DOI: 10.5137/1019-5149.JTN.13241-14.1
Received: 27.10.2014 / Accepted: 08.01.2015
Published Online: 24.02.2016

Original Investigation

Decompressive Hemicraniectomy for Malignant Middle Cerebral Artery Infarct

Bulent GULENSOY, Mete KARATAY, Yavuz ERDEM, Haydar CELIK, Tuncer TASCIOGLU, Idris SERTBAS, Tansu GURSOY, Halil KUL, Cevdet GOKCEK, Ugur YASITLI, Mehmet Akif BAYAR

Ankara Training and Research Hospital, Neurosurgery Clinic, Ankara, Turkey

ABSTRACT

AIM: Decompressive hemicraniectomy for a malignant middle cerebral artery infarct can be a life-saving surgical treatment. We aimed to investigate the surgical treatment results in cases that underwent decompressive hemicraniectomy for a malignant middle cerebral artery infarct in this study.

MATERIAL and METHODS: The clinical condition, radiological findings and surgical treatment results of 42 cases that underwent decompressive hemicraniectomy for a malignant middle cerebral artery infarct were retrospectively evaluated in this study.

RESULTS: There were 19 males and 23 females. The age range was 27 to 78 years with a mean age of 57.6 years. The infarct area was the non-dominant hemisphere in 20 cases and the dominant hemisphere in 22 cases. Preoperative Glasgow coma scale (GCS) scores were 5 to 12. The 42 cases with a malignant middle cerebral artery infarct were divided into 2 groups according to the Glasgow outcome scale (GOS) as the unfavorable outcome group (Group 1) with a score of 1 to 3 and the favorable outcome group with a score of 4 to 5 (Group 2). There were 27 cases in Group 1 and 15 in Group 2. There was a statistically significant association between a good result and age, Glasgow coma scale at the time of surgery, duration until surgery, and non-dominant hemisphere involvement. All cases with a Glasgow coma scale score of 7 or below had a poor outcome.

CONCLUSION: Decompressive hemicraniectomy in malignant middle cerebral artery infarct can be a life-saving procedure but is not useful in cases with a Glasgow coma scale score of 7 and below.

KEYWORDS: Malignant middle cerebral artery infarct, Decompressive hemicraniectomy, Glasgow outcome scale

INTRODUCTION

Malignant hemispheric infarction usually develops due to acute internal carotid artery or middle cerebral artery (MCA) occlusion and has high a mortality rates. A mass effect develops due to brain edema following local brain swelling in ischemic stroke. The subtypes of edema are vasogenic, cytotoxic and interstitial. All these subtypes play a role in severe ischemic stroke but the most important one is cytotoxic edema. Cytotoxic edema is the result of cell swelling due to decreased oxygen causing a failure in the supply of substrates and energy and ultimately the ion pumps. Serious brain swelling usually emerges between the second and fifth days and reaches its maximum level on the fourth day with a malignant middle cerebral artery infarct (3, 17). All kinds of conservative treatment are used in these cases to no avail and mortality rates up to 80% are seen as a result of herniation (2, 8). Malignant cerebral edema usually does not respond to medical treatment. Decompressive hemicraniectomy can be a life- saving procedure in such cases (11). However, it is not certain which cases will benefit from decompressive hemicraniectomy and attempts to determine such cases continue in published series (6, 9, 12, 16, 20, 21). Cases that benefit from decompressive hemicraniectomy the most are those under the age of 60 with a preoperative admission Glasgow Coma

Corresponding author: Mete KARATAY
E-mail: lexel26@hotmail.com

Scale (GCS) score of 8 and over and non-dominant hemisphere infarcts, that are operated on within the first 48 hours (4, 5, 7, 14). Decompressive hemicraniectomy in patients not suitable for surgery increases the number of cases in a persistent vegetative state (15).

■ MATERIAL and METHODS

We retrospectively analysed 42 patients with acute malignant MCA infarct that presented to our institution between January 2007 and August 2014. All spontaneous acute malignant MCA infarction patients were admitted to our Neurology Department. The clinical history, neurological examination findings, and brain computed tomography (CT) were used to make the diagnosis of stroke. Patients were first treated medically followed by surgical treatment depending on the presence of neurological deterioration despite aggressive medical management with antiedema agents (mannitol, furosemide, steroids), and hyperventilation, together with the results of serial brain CT investigations. A neurosurgery consultation was requested in the presence of neurological deterioration and radiological evidence of cerebral edema secondary to the cerebral infarct. A large decompressive craniectomy was then performed unless the patient had a definite medical contraindication to surgery. All patients were admitted within three hours following the onset of symptoms. The data collected were age, sex, stroke etiology, the dominance of the affected hemisphere, preoperative GCS score, functional recovery according to the GOS score, septum pellucidum level midline shift measurement and the improvement of this shift after decompressive craniectomy, and the duration between the stroke and the surgery. The 42 patients with malignant MCA infarction were divided into two subgroups using the Glasgow Outcome Scale (GOS) with patients with a GOS score of 1 to 3 included in the unfavorable outcome group (Group 1) and those with a score of 4 to 5 in the favorable outcome group (Group 2).

Decompressive hemicraniectomy was performed with a large frontoparietotemporal curvilinear incision to remove a large hemicraniectomy bone flap including the frontal, parietal, temporal and occipital squama. The floor of the middle cranial fossa was exposed by applying a rongeur to the temporal squama to prevent uncal herniation. A curvilinear dural incision with radial cuts that followed major sulcal vessels was used to prevent the edematous brain kinking at the dural margin. All patients were monitored at the neurosurgical intensive care unit postoperatively.

Statistical Analysis

SPSS for Windows, version 11.5 (SPSS Inc., Chicago, IL, United States) was used for data analysis. The presence or absence of a normal distribution for metric discrete variables was determined with the Shapiro-Wilk test. Data were presented as mean ± SD or median (min-max) as applicable.

Student's t test was used to compare mean differences between groups and the Mann-Whitney U test was used for comparisons of the median values. Pearson's Chi-square or Fisher's exact test were used to analyze nominal data as appropriate. The Wilcoxon Signed Rank test or McNemar test was used to analyze the statistical significance of the differences between preoperative and postoperative shift measurements. Factors best differentiating the GOS 4-5 (Group 2) and GOS 1-2-3 (Group 1) groups were analyzed with Multiple Logistic Regression analysis. We also calculated adjusted odds ratios and 95% confidence intervals for each independent variable and accepted any variable with a p value <0.25 on the univariate test as a candidate for the multivariate model along with variables known to be of clinical importance. We accepted a p value less than 0.05 as statistically significant and used the Bonferroni Correction to control Type I errors for all possible multiple comparisons.

■ RESULTS

Decompressive surgery was performed in 42 patients with malignant MCA infarction (19 males and 23 females, average age 56 years) that showed neuroclinical deterioration despite aggressive medical management. The median time to surgery was 76.5 hours. The mean age was 53 (range 39-71) and 59 (range 27-78) years for the male and female patients respectively with a normal distribution. The risk factors were hypertension (15 patients), atrial fibrillation (5 patients), diabetes mellitus (5 patients), hyperlipidaemia (9 patients), and ischemic heart disease (8 patients). We did not come across any surgical complication directly related to the decompression procedure.

Outcome was determined at the time of discharge according to the GOS. We had 3 patients with good recovery, 12 with moderate disability, 9 with severe disability, and 9 in a persistent vegetative state, while 9 patients died with an overall mortality rate of 21.4% (Table I).

At discharge, 64% of our patients were in Group 1 and 36% in Group 2 according to their GOS score. Group 1 consisted of 9 men and 18 women with a mean age of 59.6 years (age range 27 to 78 years) while Group 2 consisted of 10 men and 5 women with a mean age of 47.1 years (age range 30 to 71 years). Nine Group 1 (n: 27) patients died during follow-up, succumbing to transtentorial herniation that developed as a result of increased intracranial pressure. Nine patients had severe disability and 9 went into a persistent vegetative state. Secondary brain damage was prevented in all Group 2 (n: 15) cases where there were 12 moderately disabled patients and 3 with good recovery.

There was a statistically significant increase of the possibility of being in Group 1 as the age of the patients that underwent decompressive hemicraniectomy increased [OR=1.069 (95% CI:1.014-1.128) and p=0.004]. Only one case in Group 2 was over the age of 65 years. The infarct was in the non-dominant hemisphere in this case and early surgical intervention (within the first 24 hours) was implemented. The possibility of being in Group 1 was significantly higher in the females compared to the males [OR=4,000 (95% CI: 1.049-15.260) and p=0.038]. The possibility of being in Group 1 showed a statistically significant increase when the infarct was in the dominant hemisphere compared to the non-dominant hemisphere

[OR=5.500 (95% CI: 1.361-22.223) and p=0.013]. There was a statistically significant decrease in the possibility of being in Group 1 as the admission GCS score increased [OR=0.230 (95% CI: 0.067-0.784) and p<0.001]. The risk of being in Group 1 showed a statistically significantly decrease as the as preoperative GCS score increased [OR=0.352 (95% CI: 0.187-0.661) and p<0.001]. The risk of being in Group 1 increased in a statistically significant manner as the time to surgery increased [OR=1.047 (95% CI: 1.011-1.085) and p=0.004]. The risk of being in Group 1 also showed a statistically significantly increase in cases that were found have a preoperative shift of 11 mm or more compared to those with less shift [OR=7.000 (95% CI: 1.454-33.696) and p=0.020]. The same risk increase also applied for a postoperative shift of more than 11 mm or more compared to those with less shift (p<0.001) (Table II).

The postoperative shift level within Group 1 and Group 2 showed a statistically significantly decrease compared to preoperative values (p<0.001). However, the decrease in postoperative shift levels compared to preoperative levels in Group 2 was statistically significantly more marked than the decrease in Group 1 (p<0.001) (Table III).

Table I: Glasgow Outcome Scale (GOS) Scores at Discharge

GOS		Number (n)
5	good recovery	3
4	moderate disability	12
3	severe disability	9
2	persistent vegetative state	9
1	death	9

Table II: The Demographic and Clinical Characteristics of the Cases by Group

Variables	Group 2 (n= 15)	Group 1 (n= 27)	p-value	OR (95% CI)
Age (years)	47.1±11.0	59.6±14.8	0.004[a]	1.069 (1.014-1.128)
Gender				
Male	10 (66.7%)	9 (33.3%)	-	1,000
Female	5 (33.3%)	18 (66.7%)	0.038[b]	4.000 (1.049-15.260)
Infarct Area				
Non-dominant	11 (73.3%)	9 (33.3%)	-	1,000
Dominant	4 (26.7%)	18 (66.7%)	0.013[b]	5.500 (1.361-22.223)
Admission GCS	14 (13-15)	12 (6-14)	<0.001[c]	0.230 (0.067-0.784)
Pre-op GCS	10 (8-12)	7 (5-10)	<0.001[c]	0.352 (0.187-0.661)
Time to Surgery (hours)	24 (24-72)	72 (24-120)	0.004[c]	1.047 (1.011-1.085)
Pre-op Shift ≥11mm	8 (53.3%)	24 (88.9%)	0.020[d]	7.000 (1.454-33.696)
Post-op Shift ≥11mm	0	18 (66.7%)	<0.001[b]	-

***OR:** Odds Ratio, **CI:** Confidence Interval, **a:** Student's t test, **b:** Pearson's Chi-square test, **c:** Mann Whitney U test, **d:** Fisher's exact test.*

Table III: Preoperative and Postoperative Shift Measurements of the Cases by Group

Variables	Pre-op	Post-op	p-value[a]	Change	p-value[b]
Shift (mm)					<0.001
Group 2	11 (9-14)	5 (3-10)	<0.001[c]	5 (4-8)	
Group 1	15 (10-17)	11 (8-14)	<0.001[c]	3 (2-5)	
Shift ≥11mm					0,040
Group 2	8 (53.3%)	0 (0.0%)	0.008[d]	8 (53.3%)	
Group 1	24 (88.9%)	18 (66.7%)	0.031[d]	6 (22.2%)	

***a:** Comparisons made between the preoperative and postoperative periods within the groups; the results were accepted as statistically significant for p<0.025 according to Bonferroni Correction, **b:** Comparisons made between the groups in terms of changes occurring in the postoperative period compared to the preoperative state; the results were accepted statistically significant for p<0.05, **c:** Wilcoxon Signed Rank test, **d:** McNemar test.*

■ DISCUSSION

Decompressive surgery provides an improvement in functional outcome in cases developing malignant middle cerebral artery infarct and decreases the mortality rate. However, the results are poor in old cases with a hemisphere infarct. The use of decompressive hemicraniectomy in these patients usually does not provide any benefit and can result in severe disability, persistent vegetative state or death. Most series in the literature are retrospective studies with a low number of cases (4, 8, 13, 14, 19). The results of these studies are similar. Randomized studies have shown the best results to be obtained in patients under 60 years of age undergoing early surgery with the infarct in the non-dominant hemisphere among malignant middle cerebral artery infarct patients undergoing decompressive hemicraniectomy (6, 9, 12, 21). A significant decrease in mortality and an improvement in functional outcome (GOS) were observed in cases undergoing surgical decompression when compared with conservative treatment (6, 9, 12, 21). The mortality rate was 5% and 67% in the first week and 16% and 33% in the fourth week in groups that underwent decompression or medical treatment respectively in the 38 patients randomized in the DECIMAL study (21). The mortality rate was 12% in the group that underwent decompression and 53% in the group that did not undergo surgery at the end of one month in the DESTINY study where 32 patients were randomized (12). The HAMLET study randomized 64 patients. The mortality rate was 16% on the fourteenth day in the group that underwent decompression and 56% in the group that did not undergo decompression (9). Death developed in 9 (21.4%) of 42 cases in our retrospective study.

Age is one of the significant factors in decompressive hemicraniectomy cases. As the age advances, the result becomes less successful and the mortality increases (10, 22, 23). Elderly patients usually have more medical risk factors, which may increase the risk of poor outcomes and mortality. The mean age was 59.6±14.8 in Group 1 in our study and 47.1±11.0 in Group 2 where good results were obtained. The rate of poor results (Group 1) increased with advanced age and the age difference between these two groups was statistically significant.

Another factor affecting the result is whether the affected hemisphere is the dominant one. While some authors suggest that surgical treatment will not be useful in a malignant middle cerebral artery infarct occurring in the dominant hemisphere, others state no significant difference depending on the hemisphere (7, 9, 21). However, the results are better when surgery is performed on the non-dominant hemisphere in most series. We obtained good results in 73.3% of the non-dominant hemisphere cases in Group 2 in our study but only in 26.7 of the dominant hemisphere cases in the same group. In conclusion, an infarct in the dominant hemisphere is not a contraindication for surgery although the results are worse.

Another factor in obtaining a good result is surgical timing. Randomized studies show that better results are obtained when decompression is performed within 48 hours after the symptoms emerge (8, 9, 18). Certain authors suggest that the best result can be obtained within the first 24 hours and suggest early surgery (18). However, some studies have found no relationship between the surgical timing and the result (5, 14). We obtained better results in cases operated within the first 24 hours in our study. The mean time to surgery was 24 hours in Group 2 and approximately 72 hours in Group 1. Decompression should therefore be performed as soon as possible in cases not responding to medical treatment if it is to be used.

The preoperative and postoperative midline shift level plays an important role in the prognosis. These measurements in Group 2 were significantly lower than in Group 1 in our study. Similar results have been obtained in the literature (1, 23).

Postoperative neurological scores play a determinant role in the prognosis in almost all studies (6, 8, 9, 12, 21). Significantly better results were obtained in cases with high postoperative GCS scores. A good result could not be obtained in any cases with a preoperative GCS score of 7 and below in our study and the most important factor for the prognosis following decompressive hemicraniectomy was found to be the preoperative GCS score.

■ CONCLUSION

Decompressive hemicraniectomy in cerebral edema developing due to malignant middle cerebral artery stroke can be a life-saving procedure in selected cases. The use of decompressive hemicraniectomy in patients who are not suitable for surgery causes an increase in the number of patients in a persistent vegetative state or with severe disability so that the requested quality of life cannot be provided and there is no effect on mortality. Previous studies and our study involved a low number of cases. Studies on larger series are therefore required. Age, time to surgery, dominance of involved hemisphere, and the preoperative and postoperative shift level are factors influencing the results but the preoperative GCS score is the most important factor. Decompressive hemicraniectomy is not useful in cases with a GCS score of 7 or below.

■ REFERENCES

1. Barber PA, Demchuk AM, Zhang J,Kasner SE, Hill MD, Berrouschot J, Schmutzhard E, Harms L, Verro P, Krieger D: Computed tomographic parameters predicting fatal outcome in large middle cerebral artery infarction. Cerebrovasc Dis 16(3): 230-235, 2003
2. Berrouschot J, Sterker M, Bettin S, Köster J, Schneider D: Mortality of space-occupying (‘malignant’) middle cerebral artery infarction under conservative intensive care. Intensive Care Med 24(6): 620-623, 1998
3. Bounds JV, Wiebers DO, Whisnant JP, Okazaki H: Mechanisms and timing of deaths from cerebral infarction. Stroke 12(4): 474-477, 1981
4. Chen CC, Cho DY, Tsai SC: Outcome of and prognostic factors for decompressive hemicraniectomy in malignant middle cerebral artery infarction. J Clin Neurosci 14(4): 317-321, 2007
5. Curry WT Jr, Sethi MK, Ogilvy CS, Carter BS: Factors associated with outcome after hemicraniectomy for large middle cerebral artery territory infarction. Neurosurgery 56(4): 681-692, 2005

6. Frank JI, Schumm LP, Wroblewski K, Chyatte D, Rosengart AJ, Kordeck C, Thisted RA; HeADDFIRST Trialists: Hemicraniectomy and durotomy upon deterioration from infarction-related swelling trial: Randomized pilot clinical trial. Stroke 45(3):781-787, 2014
7. Gupta R, Connolly ES, Mayer S, Elkind MS: Hemicraniectomy for massive middle cerebral artery territory infarction: A systematic review. Stroke 35(2):539-543, 2004
8. Hacke W, Schwab S, Horn M, Spranger M, De Georgia M, von Kummer R: 'Malignant' middle cerebral artery territory infarction: Clinical course and prognostic signs. Arch Neurol 53(4):309-315, 1996
9. Hofmeijer J, Kappelle LJ, Algra A, Amelink GJ, van Gijn J, van der Worp HB; HAMLET investigators: Surgical decompression for space-occupying cerebral infarction (the Hemicraniectomy After Middle Cerebral Artery infarction with Life-threatening Edema Trial [HAMLET]): A multicentre, open, randomised trial. Lancet Neurol 8(4):326-333, 2009
10. Inamasu J, Kaito T, Watabe T, Ganaha T, Yamada Y, Tanaka T, Imizu S, Hayashi T, Hayakawa M, Kato Y, Hirose Y: Decompressive hemicraniectomy for malignant hemispheric stroke in the elderly: Comparison of outcomes between individuals 61-70 and >70 years of age. J Stroke Cerebrovasc Dis 22(8):1350-1354, 2013
11. Johnson RD, Maartens NF, Teddy PJ: Decompressive craniectomy for malignant middle cerebral artery infarction: Evidence and controversies. Clin Neurosci 18(8):1018-1022, 2011
12. Jüttler E, Schwab S, Schmiedek P, Unterberg A, Hennerici M, Woitzik J, Witte S, Jenetzky E, Hacke W; DESTINY Study Group: Decompressive surgery for the treatment of malignant infarction of the middle cerebral artery (DESTINY): A randomized, controlled trial. Stroke 38(9): 2518-2525, 2007
13. Lee SC, Wang YC, Huang YC, Tu PH, Lee ST: Decompressive surgery for malignant middle cerebral artery syndrome. J Clin Neurosci 20(1):49-52, 2013
14. Pillai A, Menon SK, Kumar S, Rajeev K, Kumar A, Panikar D: Decompressive hemicraniectomy in malignant middle cerebral artery infarction: An analysis of long-term outcome and factors in patient selection. J Neurosurg 106(1):59-65, 2007
15. Puetz V, Campos CR, Eliasziw M, Hill MD, Demchuk AM: Assessing the benefits of hemicraniectomy: What is a favourable outcome? Lancet Neurol 6(7):580, 2007
16. Rieke K, Schwab S, Krieger D, von Kummer R, Aschoff A, Schuchardt V, Hacke W: Decompressive surgery in space-occupying hemispheric infarction: Results of an open, prospective trial. Crit Care Med 23(9):1576-1587, 1995
17. Ropper AH, Shafran B: Brain edema after stroke. Clinical syndrome and intracranial pressure. Arch Neurol 41(1):26-29, 1984
18. Schwab S, Steiner T, Aschoff A, Schwarz S, Steiner HH, Jansen O, Hacke W: Early hemicraniectomy in patients with complete middle cerebral artery infarction. Stroke 29(9):1888-1893, 1998
19. Unterberg A, Juettler E: The role of surgery in ischemic stroke: Decompressive surgery. Curr Opin Crit Care 13(2):175-179, 2007
20. Vahedi K, Hofmeijer J, Juettler E, Vicaut E, George B, Algra A, Amelink GJ, Schmiedeck P, Schwab S, Rothwell PM, Bousser MG, van der Worp HB, Hacke W; DECIMAL, DESTINY, and HAMLET investigators: Early decompressive surgery in malignant infarction of the middle cerebral artery: A pooled analysis of three randomised controlled trials. Lancet Neurol 6(3):215-222, 2007
21. Vahedi K, Vicaut E, Mateo J, Kurtz A, Orabi M, Guichard JP, Boutron C, Couvreur G, Rouanet F, Touzé E, Guillon B, Carpentier A, Yelnik A, George B, Payen D, Bousser MG: DECIMAL Investigators: Sequential-design, multicenter, randomized, controlled trial of early decompressive craniectomy in malignant middle cerebral artery infarction (DECIMAL Trial). Stroke 38(9):2506-2517, 2007
22. Yao Y, Liu W, Yang X, Hu W, Li G: Is decompressive craniectomy for malignant middle cerebral artery territory infarction of any benefit for elderly patients?. Surg Neurol 64(2):165-169, 2005
23. Yu JW, Choi JH, Kim DH, Cha JK, Huh JT: Outcome following decompressive craniectomy for malignant middle cerebral artery infarction in patients older than 70 years old. J Cerebrovasc Endovasc Neurosurg 14(2):65-74, 2012