

# Functional Outcomes of Decompressive Hemicraniectomy for Treatment of Malignant Infarctions of the Middle Cerebral Artery

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## Abstract

**Introduction:** Malignant middle cerebral artery (MCA) infarction is a devastating entity that is associated with up to 80% mortality. Decompressive Hemicraniectomy has been utilized to treat brain swelling and mass effect secondary to these infarctions in an attempt to improve functional outcome. **Aim:** To evaluate the functional outcome of decompressive hemicraniectomy in management of malignant MCA infarctions. **Methods:** The study included 30 patients with malignant MCA infarctions operated upon by decompressive hemicraniectomy and duroplasty with pericranium or fascia lata graft in the period from June 2016 to January 2019. Pre-operative neurological condition, associated morbidity, location and extent of the infarction were assessed. Surgery was performed within 48 hours of the onset of stroke or 12 hours within deterioration of conscious level. Pre-operative CT scan as well as sequential post-operative CT was done. Functional outcome was assessed by the modified Rankin Scale (mRS) at the time of discharge and 3 months following surgery. **Results:** The study included 18 males and 12 females with a mean age of 54.7 years. The pre-operative GCS was <8 (5 - 7) in 11 patients and 8 or higher (8 - 13) in 19 patients. Good functional outcome (mRS 0 - 3) was achieved in 13 (43.3%) cases while poor outcome (mRS 4 - 5) occurred in 8 (26.7%) cases and mortality (mRS 6) occurred in 9 (30%) cases. **Conclusion:** Decompressive hemicraniectomy improves functional outcome in cases of malignant MCA infarction. Pre-operative GCS, age, volume of infarction, degree of midline shift, timing of surgery and associated morbidity are the most important factors affecting the outcome.

## Keywords

Decompressive Hemicraniectomy, Malignant MCA Infarction, Functional Outcome, Modified Rankin Scale

## 1. Introduction

Malignant middle cerebral artery (MCA) infarction is the condition where MCA infarction is followed by massive, space-occupying brain edema involving more than 50% of the MCA territory [1] [2]. It is most commonly caused by an embolus or thrombus occluding the distal part of the internal carotid artery or the M1 segment of the MCA [3].

The resulting brain edema together with the infarcted brain results in increased intracranial pressure and progressive deterioration of conscious level. Mortality may reach up to 80% with conservative medical treatment which is directed mainly to reduce the intracranial pressure by hyperosmotic agents, hyperventilation, hypothermia, raising head position and sedation [4] [5].

Decompressive Hemicraniectomy (DHC) involves the removal of a large fronto-temporo-parietal bone flap giving space for the brain to expand to reduce the intracranial pressure and reduce morbidity and mortality. The size of the flap is crucially important for adequate decompression. A flap less than 10 cm increases the incidence of shearing injury of herniating brain [3]. Duroplasty has nowadays become an important part of the procedure [4]. Many studies have shown marked reduction in mortality in patients with malignant MCA infarction treated by DHC. On the other hand, speculations have been made that life may be preserved at the potential cost of marked disability as the reduced mortality rate results in increase in patients with both favorable and unfavorable outcome [6]. Early complications associated with DHC include insufficient decompression, hemorrhage, infection and subdural effusions while late complications include hydrocephalus, subdural hemorrhage and sinking flap syndrome [3] [7] Our study was conducted to evaluate the functional outcome of decompressive hemicraniectomy for surgical management of patients suffering malignant MCA infarctions and to identify the factors affecting the functional outcome of this procedure.

## 2. Patients and Methods

This study included 30 patients with malignant unilateral MCA infarction who were operated upon by DHC in Cairo University Hospitals in the period from June 2016 to January 2019. Inclusion criteria included age range 13 - 70, Glasgow Coma Scale (GCS) between 5 and 13, infarction involving more than 50% of the MCA territory, duration of less than 48 hours from the onset of stroke or 12 hours from deterioration of conscious level and fitness for general anesthesia. On the other hand, patients above 70 years, patients with GCS < 5 or >13, patients with infarction involving less than 50% of the MCA territory, patients who passed more than 48 hours from the onset of stroke, patients with severe medical comorbidity and patients whose family members refused surgical intervention were excluded from the study.

Preoperatively, all patients were subjected to complete general and neurological examination. This included assessment of conscious level (by GCS), speech,

motor power in upper and lower limbs and sphincters. Computed Tomography (CT-scan) of the brain was performed in all patients to confirm the diagnosis and to assess the location and extent of the infarcted area, degree of midline shift, associated brain edema, effacement of sulci and basal cisterns and the presence of associated hemorrhage. Diffusion weighted magnetic resonance imaging (MRI) of the brain was also performed in some patients for more accurate localization of the extent of the infarcted area.

**Surgical technique:** Under general anesthesia with the patient placed in the supine position, a question mark skin incision based on the ear was performed on the ipsilateral side of the infarction. A wide craniectomy (12 cm or more in diameter) was done with partial removal of the frontal, temporal and parietal bones. The anterior limit of the craniectomy was designed to avoid violating the frontal air sinus, the medial limit of the flap was 2 - 3 cm from the midline, posteriorly, the flap was extended about 5 cm behind the external auditory canal. The squamous part of temporal bone was excised down to the middle cranial fossa floor. The dura was opened radially in a stellate fashion to the extents of the craniectomy flap. Duroplasty was then performed using pericranium or fascia lata graft. This was followed by meticulous hemostasis and suturing of the temporalis muscle and skin flap in layers. A subcutaneous drain was inserted to be removed after 24 - 48 hours. The excised bone flap was placed in a subcutaneous abdominal pocket to be used later (usually within 3 - 4 months) for subsequent cranioplasty.

Postoperatively, patients were placed in Intensive Care Unit (ICU) until stabilization of their condition. Patients were followed up clinically and radiologically until they were discharged from the hospital and then at 1, 2 and 3 months following surgery. We used the modified Rankin Scale (mRS) [Figure 1] to assess the functional outcome following surgery where a mRS of 0 - 3 was considered good functional outcome whereas a mRS of 4 - 5 was considered poor functional outcome. CT brain was performed routinely postoperatively and if any deterioration in the patient's condition occurs.

Score	Definition
0	NO SYMPTOMS
1	No significant disability. Able to carry all usual activities, despite some symptoms.
2	Slight disability. Able to look after all affairs without assistance but unable to carry out all previous activities.
3	Moderate disability. Requires some help, but able to walk unassisted.
4	Moderate severe disability. Unable to attend to own bodily needs without assistance and unable to walk unassisted.
5	Severe disability. Requires constant nursing care and attention, bedridden, incontinent.
6	Dead.

**Figure 1.** Modified Rankin scale from Rankin J [8].

The primary outcome in this study was mRS at 3 months follow up. The secondary outcomes were age, sex, preoperative GCS, midline shift and risk factors associated with MCA infarction.

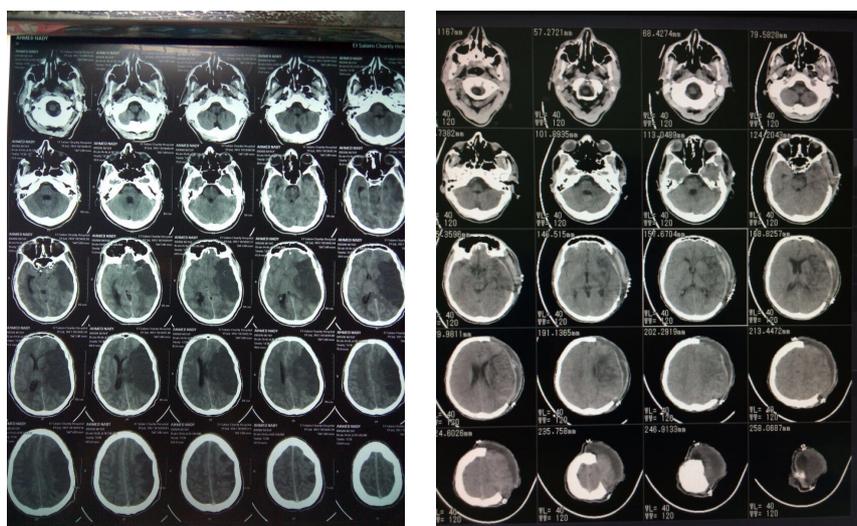
Statistical analysis: Analysis of the data was performed using Statistical package for social science (SPSS) software, version 15 for Microsoft Windows (SPSS Inc., Chicago, IL, USA). Categorical data was reported as number and percentages.

### 3. Results

The study included 30 patients with malignant MCA infarction who were operated upon by DHC [Figure 2]. 18 (60%) were males while 12 (40%) were females. Their ages ranged from 34 - 70 years with an average of 54.7 years. The location of the infarction was on the right (non-dominant) side in 17 (56.7%) cases and was on the left (dominant) side in 13 (43.3%). Preoperative GCS was <8 (5 - 7) in 11 (36.7%) patients and 8 or higher (8 - 13) in 19 (63.3%) patients. The midline shift in preoperative CT scan was <10 mm in 11 (36.7%) cases and 10 mm or more in 19 (63.3%) cases (Table 1).

All patients were operated upon in the first 48 hours after the onset of stroke or within 12 hours from deterioration of conscious level. Among the patients in this study, 80% had at least 1 risk factor related to MCA infarction ( 50% had 1 risk factor, 23.3% had 2 and 6.7% had more than 2 risk factors) while only 20% had no risk factors. Hypertension (50%), obesity (46.7%) and Diabetes Mellitus (33.3%) were the most dominant risk factors (Table 2).

At 3 months follow-up, 13 (43.3%) patients had good (mRS 0 - 3) functional outcome while 8 (26.7%) had poor functional outcome (mRS 4 - 5). The mortality rate was 30% as 9 patients died during the follow-up period (Table 3). Deaths were related to either progressive neurological deterioration or associated complications like pulmonary embolism and severe chest infection.



**Figure 2.** Pre and postoperative CT scan of a left sided malignant MCA infarction operated upon by DHC.

**Table 1.** Patient characteristics.

Variable	Number	Percentage (%)
Sex		
Male	18	60
Female	12	40
Age (years)	Range: 34 - 70	Average: 54.7
Location		
Right	17	56.7
Left	13	43.3
Pre-operative GCS		
<8	11	36.7
≥8	19	63.3
Midline shift		
<10 mm	11	36.7
>10 mm	19	63.3

**Table 2.** Associated risk factors.

Risk factor	Percent of patients (%)	Number of patients
<b>Hypertension</b>	50	15
<b>Obesity</b>	46.7	14
<b>Diabetes mellitus</b>	33.3	10
<b>Smoking</b>	23.3	7
<b>Cardiac disorders</b>	16.7	5
<b>Hyperlipidaemia</b>	16.7	5
<b>Other</b>	20	6

N.B. some patients had 2 or more risk factors.

**Table 3.** Functional outcome at 3 months follow up.

<b>Good (mRS 0 - 3)</b>	13 (43.3%)
<b>Poor (mRS 4 - 5)</b>	8 (26.7%)
<b>Mortality</b>	9 (30%)

The age of the patients had a significant impact on the functional outcome. Among the 21 patients below the age of 60 years, 12 (57.1%) had good functional outcome, 4 (19%) had poor outcome and 5 (23.9%) died while on the other hand, in 9 patients aged 60 years or more only 1 (11%) had good functional outcome while 4 (44.5%) had poor functional outcome and 4 (44.5%) died (**Table 4**).

The preoperative GCS also significantly affected the outcome. In 19 patients with GCS of 8 or higher, 13 (68.4%) had good outcome while 3 (15.8%) had poor outcome whereas mortality occurred in 3 (15.8%) patients. In patients with GCS of less than 8, no patients achieved good outcome at 3 months following surgery while 5 (45.5%) had poor outcome and 6 (54.5%) patients died (**Table 5**).

On preoperative CT scan, 11 patients had a midline shift of 10 mm or less, among these patients, 6 (54.5%) had good outcome while 3 (27.3%) had poor outcome and 2 (18.2%) patients died. In 19 patients with a shift of more than 10 mm, 7 (36.8%) had good outcome, 5 (26.3%) had poor outcome and 7 (36.8%) died (**Table 6**).

In patients with no associated co-morbidity (6 patients), good outcome was achieved in 3 (50%) patients, similar results (46.7% and 42.9%) were achieved in patients with 1 and 2 associated morbidity factors respectively. On the other hand, both patients having more than 2 associated morbidity factors died. Patient's sex and side of the infarction didn't affect the outcome markedly (**Table 7**). The most common postoperative complication was severe chest infection that occurred in 3 patients and deep venous thrombosis (DVT) in 2 patients. Superficial wound infection, extradural hematoma and basal ganglia hematoma were each encountered in 1 patient.

**Table 4.** Functional outcome according to age.

Functional Outcome	Below 60 years	Above 60 years
	21	9
<b>Good (mRS 0 - 3)</b>	12 (57.1%)	1 (11%)
<b>Poor (mRS 4 - 5)</b>	4 (19%)	4 (44.5%)
<b>Mortality (mRS 6)</b>	5 (23.9%)	4 (44.5%)

**Table 5.** Functional outcome according to preoperative GCS.

Functional Outcome	GCS < 8 (5 - 7)	GCS 8 or higher (8 - 13)
	11	19
<b>Good (mRS 0 - 3)</b>	0 (0%)	13 (68.4%)
<b>Poor (mRS 4 - 5)</b>	5 (45.4%)	3 (15.8%)
<b>Mortality (mRS 6)</b>	6 (54.5%)	3 (15.8%)

**Table 6.** Functional outcome according to midline shift in preoperative CT.

Functional Outcome	10 mm or less	>10 mm
	11	19
<b>Good (mRS 0 - 3)</b>	6 (54.5%)	7 (36.8%)
<b>Poor (mRS 4 - 5)</b>	3 (27.3%)	5 (26.3%)
<b>Mortality (mRS 6)</b>	2 (18.2%)	7 (36.8%)

**Table 7.** Functional outcome as regards sex and side of infarction.

Functional outcome	Male	Female	Right side	Left side
	18	12	17	13
Good	8 (44.4%)	5 (41.7%)	8 (47%)	5 (38.5%)
Poor	5 (27.8%)	3 (25%)	4 (23.5%)	4 (30.8%)
Mortality	5 (27.8%)	4 (33.3%)	5 (29.5%)	4 (30.8%)

#### 4. Discussion

Decompressive surgery for management of increased intracranial pressure (ICP) has been first described by Harvey Cushing in 1905 [9]. The use of decompressive craniectomy for management of ischemic brain insults has been described by Giuseppe Scarcella in 1956 [10]. By surgical removal of a part of the skull bone, the edematous brain is allowed to herniate outwards thus preventing uncal herniation and damage to other regions of the cerebral hemisphere [11] [12].

The use of DHC in management of malignant MCA infarction can reduce the mortality rate from 80% to around 30% [13] [14] [15]. However, the risk of survival with poor functional outcome may also be raised due to the large reduction in infarction-related mortality [16] [17] [18]. In this study, we evaluated the functional outcome of 30 patients with malignant MCA infarction who were operated upon by DHC and studied the different factors that may have an influence on the outcome.

The mortality rate in our study 3 months following surgery was 30%. Several studies have shown similar reduction in mortality in patients treated by DHC. In the meta-analysis performed by Streib *et al.* [16], the mortality rate was 30% among 289 patients managed by DHC. In the studies by Hao *et al.* [19] and Alexander *et al.* [5], similar mortality rates were also recorded. Further reduction in mortality was achieved in the European randomized controlled trials (RCTs) of DECIMAL [20], HAMLET [17] and DESTINY [21] where the mortality rates were 25%, 22% and 17.6% respectively.

We used the modified Rankin Scale (mRS) for functional outcome assessment. Good functional outcome all patients who could walk and care for themselves (mRS 0 - 3) while poor functional outcome included patients who were bedridden or vegetative and needed continuous care by family members or nursing staff (mRS 4 - 5). At 3 months follow up, good functional outcome was achieved in 43.3% of patients while the percentage of poor outcome was 26.7%. In the meta-analysis performed by Alexander and colleagues [5] that included 173 patients managed conservatively, good outcome was reported in 14% and poor outcome in 17%. This shows that surgery has raised markedly the incidence of good outcome but at the same time the incidence of poor outcome has also been raised. This can be explained by the fact that surgery has dramatically lowered the incidence of mortality following malignant MCA infarction and thus the chances of good and poor outcome were both raised. Other studies have also shown significant difference in functional outcome between surgically and med-

ically treated patients [3] [4] [20] [21]. On the contrary, the HAMLET study [17] showed no difference in good functional outcome between surgically and medically treated patients at 1 year follow up (25% vs 25%).

One of the factors that may have a big impact on the outcome is the timing of surgery. Many studies recommended early surgical intervention (in the first 24 hours after stroke onset) and don't recommend surgery if more than 48 hours have passed [3] [20] [21]. In our study, all patients were operated upon within 48 hours of stroke onset or within 12 hours after deterioration of conscious level of a previously conscious patient (patients with GCS > 13 were excluded from the study). The early intervention has probably played a role in the high rate of favorable outcome in our study.

In our study we excluded patients above 70 years of age. The study included 21 patients below the age of 60 and 9 patients aged 60 - 70 years. Good outcome was significantly higher in patients below 60 years (57.1% vs 11%). The study by Chen and colleagues [22] reported similar results with higher mortality among patients older than 60. They considered age to be the most important factor influencing the outcome of surgery. On the other hand, the studies by Rahmanian and colleagues [13] and Alexander and colleagues [5] showed no significant difference in the outcome among different age groups. The DESTINY, DECIMAL and HAMLET trials didn't include any patients above 60 years.

The outcome in our study in patients with preoperative GCS of 8 or higher was better than those with GCS of less than 8 (patients who needed intubation and mechanical ventilation prior to surgery). In the first group, good outcome was reported in 68.4% of cases while the rate of mortality was only 15.8%, in the latter group, none of the patients achieved good outcome while the mortality rate was 54.5%. These results suggest that preoperative GCS was one of the most important factors influencing the outcome. Kamal Alam *et al.* [4] showed similar results and pointed to the importance of GCS in patient's selection for decompressive surgery.

CT scan of the brain was performed in all our patients before surgery and following surgery for follow up and to detect any postoperative complications. Patients with midline shift of 10 mm or less on preoperative CT scan showed better functional outcome (54.5%) than those with midline shift of more than 10 mm (36.8%). On the other hand, patient's sex and side of infarction didn't show marked difference in patient's outcome. This is despite the fact that the incidence of aphasia and language disorders was much higher in infarctions involving the dominant hemisphere but since we used the modified Rankin Scale for assessment (which doesn't take in consideration language as a major disability factor), the functional outcome was not significantly different between infarctions involving the dominant and non-dominant hemisphere.

2 groups of complications were detected in our patients. The 1<sup>st</sup> group was complications related to the medical condition of the patients and were more common in bedridden and comatosed patients who required prolonged intubation and mechanical ventilation. The most common of these complications were

DVT and severe chest infection. The other group was complications related to surgical intervention and included 2 cases of hemorrhage (a patient developed extra-dural hematoma that required surgical intervention and the other a deep basal ganglia hematoma that was managed conservatively). Another patient had superficial wound infection which was managed by repeated dressing and intravenous (IV) antibiotics according to the results of culture and sensitivity.

One of the limitations of this study was the short follow-up period as with longer follow-up, more beneficial results may be obtained regarding the long term outcome and possible late complications. We recommend performing studies including a larger number of patients with longer follow-up period to obtain more accurate information about long term outcome of DHC in management of malignant MCA infarction. Some factors that may have an influence on the outcome (GCS < 5, age > 70 years, late surgical intervention and infarctions involving also anterior and/or posterior cerebral artery) were not analyzed in this study.

## 5. Conclusion

Decompressive hemicraniectomy reduces mortality and improves functional outcome in patients with malignant MCA infarction. At the same time, the number of patients with unfavorable outcome is also raised which necessitates proper choice of patients who are candidates for surgical intervention. Patients younger than 60 years, with GCS > 8, showing midline shift of 10 mm or less who are operated upon in the first 48 hours after the onset of stroke have the best chance of achieving good functional outcome.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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## Abbreviations

CT: Computed Tomography  
DHC: Decompressive Hemicraniectomy  
DVT: Deep Venous Thrombosis  
GCS: Glasgow Coma Scale  
ICP: Intracranial Pressure  
ICU: Intensive Care Unit  
IV: Intravenous  
MCA: Middle Cerebral Artery  
MRI: Magnetic Resonance Imaging  
mRS: Modified Rankin Scale  
RCTs: Randomized Controlled Trials