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Role of Cisternal Drainage in Patients with Traumatic Brain Injury Undergoing Decompressive Craniectomy

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The effect of decompressive craniectomy (DC) on survival and functional outcome in traumatic brain injuries (TBI) is far from satisfactory. Additional modalities including cisternal drainage (CD) that provides good control of refractory intracranial pressure (ICP) intra-operatively need careful scrutiny.

Two centre retrospective superiority study with one centre offering only standard decompressive craniectomy (DC) i.e. Group 1 and the other centre supplementing cisternal drainage (CD) to standard DC i.e. Group 2 was conducted. Consecutive patients with traumatic brain injury with signs of brain herniation or CT scan showing mass lesion or diffuse brain edema or midline shift or with GCS less than 9 or rapid fall in GCS over 2 points with persistently raised ICP of 25 mmHg over 15 minutes between August 2012 and July 2017 were included. The primary outcome was rating on Glasgow Outcome Scale (GOS) at 6 months post operatively, with GOS (1-3) categorized as 'Unfavorable' and GOS (4,5) as 'Favorable'.

Patients either received DC alone (Group 1=73 patients, 48.7%) or DC with CD (Group 2=77 patients, 51.3%). 107 (71.3%) severe, 36 (24%) moderate, and 7 (4.7%) mild head injuries cases received 72 unilateral and 78 bilateral DC. GOS 1 was observed in 32 DC only group (43.8%) and 22 DC plus CD group (28.6%) (p=0.052), an absolute risk reduction of 15.2% was found. Outcome (favorablevsunfavorable) against all strata of head injury severity, predominant radiological feature, laterality of surgery, and patient characteristics across the two groups were statistically not significant, however the groups were statistically significantly different on age and GCS at presentation (p=0.016 & 0.034 consecutively).

Distinct survival benefit in patients with traumatic brain injury receiving cisternal drainage during decompressive craniectomy did not translate to better functional outcome.

Keywords: Traumatic Brain Injury, cisternal drainage, decompressive craniectomy, outcome, Nepal

Traumatic Brain Injury (TBI) has become a growing pandemic causing a major disease burden due to the productive 15-45year age group being particularly involved.[1]Currently management of TBI involves decreasing the intracranial pressure (ICP) and maintaining adequate cerebral perfusion pressure (CPP). Refractory intracranial hypertension (ICH) raises the mortality to 85-100% in TBI.[2]

Decompressive craniectomy (DC) is a surgical method of allowing the swollen brain to expand thereby decreasing the intracranial pressure (ICP). However other components of the skull that is blood and cerebrospinal fluid (CSF) still occupy volume and hence manoeuvres to decrease these components should theoretically improve the outcome of patients with raised ICP. Recently there is resurgence in interest in CSF drainage procedures including lumbar drainage and cisternal drainage (CD), however clinical studies are limited to few series or case reports.[3,4,5]

Though cisternal drainage also called ‘cisternostomy’ in some publications is being advocated as stand-alone procedure and as a substitute to morbid decompressive craniectomy (DC),[4,5] the advantage it seems is limited and unlike being advocated as panacea for all condition leading to brain swelling is limited in its application.

We conducted this study to evaluate the clinical advantage of adding cisternal drainage to decompressive craniectomy procedure in patients with traumatic brain injury (TBI) with raised intracranial pressure (ICP).

Methods

The study was conducted as a 2 centre retrospective superiority study (a comparative observational study) with one centre i.e. Kathmandu Medical College Teaching Hospital (KMCTH) offering only standard decompressive craniectomy (DC) and the other center i.e. Grande International Hospital (GIH) supplementing cisternal drainage (CD) to standard DC. All consecutive patients who were eligible for study were included in the trial between August 2012 and July 2017.

Inclusion criteria: Traumatic brain injury with signs of brain herniation or CT scan showing mass lesion or diffuse brain edema or midline shift or with GCS less than 9 or rapid fall in GCS over 2 points or with persistently raised ICP of 25mmHg over 15 minutes within 1-hour period.

Exclusion criteria: GCS less than 4 at presentation, pupils bilateral dilated and fixed,polytrauma with hypovolemic shock or imaging showing hypoxic brain damage.

After initial resuscitation, all patients were initially administered sequential medical management as laid out by Brain trauma foundation (BTF) guidelines except for barbiturate coma and hypothermia.[2]

Since the departmental protocol of the sites of study have similar criteria for intervention as adopted in this study, patient was taken for surgical intervention if he met the criteria. Depending upon which centre patient has presented, the corresponding surgery was performed. Decompressivecraniectomy (DC) performed at both the centre was standardized and the same was performed by all the co-authors. Patients who had bilateral lesions or diffuse brain swelling underwent bilateral DC.

Decompressive craniectomy (DC)

A large, unilateral, curvilinear incision in the frontotemporoparietal region for unilateral DC and bicoronal incision for bilateral DC was made. This was followed by preparation of a myocutaneous flap and craniectomy with elevation of a free frontotemporoparietal bone flap (12 cm x15 cm). The dura was then opened beginning at the temporal base of the opening in the dura, the hematoma was gently removed, and necrotic, contused brain tissue was gently suctioned out. The dura was then expanded by dovetailing with the temporal fascia, and a watertight closure was performed. The sagittal sinus and falxcerebri were not divided. Bone flap was preserved in alcohol solution and later sterilised in ethylene oxide (EtO) sterilisation. Bone flap replacement was performed after 3 weeks to let the brain oedema subside.

However, cisternal drainage (CD) being a new procedure that was modified to avoid harm, provide maximal efficacy and to maintain uniformity of procedure, CD was performed by the senior author, AT as described below. CD was not performed in patients who already had CSF diversion procedure like intra-ventricular drain or lumbar drain in situ at the time of surgery.

Cisternal Drainage (CD)

Patient was positioned in supine with head extended to keep the malar prominences at the highest position (to let frontal lobe fall away from orbital roof and rotated to 20^0 opposite to site of surgery. During fronto-temporal craniectomy, anterior part of craniotomy was extended above the key burr hole to include anterior part of frontal skull. Extradural sphenoid wing was drilled (extradural anterior clinoid drilling was done in pre-fixed chiasma, however posterior clinoid was never drilled). Using a malleable brain retractor, a gentle but continuous retraction was applied over frontal lobe under microscopic vision, to expose the basal cistern over optic nerve. Initially supra-chiasmatic and then optico-carotid cistern was opened by sharp dissection of the arachnoid. This released the cerebrospinal fluid (CSF) from the cistern. Allowing time for gentle suction of the CSF made the brain lax. Carotid-occulomotor cistern was opened only if optico-carotid cistern was too narrow due to post-fixed chiasma. Through the optico-carotid cistern or carotid-occulomotor cistern (if needed to open), arachnoid bands were cut and Liliequist membrane was dissected to expose the basilar artery **(see figure 1)** carefully avoiding perforators and posterior communicating artery. Occasionally medial half of sylvian fissure required to be opened to spilt the frontal lobe off the temporal lobe to avoid tractional injury over the frontal lobe if brain was found to be tight. Temporal lobe was never retracted.

Then under direct vision, external ventricular drainage catheter (EVD) tip was inserted into pre-pontine cistern over the dorsum sella till the last hole (5 cm) was seen into the optico-carotid cistern. We did not drill posterior clinoid in any of our case. The EVD tip was taken out of dura and tunneled under scalp (at least 3 cm) and fixed to ventriculostomy bag. The EVD bag was hung 15 cm above tragus to allow drainage of CSF above normal ICP and allowed to drain CSF over next 5 days.

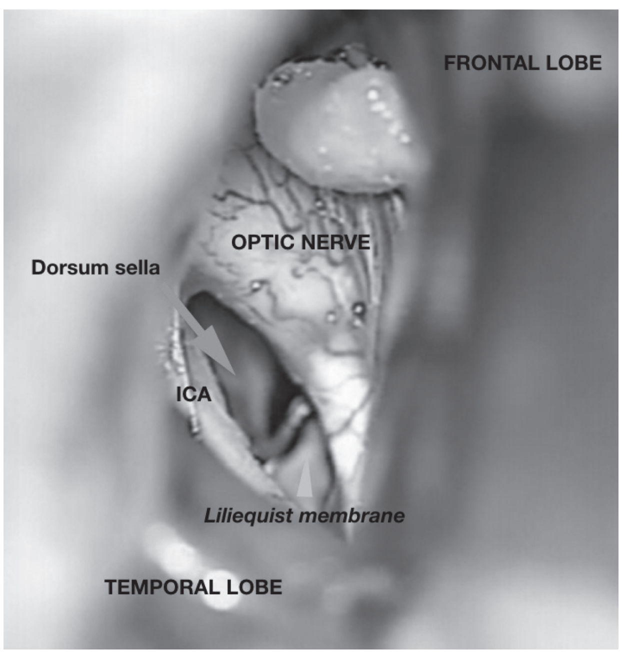

Figure 1: Cisternal Drainage procedure

Note: External ventricular drainage (EVD) catheter tip is inserted into pre-pontine cistern over dorsum sella

Null Hypothesis

The null hypothesis in our superiority study design was “there is no difference in survival and outcome of patients with traumatic brain injury when CSF is drained from cistern as a supplement al procedure to decompressi vecraniectomy(DC)”.

Sample size calculation

To decrease the probability of committing type 1 error we predefined a statistical significance level of $\alpha = 0.05$ and the power at 0.80. Literature quotes chances of favourable outcome in patients undergoing decompressive craniectomy (DC) around 40%.[2] With an expected increase in favorable outcome of 23% by supplementing DC with cisternal drainage (CD),[4] for the dichotomous variable (outcome) comparison in 2 independent treatment arm, each group was calculated to have at least 73 patients.

The two groups were compared for mortality, complications, Glasgow Outcome Scale (GOS) at 6 months, ease of procedure and overall cost effectiveness. GOS ≤ 3 was considered as unfavourable outcome and GOS ≥ 4 as favorable outcomes. Statistical analysis was performed on SPSS Statistics version 17.0.0 (SPSS Inc., Chicago, IL, USA). Unpaired t-test, $\chi 2$ test, Fisher’s exact test, and Mann–Whitney U tests were used to perform univariate comparisons. P<0.05% was used to identify statistical significance.

This study was conducted as a standard departmental protocol in both the hospitals. Attendants of all the patients were counseled regarding the procedure and consent taken. This study served as audit of the work in respective department. Permission of the institutional review committee was taken to publish this study.

Results

A total of 150 patients were included in the study. Mean age of patients was 34.97 years (range 2 to 80 years). 117 patients (78%) were male. 107 patients (71.3%) had severe head injury (GCS $\leq$ 8), 36 (24%) had moderate head injury (GCS 9-12) and 7 (4.7%) had mild head injury (GCS 13-15) at presentation. On CT scan evaluation, 45 patients (30%) had intracranial hemorrhage (ICH), 47 (31.3%) had subdural hematoma, 25 (16.7%) had burst lobe and 33 (22%) had diffuse brain edema. 72 patients (48%) underwent unilateral DC as compared to 80 (52%) who underwent bilateral DC.

73 patients underwent decompressive craniectomy (DC) only (group 1) and 77 supplemental CD to DC (group 2). Characteristic of each group has been discussed in table 1. Though the difference in age (38.5 years in group 1 vs 31.7 years in group 2) and GCS at presentation were seemingly not major but statistical analysis showed significant difference between 2 groups, p=0.016 and p=0.034 consecutively. However, between the two groups, gender, type of lesions on CT scan head and laterality of craniectomy were statistically similar.

	Group1 (DC only) n=73	**Group 2(DC with CD) n=77**	**p**
Age (mean +/- standard deviation)	38.45 +/- 16.92	31.67+/- 17.06	0.016
Gender (male: female)	56:17	61:16	0.711
GCS at presentation Minor head injury (GCS13-15) Moderate head injury (GCS 9-12) Severe head injury (GCS <9)	 2 24 47	 5 12 60	0.034
Lesion on CT scan Intracranial hemorrhage Subdural hemorrhage Burst lobe Diffuse brain edema	 25 25 10 13	 20 22 15 20	0.372
Laterality of craniectomy Unilateral Bilateral	 41 32	 31 46	0.072
Death	32	22	0.052
Glasgow outcome score at 6 months GOS 1 GOS 2 GOS 3 GOS 4 GOS 5	 32 1 2 9 29	 22 5 3 14 33	0.202
Mean Glasgow outcome score at 6 months	3.03+/- 1.878	3.4+/- 1.726	0.204
Glasgow outcome score at 6 months Good (GOS 4&5) Poor (GOS 2 &3)	 38 35	 47 30	0.323

Table 1: Characteristics of study population (n=150)

The procedure of cisternal drainage added an additional average of 10 minutes to surgical time. We did not encounter any failure to open the cistern and in all cases, cisternal drain drained for at least 5 days except for 5 patients who had accidental pull out of the catheter.

Following the CD and DC, in group 2 only 22 out of 77 (28.6%) died as compared to 32 out of 73 (43.8%) patients in group 2, an absolute risk reduction of 15.2% was seen on adding CD to DC (p=0.052). However, on following these patient for over 6 months, there was no significant difference in GOS scores (p=0.202). Mean GOS for group 1 (DC only) was 3.03 as compared to group 2 (CD with CD) 3.40 (p=0.204). On dichotomous GOS outcome evaluation, group 2 had 61.03% favourable prognosis as compared to group 1 which had 52.05% favourable prognosis (p=0.323).

Since GCS at presentation is a major predictor of outcome, to mitigate the statistically significant difference in GCS between group 1 and group 2, GCS matched χ2 test was performed to see the dichotomous GOS outcome in both the groups, however in none of the category there was a significant difference in outcome (see table 2).

GCS at presentation		**Group1 (DC only) n=73**	**Group 2(DC with CD) n=77**	p
Minor head injury (GCS13-15)	Good (GOS 4&5)	1	4	0.427
	Poor (GOS 2 &3)	1	1	
Moderate head injury (GCS 9-12)	Good (GOS 4&5)	16	11	0.102
	Poor (GOS 2 &3)	8	1	
Severe head injury (GCS <9)	Good (GOS 4&5)	21	32	0.377
	Poor (GOS 2 &3)	26	28	

Table 2: GCS matched dichotomous GOS outcome at 6 months in 2 groups

No patient in group 2 during the EVD drainage of CSF developed midline subdural hygroma, as compared to 5 patients (6.4%) in group 1 who due to shift of brain outside the decompressive site developed midline subdural hygroma. There was no significant difference in brain swelling outside DC site or post operative hydrocephalus between both groups. 2 patients in group 2 developed meningitis which was managed on intrathecal antibiotics and did not influence the outcome except for prolonged ICU stay. They both had pneumocephalus and CSF rhinorrhea pre-operatively. None of the patients in group 2 had retraction brain injury during CD. However, as microscope was used during CD, the procedure took little longer and an external ventricular catheter was used for cisternal drainage.

Discussion

Brain Trauma Foundation (BTF) guidelines lays a sequential approach to intracranial hypertension (ICH) in traumatic brain injury which includes general measures as haemodynamicstabilization, sedation and relaxation, normothermia and normovolemia, and first tier measures as ventricular drainage, mannitol, and hypertonic saline. If these measures fail to control intracranial pressure (ICP), second line therapies are required, including barbiturate coma, moderate hypothermia, moderate hyperventilation according to jugular bulb saturation values, and decompressive craniectomy.[2] However, in spite of all these efforts, some patients remain refractory to medical management, for such cases many ancillary methods have been suggested.[3,5]

Drainage of CSF via ventriculostomy has been advised as first level measure in the Traumatic Coma Data Bank (TCDB) guidelines.[1]This is a routine practice in our scenario as ventricular catheter (EVD) is being used to monitor ICP, the same can be used to drain CSF. Studies have confirmed that external lumbar drainage (ELD) as an effective procedure to treat refractory ICH in patients with TBI when basal cisterns are discernible in CT scan.[3]

Cisternal Drainage (CD) is a procedure to open the basal cisterns and communicating pre-pontine cistern (posterior skull base) to supra chiasmatic cistern (anterior skull base). As most of the CSF resides in cisterns, this allows drainage of substantial CSF thereby decreasing the skull volume.[3] Opening the optico-carotid cistern to drain the CSF is a frequently undertaken procedure during aneurysm surgery for acute sub-arachnoid haemorrhage.[6,7]Extending this procedure to let the CSF flow out continuously is a clever method of controlling ICP in patients with TBI where brain swells during the first one week after trauma. It is presumed that draining the CSF from the cistern allows fluid shift from brain into Virchow Robin (VR) Spaces (glymphatic pathway) relaxing the brain oedema.[4,5,8,9,10] Draining the CSF for 5 days allows clearance of metabolites like lactate, tau and free radicals present within the injured brain, minimizing the secondary damage.[11,12,13]

This is superiority study which directly compares the advantage of adding Cisternal Drainage (CD) to DecompressiveCraniectomy (DC) and we found 15.2% absolute risk reduction of death. Compared to retrospective study published as an audit in 2013, our risk reduction is much higher (reportedly 8.4%). However, the authors quoted previously, reported a mortality of 15.6% after cisternal drainage alone is the best reported till date and has not been replicated in any study.[4,14] The paucity of literature limited to case reports on this issue pose ethical difficulty in conducting a large scale true randomized clinical trial.[15]

In our own personal experience, we did not find benefit of CD with DC in patients with GCS poorer than 4 with pupils dilated and fixed or for other conditions like malignant brain swelling due to stroke, however it needs further studies to qualify. Theoretically this could be because of ischemic changes in brain.[4] Due to this inclusion criteria, it is possible we did not have any failure to open the cistern in our study.

Theoretically CD provides advantage over external lumbar drainage (ELD) as the procedure does not require expanded cisternal space on CT scan studies. Personally we did find immediate reduction of brain swelling after draining the CSF from the basal cisterns. In addition, it also avoids occurrence of midline subdural hygroma seen with patients undergoing DC.

However, CD is fraught with danger of retraction injuries which in our series due to modified technique and careful case selection have been negligible. 2 patients developed meningitis which could be due to pre-operative CSF leak. Even ELD have insignificant complications compared to conventional second level measures as barbiturate coma,[16] moderate hypothermia,[17] or decompressive craniectomy.[18]

Modification of technique of cisternal drainage

We performed a modified cisternal drainage (CD) by opening the sylvian cistern, minimal brain retraction limited to frontal lobe, staged CSF drainage from basal cistern to allow the brain to become lax, sharp dissection of basal cistern and placement of drainage catheter in pre-pontine cistern through preferred optico-carotid cistern. By following this method, we did not find retraction injury in any of our patient. However, we advise caution in this procedure and should not be attempted in tense tight brain without any cisternal CSF. This is supposed to be a sequential yet gentle procedure under microscope using principle of microvascular surgery and needs time and patience to master.[5] An alternative method has been suggested by Cherian et al, which involves extradural access to optico-carotid cistern.[8,14] Extradural approach has been suggested to provide safe approach in tight tense brain but does not allow drainage of subdural blood which itself could have compressed the brain. This approach is the modification of the technique published in 2013.[19]

Limitation of the study

This study being a retrospective superiority study does not exclude selection bias as the patients included in each arm did not have equal probability to receive either surgical management. Pupillary reactivity may have bearing on prognostic outcome which in this study has not been studied. Besides due to statistical difference in age group and Glasgow Coma Score (GCS) at presentation between two groups, the subsequent difference in outcome in terms of mortality and morbidity may have been affected. Hence it is advisable to undertake a randomised clinical trial with GCS and age matched groups to find the advantage of supplementing cisternal drainage to decompressivecraniectomy in patients with traumatic brain injury.

With this study we see a potential benefit of supplementing decompressivecraniectomy with cisternal drainage in traumatic brain injuries with refractory raised ICP however the risk of retraction injury and over jealous manoeuvres to drain CSF should be avoided. A large scale multi-centric randomised study with a standardised method should be conducted to see for real benefits of the procedure and its replicability across different geographical regions.

Conclusion

Within the limits of our study, our findings suggest survival benefit of supplementing cisternal drainage to decompressivecraniectomy procedure for patients with traumatic brain injury, however the supplemental procedure does not improve the overall functional outcome of patients. This procedure needs validation in large clinical trial and as such should be used as a supplemental procedure to decompressivecraniectomy to relieve raised intracranial pressure in traumatic brain injured patients.

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Conflict of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional review committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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