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ORIGINAL ARTICLE

Decompressive Craniectomy in patients with unilateral middle cerebral artery infarction;When to decompress and when to abort?

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ABSTRACT

Background: The skull is a non-expandable structure like a 'closed box' holding constant contents of blood, water, and precious brain tissue. Decompressive Craniectomy (DC) is a short simple life-saving procedure directed to open the "closed box" in patients with refractory intracranial hypertension. Whether to do it or not, is a matter of argument as making the right decision is a very difficult process.
This study aims to present how we selected the patients for such procedure based on our institution experience.
Methods: 75 patients with unilateral Middle Cerebral Artery (MCA) infarction who underwent decompressive craniectomy between 2014 and 2019 at Banha University were analyzed prospectively. The decision of surgery was discussed with the family based on the clinical and radiological basis. The modified Rankin Scale (mRS) was used to evaluate the clinical outcome.
Results: A 12-month follow-up revealed; that 30 patients had a mild disability or good outcome, 35 patients were vegetative or severely disabled, and 10 patients had died. Favorable prognostic factors were younger age and preoperative GCS score (9 or higher).
Conclusion: Decompressive craniectomy in patients with unilateral MCA infarction is a simple life-saving procedure for patients with acute refractory elevated ICP after the failure of conservative measures to prevent fatal brain herniation and improves cerebral hemodynamics. Early DC with the dural expansion is more favorable in young patients. Decision-making and patient selection for DC is an important complex procedure that should be evaluated from many aspects. We designed Em-Li scale and recommend it as a useful tool to help the surgeon not to miss a hopeful patient and to avoid operating on the patient who will not get the benefit of DC as not to decompress is also the right decision.
Keywords; Decompressive craniectomy, Malignant infarction, Traumatic brain injury.

INTRODUCTION

Ischemic stroke is one of the medical emergencies which is considered the first cause of morbidity and the second-leading cause of death worldwide [1]. Rapid development of fatal brain edema in cases of Middle Cerebral Artery (MCA) infarction is the reason to call it a "malignant" infarct [2]. Swollen infarcted brain tissue acts as mass compressing neurovascular structures leading to secondary ischemic injury associated with brain herniation followed by death therefore, the prognosis is poor [3]. Despite maximal medical treatment, 80% of MCA infarctions can lead to death in the first 7days [4]. An alternative more aggressive therapeutic procedure is needed for those patients to save their lives [5].
Decompressive craniectomy (DC) is a simple surgical procedure directed to open the skull by removing a bone flap to relieve interactable elevation of Intracranial Pressure (ICP) allowing the edematous brain to shift outward instead of compressing neurovascular structures, preventing

life-threatening downward herniation, avoiding compression of the vascular structures giving the chance to improve cerebral blood perfusion, cerebral oxygen supply, and cerebral compliance thus, preventing secondary brain injury [6].

This study aims to evaluate the accuracy of a scale we proposed to assess the preoperative patients' clinical status as well as to correlate the functional outcome of the patients with their preoperative scores to support the proper selection of those patients who will get the maximum benefit from the procedure in a trial to solve the ethical dilemma saving life on the expense of quality.

METHODS

This clinical study is conducted from March 2014 to August 2019 at Benha University Hospital which included 75 patients with refractory high intracranial pressure due to unilateral MCA infarction, with involvement of at least 2/3 of MCA territory. Complete general and neurological examinations were done for all patients on admission. Computed Tomography (CT) brain scans were done initially to evaluate the pathology, extent of midline shift, and brain edema. We used a preoperative scale containing scored specific items ranging from 4:12 points based on the clinical and radiological data of each patient and we called it the Em-Li scale (table 1).

The decision of surgery was based on the sum of these points correlating these factors together in one structure to give a predictive image of the postoperative functional outcome according to the modified Rankin Scale (mRS) (table 2). The clinical outcome was evaluated 3-, 6-, and 12-months after surgery based on the modified Rankin Scale (mRS) (table 3).

Table 1: Em-Li scale.

	Description	Points
Age of the patient:	< 30 years	3
	31 -60 years	2
	> 60 years	1
Time window*:	< 12 hours =3	3
	12-24 hours	2
	> 24 hours	1
Preoperative GCS:	9-15	3
	5-8	2
	< 5	1
Preoperative Mid line shift in CT brain :	< 5 mm	3
	> 5-10 mm	2
	> 10mm	1
Maximum score (Favorable)		**12**
Least score (Bad)		**4**
*Time window = (time between onset of symptoms and surgery)		

The study was done according to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Surgical technique:

After general anesthesia and positing of the patient shaving and sterilization were done, and a large question mark scalp incision was followed by elevation of skin flap and dissection of pericranium to obtain a good dural graft for duroplasty. Then a large front-temporoparietal decompressive craniectomy was done. Finally, duroplasty was done using the previously harvested pericranium followed by the closure of the skin. Reconstruction of the skull defect was always performed in a second session depending on the patient's general condition using Titanium mesh

.

Table 2: modified Rankin Scale (mRS)[7].
The patients with GCS 3, bilateral dilated fixed pupils, or pregnant females were excluded from our study.

	Description	Points
Age of the patient:	< 30 years	3
	31 -60 years	2
	> 60 years	1
Time window*:	< 12 hours =3	3
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*Time window = (time between onset of symptoms and surgery)		

Our research has been approved by the Research Ethics Committee (REC) of the Neurosurgery Department, Benha Faculty of Medicine, Benha University. Informed consent was obtained from the legal guardians of all patients included in this study.

Statistical analysis:

The mean and Standard Deviation were used to describe numerical data, while the frequency and percentage were used to describe categorical data. All statistical analyses were carried out using Software (SPSS, Version 26.0 for Windows).

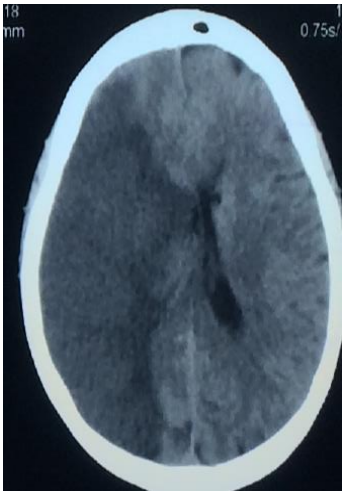
RESULTS

34 patients were females and 41 were males. The ages ranged from 38 to 67 years with a mean age of 58 years. GCS on admission ranged from 5 to 13 with a mean score of 8. Preoperative presentations were in form of disturbed consciousness, aphasia, hemiparalysis, and third nerve palsy. All patients had MCA infarction in the initial CT scan with mid-line shifts ranging from 4- 9mm. Surgeries were performed for 50 patients within the first 48 hours after the insult (started from the initial symptom), 15 patients of them had been operated upon in the first 24 hours with GCS 9-12. On the other hand, 25 patients were operated upon after 48 hours as they had GCS < 8 after deterioration with failure of medical treatment.

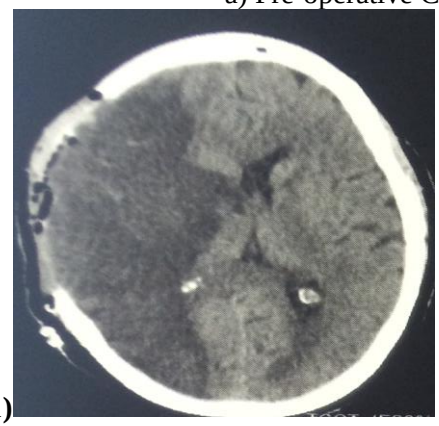
From the collected data in table 3, we can conclude that the less the number of points on the Em-Li scale, the poorer the functional outcome on mRS, the advice is not to interfere. At 12 months follow-up, 30 patients had a good functional outcome (mRS 1,2,3,4) and 35 patients had a poor outcome (mRS5).

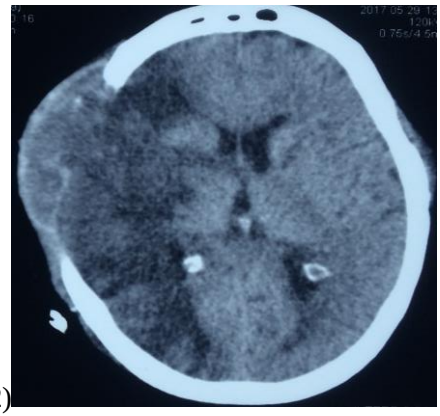
During this study 10 patients died (mRS6); 8 of them were operated upon after clinical deterioration and died in the Intensive Care Unit (ICU) within 2-3weeks after surgery, and the other 2 patients died at 4 and 5 weeks after surgery from a chest infection.

Case (1): Female patient 65years old was admitted to the neurology unit with GCS 9/15 and the initial CT brain showed Rt. MCA infarction with mid-line shift (a). Putting the patient on Em-Li scale she got 8 out of 12. So, the patient underwent DC within 24h after the initial insult (b). The patient stayed 4 weeks post-op. in ICU then discharged from hospital with left-sided weakness.



a) Pre-operative CT Brain showing right side MCA infarction with midline shift.

(1) 

(2) 

b) Post-operative CT Brain showing right side craniectomy.

1- immediate postoperative.
2- follow up after 8 months.

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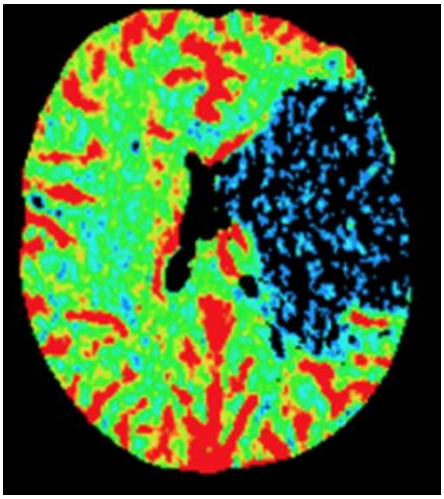
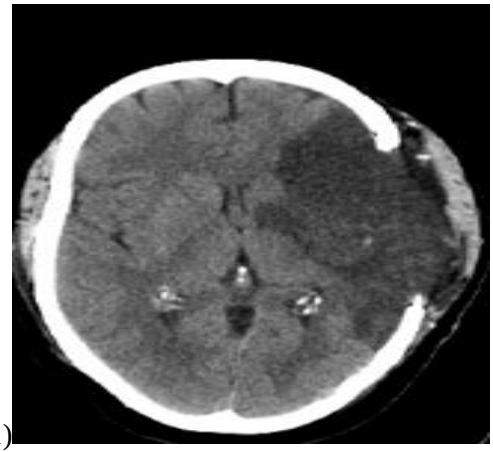
Case (2): Male patient 45 years old was admitted to the neurology unit with GCS 11/15 and initial CT brain showed Lt. MCA infarction with a mid-line shift. 12 hours later the patient deteriorated and GCS dropped to 9. CT perfusion was done to measure cerebral blood volume (a). He got 10 out of 12 on Em-Li scale so, the patient underwent DC (b). The patient had post-op. 12 days ICU follow up then discharged from hospital with right-sided weakness.

Limitations in our study are due to a few cases, but we hope that future studies will be able to make use of this scoring system selecting the appropriate cases to solve the ethical dilemma of saving life at the expense of quality.



a) Pre-operative measurement of cerebral blood volume in CT perfusion images showing left side MCA infarction with midline shift.

(1) 

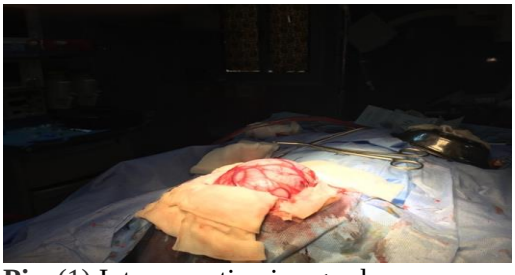
 (2)

b) Post-operative CT Brain showing left side craniectomy.

1- immediate postoperative CT.

2- after 8 months follow up.

Case (2): Male patient 45 years old was admitted to neurology unit with GCS 11/15 and initial CT brain showed Lt. MCA infarction with mid-line shift. 12 hours later the patient deteriorated and GCS dropped to 9. CT perfusion was done to measure of cerebral blood volume (a). He got 10 out of 12 on Em-Li scale so, the patient underwent DC (b). The patient had post-op. 12 days ICU follow up then discharged from hospital with right-sided weakness.



Pic. (1) Intraoperative image shows herniation of the brain due to high ICP.

Pic. (2) Post-operative CT 3D reconstruction of the bony skull shows the standard craniectomy.

Table 3: Preoperative points on Em-Li scale with post-operative functional outcome after 12 months follow up.

	Description	Points
Age of the patient:	< 30 years	3
	31 -60 years	2
	> 60 years	1
Time window*:	< 12 hours =3	3
	12-24 hours	2
	> 24 hours	1
Preoperative GCS:	9-15	3
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Preoperative Mid line shift in CT brain :	< 5 mm	3
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Maximum score (Favorable)		**12**
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*Time window = (time between onset of symptoms and surgery)		

DISCUSSION

Decompressive craniectomy is considered the most common surgical procedure to open a cranial window providing definitive relief of refractory high ICP in cases with unilateral or bilateral diffuse cerebral swelling [8,9]. The window will permit outward shifting of the swollen brain tissue, thus lowering ICP [10] as shown in the intraoperative pic. (1). It can be applied for space-occupying lesions such as major ischemic stroke, and cerebral sinus venous thrombosis [11]. The value of DC was documented to spare the ischemic but not infarcted area in case of malignant infarction through analyzing perfusion CT before and after DC [12]. This procedure is useful for large hemispheric infarctions and can improve functional outcome [13]. Different forms of DC can be applied to decompress the brain at risk for sequelae of elevated ICP including; subtemporal decompression,[14] circular decompression, [15] front- or temporoparietal DC,[16] large front-temporoparietal, bifrontal and hemisphere craniectomy[17]Alexander et al. found that the space obtained via subtemporal decompression can be ranged from 26 to 33 cm3[18] The decompressive beneficial effect depends mainly on the size of the created bony window. A small one has a limited value to reduce refractory intracranial hypertension. A more wide craniotomy as a large front-temporoparietal craniectomy could provide 92.6 cm3 additional space (median, 73.6 cm3)[14]. We used the large front-temporoparietal DC (standard trauma craniectomy shown in pic. (2)) as Jiang et al. suggested that large craniectomy can improve the outcome significantly in such a procedure [19].

Yang et al. found that when the bone removal is combined with augmentation duraplasty, the outcome is better as the dura will act as a bag to protect and enclose the underlying brain tissue which can reduce the postoperative complications (such as hydrocephalus, subdural effusion, and epilepsy)[16].

Patient selection: Age of patient: A patient's age is considered one of the important predictors of the outcome for DC. Younger patients have better functional outcomes in comparison to older patients[20]. Optimal recoveries can occur in patients less than 50 years[21]. Patients older than 50 years may have other medical risk factors such as arrhythmia, hypertension, ischemic heart disease, and hyperlipidemia which affect the prognosis. Therefore, old age is a significant predictor of poor neurological as well as functional outcomes following DC[22]. On the other hand, younger patients with dominant hemisphere strokes treated with DC can show improvement in their presenting aphasia on long-term follow-up[23].

We agree with the recommendation of the American Heart Association/ American Stroke Association (AHA/ASA) to do DC for unilateral malignant MCA infarction in patients with age ≤ 60 years old especially those who are deteriorating

neurologically and not responding to maximal medical treatments within 48 hours[24].Younger patients are given a high rank on our scale due to favorable prognoses in those patients rather than older ones.

Timing of surgery: Early or primary DC is done at the time of mass lesion evacuation. Late or secondary DC is done to treat the refractory ICP after the failure of conservative measures. Secondary DC is the most commonly applied procedure[25]. The golden hours for surgical interference are either before or immediately after the (clinical/radiological) deterioration as a result of persistent high ICP. In cases of MCA, surgery can be done early in the first 48 hours or late on day 7 after stroke onset[26]. However, the outcome of DC is favorable if surgery is decided before appearing signs of herniation[27].

Matching with literature we found that early DC prevents fatal brain herniation and improves cerebral hemodynamics[28]. Surgical interference beyond 48h from the onset of symptoms did not improve any of the outcome measures[22]. Clinical signs of deterioration or herniation can precede the increase in ICP. So, ICP monitoring is not sufficient alone to determine the surgical timing[29]. However, surgery is indicated if patients showed clinical deterioration or if there are radiological signs of significant mass effect and /or brain herniation due to cerebral edema[30].

The time window between the onset of symptoms and surgery is one of the important factors that determine the functional outcome. We found that the patient can get a better functional outcome when DC is done during the first hours of the insult.

Clinical and Radiological data: Regarding the clinical presentation and conscious level, we found matching with Schwab et al., that patients with preoperative GCS of 9 or higher exhibit better functional outcomes than those with preoperative GCS deteriorated to 8 or below[31]. We can conclude from our results that the higher the GCS, The better the functional outcome.

We agree with Andre et al, that the following radiological findings are associated with a high mortality rate; midline shift > 4 mm, large lesion volume (> 50ml), submassive infarction, or massive hemispheric infarction due to anterior, middle, posterior cerebral arteries occlusion[32].

That's why we document in our scale less rank for more distance of mid-line shifting in CT brain.

Functional outcomes: Some authors document the direct relationship between DC and raising the number of disabled survivors reducing the mortality rate at the expense of quality of life. (DESTINY, DECIMAL, and HAMLET) are the first three European trials that defined 'unfavorable' outcomes as a modified Rankin Scale (mRS) score > 3 [33].The definition of 'unfavorable' functional outcome has been changed by the time to consider mRS > 4 as an 'unfavorable' outcome. This is a result of changing views of physicians as well as patients on the quality of life after large cerebrovascular accidents [34]. Vahedi and colleagues found that early DC doubled the chance of survival with a favorable functional outcome from 21% to 43% [33].Which is comparable to our result documenting that 40% of our patients had a favorable functional outcome.

Finally, we document the importance to define what is an 'acceptable' outcome for patients and their families. Survival with a severe disability is the expected outcome after DC and death is the endpoint for patients with refractory high ICP and brain herniation who do not undergo surgery.

Family discussion: A detailed discussion with the patient's family is a very important step before doing the surgical procedure. It is vital to mention, that despite the favorable result of DC, mortality remains between 20% and 30%. The decision should be made based on the balance between the expected outcome and the patient or family's willingness to accept that outcome [35].A lot of surviving patients after DC are severely disabled needing continuous support for daily activities and some of them are bedridden and need continuous care.

CONCLUSION

Decompressive craniectomy in patients with unilateral MCA infarction is a simple life-saving procedure for patients with acute refractory elevated ICP after the failure of conservative measures to prevent fatal brain herniation and improves cerebral hemodynamics. Early DC with the dural expansion is more favorable in young patients. Decision-making and patient selection for DC is an important complex procedure that should be evaluated from many aspects. We designed Em-Li scale and recommend it as a useful tool to help the surgeon not to miss a hopeful patient and to avoid operating on the patient who will not get the benefit of DC as not to decompress is also the right decision.

Conflict of interest: None.

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