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Outcome Determinants of Decompressive Craniectomy in Patients with Traumatic Brain Injury; A Single Center Experience from Southern Iran

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ABSTRACT

Objective: To investigate the determinants of outcome in patients with traumatic brain injury (TBI) undergoing decompressive craniectomy (DC) in a large level I trauma center in southern Iran.
Methods: This retrospective cross-sectional study was conducted during an 18-month period from 2013 to 2014 in Shahid Rajaei hospital, a Level I trauma center in Southern Iran. Patients with TBI who had undergone DC were included and the medical charts were reviewed regarding demographics, clinical, radiological and outcome characteristics. The outcome was determined by extended Glasgow outcome scale (GOS-E) after one year of surgery. The variables were compared between those with favorable and unfavorable outcome to investigate the outcome determinants.
Results: Overall 142 patients with mean age of 34.8±15.5 (ranging from 15 to 85) years were included. There were 127 (89.4%) men and 15 (10.6%) women among the patients. After 1-year, the mortality rate was 58 (40.8%) and 8 (5.6%) patients were persistent vegetative state. The final outcome was found to be unfavorable in 77 (54.2%) patients. Unfavorable outcome was associated with lower GCS on admission ($p<0.001$) as well as occurrence of postoperative hydrocephalus ($p=0.011$). Formation of the postoperative subdural hygroma after the operation was found to be associated with favorable outcome ($p=0.019$).
Conclusion: DC in patients with TBI is associated with favorable outcome in most of them. On admission GCS, postoperative hydrocephalus and presence of postoperative subdural hygroma are among the important predictors of outcome in TBI patients undergoing DC.

Keywords: Decompressive craniectomy (DC); Traumatic brain injury (TBI); Glasgow coma scale (GCS); Glasgow outcome score extended (GOS-E)

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Introduction

Road traffic accidents are considered as a major global public health problem which causes significant mortality and morbidity worldwide. According to WHO, annual mortality rate of 1.2 million people which equates to nearly 3500 lives every day shows the significance of this subject and traumatic brain injury (TBI) accounted for the major cause of mortality and was diagnosed in 72.1% of all autopsies [1]. Iran lies among the countries with high incidence of road traffic accidents with 22,918 traffic accident related deaths recorded in 2007-2008 [2]. The motorcycle accidents are considered the most common cause of road traffic accidents accounting for 49.1% of all accidents [2-4]. Many intracranial pathologies can be formed due to traumatic brain injury which may further result into increased intracranial pressure (ICP), disturbed cerebral blood flow (CBF) and cerebral perfusion pressure (CPP) which all may lead to secondary brain damage [5]. Thus controlling the ICP seems to be necessary in the management of patients with severe TBI [6]. Minimizing the secondary brain damage can be achieved by both medical and/or surgical therapies with the goal of preventing intracranial hypertension which usually is caused by cerebral edema [7]. Decompressive craniectomy (DC) is among the most important surgical procedures in treatment of patients with severe TBI [8-11]. The DECRA (Decompressive Craniectomy in Patients with Severe Traumatic Brain Injury) compared early decompressive craniectomy for diffuse traumatic brain injury with standard medical therapy and found that patients in the surgical arm of the trial had worse outcomes than those treated medically [12]. However, it was further revealed that the ICP threshold was not set appropriately in DECRA study and currently it's revealed that DC is associated with better functional recovery when performed <5 hours of injury in patients with GCS>5 [9, 13]. The recently published results of RESCUEicp trial revealed that DC is associated with lower 6-month mortality rate and higher rate of persistent vegetative state [14]. Several lines of evidence suggest that some factors such as age, on admission GCS and pupil reactivity are among the important predictors of outcome in patients with severe TBI undergoing DC [15, 16]. In the current study we report the outcome of DC in patients with TBI referring to a large level I trauma center in southern Iran and also we report the outcome determinants in this group of patients.

Materials and Methods

Study Population

This cross-sectional study was conducted during an 18-month period from March 2013 to September 2014 at Rajaee hospital, a level I trauma center in Southern Iran affiliated with Shiraz University of Medical Sciences. We included all the adult patients (>16 years) with severe TBI (GCS 5-8) who underwent DC in our center during the study period. DC was performed in our patient population either after evacuation of a mass lesion or after intractable intracranial hypertension. Unilateral decompressive craniectomies were performed after evacuation of a mass lesion. Bifrontal DC was performed for diffuse brain swelling without significant midline shift but with absent cisterns. We excluded those with bilateral fixed and dilated pupils, those with bleeding diathesis, those with devastating injury who did survive less than 24 hours and those whose medical charts lacked complete information and data. The study protocol was approved by the institutional review board and the medical ethics committee of Shiraz University of Medical Sciences. As it was a retrospective review of the medical charts, we did not require to obtain informed written consents.

Study Protocol

All the patients were managed according to the guideline for management of patients with severe traumatic brain injury, third edition [17]. Accordingly, all the patients underwent intracranial pressure (ICP) monitoring via insertion of an external ventricular drainage either before and after DC. The drain was removed if 48-hout of normal ICP was recorded. The results ICP monitoring of the same series has been previously reported [6]. The medical charts of the patients were reviewed for demographic characteristics (age, gender); trauma information (mechanism of injury, time interval between injury and operation), early clinical condition (on admission GCS, Brain CT scan findings and Rotterdam score); surgical information including type and reason for DC (intractable ICP rise during monitoring or SDH evacuation), bleeding amount and duration of operation; and hospital course including length of stay (LOS) in ICU and hospital, any other surgical procedures or need to neurosurgical reoperation. We also recorded the postoperative complications such as meningitis, hydrocephalus and subdural hygroma. All the patients' follow up data were also retrieved and recorded: the functional recovery measured by Extended Glasgow Outcome Sale (GOS-E) was recorded at 2 months, 6 months and 1-year post trauma from. Death and severe disability considered as unfavorable outcome while GOS-E of 5 and higher was regarded as favorable outcome.

Surgical Procedure

All the admitted patients were initially evaluated by a neurosurgery resident and the data were recorded. The decision to perform DC was made by the attending neurosurgeon and all the operations were performed by a same team of neurosurgery attending and residents. Unilateral, bilateral or bifrontal DC was performed based on the presence of the lesion or diffuse brain swelling. A traumatic skin flap was rotated in unilateral DC and the temporalis muscle was shaved from the bone when attached to the flap. Dura was opened in C-shape manner with a base over superior sagittal sinus and it was grafted in water-tight manner with pericranial fascia. An anti-adhesive film was applied between the temporalis muscle and the dura in order to prevent further adhesion according to the previously described method [18]. In bifrontal DC, after a bicoronal skin incision, large craniectomy was carried out from both temporal fossa and the superior sagittal sinus was obliterated. Dura was opened and grafted in C shape manner with a base over frontal. Again an anti-adhesive film was applied on the dura before closure.

Statistical Analysis

All the statistical analyses were carried out utilizing statistical package for social sciences (SPSS Inc., Chicago, Illinois, USA). Data are presented as mean±SD and proportions as appropriate. In order to determine the outcome determinants, we compared the results between favorable and unfavorable groups. Proportions were compared using chi-square test. Parametric data with normal distribution were compared using independent t-test and those without normal distribution were compared using Mann Whitney U-test. Multivariate logistic regression analysis was also performed in order to eliminate the effects of confounders. A 2-sided p-value of less than 0.05 was considered statistically significant.

Results

Overall we included 142 patients who underwent DC during an 18-month period in our center. The mean age of the patients was 34.8±15.5 (ranging from 15 to 85) years. There were 127 (89.4%) men and 15 (10.6%) women among the patients. The mean interval between admission and operation was 1.66±0.6 (ranging from 1 to 10) days and 107 (75.4%) patients underwent DC within the first day of admission. Among the documented intracranial pathologies in brain CT-scan, SDH was the most common one being reported in 94 (66.2%) patients. Unilateral DC was performed in 116 (81.7%) while bifrontal in 22 (15.5%). Table 1 summarizes the baseline characteristics of the patients.

The most common complication of the DC in our series was found to be meningitis being recorded in 55 (38.7%) and followed by subdural hygroma in 22 (15.5%) patients. Overall rate of hydrocephalus was 17 (12.1%) patients in which 13 (9.2%) of them underwent ventriculo-peritoneal shunting. Finally, 49 (34.5%) patients required tracheostomy and 8 (5.6%) patients needed gastrostomy tube insertion during the hospital course. The final outcome was found to be unfavorable in 77 (54.2%) patients (GOS-E<5) with 62 (43.7%) of them being death in the first 2 months of trauma. After 1-year, the mortality rate was 58 (40.8%) and 8 (5.6%) patients

Table 1. Baseline characteristics of 142 patients with severe traumatic brain injury undergoing decompressive craniectomy.

Characteristics	Value (n=142)
Age (years)	34.8±15.5
Gender	
Men (%)	127 (89.4%)
Women (%)	15 (10.6%)
Admission to operation interval (days)	1.66±0.6
Glasgow Coma Scale	
On admission	6.71±2.8
After resuscitation	7.90±4.2
Rotterdam score	
1 (%)	4 (2.8%)
2 (%)	19 (13.4%)
3 (%)	78 (54.9%)
4 (%)	23 (16.2%)
5 (%)	18 (12.7%)
ICP[a] monitoring (%)	57 (40.1%)
Decompressive craniectomy type	
Unilateral (%)	116 (81.7%)
Bifrontal (%)	22 (15.5%)
Bilateral (%)	4 (2.8%)
Diagnosis	
Subdural hematoma (%)	94 (66.2%)
Contusion (%)	48 (33.8%)
Tight brain (%)	27 (19.0%)
Epidural hematoma (%)	22 (15.5%)
Operation characteristics	
Duration (minutes)	171.2±41.1
Bleeding (mL)	1132.7±846.3

[a]ICP: Intracranial pressure

Table 2. Outcome of 142 patients with severe traumatic brain injury undergoing decompressive craniotomy.

Characteristics	Value (n=142)
ICU[a] length of stay (days)	15.9±12.6
Hospital length of stay (days)	21.4±17.9
GOS-E[b]	
2 months	3.48±2.19
6 months	3.63±2.54
12 months	3.72±2.71
Time to cranioplasty (days)	54.7±20.3
Complications	
Meningitis (%)	55 (38.7%)
Subdural hygroma (%)	22 (15.5%)
Hydrocephalus (%)	17 (12.1%)
Reoperation (%)	3 (2.1%)
Other Operations	
ICP[c] monitoring (%)	57 (40.1%)
Tracheostomy (%)	49 (34.5%)
Deep Peritoneal Aspiration (%)	47 (33.1%)
VP-Shunt insertion (%)	13 (9.2%)
Gastrostomy (%)	8 (5.6%)
Final outcome	
Favorable (%)	65 (45.8%)
Unfavorable (%)	77 (54.2%)

[a]ICU: Intensive Care Unit; [b]GOS-E: Extended Glasgow Outcome Scale; [c]ICP: Intracranial Pressure

were persistent vegetative state. There were 3 (2.1%) patients with upper and 23 (16.2%) with lower good recovery. The outcome of patients is demonstrated in Table 2.

Unfavorable outcome was associated with lower GCS on admission ($p<0.001$) as well as occurrence of postoperative hydrocephalus ($p=0.011$). Vice versa, formation of the subdural hygroma after the operation was found to be associated with favorable outcome ($p=0.019$). ICU LOS ($p=0.204$), hospital LOS ($p=0.435$) and time interval to cranioplasty ($p=0.867$) were not associated with patients' outcome (Table 3). GCS on admission ($p<0.001$) and hydrocephalus ($p=0.013$) remained significant determinants of unfavorable outcome after normalizing for confounding factors such as age, gender and Rotterdam score using a binary logistic regression model. In the same way the subdural hygroma remained significant determinant of favorable outcome after eliminating the confounders.

Discussion

DC is still among the most important surgical procedures being performed in patients with TBI although the role and effects has remained controversial [9, 10, 12, 15, 19]. Although some new techniques have been introduced to replace DC, it still remains the most frequently operation in TBI [20, 21]. Recently, RESCUEicp trial revealed that DC in TBI patients with intractable intracranial hypertension is associated with reduced 6-month mortality, increased persistent vegetative state, lower severe disability, and upper severe disability than medical care [14].

Despite several advancements in management of patients with TBI, the mortality and morbidity of severe TBI yet remains high in injured patients; many prognostic models have been introduced to predict the outcome, yet no model has satisfied all the characteristics of an ideal model [22, 23]. Currently, there is a need for a prognostic model to determine the outcome in patients undergoing DC after severe TBI. In the current study we have reported the outcome of patients with TBI undergoing DC in our center and also determined the outcome determinants in our series in southern Iran. We demonstrated that most of the patients undergoing DC would have favorable outcome determined by GOS-E. On admission GCS, postoperative hydrocephalus and presence of postoperative subdural hygroma were among the outcome determinants of these patients.

In a previous study from Iran, Moein *et al*., [24] reported a favorable outcome in 60% of patients undergoing DC while the mortality rate was reported to be 10%. Grille and Tommasino [25] in their series of 64 TBI patients undergoing DC found that factors such as age, GCS and type of craniectomy had no significant effect on outcome; whereas post decompression intracranial hypertension significantly worsen the outcome [25]. Recently Kapapa *et al*., [26] reported the

Table 3. Determinants of outcome in 142 patients with severe traumatic head injury undergoing decompressive craniectomy.

	Favorable (n=65)	Unfavorable (n=77)	*p*-value
Age (years)	32.9±13.9	36.5±16.7	0.171
Gender			
Men (%)	58 (89.2%)	69 (89.6%)	0.577
Women (%)	7 (10.8%)	8 (10.4%)	
Time interval (days)	1.66±1.48	1.66±1.83	0.998
Glasgow Coma Scale			
On admission	8.03±2.89	5.60±2.35	<0.001
After resuscitation	11.62±1.99	4.77±2.86	<0.001
Operation characteristics			
Duration (minutes)	169.0±35.81	173.1±45.10	0.559
Bleeding (mL)	996.9±840.9	1247.4±872.5	0.085
Time to cranioplasty (days)	53.69±20.16	58.00±21.14	0.867
ICU length of stay (days)	15.67±11.08	16.10±17.87	0.204
Hospital length of stay (days)	23.47±13.88	19.61±20.62	0.435
Complications			
Meningitis (%)	24 (36.9%)	31 (40.3%)	0.408
Subdural hygroma (%)	15 (23.1%)	7 (9.1%)	0.019
Hydrocephalus (%)	3 (4.6%)	14 (18.2%)	0.011
Reoperation (%)	2 (3.1%)	1 (1.3%)	0.436
Other Operations			
ICP monitoring (%)	24 (36.9%)	33 (42.9%)	0.293
Tracheostomy (%)	22 (33.8%)	27 (35.1%)	0.511
DPA[a] (%)	23 (35.4%)	24 (31.2%)	0.362
VP-Shunt insertion (%)	3 (4.6%)	10 (13.0%)	0.074
Gastrostomy (%)	2 (3.1%)	6 (7.8%)	0.200

[a]DPA: Deep Peritoneal Aspiration

outcome of DC in different pathologies. They found that the outcome after DC does not differ significantly in different pathologies once the final pathophysiological pathway of refractory intracranial hypertension, coma, compression of the basal cisterns and/or midline shift has been reached [26]. Hukkelhoven *et al*., [27] also determined the effects of age on outcome of TBI patients. They reported that an older age is continuously associated with a worsening outcome after TBI [27]. Dhandapani *et al*., [28] also demonstrated that age is an independent predictor of outcome in those with severe TBI. Although we have also reported the same results in TBI patients [6], in the current series we did not identified the age as an predictor of outcome in TBI patients undergoing DC. That might be explained due to the fact that most of TBI patients in our series are young men without significant variance and range. Thus the age would not be an indicator of outcome because the variance is limited. Other series such as those described above [15, 25, 27] included a heterogeneous group of TBI patients with a wide range of age. However our results are consistent to some previous reports [15, 25].

GCS on admission has been shown to strongly predict the outcome in patients with severe TBI, yet in patients undergoing DC this could be a controversy; our study showed GCS to be a significant prognostic factor determining the outcome after DC as well as previous reports [15, 29]. Gouello *et al*., [30] in their study of 60 patients from 2005 to 2011 undergoing DC due to severe TBI and also Grille and co-workers [25] in their study of 64 patients undergoing DC in severe TBI patients found GCS a non-influencing factor of outcome. Rotterdam score based on CT characteristics of the patients has been shown to be of a great value in predicting the outcome after TBI; Some authors found Rotterdam score to be a significant indicator of outcome in patients undergoing DC [6, 15, 22, 23, 31], while in our study there was no statistically significant correlation between the patients' Rotterdam score and their outcome.

Patients with severe TBI may need immediate surgery due to many reasons like: significant midline shift, large amount of ICH or SDH and etc. but many patients with severe TBI should be admitted in an intensive care unit and be monitored regarding ICP, late DC then would be performed in patients with refractory intracranial hypertension not responding to optimal medical therapy. Cianchi *et al*., [32] studied 186 patients with severe TBI in which 41 needed immediate DC, 124 patients responded to optimal medical therapy and 21 needed late DC, the 6 months neurological outcome were comparable in the 3 groups and no significant difference was seen; as well as our study that delayed DC compared to immediate DC had no significant effect on the prognosis; this probably is because of proper ICP management and treating raised refractory ICP when needed.

Postoperative hydrocephalus and subdural hygroma formation could be due to several factors attributable to disturbed normal CSF absorption and circulatory dynamics [33]. This could be formed in the first week after DC and gradually increase to the 4th week; however, most of them would resolve without surgical management. Ki *et al*., [33] and De Bonis *et al*., [34] demonstrated that craniotomies passing the midline are associated with postoperative hydrocephalus and subdural hygroma formation. Jeon *et al*., [35] studied 85 patients that had undergone DC and among them 19 patients developed subdural hygroma compared to the patients without subdural hygroma. They concluded that midline shift more than 5mm, subarachnoid hemorrhage, delayed hydrocephalus, compression of basal cisterns, and tearing of the arachnoid membrane were more common in patients with subdural hygroma. The interesting finding of our study was that postoperative hydrocephalus was associated with unfavorable outcome while presence of subdural hygroma was associated with favorable outcome. This could be explained to the fact the appearance of subdural hygroma in early postoperative phase is an indicator of good decompression and resolution of ICP.

We note some limitations to our study. This was a retrospective review of the data so that some information could not be revealed appropriately. We included all those with complete medical chart information. The number of patients included in this study was enormously high (take into consideration the point that these 142 patients were operated within an 18-month period). The study thus has an appropriate power and the results are among the only reported one from Iran. Prospective studies with larger sample size population and adequate trauma data registry is now underway in our center.

In conclusion, DC in patients with TBI is associated with favorable outcome in most of them. On admission GCS, postoperative hydrocephalus and presence of postoperative subdural hygroma are among the important predictors of outcome in TBI patients undergoing DC.

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