

Evaluation of Decompressive Craniectomy

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Abstract

Background and Purpose: Decompressive craniectomy is a surgery used to remove a large bone flap and opening the dura to allow edematous brain tissue to bulge extracranially. However, the efficacy of decompressive surgery to reduce the mortality and improve the outcome in patients with refractory intracranial pressure is still unclear. We investigated whether decompressive craniectomy is associated with improved conscious state and survival in patients with severely raised intracranial pressure and resistant to conservative management. **Methods:** We studied 20 patients with clinical and radiological evidence of increased intracranial pressure & indicated for decompressive craniectomy. All patients were followed postoperatively in ICU with serial follow up (CT). Consciousness level was evaluated using the Glasgow Coma Scale and Glasgow outcome score. **Results:** The overall mortality was 11 cases (55%), two cases remain in a vegetative state (10%), one case (5%) was severely disabled and six cases (30%) discharged with mild disability. **Conclusion:** In 20 cases with severely raised intracranial pressure resistant to conservative management Decompressive Craniectomy allowed (30 %) of cases to be discharged from hospitals with mild degree of disability for rehabilitation.

Keywords

Decompressive Craniectomy, Refractory Intracranial Hypertension, Malignant Middle Cerebral Artery Infarction, Severe Traumatic Brain Injury, Spontaneous Intracerebral Haemorrhage

1. Introduction

Decompressive craniectomy (DC) is a surgical procedure which involves removing a bone flap and opening the dura to allow the edematous brain to swell outwards, thus preventing intracranial tissue shifts and life-threatening downward herniation [1].

Decompressive craniectomy is a surgical procedure used to treat elevated intracranial pressure (ICP) that is unresponsive to conventional medical management. The underlying cause of intracranial hypertension may vary and consequently there is variable numbers of different pathologies on which this procedure usually used. Traumatic brain injury (TBI) and severe cerebral infarction are conditions for which DC has been predominantly used [2].

Intracranial hypertension is a major cause of secondary brain injury and often follows trauma or stroke. Because ICP varies with changes in the volume of the intracranial contents, the traditional approach for treating intracranial hypertension has been to reduce the volume of one or more of the compartments, which include brain parenchyma, cerebrospinal fluid (CSF), and blood volume, either surgically or non-surgically [3].

An alternate procedure is to increase cranial volume by removing the skull and opening the dura. The underlying brain tissue can then swells and expand under the relatively distensible skin. The use of decompressive craniectomy to control the intracranial pressure has been used for a number of disease processes, including stroke, tumors, trauma and intracerebral hemorrhage. The target of decompressive craniectomy is to prevent secondary brain injury caused by medically refractory intracranial hypertension [4].

DC has been described in many studies as a life-saving intervention, which consistently decreases mortality and can often improve outcomes, especially when performed early in the course of the disease [5].

Few weeks to months later Cranial reconstruction can be done using the autologous bone (the removed bone flap is stored in the patient's abdominal wall or a freezer) or an implant (titanium or other synthetic material) [6].

Although decompressive craniectomy has no effect on primary brain insult, it can reduce the fatal effect of secondary lesions, such as the severe elevation of ICP that creating a significant risk for ischemia and also cerebral herniation [7].

The study aims to evaluate surgical decompressive craniectomy (when indicated) and review the efficacy of the decompressive craniectomy procedure on the post-operative clinical state of these patients.

2. Patients and Methods

2.1. Type of Study

This study is prospective retrospective clinical trial study for evaluating the clinical and functional outcomes of surgical decompressive craniectomy.

2.2. Study Population

The study includes 20 patients operated for decompressive craniectomy from 1st of January 2017 to 31st of December 2017 in Egypt in neurosurgery department in AL Azhar university hospitals in Cairo & Damanhur medical national institute (DMNI) in Damanhur.

2.3. Indications of Decompressive Craniectomy

The procedure has been performed in patients with medically refractory intracranial hypertension.

Severe traumatic brain injury is a common indication for DC. Malignant hemispheric infarction and spontaneous intracerebral hemorrhage are less frequent indications for DC.

2.3.1. Inclusion Criteria

Patients with clinical and radiological evidence of raised intracranial pressure indicated for DC will be included in the study.

2.3.2. Exclusion Criteria

- ✧ Patients with bilateral fixed and dilated pupils.
- ✧ Patients with bleeding disorders.
- ✧ Patients with other extracranial injury as (Abdominal collection, fracture ribs etc.)
- ✧ When follow up not possible.

2.4. Case Assessment

2.4.1. History

Personal history was taken from the patients' relatives including age, sex, occupation, complaint, risk factors, mode of trauma, time interval since trauma and co-morbidities in traumatized patients.

2.4.2. Examination

1) General examination

That included vital signs (pulse, blood pressure, temperature and respiratory rate) on the time of admission, abdominal palpation for any rigidity also chest and cardiac auscultation to exclude other extracranial pathology.

2) Detailed neurological examination

Conscious level was assessed using Glasgow coma scale GCS.

The scale comprises three tests: eye, verbal and motor responses. The three values separately as well as their sum are considered. The lowest possible GCS (the sum) is 3 (deep coma or death), while the highest is 15 (fully awake person).

Best eye response (E):

There are 4 grades starting with the most severe:

- 1) No eye opening.
- 2) Eye opening in response to pain (Patient responds to pressure on the patient's fingernail bed, if this does not elicit a response, supraorbital and sternal pressure or rub may be used).
- 3) Eye opening to speech.
- 4) Eyes opening spontaneously.

Best verbal response (V):

There are 5 grades starting with the most severe:

- 1) No verbal response
 - 2) Incomprehensible sounds (Moaning but no words)
 - 3) Inappropriate words (Random or exclamatory articulated speech, but no conversational exchange)
 - 4) Confused (The patient responds to questions coherently but there is some disorientation and confusion)
 - 5) Oriented
- Best motor response (M):
- There are 6 grades starting with the most severe:
- 1) No motor response
 - 2) Extension to pain (abduction of arm, internal rotation of shoulder, pronation of forearm, extension of wrist, decerebrate response)
 - 3) Abnormal flexion to pain (adduction of arm, internal rotation of shoulder, pronation of forearm, flexion of wrist, decorticate response)
 - 4) Flexion/Withdrawal to pain (flexion of elbow, supination of forearm, flexion of wrist when supra-orbital pressure applied; pulls part of body away when nail bed pinched).
 - 5) Localizes to pain (Purposeful movements towards painful stimuli; e.g., hand crosses mid-line and gets above clavicle when supra-orbital pressure applied)
 - 6) Obeys commands (The patient does simple things as asked)

In addition to determining the GCS score, the neurologic assessment of patients included the following: Brainstem examination, pupillary examination, ocular movement examination, corneal reflex, gag reflex, motor Sensory, and reflex examination

2.5. Investigations

2.5.1. Laboratory Investigations

- Complete blood count

To determine the need for blood transfusion in the operative theater and for diagnosis of hemorrhagic anemia in traumatic cases also to determine the platelets count.

- Coagulation profile

That included clotting time, bleeding time, partial thromboplastic time and international normalized ratio (INR)

2.5.2. Radiological Investigations

- CT brain at time of presentation and post-operative within 48 hours.

CT scans aids in examination of the bone windows for fractures, examination of the tissue windows for the presence of extra-axial hematoma, intraparenchymal hematomas, or contusions. CT scans also survey the brain for any evidence of pneumocephalus, hydrocephalus, cerebral edema, midline shift, or compression of the subarachnoid cisterns at the base of the brain

- Serial follow up CT brain till the patient discharged or died.

2.6. Management Strategies

Management strategy will be medical and surgical intervention with postoperative continuing on brain relaxing Intensive Care treatment.

Study will evaluate preoperative status, surgical technique and outcome of surgical decompressive craniectomy.

2.7. Follow up Evaluation

1) Postoperatively patients were admitted to the intensive care unit (ICU) and follow up CT scan performed within 48 hours after operation. All survivors were followed up after operation with CT scan and neurological examination including Glasgow coma scale (GCS) till the patients are discharged from the hospital.

2) At discharge the outcome was graded using the Glasgow Outcome Score (GOS) which defines as,

- a) Grade I as death.
- b) Grade II as persistent vegetative state.
- c) Grade III as severe disability (being conscious but disabled).
- d) Grade IV as moderate disability (being disabled but independent) .
- e) Grade V as good recovery

3) Unfavorable outcome was defined as GOS 1 - 3 and favorable outcome as GOS 4 and 5.

3. Surgical Technique

All patients operated for decompressive craniectomy, hematoma removal (in traumatic cases), augmentation of the dura and duraplasty using pericranium galia or fascia lata. Decompressive craniotomy is performed by removing a large portion of the fronto-tempo-parietal cranium (>12 cm) for lesions confined to one cerebral hemisphere [8].

Technique of Duroplasty

The dura is opened in a C-shaped fashion from the temporal tip to the frontal pole. To maximize the opening, the dural incision should run within 1 cm of the bony edge. Thus the dural flap is based on the pterion and can be reflected anteriorly to expose the hemisphere. The source of bleeding is identified and controlled and bridging veins is assessed to ensure that there is no longer bleeding. Once hemostasis is ensured, The dura could be laid back on the brain. Augmentation of the dura was done using a pericranium flap [4].

The study is prospective retrospective clinical study .The information collected included study patients inclusion and exclusion criteria, sex and age of patients, side of brain pathology, time to surgery, preoperative neurological condition and postoperative assessment of the outcome.

4. Results

The data collected from 20 cases all were operated for decompressive Craniec-

tomy aiming to decrease the severely raised intracranial pressure. The study includes 13 males and 7 females. Their age ranges between 8 and 65 years. There were different causes of increased ICP as TBI (the most common), MCA infarction & spontaneous ICH. There was a trend of increasing mortality associated with age.

The study included 4 cases with MCA infarction all of them were hypertensive & 2 cases had also DM.

The study included 2 cases with spontaneous ICH both were hypertensive.

There were no cases with past history of any brain insult (**Table 1**).

Sex

See **Table 1**.

Age

Mean age in cases with TBI was 37 years, in cases with MCA infarction was 60 years and in cases with spontaneous ICH was 56 years (**Table 2**).

Cause of raised ICP

The study includes three causes of elevated ICP that were indicated for decompressive craniectomy (**Table 3**).

Effect of DC on GOS

The overall mortality was 11 cases with **GOS I**, two cases remain in a vegetative state with **GOS II**, one case was severely disabled with **GOS III**, six cases discharged with mild disability with **GOS IV** & no cases discharged with complete recovery & got **GOS V** (**Table 4**).

Table 1. Sex.

	male	female
	13	7

Table 2. Mean age.

Pathology	TBI	MCA infarction	spontaneous ICH
Mean age	37 Y	60 Y	56 Y

Table 3. Cause of raised ICP.

cause	TBI	MCA infarction	Spont. ICH
number	14	4	2
Percentage	70%	20%	10%
TOTAL	20 CASES		

Table 4. Effect of DC on GOS.

GOS	I	II	III	IV	V
number	11	2	1	6	0
percentage	55%	10%	5%	30%	0%

Relation between age and outcome.

Younger ages associated with better outcome.

The category favorable outcome included good recovery and moderate disability and category unfavorable outcome included death, vegetative state, and severe disability as outlined by the GOS (**Table 5**).

Time consumed to surgery.

To simplify the influence of operative timings, it was subdivided within <2 hours, 2 - 4 hours, 4 - 6 hours and >6 hours after injury. Time was <2 hours in 5% 1 case (5%), from 2 - 4 hours in 5 cases (25%), from 4 - 6 hours in 8 cases 40% and more than 6 hours in 6 cases 30% of case (**Table 6**).

Relation between timing of surgery and outcome.

Early surgery is associated with good outcome (**Table 7**).

Relation between preoperative GCS & GOS.

Better preoperative GCS associated with better outcome.

The best preoperative GCS in the study was 11 & the worst was 4. To show the effect of preoperative GCS on the outcome we divided all cases into two groups. **Group A** with GCS more than or equal 8 & **Group B** with preoperative GCS less than 8 (**Table 8**).

Table 5. Relation between age and outcome.

	Number of cases	Median age
favorable outcome	6	37
Unfavorable outcome	14	46

Table 6. Time distribution of cases.

Time/ Hours	Less than 2	2:4	4:6	More than 6
NO. of cases	3	7	4	6
Percentage	15%	35%	20%	30%

Table 7. Relation between timing of surgery and outcome.

Timing of surgery	Mean GOS
Less than 2 H	4
2:4 H	2.2
4:6 H	2
More than 6 H	1

Table 8. Relation between preoperative GCS & GOS.

Group	NO. of casses	Mean GOS
A	7	3.8
B	13	1.2

Male to female ratio in cases with TBI.

The study includes 14 cases with severe TBI 10 males and 4 females.

Male to Female ratio was 2:1

Mode of trauma in cases with TBI.

Mode of trauma was road traffic accident in 8 cases and fall from height in 6 cases.

Mode of trauma had no effect on GOS.

5. Discussion

Decompressive craniectomy as a surgical treatment for refractory ICP has been performed for many years and for several different pathologies including traumatic brain injury and nontraumatic brain pathologies like malignant cerebral infarction & intracerebral hemorrhage.

The basic pathophysiological mechanism of brain edema associated with brain injury is an increase in the net water content of the brain. This causes an increase in tissue pressure which increases cerebrovascular resistance, compromises the microcirculation, and results in reduced cerebral blood flow. Various neurological conditions which cause an increase in intracranial pressure have been treated successfully with decompressive craniectomy technique. Decompressive craniectomy together with dura expansion is intended to increase the volume of the cranial cavity to create a space for the edematous brain tissue.

In our study 20 cases were operated for unilateral fronto temporo parietal decompressive Craniectomy .The study included 14 cases presented with severe traumatic brain injury (TBI), 4 cases with MCA infarction & 2 cases with spontaneous intra cerebral hemorrhage.

The incidence of TBI is much more common in males than females. In our study male: female ratio was almost (2:1) [10] males and 4 females], similarly other studies reported more incidence of such cases in males with the international data suggesting a roughly 2:1 ratio for males and females with TBI e.g. Larking P. *et al.* [9] found that 61.9% of people with TBI were males.

Another study published by Anderson *et al.* [10] concluded that males had 1.46 higher overall rates than females for TBI in Sweden.

The incidence of TBI is more common in younger age groups (15 - 45 years). In our study we found the median age of cases with severe TBI was 37 years, similarly Gan *et al.* [11] concluded that the incidence of TBI peaks in the younger patients aged 20 - 40 years.

The mechanism of injury in traumatic cases had no significant difference in mortality rate. There was no significant difference in the prognosis between males and females in spite of a 2:1 male predominance in our study, similarly other studies had the same results.

5.1. Regarding the Effect of DC on Glasgow Outcome Score

In a study made by Gaétane Gouello *et al.* [12] on cases with severe TBI and op-

erated with decompressive craniectomy showed an overall mortality rate of 28.3% The percentage of unfavorable outcome (GOS 2 and 3) was 21.7% & favorable outcome (GOS 4 and 5) was 50%, After 2 months follow up.

IN our study, cases with severe TBI with mortality outcome (50%), GOS II (14%), GOS III (7%), GOS IV (29%) and no cases with GOS V.

In a study, decompressive hemicraniectomy for malignant middle cerebral artery territory infarction by Ralph Rahme *et al.* [13] included initial 382 patients, 93 cases (24.3%) died. The outcome was assessed in 156 of the survivors in whom Favorable outcome occurred in 41% of cases.

In our study 4 cases with MCA infarction representing 20% of all cases operated for DC. Mortality outcome occurred in 3 cases of MCA infarction cases & favorable outcome was achieved in one case.

In a study conducted by Satoru takeuchi, *et al.* [14] decompressive craniectomy was done for spontaneous intracerebral hemorrhage the outcomes of 185 cases who were operated for decompressive craniectomy & haematoma evacuation was classified as follows. Outcome was favorable in 75 (41%) of 185 cases. 52 cases (28%) of the 185 patients died during various follow-up periods.

In our study 2 cases presented with spontaneous intracerebral hemorrhage representing 10% of all study cases were operated for decompressive craniectomy & haematoma evacuation to relieve the tension & allow the edematous brain to swell outwards .Only one case had postoperative GOS IV and the other case had GOS II.

5.2. Regarding the Prognostic Factors in Our Study

In our study many factors affected the outcome. Age, time of surgery, and preoperative GCS were strong predictor factors for the outcome.

5.2.1. Age

Increasing age was a strong predictor of poor outcome. In a study conducted by Woertgen C. *et al.* [15] it concluded that the mean age of the group with unfavourable outcome was 56.6 years similarly in our study the mortality increased with age & younger ages were associated with better outcome and the mean age of cases with favorable outcome was 37 while in cases with unfavorable outcome as 46.

5.2.2. Timing of Surgery

Early surgical intervention was associated with better outcome. In the study conducted by Woertgen C. *et al.* [15] it showed that early decompression after development of refractory intracranial hypertension almost always brings about an improved outcome.

In another study, Traumatic Acute Subdural Hematoma Major Mortality Reduction in Comatose Patients Treated within Four Hours conducted by Seelig, *et al.* [16]. There were 82 patients suffering from ASDH after severe TBI all of them were treated by decompressive craniectomy. In the first 4hrs the mortality was

30% and 90% in those who had surgery after 4 hrs from injury similar to our study early surgical intervention was a good prognostic factor as mortality rate in cases operated within less than 4 hours was 30% while in cases operated more than 4 hours was 80% .

5.2.3. Preoperative GCS

Preoperative GCS was a main predictive factor for outcome in cases operated for decompressive craniectomy.

In a study conducted by Kilincer *et al.* [17] it showed that the mortality rate was 75% in cases with preoperative GCS less than 8.

Similarly in our study better preoperative GCS was associated with better outcome and the mortality in cases with preoperative GCS less than 8 was 84%.

In our study mode of trauma in traumatic cases had no effect in the outcome.

Associated hypertension was present in all of the non-traumatic cases and can't be considered as a prognostic factor.

5.3. Regarding the Technique of Decompressive Craniectomy

In the current study all cases were operated by unilateral fronto temporo parietal decompressive craniectomy. A wide bone flap was removed to ensure optimum relief of intracranial tension and allow the edematous brain to expand outwards.

In a study conducted by Holland *et al.*, [4] he recommended that doing a wide craniectomy is necessary and underremoval of bone is a common pitfall and associated with high risk of complications.

In our study the dura was opened in C-shaped fashion from the temporal tip to the frontal pole to ensure maximum decompression. The underlying hematoma (In cases of acute SDH) can be evacuated. The source of bleeding is identified and controlled and bridging veins were assessed to ensure that there are no longer bleeding. Once hemostasis is ensured, the dura laid back on the brain & Augmentation of the dura using a pericranium flap was done.

Some surgeons (not in our study) makes Multiple dural snips for removal of acute subdural hematoma for quick relief of raised intracranial pressure (ICP) and to preserve the anatomical integration of the arachnoid, pia, brain tissue and its vasculature and prevent any further secondary brain damage due to opening of dural flap.

In a study conducted by Chabok *et al.* [18] it reported no significant difference in outcome between the two methods.

5.4. Study Limitations

This study had some limitations such as the lack of any nonoperative treatment group with which to compare the results and the small group of patients.

6. Conclusions

In 20 cases with severely raised intracranial pressure resistant to conservative management, decompressive craniectomy allowed (30%) of cases to be dis-

charged from hospitals with mild degree of disability for rehabilitation.

We concluded that decompressive craniectomy operation is an ideal solution for the management of conditions with persistent increased ICP when the other medical management strategies fail under the proper circumstances of early intervention.

References

- [1] Aarabi, B., Hesdorffer, D.C., Ahn, E.S., Aresco, C., Scalea, T.M. and Eisenberg, H.M. (2006) Outcome Following Decompressive Craniectomy for Malignant Swelling due to Severe Head Injury. *Journal of Neurosurgery*, **104**, 469-479.
<https://doi.org/10.3171/jns.2006.104.4.469>
- [2] Schirmer, C.M., Ackil Jr., A.A. and Malek, A.M. (2008) Cerebrovascular and Endovascular Division, Department of Neurosurgery, Tufts Medical Center, Tufts University School of Medicine.
- [3] Messing, J.A.M., Marzog, J., *et al.* (2003) Decompressive Craniectomy in Severe Brain Injury. *Zentralblatt Fur Neurochirurgie*, **64**, 171-177.
<https://doi.org/10.1055/s-2003-44616>
- [4] Holland, M. and Nakaji, P. (2004) Craniectomy: Surgical Indications and Technique. *Operative Techniques in Neurosurgery*, **7**, 10-15.
- [5] Cho, D.Y., Chen, T.C. and Lee, H.C. (2003) Ultra-Early Decompressive Craniectomy for Malignant Middle Cerebral Artery Infarction. *Surgical Neurology*, **60**, 227-232; Discussion 232-233. [https://doi.org/10.1016/S0090-3019\(03\)00266-0](https://doi.org/10.1016/S0090-3019(03)00266-0)
- [6] Kolas, A.G., Kirkpatrick, P.J. and Hutchinson, P.J. (2013) Decompressive Craniectomy: Past, Present and Future. *Nature Reviews Neurology*.
<https://doi.org/10.1038/nrneurol.2013.106>
- [7] Timofeev, I., Santarius, T., Kolas, A.G. and Hutchinson, P.J.A. (2012) Decompressive Craniectomy—Operative Technique and Perioperative Care. *Advances and Technical Standards in Neurosurgery*, **38**, 115-136.
https://doi.org/10.1007/978-3-7091-0676-1_6
- [8] Ban, S.P., Son, Y.-J., Yang, H.-J., Chung, Y.S., Lee, S.H. and Han, D.H. (2010) Analysis of Complications Following Decompressive Craniectomy for Traumatic Brain Injury. *Journal of Korean Neurosurgical Society*, **48**, 244-250.
- [9] Larking, P. (2004) Traumatic Brain Injury: Analysis of Data. ACC, Wellington.
- [10] Andersson, E.H., Bjoorklund, R., Emanuelson, I. and Stalhammar, D. (2003) Epidemiology of Traumatic Brain Injury: A Population Based Study in Western Sweden. *Acta Neurologica Scandinavica*, **71**, 124-133.
- [11] Gan, B.K., Lim, J.H.G. and Ng, I.H.B. (2004) Outcome of Moderate and Severe TBI amongst the Elderly in Singapore. *Annals Academy of Medicine Singapore*, **33**, 36-37.
- [12] Gouello, G., Hamel, O., Asehnoune, K., Bord, E., Robert, R. and Buffenoir, K. (2014) Study of the Long-Term Results of Decompressive Craniectomy after Severe Traumatic Brain Injury Based on a Series of 60 Consecutive Cases. *The Scientific World Journal*, **2014**, Article ID: 207585.
- [13] Rahme, R., Zuccarello, M., Kleindorfer, D., Adeoye, O.M. and Ringer, A.J. (2012) Decompressive Hemicraniectomy for Malignant Middle Cerebral Artery Territory Infarction: Is Life Worth Living? *Journal of Neurosurgery*, **117**, 749-754.
<https://doi.org/10.3171/2012.6.JNS111140>

- [14] Takeuchi, S., Wada, K., Nagatani, K., Otani, N. and Mori, K. (2013) Decompressive Hemicraniectomy for Spontaneous Intracerebral Haemorrhage. *Neurosurgical Focus*, **34**, E5.
- [15] Woertgen, C., Erban, P., Rothoerl, R.D., Bein, T., Horn, M. and Brawanski, A. (2004) Quality of Life after Decompressive Craniectomy in Patients Suffering from Supratentorial Brain Ischemia. *Acta Neurochirurgica* (Wien), **146**, 691-695.
<https://doi.org/10.1007/s00701-004-0280-x>
- [16] Seelig, J.M., Becker, D.P. and Miller, J.D. (1981) Traumatic Acute Subdural Haematoma. Major Mortality Reduction in Comatose Patients Treated within Four Hours. *The New England Journal of Medicine*, **304**, 1511-1518.
<https://doi.org/10.1056/NEJM198106183042503>
- [17] Kilincer, C., Asil, T., Utku, U., Hamamcioglu, M.K., Turgut, N., Hicdonmez, T., Simsek, O., Ekuklu, G. and Cobanoglu, S. (2005) Factors Affecting the Outcome of Decompressive Craniectomy for Large Hemispheric Infarctions: A Prospective Cohort Study. *Acta Neurochirurgica* (Wien), **147**, 587-594.
<https://doi.org/10.1007/s00701-005-0493-7>
- [18] Chabok, S.Y., Safaie, M., Moghadam, A.D., Behzadnia, H., KhaliliRad, M. and Larimi, S.R. (2011) Acute Subdural Hematoma, Acomparative Study of 2 Types of Operative Techniques. *Neurosurgery Quarterly*, **21**, 103-106.

List of Abbreviations

CSF: Cerebrospinal fluid
 DC: Decompressive craniectomy
 GCS: Glasgow coma scale
 GOS: Glasgow outcome score
 ICH: Intracerebral hemorrhage
 ICU: Intensive care unit
 ICP: Intracranial pressure
 INR: International normalized ratio
 MCA: Middle cerebral artery
 TBI: Traumatic brain injury