Smyrna Tıp Dergisi ***Araştırma Makalesi***

Efficacy of Extensive Decompressive Hemicraniectomy for Ischemic Stroke: Radiologic and Surgical View
İskemik İnme Olgularında Geniş Dekompresif Hemikraniektominin Etkinliği: Radyolojik ve Cerrahi Bakış

Hilal Altaş[1], Ali Yılmaz[2]

[1] Asist.Prof.Dr., Department of Radiology, School of Medicine, Ordu University, Ordu, Turkey
[2] Asist.Prof.Dr., Department of Neurosurgery, School of Medicine, Ordu University, Ordu, Turkey

Summary
Objective: Aim of the study is to evaluate clinical outcomes of patients with malignant middle cerebral artery infarction who underwent extensive decompressive hemicraniectomy.
Material and Method: Ninety four patient with ICA and/or extensive MCA infarction was retrospectively evaluated. 11 patients who underwent extensive decompressive hemicraniectomy and duraplasty -with a bone flap that extends beyond the infarction boundaries- were included in the study. Degree of stroke (stroke volume), craniectomy area preoperative midline shift, postoperative midline shift and improvement in midline shift were calculated on CT scans. Pre and post-op neurologic examination scores were measured with modified Rankin Scale (mRS).
Results: The mean age was 63 (min:53, max.73). Six patients had left middle cerebral artery (OSA) infarction, 4 patients had right middle cerebral artery (OSA) infarction, one had internal carotid artery (ICA) infarction. The post-operative follow-up period of the operated patients varies between 14-60 days. Significant improvement was detected in the neurological examination of 7 (64%) patients. Survival was observed in 9 patients (82%). It was observed that the average shift values of 11 patients, decreased from 10,04 to 3.6 postoperatively.
Conclusion: Extensive decompressive cranioectomy, which will be applied to young patients with an acceptable neurological degree in the early period with strict radiological and clinical follow-up, will increase survival and functional recovery.
Key words: Serebral stroke, decompressive hemicraniectomy, MCA infarction

Özet
Amaç: Bu çalışmanın amacı, malign orta serebral arter enfarktı geçiren ve geniş dekompresif hemikraniektomi uygulanan hastaların klinik sonuçlarını değerlendirmektir.
Gereç ve Yöntem: ICA ve / veya geniş MCA enfarktı olan doksan dört hasta retrospektif olarak değerlendirildi. İnfarktüs sınırlarının ötesine uzanan kemik flebi ile geniş dekompresif hemikraniektomi ve duraplasti uygulanan 11 hasta çalışmaya dahil edildi. BT taramasında inme derecesi (inme hacmi), kraniyektomi alanı preoperatif orta hat kayması, postoperatif orta hat kayması ve orta hat kaymasındaki düzelme hesaplandı. Preop ve postop nörolojik muayene skorları modifiye Rankin Skalası (mRS) ile ölçüldü.
Bulgular: Yaş ortalaması 63 (min:53, max:73 yaş) idi. Altı hastada sol orta serebral arter (OSA) enfarktüsü, 4 hastada sağ orta serebral arter (OSA) enfarktüsü, bir hastada internal karotid arter (ICA) enfarktüsü vardı. Ameliyat edilen hastaların ameliyat sonrası takip süresi 14-60 gün arasında değişmekteydi. Yedi hastanın (% 64) nörolojik muayenesinde anlamlı düzelme saptandı. 9 hastada (% 82) sağ kalım gözlendi. Ameliyat sonrası 11 hastanın ortalama orta hat kayma değerinin 10,04 'ten 3.6'ya düştüğü gözlendi.
Sonuç: Sıkı radyolojik ve klinik takip ile erken dönemde, genç hastalara uygulanacak geniş dekompresif kraniyektominin, sağ kalımı ve fonksiyonel iyileşmeyi artıracağı düşünülmektedir.
Anahtar Kelimeler: Cerebral stroke, dekompresif hemikraniektomi, MCA enfarktüsü

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Introduction

Stroke is defined as a neurologic deficit that occurs due to ischemia or hemorrhage in the central nervous system. It is one of the neurologic emergencies and most strokes (80%) occur as an ischemic stroke. Stroke, as in many countries, is the main cause of morbidity and long-term disability in developed countries (1).

In Turkey, cerebrovascular diseases are in the second place with 15% among the top 10 causes of death in all age groups (2).

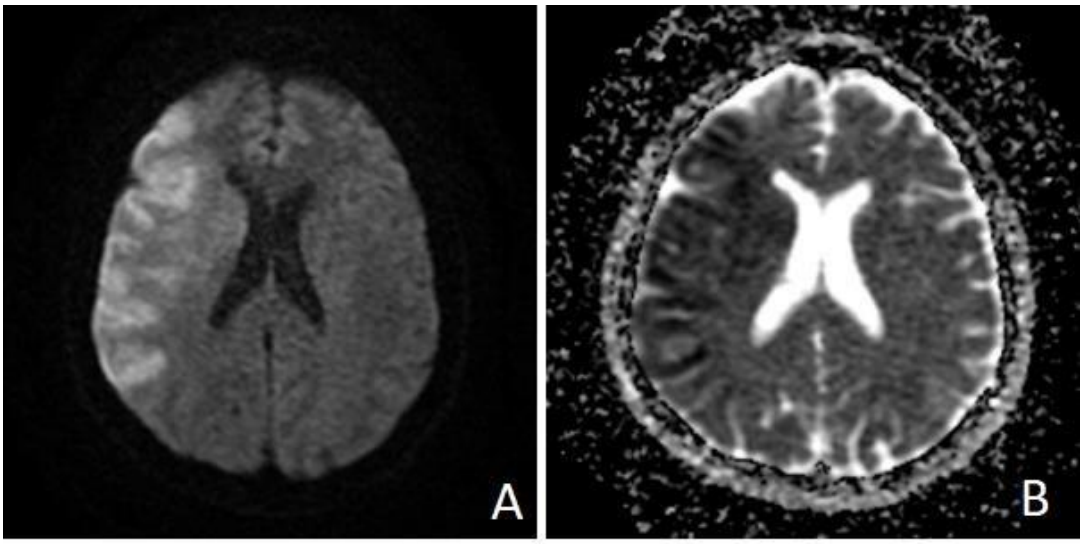
Malignant middle cerebral artery (MCA) infarction is a subgroup of stroke disease in which life-threatening widespread cerebral edema develops. Despite the lack of scientific data showing the benefits of decompressive hemicraniectomy (DHC) in patients with MCA infarction, the use of DHC procedure has been increasing gradually (3). In recent studies, DHC has been shown to reduce mortality and provide functional improvement, especially in young adults, in cases of malignant MCA infarction. However, the routine clinical use of decompressive hemicranectomy (DHC) is still under discussion due to the very high disability rate and postoperative physical dependencies among survivors (4).

In the presented study, patients with malignant middle cerebral artery (MCA) infarction, who underwent medical treatment or decompressive surgery and who underwent radiological and clinical follow-up were evaluated retrospectively. Post-operative follow-up and clinical outcomes were also evaluated.

Material and Methods

1240 patients who were admitted to Ordu University Training and Research Hospital between January 2015 - December 2018 and diagnosed with stroke were evaluated. Ischemic lesions were detected by cranial computed tomography (CT), diffusion weighted magnetic resonance imaging (DWI) and CT/MRI angiography; their locations were noted. Infarct areas were evaluated according to cerebrovascular territories and 94 patient with ICA and/or extensive MCA infarction (infarct area greater than 1/2 of MCA territory) was included in the study (Fig 1. A, B).

Figure.1 (A, B) *Right middle cerebral artery infarct (A) Diffusion weighted MRI (B) ADC map*



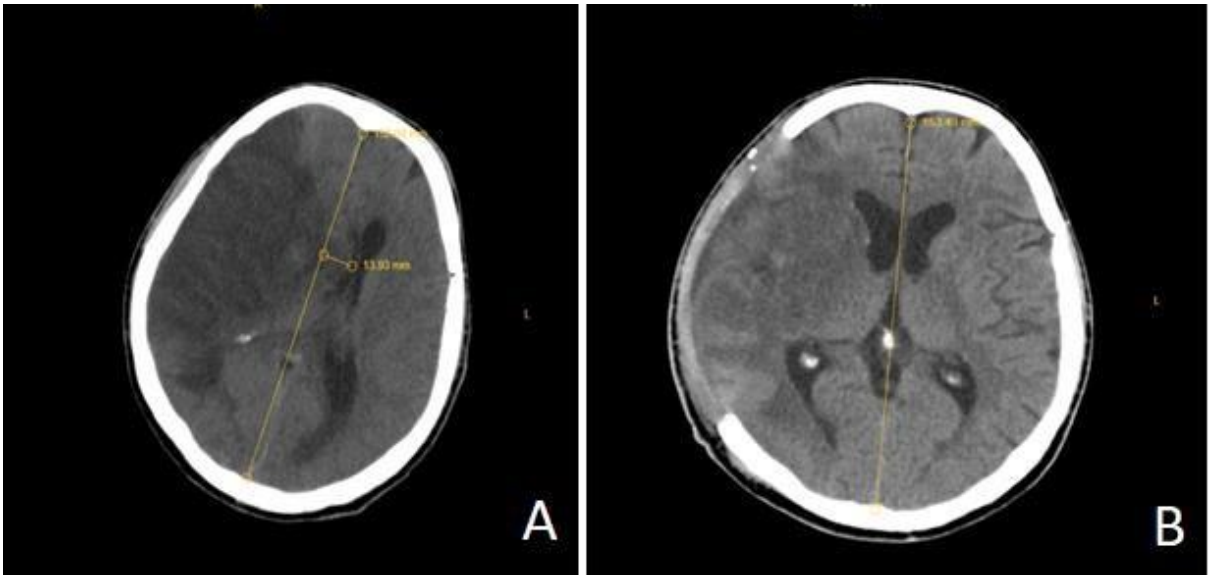
Surgical treatment is not planned for patients with known illness that interferes with surgical treatment, for patients with a modified Rankin Scale (MRS) (pre-stroke) score ≥2 and for patients with bilateral unresponsive dilated pupils. Apart from these, 11 patients who underwent wide decompressive hemicraniectomy and duraplasty - with a bone flap that extends beyond the infarction boundaries- due to progressive neurological worsening and herniation clinic were retrospectively evaluated. Detailed demographic data and neurological examinations of the patients included in the study were examined. Post-operative follow-up period, mortality rates and disability scores were noted. The modified Rankin Scale (mRS) was used to detect functional dependence and assess recovery (Table 1).

Table 1. *Modified Rankin Scale*

Score	Description
0	No symptoms at all
1	No significant disability despite symptoms; able to carry out all usual duties and activities
2	Slight disability; unable to carry out all previous activities, but able to look after own affairs without assistance
3	Moderate disability; requiring some help, but able to walk without assistance
4	Moderately severe disability; unable to walk without assistance and unable to attend to own bodily needs without assistance
5	Severe disability; bedridden, incontinent and requiring constant nursing care and attention
6	Dead

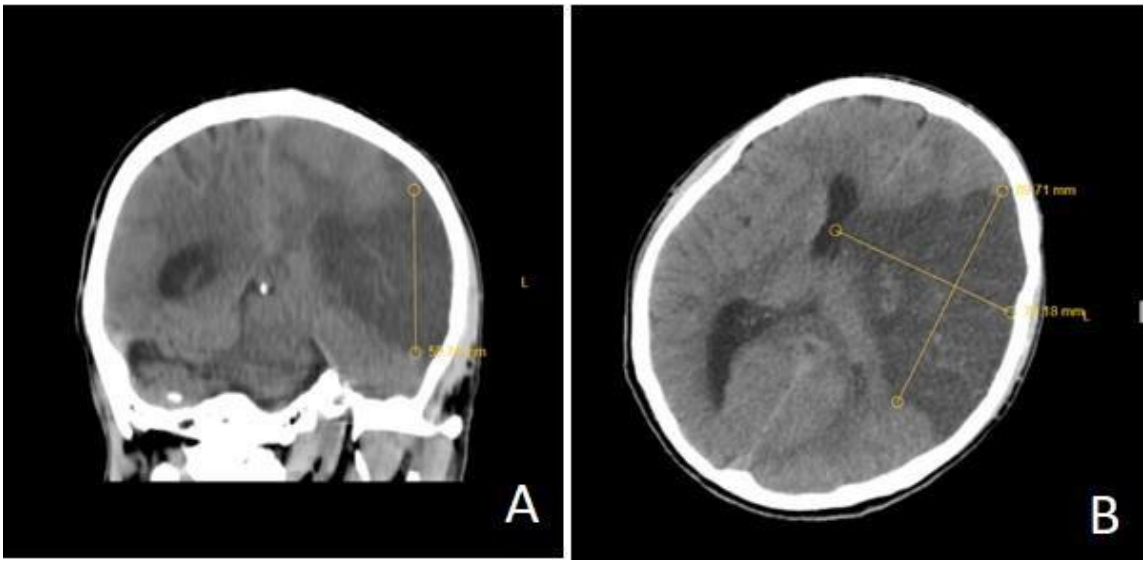
Unenhanced cranial CT (CT/CTA) and cranial magnetic resonance imaging (DWI, MRI, MRA) before and after surgery of all patients were reviewed to determine the degree of MCA and ICA stroke. Degree of stroke (stroke volume), craniectomy area preoperative midline shift, post-operative midline shift and improvement in midline shift were noted, respectively. (Fig 2. A, B)

Figure.2 (A, B) *(A) Preoperative axial CT of brain showing the left sided midline shift (13,80mm) (B) Postoperative axial CT of brain showing the improvement of midline shift*



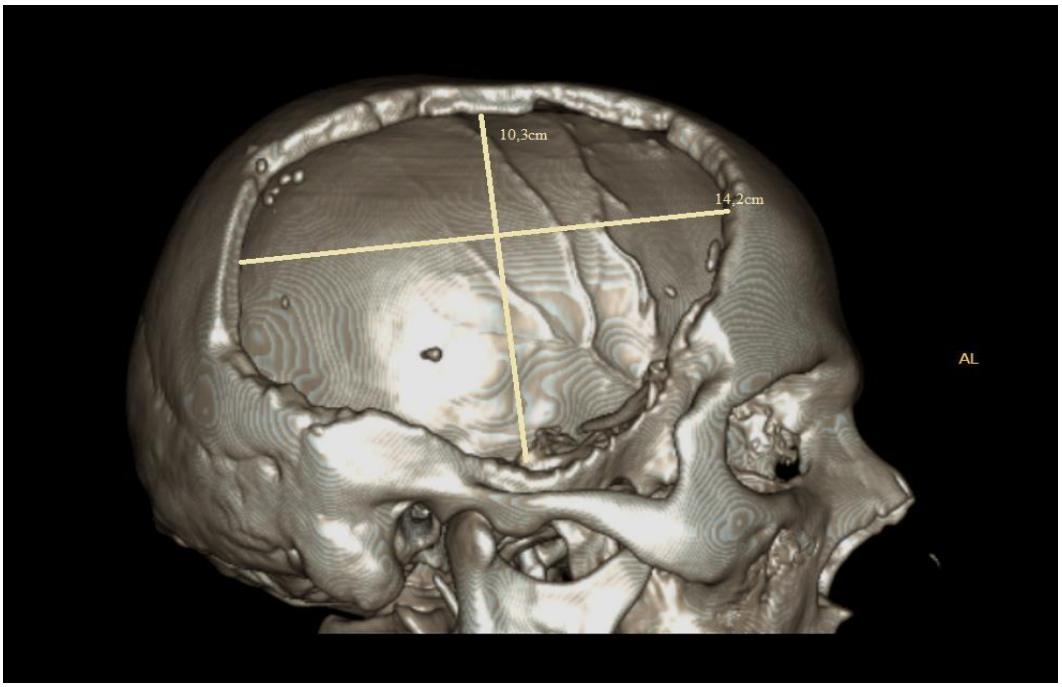
Infarct volume was calculated using the ABC/2 volume estimation of an ellipsoid, where A is the largest diameter on axial scan, B the largest perpendicular diameter on axial scan, and C the vertical diameter on coronal scan. These were measured on brain CT scans obtained within 24 hours of symptom onset.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

Figure.3 (A, B) *Preoperative CT of brain showing the left middle cerebral artery infarct measured using the ABC/2 method (A) Coronal scan (B) Axial scan*



The length, width, and area of the craniectomy boneflap were measured from the immediate postoperative brain CT scan. The area of bone flap was defined as A=D×d×π (D is the anteroposterior diameter, d is the diameter perpendicular to D of boneflap) (Figure 4).

Figure.4 *Three-dimensional reconstruction of the postoperative brain CT showing the anteroposterior diameter and width of the craniectomy bone flap.*



The statistical analysis of the study was done with SPSS 20.0 program. The data obtained in our study were analyzed with descriptive statistical methods. Central tendency measures, central distribution measures, frequency analysis and ratio analysis techniques have been applied

Results

1240 patient who applied to the center for ischemic svo were evaluated retrospectively. Despite effective and appropriate medical treatment, 11 (%12) patients who had worsened neurological examination during the follow-up and decided to undergo surgery were included in the study. As a surgical procedure, wide unilateral hemicraniectomy + wide duraplasty procedure was applied. Post-operative 3D cranial CT scans of two patient were shown above in Figure 4.

Despite medical treatment, a total of 11 ischemic svo patients, 6 men and 5 women, who showed clinical progression within 36-72 hours, underwent decompression surgery. The mean age was 63 (min:53, max:73). Five patients had left middle cerebral artery (OSA) infarction, 5 patients had right middle cerebral artery (OSA) infarction, one had internal carotid artery (ICA) infarction. Modified Rankin Score (mRS) before surgery was evaluated as 5 in 10 patients and 4 in 1 patient. Pre-operative Glaskow coma scale of patients ranges from 9 to 12. All patients had midline shifts, while 8 patients also had unisocoria. The time between the patients' admission to the hospital with the diagnosis of acute ischemic svo and their surgery varied between 36-72 hours. More than half of the cases had a history of primary hypertension (81%) and atrial fibrillation (73%) (Table 2).

Table 2. *Demographic data of the patients*

Patient	Age	Gender	GKS	Anizokori	Midline Shift	Surgery Time	Infark Area	HT	DM	Cigarette	AF	MD	Speech Disorder	Survival
1	53	E	9	+	+	36	Right MCA	+	-	-	-	5/5-1/5	Improve	+
2	54	E	10	+	+	48	Left MCA	+	-	+	+	5/54/5	Motor Aphasia	+
3	73	K	9	+	+	52	Ica	+	+	-	+	5/5	-	EX
4	71	K	11	+	+	60	Right MCA	+	+	-	+	5/5	-	EX
5	68	E	10	+	+	56	Left MCA	+	+	+	+	4/54/5	Motor Aphasia	+
6	65	K	12	-	+	48	Right MCA	+	-	-	-	5/55/5	S/M Aphasia	+
7	71	E	11	-	+	72	Right MCA	+	-	-	-	5/55/5	Improve Dysarthria	+
8	61	K	9	+	+	36	Left MCA	-	+	-	+	4/53/5	S/M Aphasia	+
9	63	E	10	+	+	48	Right MCA	+	-	+	+	5/55/5	Motor Aphasia	+
10	68	K	10	-	+	64	Left MCA	+	+	-	+	4/53/5	Improve Dysarthria	+
11	66	E	9	-	+	70	Left MCA	-	-	+	+	5/54/5	S/M Aphasia	+

The post-operative follow-up period of the operated patients varies between 14-60 days. Significant improvement was detected in the neurological examination of 7 (64%) patients. Survival was observed in 9 patients (82%). One patient with a right middle cerebral artery infarction died due to widespread posterior system infarction and an ICA infarct patient died due to post-operative clinical worsening and additional complications.

The average shift values of 11 patients, decreased from 10,04 to 3,6 postoperatively. The mean craniectomy area was found to be 412,17 (391.3-448.8), and the craniectomy area was above the average in 2 cases with the highest neurological and functional recovery. The average stroke value was measured as 188.7, and it was seen that 2 patients whose stroke value and preop midline values were highest were dead (Table 3).

Table 3. *Radiographic parameters for patients who had hemicraniectomy*

	Midline shift prior to DHC (mm)	**Midline shift after DHC (mm)**	**Improvement in midline shift after**	**Craniectomy area (cm^3)**	**Stroke volume (cm^3)**
1	13.8	0	13.8	439.6	165
2	11.24	0	11.24	448.8	152
3	12	9	3	391.3	264
4	10	8	2	396.4	269
5	8	3	5	406.2	169
6	10.2	5.4	4.8	412.4	175
7	9.8	4.4	5.4	408.1	172
8	12.7	3.8	8.9	401	183
9	8.9	1	7.9	425.2	187
10	4.3	3	1.3	398.3	176
11	9.6	2.3	7.3	406.6	164
Avg.	10.04	3.6	6.42	412.17	188.72

Discussion

Malignant MCA infarction is defined as a large MCA infarction that leads space-occupying mass effect due to the associated cytotoxic edema and occurs in 10% of all stroke patients. It presents with acute brain swelling in the first 48 h after stroke, resulting in elevated intracranial pressure (ICP) or brain herniation. Malignant MCA infarction is associated with about 80% mortality rate despite appropriate medical treatment. There is a strong relationship between ischemic brain volume (stroke volume) and mortality (5).

For the first time, Clarke and Harris suggested performing decompressive surgery on this lesion that had an intracranial mass effect (5). Decompressive hemicraniectomy has recently been accepted as an appropriate treatment method for patients with malignant MCA infarction. Studies have shown its effectiveness in reducing mortality and morbidity due to malignant ischemic stroke. In the literature, decompressive cranioectomy has been shown to reduce mortality from 80% to 30% (6). However, indication, timing, surgical technique to be applied to the patient and patient selection are still controversial in ischemic SVO. Nevertheless, it has been shown to reduce mortality in refractory intracranial hypertension and neurological worsening despite medical treatment (7).

There are contradictory data in the literature regarding the time of surgery, the surgical procedure to be performed and the selection of the appropriate patient. In their study, Gupta R et al evaluated the timing of decompressive craniectomy, and no significant difference was found when comparing the clinical results of patients who were operated early (first 24 hours) and those operated late after 24 hours (8). In their study, Foerch C, Lang et al stated that the loss of function is independent of the surgical timing (9). In our study, patients were operated at the earliest 36 hours after receiving a diagnosis of SVO, following their clinical deterioration in their neurological follow-up. Therefore, it is defined as late surgery. Similar to our study, Orakdöğen et al in their study were evaluated mortality rates (73.5%) of patients who underwent late decompresive craniectomy. When both studies were compared, it was found that mortality rates (18%) were lower in our study. It was thought that this result may be due to the differences in the demographic data of the patients participating in the studies, the difference of the co-morbid diseases that may cause mortality and morbidity, and the surgical technique.

Although there are studies stating that there is no significant difference between the clinical outcomes of patients who underwent decompressive hemicraniectomy, most clinicians have stated that the mortality is high in surgeries performed after the age of 60 (10). In the presented study, the average age of two patients with the highest rate of neurological improvement and functional recovery was 52.5.

After decompressive hemicraniectomy, a reduction in mortality was observed in patients with malignant MCA infarction. Despite DHC, the rate of herniation causing death in patients with malignant MCA infarction is reported to be between 11% and 22%. However, these rates

have been shown to decrease with extensive decompressive hemicranectomy and duraplasty, with a bone flap that extends beyond the infarction boundaries, as in our study (12). In accordance with the literature, the mortality rate in the study was determined to be 18.18%.

In studies evaluating the relationship between neurological improvement and mortality according to radiological parameters; midline shift >10 mm, presence of additional vascular area, involvement of basal ganglia, large infarction volumes and smaller cranioectomy length were found to increase mortality and morbidity. In a study conducted by Pullicino et al. midline shift was shown to be associated with mortality (11). In the presented study, all operated patients had midline shift with an average value of 10,04 mm and extensive decompression hemicraniectomy was applied to all of them. Midline shift prior to DHC, midline shift after DHC, improvement in midline shift after DHC, craniectomy area and stroke volume were measured.

In accordance with the literature, the average shift values of 11 patients, decreased from 10,04 to 3,6 postoperatively. The mean craniectomy area was above the average in 2 cases with the highest neurological and functional recovery. Patients with highest value of stroke volume and preop midline shift were ex. The data obtained in our study are consistent with the results of other studies that underwent extensive decompressive craniectomy (13).

Malignant MCA infarction is a severe form of ischemic stroke. Serious loss of function and life-threatening conditions can occur in a significant proportion of patients with ischemic stroke. Therefore, it is of great importance to select the appropriate treatment method in patients with SVO. Decompressive hemicraniectomy is an effective part of treatment in cases resistant to medical therapy. However, it is difficult to predict which patient will benefit from decompressive surgery at the time of application and it is a situation that each patient should be evaluated meticulously on its own.

Limitation

This study is a retrospective, single centered study with a small sample size. However, the majority of single-center studies in the literature that address mortality have similar dimensions and retrospective design. Due to the small sample size, only descriptive statistical analysis have been done. Therefore, possible relationships between parameters that may affect mortality and morbidity could not be evaluated using basic statistical methods.

Conclusion

In the direction of the study, it was believed that, with strict radiological and clinical follow-up, extensive decompressive craniectomy that will be applied to young patients with an agreeable neurological grade in the early period will increase survival and functional recovery. These findings should be supported by multicentre, long-term studies with a large number of patients.

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Correspondance:
Ali Yılmaz, MD.
Ordu University, Faculty of Medicine, Department of Neurosurgery, Ordu, Turkey
Tel: +90.531.7903366
E-mail: draliyilmaz19@gmail.com