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Research Article

Early Decompressive Craniectomy in Acute Cerebral Infarctions

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Abstract

Objectives: Acute cerebral ischemic stroke resulting from occlusion of major arteries constitutes a significant cause of mortality and morbidity. Early decompressive craniectomy reduces mortality and enhances the proportion of patients achieving favorable functional outcomes.

Methods: Data from patients who underwent decompressive surgery for acute cerebral ischemic stroke at our center between January 2018 and January 2023 were retrospectively analyzed. The demographic data, along with neurological outcomes at 6 months, mortality, and morbidity rates, were analyzed of the patients to assess the role of early decompressive craniectomy in acute cerebral infarctions.

Results: A total of 75 patients, 24 females and 51 males, who underwent decompressive surgery with a diagnosis of acute cerebral ischemia, were included in the study. Early surgery was defined as surgery performed within the first 72 hours of ischemia. It was observed that patients underwent early surgery had higher survival rates ($p<0.036$).

Conclusion: Decompressive cranictomy is a significant treatment option for malignant stroke. The results of this study suggest that early decompressive surgery could be an effective treatment method in increasing the survival chances of patients with acute ischemic stroke.

Keywords: Acute cerebral ischemia, craniectomy, decompressive cranial surgery

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Cerebral ischemic stroke arises due to the occlusion of major cranial arteries, representing a significant contributor to both mortality and morbidity. Despite notable advancements in treatment modalities, a majority of patients with ischemic stroke exhibit limited functional recovery. These patients develop severe parenchymal edema in a very sensitive time period, which usually occurs within 3-5 days of the development of ischemic infarction.[1,2] In some cases, parenchymal edema develops very rapidly and results in high mortality (70-80%) despite aggressive medical treatment.[3] In rare cases, the severity of cerebral edema may escalate within a 24-hour window.[4] Along with extensive parenchymal damage, secondary neuronal damage occurs with pressure-related effects such as cerebral herniation and increased intracranial pressure.[5]

Decompressive cranial surgery was first described by Kocher in 1901 for traumatic brain injury.[6] In the following years, it was also used in severe acute cerebral infarction.[7] Decompressive surgery performed at the appropriate time will reduce the intracranial pressure and prevent cerebral herniation. The benefits of decompressive craniectomy in reducing mortality in malignant cerebral ischemic stroke have been demonstrated in randomized clinical trials.[8-11]

In our study, we aimed to evaluate the role of surgery in

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6-month neurological outcomes or mortality and morbidity rates by retrospectively examining patients who underwent decompressive craniectomy in acute cerebral ischemic infarction.

Methods

In our study, data of patients who underwent decompressive surgery with a diagnosis of acute cerebral ischemic stroke presenting to our center from January 2018 to January 2023 were retrospectively analyzed. Demographic data of the patients, localization of ischemic stroke, type of surgery, time interval from stroke onset to decompressive surgery, comorbidities, physical examination findings, postoperative complications, and modified Rankin score (mRS) were recorded. In addition to demographic data, information regarding various cardiovascular risk factors was also documented. Among the patients, those eligible for thrombolysis were treated with either thrombectomy performed at our stroke center by cerebral angiography or standard treatment with intravenous tissue plasminogen activator (IV-tPA) at a dose of 0.9 mg/kg body weight, with an initial bolus of 10% and a maximum of 90 mg.[12] Decompressive craniectomy performed within 72 hours following stroke was defined as "early surgery." Functional outcomes, early surgical results, and clinical findings at one month assessed with mRS. This study was approved by Van Yuzuncu Yıl University Clinical Research Ethics Committee with the number 2023/01-17.

Surgical Procedure

The patient is positioned supine with a gel pad supporting the shoulder on the affected side, and the head is turned to the opposite side. After appropriate draping and sterilization, a wide inverted question mark-shaped incision starting 3 cm above the midline and extending to the parieto-occipital region is made. Tissues are carefully lifted in accordance with the anatomical structure, with attention given to preserving the arterial structures to ensure adequate blood supply to the frontal-parietal-temporal craniectomy flap. Support is provided under the flap to prevent compromise of the blood supply. After the skull bone is exposed, a burr hole is made using a foot-pedal drill, and a large cranial defect of at least 15 cm is created to remove a significant portion of the bone flap.[13] The cranial defect is expanded in a direction towards the basal region, specifically targeting the temporal pole. Hemostasis is achieved for the bleeding dura and bone edges. The dura is typically opened in an envelope or reverse U shape. After confirming adequate decompression, a wide duraplasty is performed using the periosteum obtained from the removed bone flap or artificial dura. Before closing, a passive Hemovac drain is placed over the dura and securely attached to the skin. The subcutaneous tissue and skin are closed in accordance with anatomical layers.

Statistical Analysis

The statistical analysis was performed using the licensed SPSS 22.0 software. The normal distribution of the data was assessed using the Shapiro-Wilk test. Data from normally distributed independent binary groups were evaluated using the Independent t-test. Categorical data were assessed using the Chi-squared test. Binary logistic regression analysis was conducted to characterize the impact of the day of surgery on the risk of mortality. A significance level of $p<0.05$ was established to determine statistical significance.

Results

Patient Characteristics

Our study included a total of 75 patients who underwent decompressive surgery for acute cerebral ischemia in our clinic between 2018 and 2023. Out of these, 24 (32%) were female and 51 (68%) were male. Among the female patients, 20 (83.3%) underwent early surgery, while 4 (16.7%) underwent late surgery. Among the male patients, 40 (78.4%) underwent early surgery, and 11 (21.6%) underwent late surgery.

Patients who underwent early and late surgery were categorized based on the localization of infarction. Among the 32 patients with right MCA infarction, 27 (84.4%) underwent early surgery, while 5 (15.6%) underwent late surgery. Among the 40 patients with left MCA infarction, 31 (77.5%) underwent early surgery, and 9 (22.5%) underwent late surgery. For the 3 patients with posterior cerebellar infarction, 2 (66.7%) underwent early surgery, and 1 (33.3%) underwent late surgery. Out of the patients included in the study, 59 had an additional disease, while 16 did not. Hydrocephalus was detected in 5 patients.

Among the patients, 44 did not experience any postoperative complications. Among the 31 patients who developed postoperative complications, 24 (77.4%) underwent early surgery, while 7 (22.6%) underwent late surgery. At the conclusion of our study, 29 patients were alive, while 46 had expired. Out of the living patients, 27 underwent early surgery, and 2 underwent late surgery. Among the 46 deceased patients, 13 (28.3%) underwent early surgery, and 33 (71.7%) underwent late surgery. A statistically significant difference was observed between the timing of surgery and the survival status. A higher survival rate was found among patients who underwent surgery in the early period ($p<0.036$) (Table 1).

As shown in Table 2, patients who underwent surgery in the early period had a mean age of 53.45, while those who underwent surgery in the late period had a mean age of 56.47. The modified Rankin score for patients who underwent early surgery was 4.48, compared to 5.40 for patients who underwent late surgery. The mean shift amount for patients who underwent early surgery was 9.80, whereas it was 8.33 for patients who underwent late surgery. There was no significant difference in terms of age, modified Rankin score, and shift amount based on the timing of surgery (p>0.05).

According to the logistic regression analysis, a delay in the day of surgery leads to a statistically significant 5.3-fold increase in the risk of death (Table 3).

Postoperative Complications

Out of the patients who underwent early surgery, 13 (81.2%) had no additional diseases, while 3 (18.8%) of those who underwent late surgery had no additional diseases. Among the patients with chronic arterial disease (CAD), 23 (82.1%) underwent early surgery, and 5 (17.9%)

Table 1. Surgical Timing and Distribution of Certain Variables.

	Day			
	Early, n (%)	Late, n (%)	Total, n (%)	p*
Sex				
Female	20 (83.3)	4 (16.7)	24 (100)	0.762
Male	40 (78.4)	11 (21.6)	51 (100)	
Localization				
Right MCA	27 (84.4)	5 (15.6)	32 (100)	0.646
Left MCA	31 (77.5)	9 (22.5)	40 (100)	
Posterior Cerebellar	2 (66.7)	1 (33.3)	3 (100)	
Comorbidities				
Absent	14 (87.5)	2 (12.5)	16 (100)	0.502
Present	46 (78.0)	13 (22.0)	59 (100)	
Hydrocephalus				
Absent	57 (81.4)	13 (18.6)	70 (100)	0.260
Present	3 (60)	2 (40)	5 (100)	
Postoperative Complication				
Absent	36 (81.8)	8 (18.2)	44 (100)	0.771
Present	24 (77.4)	7 (22.6)	31 (100)	
Outcome				
Exitus	33 (71.7)	13 (28.3)	39 (100)	0.036
Alive	27 (93.1)	2 (6.9)	29 (100)	

* Chi-squared Test; MCA: Middle Cerebral Artery.

Table 2. Distribution of Surgical Timing According to Age, Modified Rankin Scale, and Shift Amount

	Early (n=60)	Late (n=15)	p*
Age (Mean±SD)	53.45±11.38	56.47±17.65	0.418
Modified Rankin Score (Mean±SD)	4.48±1.76	5.40±1.59	0.071
Shift (Mean±SD)	9.80±4.41	8.33±3.26	0.235

* Independent t-test.

Table 3. Impact of Surgery Day on Survival Status Through Binary Logistic Regression Analysis

	B	S.E.	p	OR	95% CI	
Day of the Surgery	1.671	0.803	0.037	5.318	1.103	25.644

OR: odds ratio.

underwent late surgery. Among the patients who underwent early surgery, 12 (70.6%) had diabetes mellitus (DM), in the late surgery group, 5 (29.4%) had DM. Additionally, among the patients who underwent early and late surgery, 12 (85.7%) and 2 (14.3%) patients had other concurrent diseases respectively. Postoperative complications did not occur in 44 patients, with 34 (77.3%) of those undergoing early surgery and 10 (22.7%) undergoing late surgery.

Pneumonia developed in 16 (100%) patients, with 14 (87.5%) in the early surgery group and 2 (12.5%) in the late surgery group. Postoperative renal complications occurred in 5 (83.3%) patients who underwent early surgery and 1 (16.7%) patient who underwent late surgery. Postoperative pulmonary embolism occurred in 3 (60%) patients who underwent early surgery and 2 (40%) patients who underwent late surgery. Four patients who underwent early surgery developed postoperative complications other than those mentioned (Table 4).

Regarding additional diseases and postoperative complications, there was no significant difference in terms of the timing of surgery. According to Table 4, although not statistically significant, the occurrence of additional diseases is more frequent in patients who underwent surgery in the early period. The most common additional diseases observed were CAD and DM. Similarly, although not statistically significant, postoperative complications were more common in patients who underwent surgery in the early period. The most frequent postoperative complications were pneumonia, renal disease, and pulmonary embolism.

Table 4. Distribution of Surgical Timing According to Additional Diseases and Postoperative Complications

	Day		p
	Early n (%)	**Late n (%)**	
Comorbidities			
None	13 (81.2)	3 (18.8)	0.724
CAD	23 (82.1)	5 (17.9)	
DM	12 (70.6)	5 (29.4)	
Other	12 (85.7)	2 (14.3)	
Postoperative Complications			
None	34 (77.3)	10 (22.7)	0.540
Pneumonia	14 (87.5)	2 (12.5)	
Renal Disease	5 (83.3)	1 (16.7)	
Pulmonary Embolism	3 (60.0)	2 (40.0)	
Other	4 (100)	0 (100)	

Discussion

Acute ischemic stroke is a critical condition arising from the sudden cessation of blood flow to brain tissue, posing a life-threatening risk. This circumstance can result in cellular damage and functional impairment within the brain tissue. Early post-ischemic stroke decompressive surgery can play a significant role in reducing mortality risk. Decompressive surgery aims to lower intracranial pressure and alleviate tissue stress. This intervention is applicable when intracranial pressure elevates, with the objective of mitigating brain tissue damage and potential neurological consequences. Decompressive surgery necessitates a multidisciplinary approach and can emerge as a prominent consideration within the post-stroke treatment process.

The most comprehensive guideline regarding the management of patients with ischemic stroke was published in 2018 by the American Heart Association and the American Stroke Association.[14] Early transfer of patients at risk of malignant brain edema to a center with expertise in neurosurgery is recommended in this guidline. Decisions about interventions and care should be made in an early stage based on patient-centered preferences. Furthermore, in terms of neurosurgical management, early intervention is recommended for patients who experience neurological deterioration within the next 48 hours after middle cerebral artery (MCA) infarction.

Ischemic stroke due to occlusion of a major vessel or large infarction in a hemisphere constitutes 24-38% of all acute ischemic strokes.[15] Approximately 10-15% of acute cerebral ischemic infarctions involve a large territory of the MCA.[15] The majority of our patients also had MCA infarction. Malignant cerebral infarction is describes as an infarct that negatively affects survival, involving basal ganglia, affecting more than 50-75% of the MCA territory with involvement of the vascular area, and causing midline shift of the brain of 4 mm or more.[16, 17] Neurological deterioration occurs within 5 days, and brain death occurs after the 3rd day. The mortality rate of malignant infarctions is approximately 80% without neurosurgical intervention.[17]

In cases of malignant infarctions, prior to the year 2009, surgery was performed based on neurological deterioration indicated by a decrease in the Glasgow Coma Scale (GCS). However, after 2009, early surgery began to be performed on patients showing radiological features of the malignant infarction without waiting for neurological deterioration. Early ischemic changes seen in computed tomography and magnetic resonance imaging include extensive involvement of the vascular territory, displacement of the pineal gland leading to herniation, subsequent edema formation, and as a result, higher mortality and poor outcomes.[18-20]

In ischemic stroke, since usually a single cerebral hemisphere is predominantly affected, the surgical aim is to decompress the affected area. The typical operation performed for these patients is a fronto-temporo-parietal decompressive hemicraniectomy. To achieve the necessary decompression effect, a minimum cranial diameter of 12 cm needs to be obtained from front to back, and as mentioned in the literature, our goal was to achieve an average front-back diameter of around 15 cm in our patients and to include the decompression of the base of the middle cranial fossa.[21] A sufficiently sized craniectomy is essential to achieve the desired decompressive effect. Moreover, suboptimal decompression can lead to intraparenchymal hemorrhage, severe external brain herniation at the edges of the bone, and twisting of cerebral veins, resulting in shear forces.[22] After achieving adequate decompression, allogeneic or autologous dural grafts are used to perform wide duraplasty following the dura incision to create a large dural opening.

The Destiny II study, suggests that favorable outcomes were achieved in patients who underwent decompressive craniectomy within 48 hours after the onset of symptoms in middle cerebral artery (MCA) ischemic infarctions.[9,23,24] In our study, positive functional outcomes at 6 months were observed with early decompressive craniectomy (performed within the first 72 hours) in ischemic stroke. There was a statistically significant difference in the survival status of patients based on the time of surgery. Higher survival rates were found in those who underwent surgery early (p<0.036) (Table 1). Logistic regression analysis revealed a statistically significant 5.3-fold increase in the risk of death with delayed surgery (Table 3).

Regarding functional outcomes, although not statistically significant, a similar trend was observed in the modified Rankin Score (mRS) ranging from 0 to 4, indicating better results in the early surgery group, aligning with the literature.

In our study, patients who underwent early surgery had more comorbidities compared to those in the late surgery group. The most common additional diseases observed were coronary artery disease (CAD) and diabetes mellitus (DM). Although not statistically significant, postoperative complications were more frequent in patients who underwent early surgery. This might be attributed to the higher burden of comorbidities in the early surgery group. Additionally, the question of whether additional diseases and comorbidities trigger early neurological deterioration should be explored. The most common postoperative complications were pneumonia, renal disease, and pulmonary embolism. Despite the presence of additional diseases and postoperative complications in the early surgery group, the lower mortality rate in this group could be attributed to meticulous and careful postoperative care in the intensive care unit.

Conclusion

Decompressive surgery stands as a significant treatment option for malignant stroke. These findings suggest that early decompressive surgery could be an effective method in increasing the survival chances of patients with acute ischemic stroke. The literature highlights the potential benefits of surgery within the first 48 hours, while our study demonstrated that surgery within the first 72 hours could also be beneficial. Moreover, we have seen the importance of postoperative care in the intensive care unit. In addition to cohort or case-control studies designed for surgical outcomes in ischemic stroke patients, we believe that prospective multicenter registries could be valuable. We anticipate that broader and multicenter studies conducted in the future will enhance our understanding of decompressive surgery and lead to a better appreciation of the significance of early intervention.

Disclosures

Ethics Committee Approval: This retrospective study was conducted inthe neurosurgery clinic of Van Yuzuncu Yil University Faculty of Medicine. This study was approved by Van Yuzuncu Yıl University Clinical Research Ethics Committee with the number 2023/01-17.

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