ORIGINAL ARTICLE

Role of early decompressive craniectomy in traumatic brain injury: Our clinical experience

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ABSTRACT

BACKGROUND: Traumatic brain injury (TBI) is an important cause of death, especially in underdeveloped and developing countries. Diffuse edema in the damaged cerebral tissue as a result of trauma and the subsequent increase in intracranial pressure cause significant neurological deterioration. Consequently, decompressive craniectomy (DC) is performed as the surgical treatment of TBI. The aim of this study is to evaluate the post-operative mortality and morbidity rates of patients who underwent DC for TBI in our clinic.

METHODS: The data of 57 cases of TBI were retrospectively analyzed. Clinical, radiological and surgical features of these cases were reviewed. The rates of mortality and morbidity, as well as main indicators of mortality were investigated.

RESULTS: Twenty-five (43.8%) patients were female and 32 (56.1%) were male. The mean age was 54.5 years. Fourteen (24.5%) patients were presented with subdural hematoma, 5 (8.7%) with epidural hematoma, 18 (31.5%) with intracerebral hematoma, 13 (22.8%) with subarachnoid hemorrhage, and 7 (12.2%) with other radiological findings. DC was performed in all cases as soon as possible after admission. Twelve (21.1%) patients died in the first 3 days postoperatively and 7 (12.2%) patients in the postoperative 3-15 days due to progressive cerebral damage and secondary infections. Six (10.5%) patients recovered completely and were discharged. Thirty-two (56.1%) patients were transferred to palliative care clinics and physical therapy clinics after the surgical treatment.

CONCLUSION: DC, which is performed in the early period of treatment in TBI, is as important as the degree of intracerebral damage at the time of admission and the high Glasgow coma scale score. Post-operative results are more satisfactory in patients who underwent DC at an earlier stage of treatment.

Keywords: Decompressive craniectomy; outcome; surgery; traumatic brain injury.

INTRODUCTION

Traumatic brain injury (TBI) is a condition characterized by diffuse edema and increased intracranial pressure (ICP), which occurs as a result of the damage to the cerebral tissue following a trauma involving the intracranial area. In these patients, decreased level of consciousness and amnesia can be seen with other neurological or neuropsychological abnormalities.[1–3] According to the mechanism of injury, TBI is divided into two classes as closed (non-penetrating) and penetrating injuries. TBI is a major health problem worldwide. 69 million individuals are estimated to have TBI each year in the world,[2,3] and a significant proportion occurs in low- and middle-income countries.[2] While motor vehicle accidents and falls are the most common causes of TBI-related deaths in the civilian population, gunshot injuries are the most common cause of TBI-related deaths in military personnel.[4] In general, TBI is known to be more common in people between 25 and 75 years old. TBI occurs at a younger age in men compared to women. Its incidence in men is from 1.2 to 4.6 times higher in comparison to women.[2,3,5]

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The management of cerebral edema and high ICP plays a key role in the treatment of TBI.[6] The main purpose of the algorithms used in TBI management is to prevent and treat the pathological increase in ICP, which can endanger cerebral perfusion and cause more neurological deterioration and brain herniation, which threatens life. Therefore, medical and surgical options have emerged in the treatment of TBI. Anti-edema drugs used in medical treatment are therapies used to reduce ICP by affecting the patient's hemodynamics. Whereas, decompressive craniectomy (DC) is used in surgical treatment.

DC is the removal of a sufficiently large skull fragment to facilitate the reduction of ICP and the maintenance of cerebral physiological balance to prevent neurological deterioration. DC was first suggested to patients by Theodor Kocher.[7] Later, Cushing wrote about subtemporal and suboccipital decompression procedures to alleviate high ICP in patients with inoperable brain tumors in 1905.[8] There are two technical points that are very important in DC. The first one is that the bone to be extracted for decompression is of sufficient size. Because craniectomy that is not large enough can lead to venous infarction by causing herniation of cerebral tissue. The second is to perform a large duratomy.[9–13] DC may occasionally cause important early and late complications such as post-operative seizures, subdural hygroma, hydrocephalus, and infection.

In this study, we aimed to retrospectively examine patients who underwent DC for TBI in our clinic between 2015 and 2021 and evaluate the relationship between surgery and post-operative mortality-morbidity in TBI.

Table 1. Basic characteristics of 57 patients with TBI who underwent decompressive craniectomy

	Number (%)
Etiology	
Traffic accident	23 (40.3)
Fall	21 (36.8)
Gunshot injury	13 (22.8)
Intracranial radiological abnormality	
Subdural hematoma	14 (24.5)
Epidural hematoma	5 (8.7)
Subarachnoid Hemorrhage	13 (22.8)
Intracerebral hematoma	18 (31.5)
Others	7 (12.2)
Glaskow Coma Scale	
<8	45 (78.9)
8–12.	10 (17.5)
>12	2 (3.5)
Decompressive craniectomy time (h)	
<6	23 (40.3)
6–12.	16 (28.1)
>12	18 (31.5)
Postoperative outcome	
Alive	38 (66.6)
Exitus	19 (33.3)

TBI: Traumatic brain injury.

MATERIALS AND METHODS

Patient Population

Ethics committee approval was obtained for the study (2021/170). We analyzed 57 cases who admitted to our clinic between January 2015 and December 2021, who developed TBI and subsequently underwent DC. 25 (43.8%) of the cases were female and 32 (56.1%) were male. The youngest case was 1-year-old and the oldest patient was 82 years. The average age was 54.5 years. Etiological factors belonging to the cases are given in Table 1.

Clinical and Radiological Evaluation

All cases were consulted to us after their admissions to the emergency department. Afterward, detailed neurological examinations of the patients were performed and scored using Glasgow coma scale (GCS). Brain computed tomography (CT) and diffusion magnetic resonance imaging (MRI) were routinely performed in all cases (Figs. 1 and 2). In addition, CT angiography was performed in cases with subarachnoid hemorrhage and diffusion restriction in MRI. All cases were admitted to the intensive care unit (ICU) after radiological and clinical evaluations. When the cases are scored based on GCS in admission; GCS score was found to be <8 in 45 (78.9%) cases, 8–12 in 10 (17.5%) cases, and >12 in 2 (3.5%) cases (Table 1).

Surgical Technique

In all cases, surgery was planned as soon as the necessary conditions for surgical intervention were met. In all cases, mannitol (1 mg/kg) was started as an anti-edema treatment before the surgical intervention and this treatment was continued throughout the operation. Antiaggregant-anticoagulant drug usage of the patients was questioned before surgery. Thrombocyte infusion was given to patients using acetyl salicylic acid whereas Vitamin K was given to patients using Warfarin. Hematoma evacuation and DC were performed in cases with epidural hematoma, subdural hematoma, and intracerebral hematoma.

As a surgical technique, after the patient was intubated and stabilized hemodynamically by the anesthesiologist, a wide skin incision was made only in the area of the cranium with pathology or in both hemicraniums in the presence of diffuse bilateral edema. Frontotemporoparietal craniectomy or suboccipital craniectomy in the posterior fossa was per-

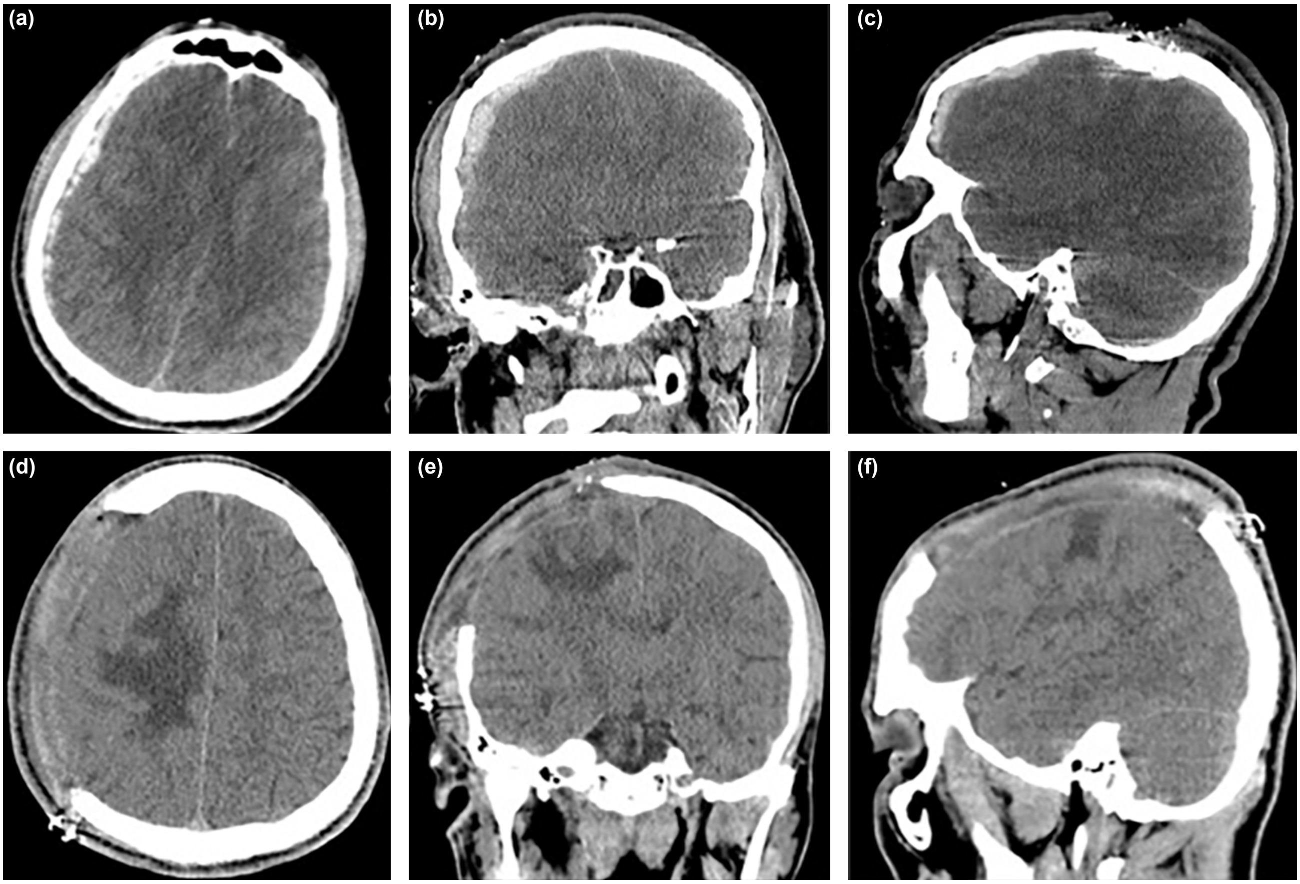

Figure 1. (a-c) Pre-operative Axial, Coronal and Sagittal Brain tomography (BT) images, **(d-f)** Post-operative 25th day, Axial, Coronal and Sagittal BT images. A 26-year-old male patient was brought to the emergency room after a gunshot wound. Glaskow coma score (GCS) was 7. A displaced fracture in the right parietal bone and acute subdural hematoma were detected in the brain tomography (BT) imaging **(a-c)**. The patient was immediately taken into surgery, the hematoma was evacuated and a decompressive craniectomy was performed **(d-f)**. The patient was followed up in the intensive care unit in the post-operative period, and a tracheostomy was performed on the post-operative 15th day. On the post-operative 35th day, the patient was transferred to the physical therapy center. It was observed that he could walk without support in the post-operative 3rd month.

formed in accordance with the lesion location closest to the skin borders. During this process, bone was drilled up to the floor of the middle fossa. The dura was opened, close to the craniotomy margins. Hematoma was evacuated in cases with intracerebral and subdural-epidural hematoma. Subsequently, the dura mater was sutured to the surrounding dura mater in several places with the help of a synthetic dura mater graft so as not to put pressure on the cerebral tissue. The skin flap was closed properly by placing a drain in the epidural area.

RESULTS

Anti-edema medication and other supportive treatments continued in the early postoperative period in all cases. Twelve (21.1%) of the patients who were taken to the ICU during the post-operative period died within the first 3 days, and 7 (12.2%) within 3–15 days due to progressive cerebral damage, diffuse intracerebral edema, and secondary infections. The average length of stay in hospital was 168 days (1–205). Six (10.5%) patients recovered completely and were discharged at home. Thirty-two (56.1%) cases were transferred to palliative care clinics and physical therapy clinics after intensive care follow-up. To the treated cases; because of large skull defects rendering the brain unprotected and dysregulation of ICP, 16 cranioplasty was performed using their own bone flaps, and nine using titanium cranioplasty material produced by 3D reconstruction.

DISCUSSION

TBI continues to be an important source of morbidity and mortality in the USA and worldwide, accounting for about a third of injury-related deaths.[5,14–16]

Traumatic hematomas are present in approximately 45% of severe TBI cases.[17] Acute subdural hematomas are found in about a third of patients with severe TBI.[3] Acute subdural hematomas (ASDH) are also often associated with the presence of intraparenchymal contusions or hematomas and a tendency for brain edema.[18,19] Numerous studies in TBI patients have shown that intracranial hypertension is associated with a higher risk of death.[20–22]

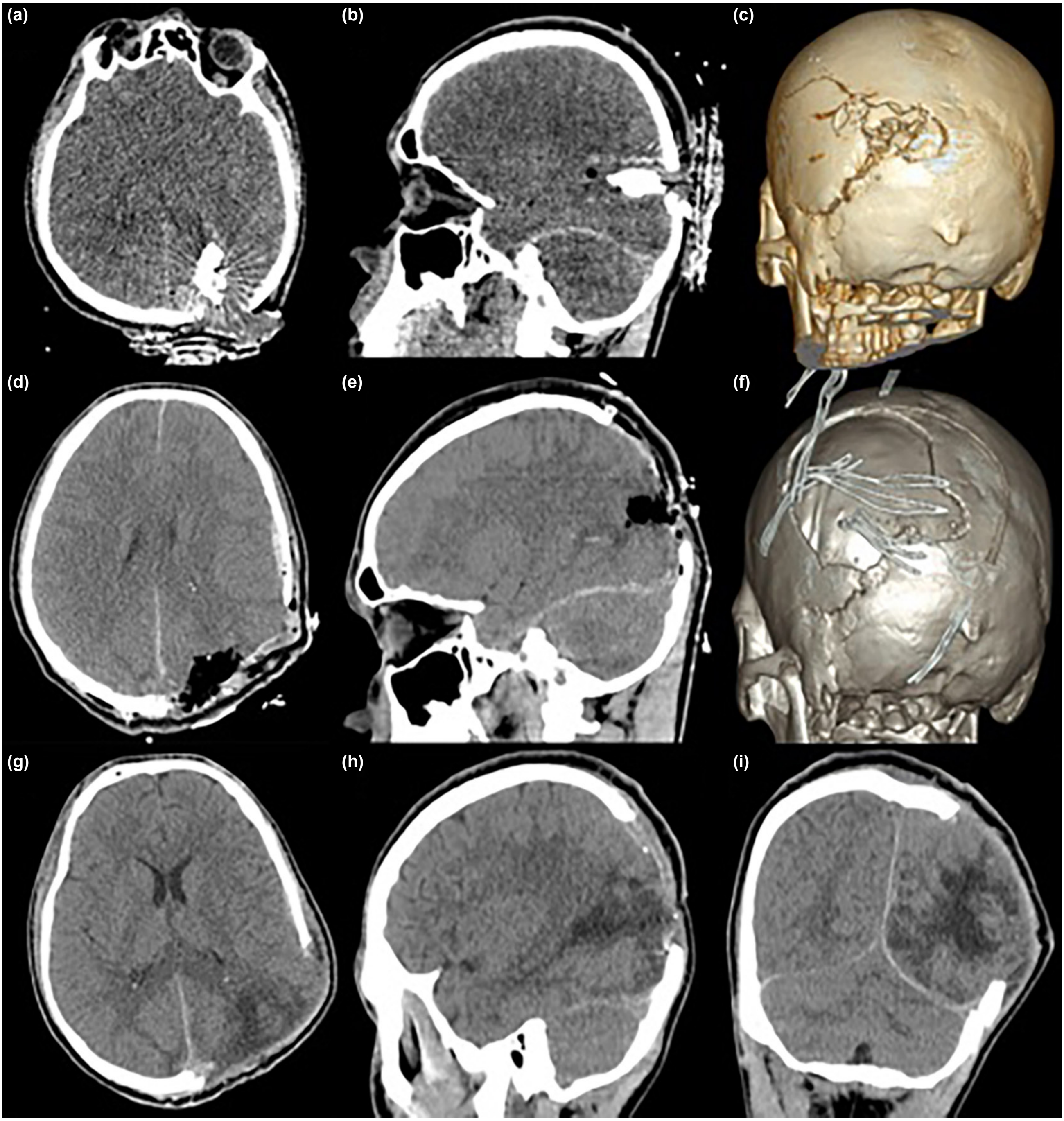

Figure 2. (a-c) Pre-operative axial, sagittal, and 3D brain tomography (BT) images. **(d-f)** Early post-operative period, axial, sagittal, and 3D BT images. **(g-i)** Post-operative 15th day, axial, sagittal, and coronal BT images. A 17-year-old male patient was brought to the emergency room after a gunshot wound. GCS was 9. A displaced fracture in the left occipital bone and foreign body and bone materials were detected in the intraparenchymal region in the brain tomography (BT) imaging **(a-c)**. The patient was immediately taken into operation. Foreign bodies were removed and decompressive craniectomy was performed **(d-f)**. The patient, who was intubated in the intensive care unit in the post-operative period, was extubated on the post-operative 15th day **(g-i)**. He was discharged on the post-operative 27th day while in normal neurological condition.

ICP monitoring provides physiological information about the underlying benefits of the surgical intervention. Critical elevation of the ICP disrupts the cerebral perfusion pressure by limiting the effective cerebral blood flow, and this situation causes adverse neurological consequences by reducing the oxygenation of the brain tissue. consequently, increased total time in patients with ICP >20 mm Hg is associated with increased morbidity and mortality.[23]

DC is widely used in neurosurgery as a palliative therapy to alleviate high ICP in people with inoperable brain tumors, hydrocephalus, or head injuries.[1,24,25] Decompressive surgery for increased ICP is aimed to improve cerebral perfusion, prevent ischemic damage and avoid mechanical compression of the brain. The rationale for decompressive surgery is based on the Monro-Kellie law.[26] According to this theory, the intracranial volume should remain constant, so the balance between the cerebrospinal fluid (CSF) and the cerebral blood volume ensures that the ICP remains constant. Removal of the bone in the required size without suturing or suturing the dura mater is a fast and effective method to decrease ICP by increasing intracranial volume. Although surgical decompression does not have a proven effect on primary brain injury, it can reduce damage caused by secondary factors (delayed brain injury) such as brain herniation and elevated ICP.

DC can involve many different procedures. Unilateral or bilateral frontotemporoparietal craniectomy or posterior fossa craniectomy can be performed. In addition, the dura mater can be opened in one piece or by cutting in multiple places, and duraplasty can be performed using synthetic dura material to prevent tight closure.[27]

In the previous studies, it was considered that DC provided a limited benefit in TBI and its relative complications were higher. In addition, the use of hyperosmolar agents (urea, glycerol, and mannitol) and corticosteroids in the treatment of patients with high ICB has reduced the need for this surgical intervention by most neurosurgeons. However, since the early 2000 s, both clinical and experimental studies have shown that DC significantly reduces post-traumatic increased ICP. In addition, these studies have proven that DC improves ICP dynamics, brain oxygenation, and brain metabolism in patients with refractory high ICP.[23,28]

DC surgery is frequently used in many centers that manage acute brain injuries, especially by military neurosurgeons specializing in gunshot wounds.[29–32]

In a study reported by Josan and Sgouros, four patients with GCS scores ranging from 3 to 8 underwent DC within 2–10 h after injury. Pre-operative ICP levels in these patients ranged between 28 and 36 mm Hg, while post-operative ICP values were reported to range between 9 and 16 mm Hg. At 1-year follow-up, all patients had a GCS score of 4–5.[33]

Jagannathan et al.[34] in the pediatric group of 23 patients who underwent DC due to TBI, it was reported that the time elapsed until surgical intervention after admission was long, patients with high ICP in the pre- and post-operative periods were exposed to long-term neurological deficits and were mortal. Early DC has a key role in the current management of severe TBIs in both the adult and pediatric population. The aim of such an intervention is to completely control the levels of ICP that do not decrease and cannot be controlled with the first maximal medical treatment. Reducing the ICP at the earliest time with surgical intervention may reduce pathological cascades.[35] Fatima et al.[24] in a study conducted in an adult population, they supported the efficacy and safety of early DC after TBI, but stated that more studies are needed for the efficacy of early decompression in terms of mortality.

There are some studies evaluating that early DC significantly reduces the risk of death and major disability.[36–40] Taşkapılıoglu et al.[41] reported that they performed surgery within 4 h at the latest in seven cases with DC after TBI in the pediatric age, and that all cases survived in the post-operative period. In our cases, 23 cases were operated within the first 6 h, 16 cases within 6–12 h and 18 cases for more than 12 h and 66.6% (n=26) of the cases benefited from surgery.

In many studies examining patients who underwent DC after TBI, mortality rates were reported to be between 10-36% during the 6-month follow-up period.[1,42,43] In our cases, the mortality rate was 33.3% (n=19).

The DECRA study is a randomized, multi-agency, and multinational clinical trial aimed at determining whether DC improves functional outcome in patients with intracranial hypertension who do not respond to maximal medical therapy.[1] Patients from Australia, New Zealand, and Saudi Arabia were included in the study between 2002 and 2010. The patients were between 15 and 59 years old. These patients were being treated in the ICU for severe, non-penetrating TBI. In this study, although a decrease in IDB was detected in the post-operative period, negative results were found in 70% of the patients in the craniectomy group and 51% of the patients in the control group during the 6-month follow-up.[1,25]

DC is a life-saving procedure when performed for properly selected patients and therefore there has been a dramatic increase at the performed procedure rate.[44] However, complications such as bleeding, infection, CSF fistula, subdural hygroma, hydrocephalus, and Trephine syndrome (sinking skin syndrome) may occur after DC.[45–49]

Cranioplasty operations are performed to protect brain tissue, prevent the sinking skin flap syndrome and regulate the cerebral hemodynamics in patients whose general condition improves in the post-operative period. This is sometimes performed with the patient's own preserved bone flap and sometimes with titanium-containing cranioplasty materials produced by three-dimensional reconstruction. We also performed cranioplasty in 16 of our cases with their own bone flaps and 9 of them using titanium cranioplasty material produced by 3D reconstruction.

Conclusion

The aim of the treatment of patients with TBI is to reduce the ICP, improve regional perfusion, reduce midline shift, and prevent fatal compression of the brain stem due to edematous brain. Therefore, DC is an effective and safe intervention that should be recommended to patients. Although there are studies showing that early DC affects mortality and morbidity, more studies are needed for clear evidence.

Ethics Committee Approval: This study was approved by the Health Sciences University Gulhane Scientific Research Ethics Committee (Date: 08.04.2021, Decision No: 2021/170).

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Travmatik beyin hasarında erken dekompresif kraniyektominin yeri: Klinik deneyimimiz

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AMAÇ: Travmatik beyin hasarı özellikle geri kalmış ve gelişmekte olan ülkelerde önemli bir mortalite nedenidir. Serebral dokunun etkilenmesi etkilenmesi nedeniyle, kafa içi basınç artışı ve yaygın ödem sonucu ciddi nörolojik disfonksiyonlarla kendini gösteren bu tabloda, dekompresif kraniyektomi cerrahi tedavi modalitesi olarak kullanılmaktadır. Bu çalışmanın amacı, travmatik beyin hasarı nedeniyle kliniğimize başvuran ve dekompresif kraniyektomi yapılan olguların ameliyat sonrası mortalite ve morbidite oranlarını değerlendirmektir.
GEREÇ VE YÖNTEM: Farklı nedenlere bağlı olarak travmatik beyin hasarı gelişen 57 olgu incelendi. Olguların 25'i (%43.8) kadın, 32'si (%56.1) erkek'ti. Olgularda ortalama yaş 54.5'di (1–82). Olguların 14'ü (%24.5) subdural hematom, beşi (%8.7) epidural hematom, 18'i (%31.5) intraserebral hematom, 13'ü (% 22.8) subaraknoid kanama ve yedisi (%2.2) de tanımlanamayan radyolojik bulgular ile başvurmuştu.
BULGULAR: Elli yedi olgunun tamamına başvuru sonrası en kısa sürede dekompresif kraniyektomi yapıldı. Ameliyat sonrası ilk üç günde 12 (%21.1), ameliyat sonrası 3–15. günler arasında ise yedi (%12.2) hasta ilerleyici serebral hasar ve sekonder enfeksiyonlar nedeniyle kaybedildi. Altı (%10.5) olgu tamamen iyileşerek taburcu edildi. İyileşen olguların 32'si (%56.1) palyatif bakım klinikleri ve fizik tedavi kliniklerine nakil edildi.
TARTIŞMA: Travmatik beyin hasarının tedavisinde hastanın başvuru anındaki nörolojik durumunun iyiliği ve intraserebral etkilenme derecesinin yanısıra erken dönemde yapılan dekompresif kraniyektominin etkinliği yüksektir. Daha erken süreçte dekompresif kraniektomi yapılan olgularda ameliyat sonrası sonuçlar daha yüz güldürücüdür.
Anahtar sözcükler: Cerrahi; dekompresif kraniyektomi; sonuç; travmatik beyin hasarı.

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