness, stroke severity along with laboratory and radiological data were obtained. Outcome was measured using modified Rankin score during follow-up.

Results: Among the 59 patients who underwent DC, 29 had acute ischaemic stroke, 14 had ICH and 16 had CVST. CVST patients were younger (36.25 ± 12.24 years) than AIS (53.72 ± 14.36) and ICH (56.36 ± 13.65) patients ($p = 0.0005$). Favourable outcome was achieved in 43.8% of CVST patients versus 13.8% AIS and 7.1% ICH ($p = 0.022$). Mortality was 58.6%, 64.3%, and 25.0% in AIS, ICH, and CVST respectively ($p = 0.05$). Older age, lower Glasgow coma score, high NIHSS, dominant hemisphere involvement, and postoperative sepsis were significant predictors of mortality.

Conclusion: Large strokes due to CVST were associated with substantially better functional recovery and lower mortality after DC, while AIS and ICH had broadly comparable and uniformly poor post-surgical prognoses. Patients with older age, impaired consciousness, high NIHSS, dominant hemisphere involvement, and postoperative sepsis had increased mortality.

KEYWORDS: Decompressive craniectomy Acute ischaemic stroke Intracerebral haemorrhage Cerebral venous sinus thrombosis modified Rankin Scale

INTRODUCTION

Acute large strokes with mass effect and impending herniation due to arterial ischaemic stroke (AIS), hypertensive intracerebral haemorrhage (ICH) or cerebral venous sinus thrombosis (CVST) represent one of the critical and time-sensitive presentations in neurology. In each of these conditions, timely decompressive craniectomy (DC) is a life-saving intervention when maximal medical therapy fails to control rising intracranial pressure. The benefit of DC over medical management in large arterial ischaemic strokes was established by landmark randomised controlled trials including DESTINY, HAMLET, and DECIMAL which demonstrated significant mortality reduction in malignant MCA infarctions.[1,2,3] In pooled analyses, mortality reduced from approximately 71% to 22%, but approximately half of survivors experienced moderate-to-severe disability.[4] The SWITCH trial in severe intracerebral haemorrhage demonstrated a trend toward reduced death or profound disability with DC compared to best medical treatment alone (44% vs 58%; adjusted risk ratio 0.77), providing the prospective evidence supporting DC in the ICH population, though the difference did not reach statistical significance.[5]

CVST predominantly affects younger individuals, leading to venous congestion, venous infarction and raised intracranial pressure rather than primary ischaemia which may render the brain insult more reversible once decompression is achieved and anticoagulation is initiated.[6] Reported mortality after DC for CVST ranges from 13–32%, with good functional outcomes achieved in up to 57% of patients which is considerably better than the approximately 14% rate of favourable outcome reported after DC for arterial infarctions.[7,8]

The existing trials and registries have each benchmarked DC against medical management within a single diagnostic category of AIS, ICH or CVST in isolation and have not directly compared postoperative functional outcomes across these three groups in a single cohort. The present study was therefore undertaken to directly compare post-operative functional outcomes following DC across three aetiologically distinct groups of AIS, ICH, and CVST and to identify clinical predictors of mortality that may further refine pre-surgical prognostic

counselling.

MATERIALS AND METHODS

This was an ambispective observational study conducted in a university teaching hospital from south India from January 2020 to December 2024. All adult patients with age more than 18 years who underwent decompressive craniectomy for large arterial infarctions, hypertensive intracerebral haemorrhage and venous infarctions during the study period were included. Patients with incomplete clinical records, those who underwent decompressive surgery for secondary haemorrhages, traumatic brain injuries, and patients lost to follow-up were excluded.

Data were retrospectively collected from hospital records and prospectively for enrolled patients. Variables recorded included age, sex, symptom duration, interval from admission to surgery, Glasgow coma score (GCS) and National Institutes of Health Stroke Scale (NIHSS) at admission, blood pressure, comorbidities, symptomatic seizures, location and side of lesion, laboratory parameters, and neuroimaging findings. For the CVST group, sinuses and cerebral veins involved were documented. For the AIS group, side of infarction, involved arterial territory, location of infarction were documented. Location, volume, presence of intraventricular extension were noted for ICH group. Functional outcome was assessed using the mRS at discharge and at follow-up (minimum six months post-surgery). Primary outcomes were favourable functional outcome (mRS ≤ 2) at follow-up and severe disability or death (mRS ≥ 5) at follow-up. Secondary outcome was predictors of mortality across the combined cohort.

Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR) and compared using the Kruskal-Wallis test. Categorical variables were compared using the Chi-square or Fisher's exact test. Predictors of mortality were analysed using univariate analysis. A p-value of < 0.05 was considered statistically significant.

The study was conducted in accordance with the Declaration of Helsinki. Institutional ethical committee approval was obtained prior to initiation. Informed consent was obtained from all prospectively enrolled patients or their legal representatives.

RESULTS

A total of 59 patients who underwent decompressive craniectomy during the study period were included in the study. Twenty-nine patients had acute ischaemic stroke, 14 had hypertensive intracerebral haemorrhage, and 16 had cerebral venous thrombosis. Fourteen had dominant hemispheric infarction, 12 had non-dominant hemispheric infarction, one had bilateral infarctions and two patients had cerebellar infarctions. Parenchymal haemorrhage was supratentorial in 13 patients and one had cerebellar infarction. Among patients with CVST, 15 had transverse and / or sigmoid sinus thrombosis; superior sagittal sinus in eight and cortical vein in one patient.

Patients with CVST were younger than AIS and ICH patients ($p = 0.0005$). Gender distribution was comparable across all three groups. NIHSS at admission was higher in AIS (19.14 ± 5.25) and ICH (19.23 ± 6.38) compared to CVST (13.81 ± 7.50), though this did not reach statistical significance ($p = 0.075$). GCS at admission did not differ significantly across groups. Symptomatic seizures were more frequent in the CVST group compared to AIS and ICH, though this did not reach statistical significance. Interval from symptom onset to surgery was similar between the three groups. However, CVST patients underwent surgery following admission earlier than AIS and ICH patients ($p = 0.022$).

Disability at discharge did not differ significantly across groups ($p = 0.19$), reflecting uniformly poor early outcomes across all three groups. However, during follow-up, favourable outcome was significantly higher in the CVST patients (43.8%; n=7) compared to AIS (13.8%; n=4) and ICH (7.1%; n=1). mRS at last follow-up was significantly better ($p = 0.007$) in the CVST group (3.19 ± 1.97) compared to AIS (4.79 ± 1.68) and ICH (5.21 ± 1.25), underscoring the greater potential for delayed neurological recovery in venous infarction. Conversely, severe disability or death was significantly more frequent in the AIS (62.1%; n=18) and ICH (71.4%; n=10) groups compared to CVST (25.0%; n=4; $p = 0.0193$). Mortality was significantly higher in AIS and ICH compared to CVST ($p = 0.050$). (Table 1)

Table 1: Clinical characteristics at presentation and functional status at discharge and last follow-up in the patients following decompressive craniectomy.

Parameter	AIS (n=29)	ICH (n=14)	CVST (n=16)	p-value
Age (years), mean ± SD	53.72 ± 14.36	56.36 ± 13.65	36.25 ± 12.24	0.0005
Male n (%)	20 (69.0%)	10 (71.4%)	11 (68.8%)	0.984
Female, n (%)	9 (31%)	4 (28.6%)	5 (31.2%)	
Symptom duration before surgery (days)	3.32 ± 2.18	4.86 ± 4.87	4.38 ± 3.32	0.379
Interval from admission to surgery (days)	2.52 ± 2.90	3.36 ± 4.29	1.12 ± 1.45	0.022
NIHSS at admission	19.14 ± 5.25	19.23 ± 6.38	13.81 ± 7.50	0.075
GCS at admission	10.97 ± 2.65	11.14 ± 2.82	11.50 ± 2.92	0.704
Seizures	3 (10.3%)	2 (14.3%)	6 (37.5%)	0.072
Median follow-up duration (IQR) months	51.4 (37.5–59.2)	40.0 (32.1–53.1)	55.6 (33.1–65.5)	0.374

Side of lesion				
Dominant hemisphere	14 (48.3%)	4 (28.6%)	10 (62.5%)	0.453
Non-dominant hemisphere	12 (41.4%)	9 (64.3%)	5 (31.2%)	
Bilateral	1 (3.4%)	0 (0.0%)	1 (6.2%)	
Infratentorial	2 (6.9%)	1 (7.1%)	0 (0.0%)	
Functional outcome				
mRS at discharge	5.15 ± 0.54	5.14 ± 0.53	4.44 ± 1.36	0.192
mRS at last follow-up	4.79 ± 1.68	5.21 ± 1.25	3.19 ± 1.97	0.007
mRS ≤ 2	4 (13.8%)	1 (7.1%)	7 (43.8%)	0.021
mRS ≥ 5	18 (62.1%)	10 (71.4%)	4 (25.0%)	0.019
Mortality	17 (58.6%)	9 (64.3%)	4 (25.0%)	0.05

In-hospital mortality was comparable across all three groups (AIS 20.7%, n = 6; ICH 21.4%, n = 3; CVST 25.0%, n = 4; p = 0.944), indicating that DC confers a similar short-term survival benefit irrespective of aetiology. However, the divergence in long-term mortality was driven entirely by post-discharge deaths. Eleven of 17 AIS deaths (64.7%) and 6 of 9 ICH deaths (66.7%) occurred after hospital discharge, whereas none of the CVST patients died after discharge from the hospital.

Univariate analysis of clinical variables as predictors of mortality revealed older age as a significant predictor of mortality, with only 12 of 29 survivors being older than 45 years compared to 24 of 30 who succumbed (p = 0.0004). Impaired consciousness at admission (GCS ≤9) was associated with significantly higher mortality (p = 0.034). Higher NIHSS score at admission (>15) significantly predicted death (p = 0.019). Dominant hemisphere involvement was associated with higher mortality compared to non-dominant lesions (p = 0.035). Postoperative sepsis was the strongest potentially modifiable predictor of mortality, with 22 of 24 patients who developed sepsis dying during follow-up (p = 0.0005). Symptom duration, presence of symptomatic seizures prior to surgery, and comorbidities did not reach statistical significance. (Table 2)

Table 2: Univariate analysis of clinical predictors of mortality in the combined cohort.

		Alive (n=29)	Expired (n=30)	p-value
Age	≤ 45 years	17	6	0.0004
	> 45 years	12	24	
Glasgow coma score	≤ 9	5	12	0.034
	> 9	24	18	
Seizures	Absent	23	25	0.159
	Present	6	5	
Symptom Duration	≤ 48 hours	3	18	0.450
	> 48 hours	26	12	
Side of Lesion	Dominant	6	23	0.035
	Non-dominant	23	7	
NIHSS Score	≤ 15	10	11	0.019
	> 15	19	19	
Sepsis	No	27	8	0.0005
	Yes	2	22	

DISCUSSION

This study was motivated by a specific clinical need of the lack of direct cross-aetiology outcome data to inform pre-surgical counselling in patients undergoing DC for malignant stroke. Existing evidence, robust as it is within each diagnostic category informs the clinician that DC reduces mortality compared to medical management in AIS[1,2,3,9] and supports survival in CVST,[10] but does not tell the clinician how outcomes compare between a patient with a malignant arterial infarction, one with a large intracerebral haemorrhage, and one with a massive venous infarction from CVST. The aetiology of the stroke carries meaningful prognostic weight after DC: CVST is associated with substantially better functional recovery and lower mortality compared to both AIS and ICH, while AIS and ICH have broadly comparable and uniformly poor outcomes. These findings provide the clinician with aetiology-specific data that can be directly applied when counselling patients and families before surgery.

The striking difference in age of CVST patients (mean age of 36.25 years) in comparison to AIS and ICH is consistent with established epidemiological patterns.[6] CVST predominantly affects women of reproductive age and young adults due to prothrombotic states including postpartum status, oral contraceptive use, and nutritional deficiencies particularly prevalent in the south Asian context.[11] The younger age of CVST patients confers greater neuroplasticity and physiological reserve, which partly contributes to superior outcomes, though it does not fully explain the difference.[12]

In our cohort, GCS at admission was comparable across all three groups, indicating that the superior outcomes observed in CVST cannot be attributed to differences in admission neurological severity. This points instead to

the biological substrate of venous infarction as the key driver of better post-operative recovery. Unlike arterial infarction, where neuronal necrosis is established within hours of ischaemia onset,[13] venous infarction arises from venous congestion and raised intracranial pressure, a mechanism that may be substantially reversible once decompression is achieved and anticoagulation is initiated.[14] Venous infarction may therefore involve a greater proportion of salvageable tissue retaining the capacity for recovery if venous outflow is restored, which may explain why CVST patients who survive surgical decompression demonstrate meaningfully better functional outcomes than their arterial counterparts.

Our mortality rate of 60.5% in the combined arterial group (AIS and ICH) reflects the heterogeneity of our cohort. For the AIS subgroup specifically, the pooled RCT mortality of approximately 22% is lower than our observed rate, reflecting the stricter inclusion criteria of those trials (patients aged 18–60 years with unilateral MCA infarctions presenting within 48 hours).[1,15] For the ICH subgroup, the SWITCH trial, the most recent benchmark study, demonstrated that DC reduced death or profound disability from 58% to 44% (aRR 0.77) in severe deep intracerebral haemorrhage[5]; our ICH mortality of 64.3% is higher, likely reflecting more severe cases selected for surgery in a real-world setting and the inclusion of both deep and lobar haemorrhage. The 25% mortality in our CVST group is consistent with the 13–40% range reported in published series.[16]

The favourable outcome rate of 43.8% (mRS ≤ 2) in our CVST group is consistent with the DECOMPRESS 2 registry, which reported that more than one-third of CVST patients who underwent DC achieved functional independence at one year.[8] This figure is considerably better than the 13.8% and 7.1% favourable outcome rates in our AIS and ICH groups respectively, a difference that is directly translatable into clinical language at the bedside. When counselling the family of a CVST patient before DC, the clinician can convey a realistic chance of meaningful recovery. For AIS and ICH, the conversation must be more guarded, acknowledging that while DC is likely to prevent death, independent functional recovery is achieved in a minority. This distinction, not previously available from a single directly comparative dataset, is precisely the kind of prognostic information that guides the quality of pre-surgical counselling. CVST presenting with malignant oedema should therefore be approached aggressively with DC along with anticoagulation, while for AIS and ICH, the limited likelihood of independence must be explicitly discussed with families in advance.

The temporal disaggregation of mortality in this cohort offers a clinically important insight. The comparable in-hospital mortality across all three aetiologies (approximately 21–25%) suggests that DC itself is similarly effective at preventing early herniation-related death regardless of stroke type. The long-term survival advantage of CVST is therefore not a product of better immediate surgical outcomes, but rather of the biological reversibility of venous infarction, once the acute intracranial pressure crisis is relieved and anticoagulation is initiated, venous oedema resolves and secondary neuronal injury is curtailed. The observation that no CVST patient who survived to discharge subsequently died during follow-up is particularly striking, and has direct implications for post-discharge planning and family counselling in this subgroup.

Beyond aetiology, a number of clinical variables provide additional prognostic information that further refines pre-surgical counselling. Increased age (>45 years) was the most significant predictor of mortality in our cohort, consistent with the DESTINY II trial which demonstrated that while DC reduces mortality even in older patients, the majority of elderly survivors experience severe disability.[2] This finding reinforces the importance of age as a counselling variable: families of older patients should understand that survival after DC does not guarantee functional independence. Poor conscious state (GCS ≤9) and high NIHSS (>15) at admission similarly carry adverse prognostic weight, and dominant hemisphere involvement was significantly associated with mortality, likely reflecting the greater eloquence of dominant hemisphere tissue and the compounding impact on functional recovery. Postoperative sepsis was the strongest modifiable predictor of mortality ($p = 0.0005$), with 22 of 24 patients who developed sepsis dying — underscoring that meticulous postoperative ICU care, including early mobilisation, aspiration prophylaxis, and aggressive infection management, is as critical a determinant of outcome as the surgical decision itself.

Stroke symptom duration prior to DC did not significantly predict mortality in our cohort, consistent with the observation that timing may be less critical in CVST due to its subacute onset.[17] This finding is also aligned with emerging data from arterial stroke series, where several observational studies have reported no significant association between time to surgery and outcome after DC, suggesting that the 48-hour window established by the landmark trials may reflect patient selection criteria rather than a true biological threshold.[18] The hamlet trial, however, did demonstrate a significant benefit of surgery within 48 hours over later surgery,[3] and current guidelines continue to recommend DC within this window where feasible.

LIMITATIONS

The limitations of this study include its single-centre observational design, the relatively small sample size which limits statistical power, and the heterogeneity of the arterial group. Multivariate logistic regression analysis to identify independent predictors of mortality was limited by sample size. Despite these limitations, this study provides valuable real-world data from a south Asian tertiary care setting, where CVST constitutes a greater proportion of stroke-related DC cases compared to Western cohorts.

CONCLUSION

This study provides a direct comparison of aetiology-stratified dataset to aid pre-surgical prognostic counselling

for patients undergoing DC in malignant stroke. CVST carries a substantially better prognosis after DC than AIS or ICH supporting an aggressive surgical approach. In addition, older age, impaired consciousness, high NIHSS, dominant hemisphere involvement, and postoperative sepsis are clinically actionable predictors of mortality that should inform pre-surgical risk stratification.

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