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Limits and Prognostic Factors for Surgical Decompression in The Management of Massive Hemispheric Infarction

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ABSTRACT

Background: A severe kind of ischemic stroke known as massive hemispheric infarction affects either the entire or most of the middle cerebral artery (MCA) and is distinguished by the emergence of potentially fatal cerebral edema. A death rate of up to 80% has been linked to this type of space-occupying edema. In acute ischemic stroke patients, decompressive craniectomy (DC) is a surgery used to treat brain herniation and deadly progressive edema.

Objectives: This work aimed to study the limits and prognostic factors for surgical decompression in managing patients with massive hemispheric infarction.

Patients and methods: This prospective study included 17 patients with massive hemispheric infarction who were admitted and treated at the Neurosurgical Departments of Menoufia University Hospital from February 2022 to February 2024.

Results: There were no significant differences in the relation between death after treatment and Glasgow Coma Scale (GCS) (Before treatment, after one day and 6 M), MRS (before treatment), and time of surgery after the onset of symptoms/H (P>0.05). Also, NIHSS Score, mRS after 1 M and 6 M were significantly increased among death patients after treatment (P<0.05).

Conclusions: Decompressive craniotomy can reduce the mortality rate in patients with massive hemispheric infarction, provided that it is done as early as possible from the onset of symptoms. The higher the GCS the better is the outcome.

Keywords: DC, Massive hemispheric infarction, MCA.

INTRODUCTION

Large hemisphere infarctions have the potential to cause fatalities and severe impairment. About 10% of instances of supratentorial ischemic stroke are caused by occlusion of the internal carotid artery (ICA) or MCA, which results in a substantial cerebral ischemia infarction [(1)]. A life-threatening infarct volume, or malignant cerebral infarction, is indicated by hypodensity of more than 50–75% of the MCA territory, including the basal ganglia, involvement of additional vascular territories, and cerebral midline shift of more than 4 mm at the level of the pineal gland in the first 48 hours [(2)].

The most significant number of mortalities from trans-tentorial herniation and consequent brain death occurred on day three following the ictus. Neurological degeneration follows within five days. Without neurosurgical intervention, the death rate from malignant myocardial infarction is around 80% [(3)]. Pathophysiological considerations support this clinical paradigm: secondary brain injury is a cascade of events that results in reduced cerebral perfusion in the non-ischemic parenchyma due to growing cerebral edema and elevated ICP [(4)].

Finding the factors that indicate a person is more likely to have malignant cerebral edema and benefit from surgical decompression is a critical matter. Clinical, radiographic, and laboratory variables are among the predictors that have been researched [(5)]. Studies have demonstrated that in cases of stroke and traumatic brain damage, decompressive hemicraniectomy reduces intracranial pressure and enhances blood flow and perfusion in both the contralateral hemisphere and the ipsilateral penumbral region [(6)].

In patients with primary cerebral infarction, decompressive craniotomy (DC) was best performed within 48 hours of the stroke start; poorer results were only observed if the operation was performed more than 72 hours later [(7)]. Timing, herniation, and result all showed a significant interaction, suggesting that the most crucial temporal aspect is to execute DC before herniation [(4)].

The most common surgical consequences following DC are bleeding, infection, disruption of the cerebrospinal fluid, and seizures. General problems like pneumonia, UTIs, and venous thrombosis are more frequent than surgical complications [(8)]. Thirty to sixty percent of ischemic strokes undergo hemorrhagic change, with a significant percentage already occurring before DC. In these circumstances, anti-platelet medication does not seem to be associated with an increased risk of perioperative bleeding, unlike intravenous thrombolysis [(9)]. Less than 10% of patients following DC experience infections at the surgical site or in the central nervous system, including wound infections, empyema, and cerebral abscesses [(8)].

The severity and anterior circulation stroke predict an increased risk of seizures. As a result, following a malignant cerebral infarction, individuals who qualify for DC are very susceptible to seizures [(10)]. Trephined or sunken skin flap syndrome is a long-term consequence of DC that manifests weeks to months later and is frequently marked by neurological decline following early rehabilitative gains [(11)]. This work aimed to study the limits and prognostic factors for

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surgical decompression in the management of patients with massive hemispheric infarction.

PATIENTS AND METHODS

A total of 17 patients with massive hemispheric infarction were included in a prospective study. Patients were admitted and treated in the Menoufia University Hospital Neurosurgical Departments from February 2022 to February 2024.

Inclusion criteria:

Patients with radiological evidence of massive hemispheric infarction (involvement of more than 50% of the cerebral hemisphere) with deterioration of consciousness level and/ or deterioration of neurological status.

Exclusion criteria:

Patients with small hemispheric infarction (less than 50% of the cerebral hemisphere), patients with stable both conscious level and neurological status, and patients who were medically unfit for surgery.

All patients underwent history taking, complete neurological examination, and necessary investigations. CT scan of the brain was done for all cases pre- and after treatment. Disability and functional outcomes were assessed using the modified Rankin Scale (mRS).

Surgical Technique:

Decompression of the relevant region is the surgical goal. Thus, a fronto-temporo-parietal decompressive hemicraniectomy is commonly carried out in these patients. The head is turned to the contralateral side while the patient is supine during the operation. A broad, curving incision is made in front of the ear or from behind. The skull is subsequently shown by deflecting the temporalis muscle and scalp flap. To obtain an anterior-to-posterior diameter of the craniectomy region of at least 12 cm —and preferably 15 cm in adult patients— burr holes are made and then linked. At last, the DC is expanded to reveal the middle cranial fossa floor. To have the necessary decompressive effect, a craniectomy of sufficient size is required. Furthermore, an inadequate DC increases the risk of external brain herniation and shear stresses at the margins of the bones, which can result in intraparenchymal bleeding and cerebral vein kinking. Large dural openings are created by incising the dura after adequate bone decompression. Allogenic or autologous dural transplants can be utilized to cover the exposed brain. For six months, there was a follow-up once a month.

Main outcome measures

The primary result of this study included the determination of the mean changes in mRS and GCS after treatment compared to before treatment, as well as operative complications.

Ethics approval

Following a thorough and concise explanation of the study's objectives, the subject or the subject's legal guardian signed an informed consent form. The permission form was prepared by the Egyptian Ministry of Health's Quality and Improvement System guidelines and the Helsinki Declaration. The study proposal was approved by the Menoufia Faculty of Medicine's local Ethical Scientific Council in Menoufia, Egypt (IRB approval ID: 2-2023.NEUS.1-4).

Statistical analysis

SPSS V.25.0 was utilized to tabulate and analyze the data statistically. Quantitative data were presented as mean ±SD, and median and were compared by paired t-test. Qualitative data were presented as frequency and percentage and were compared by X^2-test. A statistically significant P value was defined as ≤0.05.

RESULTS

The mean age of the studied patients was 61.29±2.93 years old. Also, most of the studied patients were males (58.8%). Medical co-morbidities were in 76.5%. Infarction was found in 52.9% on the right side. Before treatment, complications were found in 23.5%, while death after treatment was recorded in 23.5% (Table 1).

Table (1): Socio-demographic data of the studied patients (N=17).

Variables	Mean ±SD	Range
Age/year	61.29±2.93	40-65
Sex, (N, %)		
Male	10	58.8
Female	7	41.2
Medical co-morbidities	13	76.5
Side of infarction		
Right	9	52.9
Left	8	47.1
Before treatment complications	4	23.5
Death after treatment	4	23.5

Mean changes in GCS were significantly increased after treatment, one day and one month, compared to before treatment. Also, it was significantly increased after one month than after one day (Table 2, Figure 1). In the same trend, mean changes of mRS increased dramatically after 1 and 6 months than before treatment; it significantly increased after 6 months than after one month (Table 2, Figure 2).

Table (2): GCS and mRS before and after treatment in the studied patient (N=17).

Variables	Before treatment	Postoperative	
		1 Day	1 Month
GCS			
Mean ±SD	8.94±2.22	9.71±1.69	13.06±3.88
t, P value	t1=2.626, p=**0.018***	t2=5.704, p<**0.001***	t3=3.746, p=**0.002***
Mean Difference ±SD	0.76±1.20	4.12±2.98	3.35±3.69
mRS			
Mean ±SD	4.82±0.39	4.29±0.77	3.71±1.40
t, P value	t1=3.04, p=**0.008***	t2=3.63, p=**0.002***	t3=3.05, p=**0.008***
Mean Difference ±SD	0.53±0.72	1.12±1.27	0.59±0.80

GCS: Glasgow Coma Scale. **mRS:** The Modified Rankin Scale. t: paired t-test. *: Significant.
P1, before treatment compared to a 1-day post-operative.
P2, before treatment compared to a 1-month post-operative.
P3, 1-day post-operative compared to 1-month post-operative.

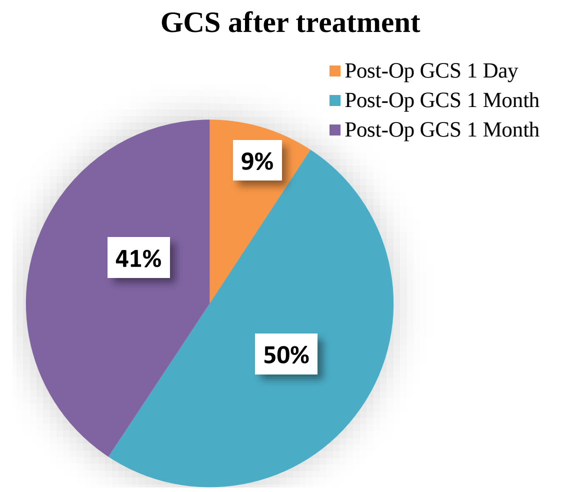


Figure (1): Mean changes of GCS after treatment compared to before treatment among the studied patients.

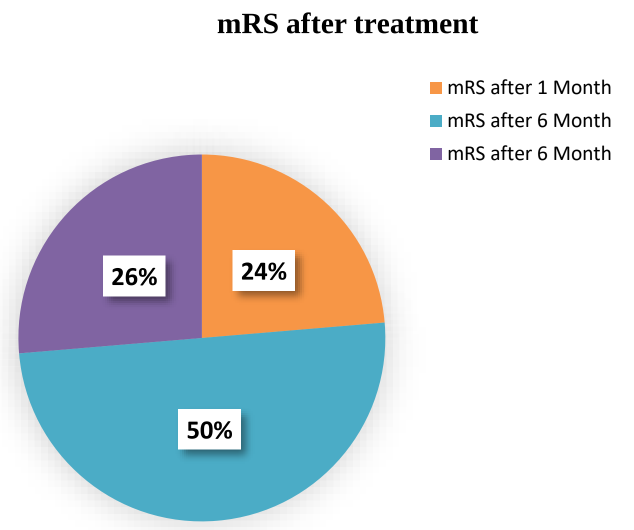


Figure (2): Mean changes of MRS after treatment compared to before treatment among the studied patients.

According to, socio-demographic data about death after treatment among the studied patients, mean age and gender were not significantly different between death and survivors' patients (Table 3).

Table (3): Socio-demographic data about death after treatment among the studied patients (N=17).

Variables	Death after treatment				Total (n=17)		t	P-value
	Yes (N=4)		No (N=13)					
Age	62.75±2.99		60.85±2.88		60.94±2.47		1.124	0.313
	No.	%	No.	%	No.	%		
Sex							X^2= 0.565	0.452
Male	3	75.00	7	53.85	10	58.83		
Female	1	25.00	6	46.15	7	41.17		

t: independent t-test. **X^2:** Chi-square test

There was no significant relation between death after treatment and GCS (before treatment, after one day, one month), mRS, time of surgery after the onset of symptoms/H. Also, the NIHSS Score, mRS (after 1 M and 6 M), significantly increased among death patients after treatment **(Table 4, Figures 3-5).**

Table (4): Comparing between GCS and mRS according to death after treatment among the studied patients (N=17).

Variables	Death after treatment		U	P-value	95%CI	
	Yes	No			Lower	Upper
GCS before treatment	7.00±2.16	9.54±1.94	2.103	0.094	-0.65	5.72
mRS before treatment	5.00±0.00	4.77±0.44	1.897	0.082	-0.50	0.03
NIHSS Score	33.00±3.74	24.08±3.55	4.222	0.009*	-14.43	-3.42
Time of surgery after the onset of symptoms/Hours	15.00±6.00	17.54±6.23	0.733	0.495	-6.27	11.35
GCS 1 Day after treatment	9.00±1.41	9.92±1.75	1.075	0.322	-1.16	3.01
GCS 1 Month after treatment	8.00±5.83	14.62±0.65	2.265	0.108	-2.64	15.87
mRS after 1 Month	5.50±0.58	3.92±0.28	5.278	0.009*	-2.46	-0.69
mRS after 6 Month	6.00±0.00	3.00±0.58	18.735	<0.001*	-3.35	-2.65

GCS: Glasgow Coma Scale. **MRS:** The Modified Rankin Scale, U: Mann-Whitney test, *: Significant. CI: Confidence interval.

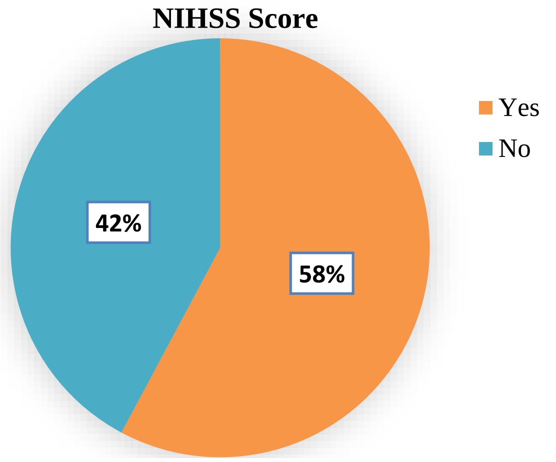


Figure (3): NIHSS Score according to death after treatment among the studied patients.

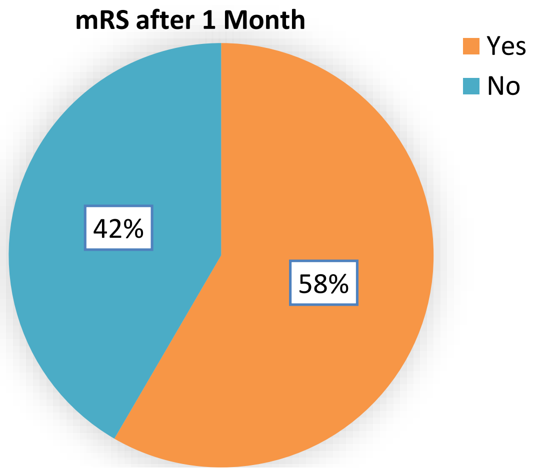


Figure (4): MRS after 1 Month according to Death after treatment among the studied patients.

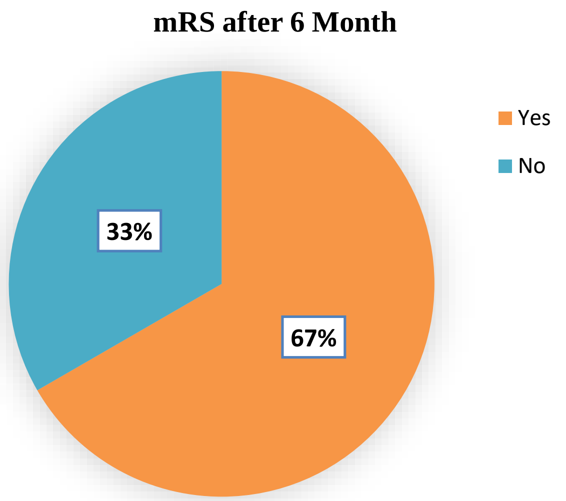


Figure (5): MRS after 6 Months according to Death after treatment among the studied patients.

There was no significant relation between death after treatment with medical co-morbidities, side of infarction, and complications before treatment **(Table 5).**

Table (5): Medical co-morbidities, side of infarction, and before-treatment complications according to death after treatment (N=17)

Variables	Death after treatment						X^2	P-value
	Yes (n=4)		No (n=13)		Total (n=17)			
	No.	%	No.	%	No.	%		
Medical co-morbidities	4	100.0	9	96.23	13	76.48	1.609	0.205
Side of infarction								
Right	3	75.00	6	46.15	9	52.95	1.022	0.312
Left	1	25.00	7	53.85	8	47.05		
Before treatment complications	2	50.00	2	15.38	4	23.52	2.037	0.154

X^2: Chi-square test

There were no significant differences among males and females regarding age, GCS (before treatment, after one day, and one month of therapy), mRS (before treatment, after1 M, and 6 M), NIHSS Score, and time of surgery after the onset of symptoms/Hours (Table 6).

Table (6): GCS and MRS among male and female patients (N=17).

Variables	Sex		t	P-value	95%CI	
	Male (n=10)	Female (n=7)			Lower	Upper
Age	60.5±2.22	62.43±3.60	1.259	0.239	-5.38	1.52
GCS before treatment	8.70±2.50	9.29±1.89	0.550	0.590	-2.86	1.69
GCS 1 Day after treatment	9.70±1.64	9.71±1.89	0.016	0.987	-1.94	1.91
GCS 1 month after treatment	12.00±4.85	14.57±0.53	1.661	0.130	-6.06	0.91
mRS before treatment	4.90±0.32	4.71±0.49	0.885	0.398	-0.29	0.66
mRS after 1 M	4.40±0.97	4.14±0.38	0.762	0.460	-0.47	0.99
mRS after 6 M	3.90±1.52	3.43±1.27	0.692	0.500	-0.98	1.93
NIHSS Score	26.70±5.93	25.43±4.35	0.510	0.618	-4.05	6.59
Time of surgery after the onset of symptoms	19.20±6.20	13.71±4.54	2.107	0.052	-0.07	11.04

GCS: Glasgow Coma Scale. **MRS:** The Modified Rankin Scale. **t:** independent t-test. **CI:** Confidence interval

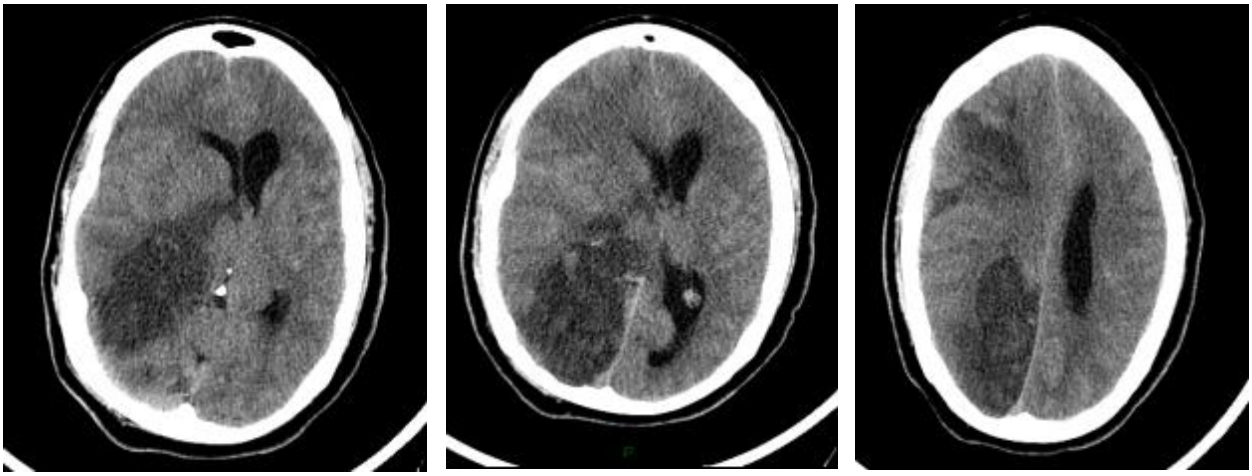
There were no significant differences among males and females regarding medical co-morbidities, side of infarction, complications (before treatment), and death after treatment (Table 7).

Table (7): Medical co-morbidities, side of infarction, complications before treatment, and death after treatment among male and female patients (N=17).

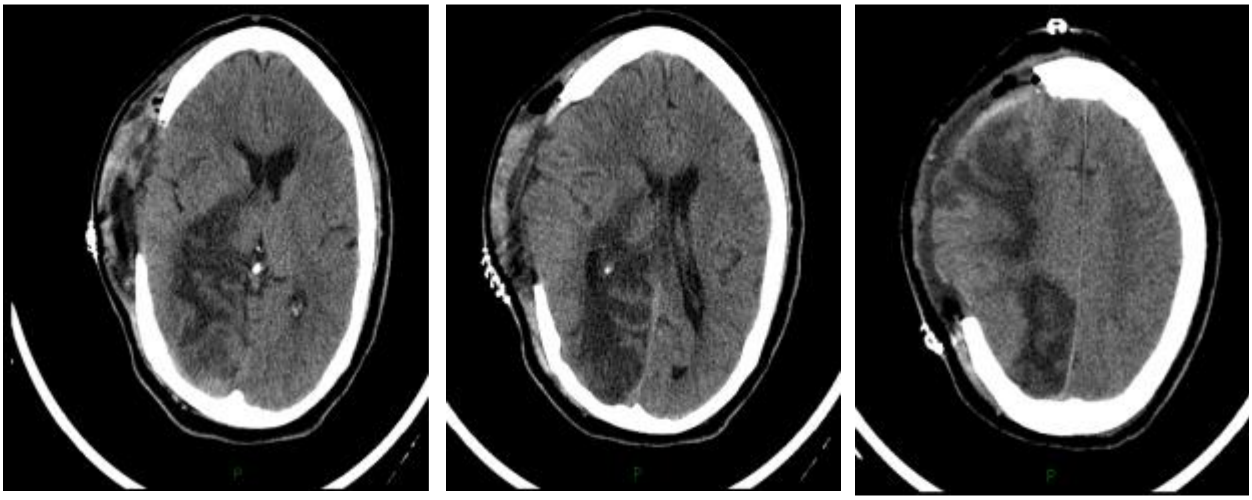
Variables	Sex						X^2	P-value
	Male (n=10)		Female (n=7)		Total (n=17)			
	No.	%	No.	%	No.	%		
Medical co-morbidities	7	70	6	85.71	13	76.47	0.565	0.452
Side of infarction								
Right	6	60	3	42.86	9	52.94	0.486	0.486
Left	4	40	4	57.14	8	47.06		
Before treatment complications	4	40	0	00.00	4	32.53	3.662	0.056
Death after treatment	3	30	1	14.39	4	32.53	0.565	0.452

X^2: Chi-square test.

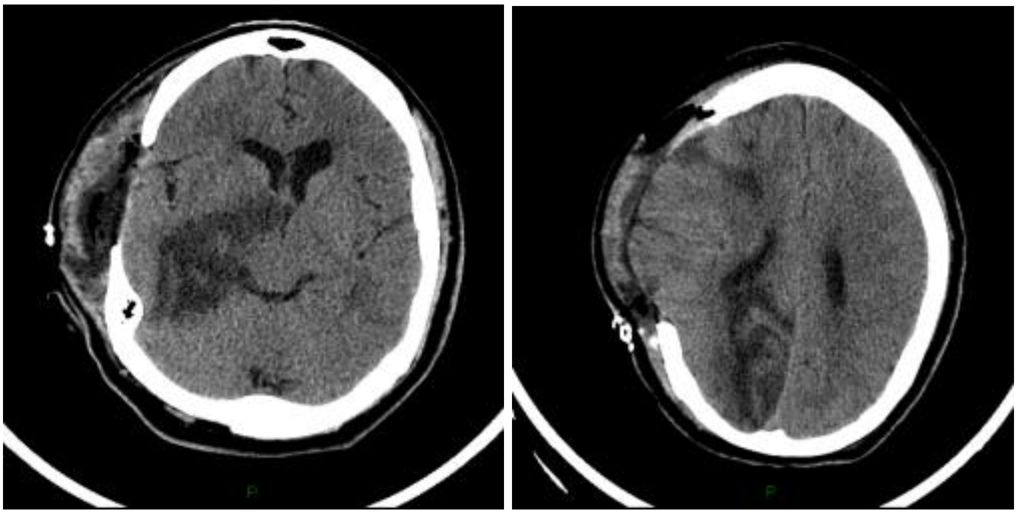
Case (1): One of our patients, 59 59-year-old male patients with infarction and left-sided hemiplegia. GCS was 7/15, and the patient was on a mechanical ventilator. The patient was operated on after 24 hours of the onset of symptoms. After treatment, the patient improved gradually and was removed from a mechanical ventilator. After one month, the patient became fully conscious.



a) CT scan before treatment



b) CT scan at one day after treatment



c) CT scan at one week after treatment.

DISCUSSION

A severe kind of ischemic stroke known as large hemispheric infarction (LHI) is defined by the development of potentially fatal cerebral edema. It affects the majority or the whole MCA distribution region, with or without the involvement of the anterior and posterior cerebral arteries [(12)]. Heart embolism is usually the cause of LHI stroke etiology; in younger patients, cervical artery dissection may be the trigger [(13)]. Furthermore, following subarachnoid hemorrhage, some infections may cause LHI [(14)]. Clinical research has used a variety of classifications for LHI, usually based on a combination of neurological signs or symptoms [(15)].

One surgical procedure for treating cerebral edema that lowers the risk of brain herniations and mortality is called a DC [(16)]. The vicious loop between infraction and cerebral edema, which results in increased occlusion owing to inadequate space and elevated intracranial pressure, may be addressed surgically using DC. According to reports, early DC has been linked to fewer neurological impairments and a faster return to daily activities [16]. In DC, certain bone pieces (such as frontal, temporal, and parietal) are temporarily removed, and then the brain is given more room by a duraplasty surgery [17]. Thus, the purpose of this study was to investigate the boundaries and predictive variables for surgical decompression in the treatment of patients suffering from significant hemisphere infarction.

In the current study, mean changes of GCS significantly increased after treatment at one day and one month compared to before treatment. Also, it significantly increased after one month compared to 1 day. In a previous study by **Reddy *et al.*** [18] noted a strong relationship between the result and the Glasgow coma scale before surgery. The 32 patients with a score of more than eight before therapy had an 88% survival rate and a GOS score of more than three at the follow-up. Conversely, just 27% of patients with a preoperative GCS of less than 8 survived, and their follow-up GOS score was 2. According to **Koh *et al.*** [19]**,** patients with a GCS of 13 or above had better results than those with a GCS of 12 or lower (25% favorable, 75% unfavorable) (50% favorable, 50% unfavorable). Also, **Mattos *et al.*** [20] reported that patients who showed a predisposition toward poor results (GCS <8 in the pre-surgical evaluation) suggest that the surgical approach shouldn't be postponed until neurological deteriorations occur.

Regarding mean changes of mRS, we found a significant increase after 1 and 6 months compared to before treatment; it was significantly increased after six months than after one month. In a meta-analysis by **Reinink *et al.*** [21], according to evidence at the patient level, surgical decompression, as compared to conservative therapy, significantly lowers the risk of mortality and raises the likelihood of a satisfactory functional result (mRS score ≤3) in patients with space-occupying hemispheric infarction. After 6 and 12 months, **Jüttler *et al.*** [22] showed a superior result in surgically treated patients, with 47% having an mRS score of ≤3. Of those receiving conservative therapy, only 27% had an mRS score of ≤3. Furthermore, negative results (mRS score of 4 to 6, Barthel Index of 0 to 25, or Glasgow Outcome Scale score of 1 to 3) are reported in 55% to 100% of patients treated with hemicraniectomy compared to 63% to 100% of patients treated conservatively in various trials with comparative data [23,24].

Another study by **Kilic *et al.*** [25] reported that following DC, mRS scores were higher in patients with high postoperative GCS scores, and 60% had a statistically significant reduction in mRS values. Comparing DC to the conservative therapy group, **Yu *et al.*** [26] demonstrated that in 22% of patients, DC produced good mRS scores (0–3). At the 3-month follow-up, 22.8% of patients in **Kürten and colleagues** [27] experiment, 44.6% of patients were still experiencing moderate-severe impairment (mRS 4), and 32.6% of patients had a bad result (mRS 5). Furthermore, two patients from the severe disability group had functional improvement at the 12-month follow-up, according to a set of **Elsayed and Elsayed** [28] notes. By the three-month follow-up, 16.5% of patients had recovered to moderate impairment (mRS 3), compared to 9%, and 33% were still mRS 5 with dismal results. In the study of **Zhao and colleagues** [29]**,** a group that at 12 months reported poor outcome (mRS 5) in 24.2% of patients and moderate impairment (mRS 3) in 11.4% of patients got approximate results. Furthermore, **Elsayed and Elsayed** [28] showed that DC reduces mortality rates in patients with malignant MCA infarction and enhances functional results at 12 months. After decompressive surgery, careful postoperative care can improve the prognosis for recovery.

According to socio-demographic data concerning death after treatment among our patients, age and sex showed no significant relation with death after treatment. It has been established that age has an important role in predicting the outcome of decompressive hemicraniectomy. Compared to younger patients, elderly individuals have been shown to have worse functional results and higher death rates [23]. Nevertheless, **Mattos *et al.*** [20] discovered no statistically significant difference when employing a 50-year-old cut-off age, which is consistent with our findings. Nonetheless, individuals over 60 had the lowest results at six months of follow-up. **Kilic *et al.*** [25] also noted no correlation between the GCS and mRS scores and mortality and gender, hemisphere dominancy, or infarction. According to research published in the literature, there is an 18% mortality rate, and better outcomes may be achieved by surgically treating the non-dominant hemisphere. However, others demonstrated no variation in the hemisphere-dependent consequences [16]. Furthermore, **Reddy *et al.*** [18] found no negative correlation between age and the result. Two individuals who were above 65 had excellent functional results. However, research by **Schwab *et al.*** [30]**, Gupta *et al.*** [31] **and Uhl *et al.*** [32] indicates that patients under 50 years old experience the best recovery.

According to a prior study, mortality decreased to around 30% following "delayed" hemicraniectomy and even further to about 20% following "early" hemicraniectomy (before herniation symptoms were evident), with 83% of patients who survived having a moderate to good functional result. Further studies by **Gupta *et al.*** [31] **and Uhl *et al.*** [32] have cast doubt on the value of decompressive surgery, particularly in light of long-term survival and functional outcome, given that only about 20% of survivors, particularly those who are older, have a favorable outcome after 12 months and that overall mortality rates can reach 50%.

Furthermore, early DC dramatically decreased mortality and improved outcomes six and twelve months after stroke, according to two randomized, controlled studies [16,22]. Furthermore, four weeks following surgery, **Vahedi *et al.*** [16] evaluated the results of conservative therapy against surgery. The death rate for the surgical group was 16%, whereas the death rate for the conservative group was 33%. Additionally, **Hofmeijer *et al.*** [33] found that when patients with infarctions are treated within 48 hours after the start of a stroke, surgical decompression improves prognosis. Furthermore, it has been proposed that there is no proof that DC, administered up to 96 hours after the start of a stroke, enhances functional results. However, **Kilic *et al.*** [25] noted that improved results and a lower-case fatality rate may result from operating on patients with space-occupying ischemic infarctions at an early stage. A National Institute of Health Stroke Scale (NIHSS) score of >20 for left or >15 for right hemisphere infarction [34], prior to therapy with a GCS score of <7, has also been established by several researchers to be predictive of whether individuals may experience malignant edema or have a bad prognosis. According to **Lam *et al.*** [35], an NIHSS > 22 predicts increased mortality.

CONCLUSION

Decompressive craniotomy can reduce the mortality rate in patients with massive hemispheric infarction, provided that it is done as early as possible from the onset of symptoms. The higher the GCS, the better the outcome.

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