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Effect of decompressive hemicraniectomy performed within the first 48 hours on mortality in the treatment of malignant infarction of the middle cerebral artery

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Abstract

To evaluate the clinical outcomes of patients with malignant middle cerebral artery (MCA) infarction who underwent wide decompressive hemicraniectomy. Fifty-two patients with large MCA infarcts were retrospectively evaluated, and 12 patients who underwent extensive decompressive hemicraniectomy and duraplasty with a bone flap extending beyond the infarct borders were included in the study. The degree of stroke (stroke volume), preoperative and postoperative midline shift of the craniectomy area and improvement in midline shift were calculated on computed tomography. Preoperative and postoperative neurologic examination scores were determined using the modified Rankin Scale. The mean age was 63 (min: 41, max: 79) years. There was left MCA infarction in one patient and right MCA infarction in 11 patients. The postoperative follow-up period of the operated patients ranged from 14 to 90 days. The neurological examination of seven patients (58.3%) showed significant improvement. Eight (66.6%) patients survived. Postoperatively, the mean midline deviation value of 12 patients decreased from 11.04 to 4.8. It is considered that wide decompressive craniectomy performed in young patients in the early period with strict radiological and clinical follow-up can increase survival and functional recovery.

Keywords: Cerebral stroke, decompressive hemicraniectomy, middle cerebral artery infarction

Introduction

Primary injuries to the brain can lead to cerebral edema and intracranial hypertension, which are the main mechanisms of secondary brain injury, and thus important predictors of mortality and poor outcomes. With the introduction of modern neurosurgery and critical care, the classical decompressive craniectomy (DC) technique, i.e., surgical opening of the skull to reduce high intracranial pressure (ICP), has been refined, becoming a focus of clinical research in particular. In this study, we aimed to provide detailed information on the current status of DC in the modern interdisciplinary care of patients with an acute ischemic stroke, discuss the timing of surgery, and offer a seminal future perspective in terms of recovery rates using the modified Rankin score (mRS).

Material and Methods

The ethics committee of the study was obtained from Lokman Hekim University Scientific Research Ethics Committee with the decision number 2022/199. Fifty-two patients who presented to Lokman Hekim University Training and Research Hospital between January 2020 and December 2021 and were diagnosed with stroke were evaluated. Ischemic lesions were detected using cranial computed tomography (CT), diffusion-weighted magnetic

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resonance imaging (DWI-MRI), and CT/MRI angiography, and their localizations were noted. The areas of infarction were evaluated according to cerebrovascular regions, and 12 patients with extensive middle cerebral artery (MCA) infarction (infarct area greater than 1/2 of the MCA area) were included in the study (Figure 1A, B).

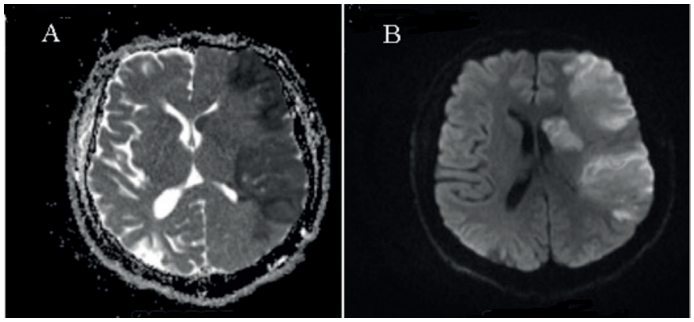

Figure 1. Left middle cerebral artery infarction. (A) ADC map, (B) diffusion-weighted magnetic resonance imaging

Surgical treatment was not planned in patients with diseases known to preclude surgical treatment, those with an mRS (pre-stroke) score of ≥2, and those with bilaterally unresponsive dilated pupils. After excluding these cases, progressive neurological deterioration and herniation were retrospectively evaluated in 12 patients that underwent wide decompressive hemicraniectomy and duraplasty with a bone flap extending beyond the infarct margins. The Detailed demographic data and neurological examinations of the patients were examined. Postoperative follow-up time, mortality rate, and disability scores were noted. mRS was used to detect functional dependence and assess recovery (Table 1).

Table 1. Modified Rankin Scale scoring

Modified Rankin score	Definition
0	No symptom
1	No significant disability despite symptoms; able to perform all normal duties and activities
2	Slight disability. Unable to perform all previous activities but able to attend to own needs without assistance
3	Moderate disability. Requires some help but able to walk without assistance
4	Moderately severe disability. Unable to walk without assistance or attend to own bodily needs without assistance
5	Severe disability. Bedridden, incontinent, requires constant nursing care and attention
6	Dead

The degree of MCA stroke was determined by examining the preoperative and postoperative non-contrast cranial CT (CT/CTA) and cranial MRI (DWI, MRI, and MRA) images of all the patients. Stroke degree (stroke volume), preoperative and postoperative midline shift of the craniectomy area, and improvement in midline shift were noted (Figure 2A, B).

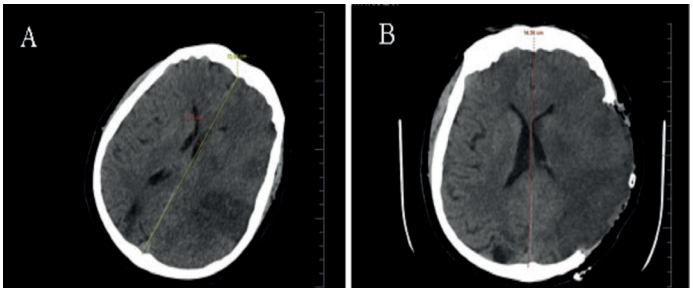

Figure 2. Axial brain computed tomography images of (A) the preoperative midline shift (13.80 mm) and (B) postoperative improvement in the midline shift

Infarct volume was calculated using the ABC/2 volume estimate of an ellipsoid, where A is the largest diameter in axial scan, B is the largest vertical diameter in axial scan, and C is the vertical diameter in coronal scan. These measurements were performed using the brain CT scans obtained within 24 hours of symptom onset (Figure 3A, B).

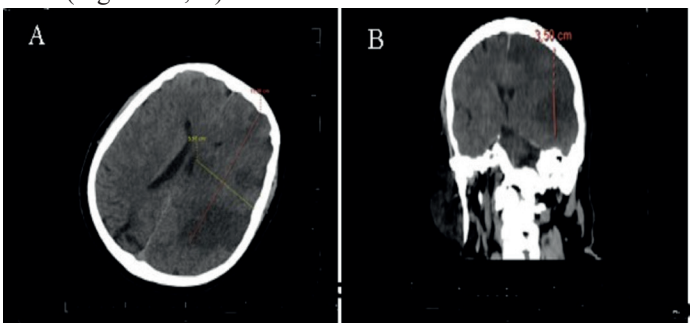

Figure 3. Preoperative brain computed tomography images showing left middle cerebral artery infarction measured using the ABC/2 method. (A) axial scan, (B) coronal scan

The length, width, and area of the craniectomy bone flap were measured on a brain CT scan obtained immediately after surgery. The bone area was defined as follows: bone flap A = D × d × π (D: anteroposterior diameter, d: the diameter perpendicular to bone flap D) (Figure 4).

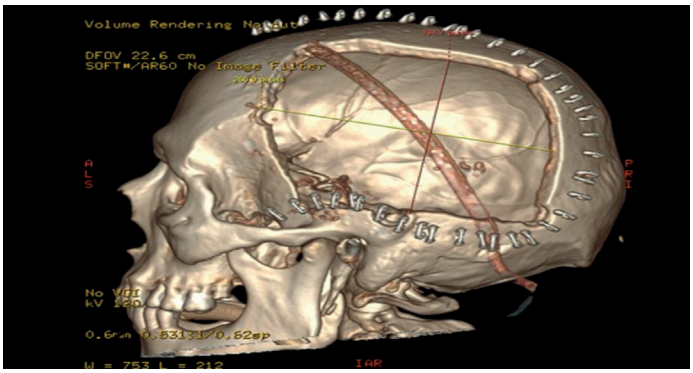

Figure 4. Three-dimensional reconstruction of postoperative brain computed tomography image showing the anteroposterior diameter and width of the craniectomy bone flap

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Statistical Analysis

Statistical analysis was performed using SPSS v. 20.0. The data obtained from the study were analyzed descriptively. Central tendency measures, central distribution measures, frequency analysis, and ratio analysis techniques were applied.

Results

Fifty-two patients that presented to our center with an ischemic cerebrovascular event (CVE) were retrospectively evaluated. Twelve (24%) cases in which neurological findings were observed to deteriorate during the follow-up despite effective and appropriate medical treatment and surgical decision was made were included in the study. Wide unilateral hemicraniectomy + wide duraplasty was performed as the surgical procedure. The postoperative three-dimensional cranial CT scans of two patients are shown in Figure 4.

Decompression surgery was performed in a total of 12 patients with an ischemic CVE, six men and six women, who showed clinical progression within 24-48 hours despite medical treatment. The mean age was 63 (min: 41, max: 79) years. One patient had left MCA infarction, and 11 had right MCA infarction. The preoperative mRS was 4.4 in eight patients and 5 in four. The preoperative Glasgow Coma Scale of the patients ranged from 4 to 13. All the patients had midline shifts, and one patient also had anisocoria. The time from the diagnosis of acute ischemic stroke and admission to the hospital and surgery ranged from 24-120 hours. More than half the cases had a history of primary hypertension (66.6%) and atrial fibrillation (58.3%) (Table 2).

The postoperative follow-up period of the patients who underwent surgery varied between 7 and 90 days. The neurological examination of seven (58.8%) patients showed significant improvement. Eight (66.6%) patients survived. One patient with right MCA infarction died due to diffuse posterior system infarction. Three other patients died due to additional complications (sepsis, pneumonia).

The mean postoperative midline shift decreased from 11.08 to 4.08 in 12 patients. The mean craniectomy area was found to be 407.81 (385.9-437.3), and the craniectomy area was above average in two cases with the highest neurological and functional improvement. The mean stroke value was measured as 185.75, and four patients with the highest stroke value and preoperative midline values died (Table 3).

Table 2. Patient data

Patient	Age	Gender	GCS	Anizocoria	Mid -line shift	Surgery time	Infarct direction	HT	DM	Smoking	AF	MRS Pre-op	MRS 3.month	Thrombectomy
1	62	male	10	-	12mm	24-48	Right	+	+	-	-	4	3	-
2	55	male	11	-	11mm	24-48	Right	+	-	+	-	4	1	-
3	64	male	13	-	15mm	72-96	Right	+	+	-	+	5	-	-
4	48	female	11	-	8mm	24-48	Right	+	-	+	-	4	3	-
5	70	female	5	-	20mm	48-72	Right	+	+	-	+	5	-	-
6	67	female	6	-	13mm	96+	Right	+	-	-	+	5	-	-
7	69	male	12	-	13mm	96+	Right	-	+	-	+	5	-	-
8	79	female	4	-	11mm	48-72	Right	+	-	-	+	4	3	+
9	63	female	9	-	7,5mm	48-72	Right	+	+	-	+	4	3	+
10	67	male	10	-	9mm	72-96	Left	-	-	-	-	4	3	-
11	73	male	9	-	5mm	0-24	Right	+	-	-	+	4	4	-
12	41	female	11	+	8mm	0-24	Right	+	-	+	-	4	3	-

GCS: Glasgow Coma Scale; HT: hypertension; DM: diabetes mellitus; AF: atrial fibrillation; preop: preoperative; mRS: modified Rankin score

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Table 3. Radiographic parameters of patients undergoing decompressive hemicraniectomy

Patient no	Preoperative midline shift (mm)	Postoperative midline shift (mm)	Postoperative improvement in midline shift	Craniectomy area (cm3)	Stroke volume (cm3)
1	12	8	4	421.6	159
2	11	4	7	437.3	155
3	15	7	8	385.9	253
4	8	2	6	398.3	271
5	20	11	9	403.1	158
6	13	5	8	410.8	177
7	13	6	7	407.7	169
8	11	3	8	399.4	188
9	7,5	0	7.5	427.2	181
10	9	3	6	396.4	177
11	5	0	5	407.4	169
12	8	0	8	398.7	172
Mean	11.04	4.08	6.95	407.81	185.75

Discussion

Malignant MCA infarction is defined as a large MCA infarct that causes a space-occupying mass effect due to associated cytotoxic edema and occurs in 10% of all stroke cases. It presents with acute brain swelling within the first 48 hours after a stroke and results in elevated ICP or brain herniation. Malignant MCA infarction is associated with a mortality rate of approximately 80% despite appropriate medical treatment. There is a strong correlation between ischemic brain volume (stroke volume) and mortality (1). Clarke and Harris were the first to recommend decompressive surgery for these lesions with an intracranial mass effect [1]. Decompressive hemicraniectomy (DHC) has recently been recognized as an appropriate treatment modality for patients with malignant MCA infarction. Studies have shown the efficacy of this method in reducing mortality and morbidity associated with malignant ischemic stroke. In the literature, it has been reported that decompressive craniectomy reduces mortality from 80% to 30% [2]. However, in ischemic CVEs, there are still controversies concerning indications, timing, surgical technique to be applied, and patient selection. Nevertheless, decompressive craniectomy has been shown to reduce mortality in patients presenting with resistant intracranial hypertension and neurological deterioration despite medical treatment [3].

In the literature, there are conflicting data concerning the time of surgery, surgical procedure to be performed, and appropriate patient selection. Gupta et al. evaluated the timing of decompressive surgery. When the authors compared the clinical results of patients who underwent surgery early (within the first 24 hours) and late (after 24 hours), they found no significant difference [4]. In another study, Foerch et al. reported that loss of function was independent of surgical timing [5]. In our study, the patients were operated on in the early and late periods. Following clinical worsening in neurological follow-ups 36 hours after diagnosis of SVO. Therefore, it is defined as late surgery. Similar to our study, Orakdogan et al. evaluated the mortality rate in patients who underwent late decompressive craniectomy (73.5%). When the two studies were compared, the mortality rate was found to be lower (18%) in our study. This was considered to be due to the differences in the demographic data of the patients participating in respective studies, comorbidities that may have been associated with mortality and morbidity, and differences in surgical techniques.

Although there are studies reporting no significant difference in the clinical outcomes of patients undergoing DHC, most clinicians state that mortality is high in operations performed after the age of 60 years [6]. In the current study, the mean age of the two patients with the highest rate of neurological and functional improvement was 58.5 years.

A decrease in mortality was observed in patients with malignant MCA infarction after DHC. Despite this surgery, the rate of herniation causing mortality in patients with malignant MCA infarction is reported to be between 11% and 22%. However, this rate has been shown to decrease with the use of a bone flap extending beyond the infarction border, extensive DHC, and duraplasty [7], as also performed in our study. In our study, consistent with the literature, mortality rate in the study was determined as 25%.

In studies evaluating the relationship between neurological improvement and mortality according to radiological parameters, a midline shift of >10 mm, presence of additional vascular space, basal ganglia involvement, large infarct volumes, and smaller craniectomy length were found to increase mortality and morbidity. In our study, complete neurologic recovery was

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achieved in only one patient. This patient's mRS was determined to be 4 preoperatively and 0 at the postoperative third-month follow-up. Pullicino et al. showed that midline shift was associated with mortality [8]. In the current study, all the operated patients had a median shift of 11.24 mm on average, and all underwent extensive DHC. The preoperative and postoperative midline shift values, improvement in midline shift after DHC, craniectomy area, and stroke volume were measured. The mean shift value decreased to 4.08 in 12 patients. Consistent with the literature, the mean shift values of 12 patients decreased from to after surgery. The mean craniectomy area was above average in the two cases with the highest neurological and functional improvement. Patients with the highest stroke volume and preoperative midline shift values died. The data obtained from this study are in agreement with the results of other studies in which wide DHC was performed [9].

Malignant MCA infarction is a severe form of ischemic stroke. Severe loss of function and life-threatening conditions may occur in a significant proportion of patients that have had an ischemic stroke. Therefore, it is vital to choose the appropriate treatment method in patients with CVEs. DHC is an effective part of treatment in patients resistant to medical therapy. However, at the time of presentation, it is difficult to predict which patient will benefit from DHC, and this evaluation should be carefully performed in each case. As seen in the literature, the effect of DHC on morbidity and mortality, especially in young patients and in the first 48 hours, is clear.

In addition to DHC, approaches such as ventriculostomy to reduce intracranial pressure are also discussed in the publications. We still believe that there is a long way to go on this issue.

Limitations

This is a retrospective single-center study with a small sample. However, the majority of single-center studies evaluating mortality in the literature also have a similar sample size and retrospective design. Due to the small number of patients, we were only able to perform descriptive statistical analyses. Therefore, we could not evaluate possible relationships between parameters that could affect mortality and morbidity using basic statistical methods.

Conclusion

In light of the results of this study, it is considered that early wide DHC performed in young patients with a suitable neurological degree with combined with appropriate radiological and clinical follow-up can increase survival and functional recovery. These findings should be supported by multicenter long-term studies involving a large number of patients.

Conflict of interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical approval
The ethics committee of the study was obtained from Lokman Hekim University Scientific Research Ethics Committee with the decision number 2022/199.

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