Original Research

Bagcilar Medical Bulletin 2018;3(2):20-25
DOI: 10.5350/BMB20180523070845

Clinical Outcomes and Factors Affecting the Outcome of Decompressive Craniectomy: Analysis of 50 Cases

Abdurrahim Tas[2], Feyza Karagoz Guzey[1], Burak Eren[1], Ilker Gulec[1], Azmi Tufan[1], Ozgur Yusuf Aktas[1], Ebru Doruk[1], Mustafa Safi Vatansever[1], Cihan Isler[3], Eyup Cetin[1]

ABSTRACT

Objective: Decompressive craniectomy (DC) is used as the last-stage method in the treatment of increased intracranial pressure (ICP). However, clinical outcomes reported in the literature are contradictory.

Methods: Medical records were retrospectively reviewed for 50 increased ICP cases that had been diagnosed and undergone DC at our hospital between February 2011 and February 2017. The patients' characteristics such as age, sex, presence of comorbidities, pre- and postoperative Glasgow Coma Scale (GCS) scores, blood pressure, hemoglobin values, radiological findings, DC time, width of craniectomy, length of stay in the intensive care unit (ICU), and Glasgow Outcome Scale (GOS) were recorded. According to their outcome, the patients were divided into two groups with good (GOS = 4-5) and poor (GOS = 1-3) prognosis, respectively, according to their last examination. It was evaluated whether these parameters showed significant differences between the groups and between the deceased patients and survivors.

Results: A total of 50 patients (35 male and 15 female) had been treated with DC. The mean age was 40.5±22.2 years. Head trauma was the etiology of increased ICP in 68% of the cases (n=34). The median of preoperative GCS was 6 (range: 3-15), and the mean midline shift on admission was 10.3±5.1 mm. Seventy-two percent of the cases (n=36) were treated with DC on the day of admission from the emergency department. The median of postoperative GCS was 7 (range: 3-15). The patients were followed up for a mean of 24.4 days in the ICU, and 30 patients were lost after a mean of 24.6 days. The survivors were followed up for a mean of 7.4±12.5 months.

Factors affecting survival periods were age of the patient, short edge length of the DC (not long edge) and early postoperative GCS score after the DC. The comparison between survivors and deceased patients showed that the mean age of survivors was significantly lower than that of deceased patients (p=0.047). Postoperative GCS scores after DC were significantly lower in the patients who had died (p=0.0001).

Conclusion: Age, short edge length of the craniectomy and postoperative neurological status are factors affecting surgical outcomes. These factors can play a role in selecting patient candidates who have to receive DC.

Keywords: Decompressive craniectomy, increased intracranial pressure, craniectomy, outcome

ÖZ

Dekompresif kraniektomi uygulanan 50 olgunun klinik sonuçları ve sondurumu etkileyen faktörlerin belirlenmesi

Amaç: Dekompresif kraniektomi (DK) kafa içi basınç (KİB) artışının tedavisinde son aşama yöntem olarak kullanılır. Ancak literatürde klinik sonuçlarla ilgili çelişkili sonuçlar vardır.

Yöntemler: Hastanemizde Şubat 2011 ile Şubat 2017 tarihleri arasında KİB artışı nedeniyle DK uygulanan 50 olgunun klinik sonuçları retrospektif olarak değerlendirildi. Hastaların yaşı, cinsiyeti, ek hastalıkları, girişim öncesi ve sonrası Glasgow Koma Skalası (GKS) puanları, kan basınçları, hemoglobin değerleri, radyolojik bulguları, DK zamanı, kraniektomi genişliği, yoğun bakım ünitesinde (YBÜ) takip süreleri ve Glasgow Sondurum Skalası (GSS) kaydedildi. Hastalar sondurumlarına göre iyi (GSS 4-5) ve kötü (GSS 1-3) olmak üzere iki gruba ayrıldı. Bu parametrelerin gruplar arasında ve ölen ve sağkalan olgular arasında anlamlı farklılık gösterip göstermediği değerlendirildi.

Bulgular: Toplam 50 olgunun 35'i erkek, 15'i kadındı, yaş ortalaması 40.5±22,2 idi. Olguların %68'inde neden kafa travması idi (n=34). Girişim öncesi GKS median 6 (3-15) idi. Orta hat şifti ortalama 10.3±5.1 mm idi. Olguların %72'si (n=36) acil polikliniktен yatırıldığı gün DK uygulandı. Girişim sonrası GKS median 7 (3-15) idi. Hastalar ortalama 24.4 gün YBÜ'sinde izlendi, 30 olgu ortalama 24.6 gün sonra kaybedildi. Sağ kalanlar ortalama 7.4±12.5 ay izlendi.

Sağkalım üstünde etkili bulunan faktörler hastanın yaşı, DK kısa kenar uzunluğu ve DK sonrası erken dönem GKS puanı idi. İyi ve kötü sondurumu olan olgular karşılaştırıldığında sağ kalan hastaların yaş ortalaması ölenlerden anlamlı olarak küçüktü (p=0.047). DK sonrası GKS düzeyleri ölen hastalarda anlamlı olarak küçüktü (p=0.0001).

Sonuç: Dekompresif kraniektomi uygulanan olgularda yaş, kraniektomi büyüklüğü, girişim sonrası nörolojik durum, sonucu etkileyen ve hasta seçiminde rol oynayabilecek önemli parametreler olarak saptandı.

Anahtar kelimeler: Dekompresif kraniektomi, kafaiçi basınç artışı, sondurum

[1]Health Sciences University, Bagcilar Training and Research Hospital, Neurosurgery Clinic, Istanbul, Turkey
[2]Health Sciences University, Gazi Yasargil Training and Research Hospital, Neurosurgery Clinic, Diyarbakir, Turkey
[3]Istanbul University, Cerrahpasa Faculty of Medicine, Department of Neurosurgery, Istanbul, Turkey

Corresponding author:
Abdurrahim Tas,
Health Sciences University, Gazi Yasargil Training and Research Hospital, Neurosurgery Clinic, Diyarbakir, Turkey
E-mail address: drabdurrahimtas@gmail.com

Date of submission: May 23, 2018
Date of acceptance: May 31, 2018

Citation: Tas A, Karagoz-Guzey F, Eren B, Gulec I, Tufan A, Aktas OY, et al. Clinical outcomes and factors affecting the outcome of decompressive craniectomy: Analysis of 50 cases. Bagcilar Medical Bulletin 2018;3(2):20-25. https://doi.org/10.5350/BMB20180523070845

Introduction

Traumatic brain injury (TBI) is an important public health problem all over the world (1-3). The most commonly reported causes for increased intracranial pressure (ICP) were hydrocephalus due to head injury, diffuse brain swelling, contusion, and intracerebral hematoma (4). Increasing intracranial pressure may cause ischemia in the brain due to decreased brain perfusion pressure (5). Decompressive craniectomy (DC) can be life-saving in increased ICP cases that are unresponsive to medical treatment and cerebrospinal fluid (CSF) evacuation (6). In this method, a part of the skull is removed and the underlying dura is enlarged, thus trying to reduce ICP (7). However, some clinical trials published recently showed that although DC decreases mortality by reducing ICP that was increased due to various causes, survivors may end up with a poor outcome.

This study retrospectively evaluated the clinical results of 50 patients who had undergone DC in our clinic for the treatment of increased ICP for various reasons with the aim to determine the factors affecting the outcome of DC.

Material And Methods

Patient Population

Medical records were retrospectively reviewed for 50 increased ICP cases that had been diagnosed and undergone DC at Bagcilar Training and Research Hospital between February 2011 and February 2017. The patients' characteristics such as age, sex, presence of comorbidityies, pre- and postoperative Glasgow Coma Scale (GCS) scores, neurological examination findings, pupil findings, blood pressure, hemoglobin values, radiological findings, DC time, width of craniectomy applied, length of stay in the intensive care unit (ICU), and Glasgow Outcome Scale (GOS) were recorded.

According to their outcome, the patients were divided into two groups, good (GOS=4-5) and poor (GOS=1-3), according to their neurological findings on last follow-up. It was evaluated whether these parameters showed significant differences between the good and poor groups and between the deceased patients and survivors.

Statistical Analysis

Statistical analysis was performed using the NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA) package.

In the evaluation of the data, descriptive statistical methods (mean, median, standard deviation) were used. For comparison of normally distributed variables between the two groups, an independent t-test was used. For comparison of abnormally distributed variables between pre- and post-intervention, paired t-test was used. According to the number of subjects, the chi-square test or the Fisher exact test were used to compare qualitative data. The Mann Whitney U test was used to compare the unpaired ordinary data and the Wilcoxon rank test for paired ordinary data. The significant level was set at $p<0.05$.

Results

A total of 50 patients (35 male and 15 female) were treated with DC. The mean age was 40.5±22.2 years. Head trauma was the etiology of increased ICP in 68% of the cases (n=34). The causes of the increased ICP are presented in Table 1.

Table 1: Causes of increased ICP in the patients.

Intracranial lesion	Pts No	%
Spontaneous intracerebral hematoma (ICH)	11	22
Acute subdural hematoma (ASDH)	10	20
Traumatic subarachnoid hemorrhage (tSAH) and ASDH	5	10
tSAH	4	8
Tumor	4	8
ICH and ASDH	3	6
Aneurysmal subarachnoid hemorrhage (aSAH)	3	6
tSAH and ICH	3	6
tSAH and ICH and ASDH	2	4
Epidural hematoma (EDH) and ASDH	1	2
tSAH and EDH	1	2
Depressed fracture and infarction	1	2
tSAH and infarction	1	2
Posttraumatic infarction	1	2
Total	50	100%

Table 2: Characteristics of DC time and other interventions.

Surgical Time	Only DC (n)	Mass Evacuation +DC (n)	Total (n)
In First 24 hours	6	30	36
After 24 hours	9	5	14

Table 3: Causes of reoperations other than cranioplasties (n=9).

No	Postoperative Day	Cause
1	2/6	EDH evacuation; external ventricular drainage (EVD)
2	20/28	EVD; EVD
3	22/29	Wound debridement; EVD
4	1/multiple times	EDH evacuation; EVD revision x 7 times
5	10	EVD
6	60	Removal of infected bone flap that placed in abdomen
7	1	EVD
8	90	Ventriculoperitoneal (VP) shunt
9	18	Duraplasty

The mean blood pressure on admission was 122/72 mmHg, and the mean hemoglobin level was 12.0±2.3 g/dl. The median of preoperative GCS was 6 (range: 3-15). The pupils were anisocoric in 25, bilaterally meiotic in 16 and bilaterally dilated in 9 patients.

Preoperative radiological examinations showed diffuse brain edema in 18 cases and intracranial hematoma in 44 cases. Types of lesions are listed in Table 1. The mean midline shift was 10.3±5.1 mm.

Decompressive craniectomy operations

In 72% of the cases (n=36), DC was performed within 24 hours after admission (early DC). In 30 out of these cases, evacuation of the space-occupying lesion (29 hematomas and 1 tumor) was performed in addition to the DC in the same operation (secondary DC). In 6 out of 36 cases, only DC (primary DC) was applied for diffuse brain edema without additional evacuation of intracranial hematoma or tumor (Table 2). In the remaining 14 patients, DC was applied due to findings during the follow-up period at the ICU after >24 hours (late DC) (in 9 of these cases primary DC and in 5 cases secondary DC) (Table 2).

The mean size of the craniectomy was 9.9x12.1 cm (120 cm^2). In two cases, bilateral DC was applied and in the remaining cases unilateral DC. Duraplasty was performed in addition to DC in 82% of the patients (n=41), and in 12% of the patients (n=6), durotomy was performed and left open. In 27 patients, the craniotomy bone flaps were placed under the abdominal skin, and in 20 patients, the craniotomy bone flaps were sterilized and kept in the refrigerator for use in cranioplasty in the same patient. In 3 patients, the bone flap was sutured in its original place with only one edge, while the other 3 edges were kept free (hinged craniotomy) during the DC session.

Postoperative course and complications

The median postoperative GCS was 7 (range: 3-15). Pupils were miotic in 48% of the patients (n=24), dilated in 32% (n=16), and anisocoric in 20% (n=10). The mean midline shift was 3.7±4.5 mm in the early postoperative period. Except for cranioplasty operations, nine patients (18%) required reoperation in the postoperative period. The causes for reoperation are given in Table 3.

The patients were followed up for a mean of 24.4±35.4 days in the ICU. Two patients contracted meningeal infections, 6 patients lung infections, 2 patients developed sepsis, and 2 patients suffered surgical site infection. In one patient with surgical site infection, the infection was under the abdominal skin where the craniotomy bone flap had been placed.

Thirty patients died after a mean of 24.6±42.6 days during ICU hospitalization. The survivors were followed up for an average of 7.4±12.5 months after DC operation. GOS scores at the final follow-up of the patients are given in Table 4. In 39 patients, the prognosis was poor (GOS 1-3), and in 11 cases, it was good (GOS 4-5) according to the patients' condition on last follow up.

Cranioplasty was performed in 15 cases after an average of 5.3±4.9 months from the DC operation. In 13 out of these patients, autograft bone, and in 2 patients, synthetic material

Table 4: GOS of the patients in last follow-up period.	
GOS	**n**
1	30
2-3	9
4-5	11

(methyl methacrylate) was used. In one of these patients, the cranioplasty flap was removed subsequently because of surgical site infection.

Factors affecting the outcome

The GCS values of surviving patients after DC were significantly higher than the preoperative level (p=0.023). In contrast, GCS values after DC in deceased patients were significantly lower compared to preoperative GCS values (p=0.012). Similar differences were also noted for pre- and postoperative midline shift values. While midline shift after operation was significantly lower in survivors, it was significantly increased in deceased patients (p=0.0001 for both groups). The pre- and postoperative ICP averages did not show any significant difference in the deceased and surviving patients (p=0.109 and p=0.180, respectively).

Age, sex, hemoglobin level, blood pressure level, length of ICU stay, midline shift pre- and post-DC, size of craniectomy, the DC time after trauma/cerebrovascular accident (CVA) (early versus late DC) and performing primary versus secondary DC were compared between deceased patients and survivors. The survivors were significantly younger than the patients who died (28 to 47, p=0.047). Post-DC GCS score was significantly lower in patients who died (p=0.0001), while no significant difference of pre-DC GCS scores was found between survivors and deceased patients. Of the craniectomy size parameters, only the length of the short edge affected the survival of patients, being significantly shorter in deceased cases. Other factors were not found to be effective for survival. A comparison between parameters for deceased patients and survivors is given in Table 5.

The same parameters were compared between patients with good and poor outcome. None of the parameters were found to be significant (Table 6).

Discussion

Traumatic brain injury (TBI) is a cause of high mortality and morbidity, especially in young adults. The main goal in the treatment of moderate/severe TBI is to reduce cerebral edema and to reduce increased ICP to maintain brain oxygen uptake (14). A similar situation is also valid for large cerebral and cerebellar infarcts. In both brain injury and ischemic lesions,

Table 5: Demographic, clinical and radiographic characteristics of patients and comparison between survivors versus deceased cases.

	Survival n:20	Deceased n:30	P
Age	32.98±19.59	45.63±22.72	0.047
Sex			
Male	15 (%75)	20 (%66.67)	0.529
Female	5 (%25)	10 (%33.33)	
SAP	126.45±37.16	126.87±33.31	0.967
DAP	66.4±27.09	65.17±15.86	0.840
Hemoglobin	12.13±2.24	12.03±2.44	0.876
ICU stay period (day)	34.55±42.87	17.73±28.27	0.101
Follow-up period (month)	18.2±14.48	0.83±1.45	0.0001
GCS			
Preop**	7 (4-13)	5 (3-15)	0.211
Postop**	8 (3-15)	3 (3-15)	0.0001
Midline shift (mm)			
Preop	10.63±5,32	10.09±5.01	0.719
Postop	2.65±3.65	4.51±4.92	0.153
Length of short edge (cm)	30.95	21.87	0.029
Length of long edge (cm)	27.85	23.93	0.349
DC area (cm²)	28.90	23.23	0.178
Early/late DC (n)	16/4	20/10	0.353
Primary/secondary (n)	6/14	10/20	0.804

**Median values are given as (minimum-maximum); significant p values are shown in bold characters; DAP: diastolic arterial pressure, DC: Decompressive craniectomy; GCS: Glasgow Coma Score; GOS: Glasgow outcome score; SAP: systolic arterial pressure

Table 6: Demographic, clinical and radiographic characteristics and comparison between good (GOS 4-5) and worse outcome cases (GOS 1-3).

	GOS 4-5 n:11	GOS 1-3 n:39	P
Age (years)	38.7	41.1	0.888
Sex			
Male	7	28	0.602
Female	4	11	0.602
SAP	129.6	125.9	0.557
DAP	78.5	69.7	0.205
Hemoglobin	11.9	12.1	0.935
ICU stay period (day)	19.5	25.8	0.590
Follow-up (month)	22.9	3.5	
GCS			
Preop	7 (4-12)	6 (3-13)	0.144
Postop	10 (5-15)	4 (3-15)	<0.001
Midline shift (mm)			
Preop	11.2	10.1	0.523
Postop	3.2	3.9	0.632
Length of short edge cm	10.1	9.6	0.083
Length of long edge cm	11.7	12	0.953
DC area cm^2	119.9	118.2	0.682
Early/late DC (n)	8/3	28/11	1
Primary/secondary DC (n)	3/8	13/26	1

**Median values are given as (minimum-maximum); significant p values are shown in bold characters; DAP: Diastolic arterial pressure, DC: Decompressive craniectomy; GCS: Glasgow Coma Score; GOS: Glasgow outcome score; SAP: systolic arterial pressure

medical treatment may be insufficient to prevent increased ICP. In these cases, DC may need to be applied. The goal is to remove a part of the cranium and open up the dura mater to gain space for edematous/infarcted brain tissue. This procedure aims to provide a reduction of ICP, increase the perfusion of brain tissue, and reduce negative effects on healthy brain tissue (8,9).

In fact, the DC operation, which has a long history, is still controversial today. Although DC improves both the survival and functional outcomes in malignant cerebral infarction patients, DC has not yet been proven in the treatment of patients with head injury (15). However, the importance of DC has been raised in head injury guidelines published in recent years, which recommend the use of DC after failed medical treatment in these cases (14). Different results have been reported in the literature regarding the application of DC in head injury. In contrast to previously published studies, the effects of DC on survival and functional recovery have shown positive results in studies published in recent years (10,14-16). However, a review published in 2017 supposed that DC for intracerebral hematoma and diffuse brain edema due to head injury cases applied early reduced the mortality but increased the rate of morbidity and led to severe neurological deficits (12).

In our study, we aimed to determine the factors affecting the outcome of DC after head injury or ischemic or hemorrhagic CVAs. We found that the most important parameter determining the outcome of DC was the age of the patient ($p<0.001$). Our results were concordant with the literature. It is well known that the prognosis for DC in head injury is better in younger patients (11,12). DC significantly reduces mortality and improves functional outcome in adult patients younger than 60 years, whereas in patients older than 60 years it reduces mortality only but does not improve the functional outcome. Therefore, Smith recommended that any decision for DC in elderly patients should be taken in view of the quality-of-life expectancies and according to their relatives' preferences (16).

Several studies reported that successful results in DC surgery are related to surgical technique (12,13). It has been recommended to perform durotomy, and the minimum diameter of unilateral DC should be about 11-12 cm (13). In our study, when we compared survivors with deceased patients, we found that there was no significant difference between the width of the craniotomy area and the length of the long edge of the craniectomy area, but the length of the short edge was found to be significantly higher in survivors. This finding suggested to us that all edges of the craniectomy area must be as long as possible to avoid squeezing of the herniated brain tissue in the craniectomy site.

The timing of DC varies according to the etiology of ICP. It is suggested that the DC surgery should be performed early in the occlusion of the middle cerebral artery before a worsening that may happen within the first 24 hours and before the appearance of herniation findings. In such cases, delayed surgery increases the severity of the neurological deficit (14,17). To date, there is no definite criterion for DC timing in head injury. According to our results, the time of DC, whether conducted on the day of the trauma/CVA or during the next days, did not impact the survival period or the GOS outcome.

This study has some limitations: first, it is a retrospective study that may suffer from inherent bias. Second, the sample size of our cohort is relatively small, and thirdly, we are evaluating different causes of increased ICP cases together. Further prospective surveillance studies with larger sample size, especially in severe head injury, will be helpful in establishing the effects of DC on outcomes.

In conclusion, the age of the patient was found to be the most important factor affecting the outcomes of DC. The length of the short edge of the applied craniectomy and the GCS score in the early post-DC period also had an impact on the outcomes of DC. Therefore, a large craniectomy in young patients was thought to have a positive effect on the patient's outcome.

Author contributions: Conception/Design of study - A.T., F.K.G., I.G., B.E., A.T., O.Y.A., E.D., M.S.V.; Data acquisition - A.T., F.K.G., I.G., B.E., E.D., M.S.V., C.I., E.C.; Data analysis/Interpretation - A.T., F.K.G., I.G., E.C., C.I., M.S.V., E.D., O.Y.A.; Drafting manuscript - F.K.G., A.T., A.T., I.G., B.E., O.Y.A., E.D., E.C.; Critical revision of manuscript - F.K.G., A.T., A.T., I.G., B.E., O.Y.A., E.D., E.C.; Final approval and accountability - A.T., F.K.G., I.G., A.T., B.E., O.Y.A., E.D., C.I., M.S.V., E.C.; Technical or material support - A.T.; Supervision - F.K.G., A.T.

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

Ethics Committee Approval: Ethics Committee approval was obtained from the local ethics committee.

Conflict of Interest: Authors declared no conflict of interest.

Financial Disclosure: Authors declared no financial support.

References

1. Goodman MD, Makley AT, Lentsch AB, Barnes SL, Dorlac GR, Dorlac WC, et al. Traumatic brain injury and aeromedical evacuation: when is the brain fit to fly? J Surg Res 2010;164(2):286-293. **[CrossRef]**
2. Wilson MH, Kolias AG, Hutchinson PJ. Neurotrauma – a multidisciplinary disease. Int J Clin Pract 2014;68(1):5-7. **[CrossRef]**
3. Ghajar J. Traumatic brain injury. Lancet 2000;356(9233):923-929. **[CrossRef]**
4. Badri S, Chen J, Barber J, Temkin NR, Dikmen SS, Chesnut RM et al. Mortality and long-term functional outcome associated with intracranial pressure after traumatic brain injury. Intensive Care Med 2012;38(11):1800-1809. **[CrossRef]**
5. Balestreri M, Czosnyka M, Hutchinson P, Steiner LA, Hiler M, Smielewski P, et al. Impact of intracranial pressure and cerebral perfusion pressure on severe disability and mortality after head injury. Neurocrit Care 2006;4:8-13. **[CrossRef]**
6. Holland M, Nakaji P. Craniectomy. surgical indications and technique. Neurotrauma 2004;7(1):10-15. **[CrossRef]**
7. Bor-Seng-Shu E, Figueiredo EG, Amorim RL, Teixeira MJ, Valbuza JS, de Oliveira MM, et al. Decompressive craniectomy: a meta-analysis of influences on intracranial pressure and cerebral perfusion pressure in the treatment of traumatic brain injury. J Neurosurg 2012;117(3):589-596. **[CrossRef]**
8. Woertgen C, Erban P, Rothoerl RD, Bein T, Horn M, Brawanski A. Quality of life after decompressive craniectomy in patients suffering from supratentorial brain ischemia. Acta Neurochir 2004;146(7):691-695. **[CrossRef]**
9. Mayer SA. Hemicraniectomy a second chance on life for patients with space-occupying MCA infarction. Stroke 2007;38(9):2410-2412. **[CrossRef]**
10. Balci K. Akut orta serebral arter infarktlı hastalarda dekompresif kraniyektomi tedavisi: Derleme. Türkiye Klinikleri J Neurol-Special Topics 2012;5(2):54-60.
11. Tu PH, Liu ZH, Chuang CC, Yang TC, Wu CT, Lee ST. Postoperative midline shift as secondary screening for the long-term outcomes of surgical decompression of malignant middle cerebral artery infarcts. J Clin Neurosci 2012;19(5):661-664. **[CrossRef]**
12. Moon JW, Hyun DK. Decompressive Craniectomy in Traumatic Brain Injury: A Review Article. Korean J Neurotrauma 2017;13(1):1-8. **[CrossRef]**
13. Kolias AG, Kirkpatrick PJ, Hutchinson PJ. Decompressive craniectomy: past, present and future. Nat Rev Neurol 2013;9(7):405-415. **[CrossRef]**
14. Nirula R, Millar D, Greene T, McFadden M, Shah L, Scalea TM et al. Decompressive craniectomy or medical management for refractory intracranial hypertension: an AAST-MIT propensity score analysis. J Trauma Acute Care Surg 2014;76(4):944-952. **[CrossRef]**
15. Bohman LE, Schuster JM. Decompressive craniectomy for management of traumatic brain injury: an update. Curr Neurol Neurosci Rep 2013;13(11):392. **[CrossRef]**
16. Smith M. Refractory intracranial hypertension: the role of decompressive craniectomy. Anesth Analg. 2017;125(6):1999-2008. **[CrossRef]**
17. Carter BS, Ogilvy CS, Candia GJ, Rosas HD, Buonanno F. One-year outcome after decompressive surgery for massive nondominant hemispheric infarction. Neurosurg 1997;40(6):1168-1176. **[CrossRef]**