Outcome and Prognostic Factors of Decompressive Hemicraniectomy in Malignant Middle Cerebral Artery Infarction

Chun-Chung Chen, Der-Yang Cho*, Shu-Chiu Tsai

Department of Neurosurgery, China Medical University Hospital, Taichung, Taiwan, R.O.C.

Background: Whether decompressive hemicraniectomy is an appropriate treatment for malignant middle cerebral artery (MCA) infarction is still a controversial issue. The aims of our study were to determine survival rate and functional outcome and to determine factors associated with survival rates and functional outcome in patients with malignant MCA infarction.

Methods: From January 2000 to December 2003, 60 patients with malignant MCA infarction were included in the study. All the patients in the study underwent a large ipsilateral craniectomy and a large duroplasty for decompression. The infarction territory was evaluated by either diffusion-weighted MRI or computed tomography. Clinical neurologic presentation was evaluated using the Glasgow coma scale. Functional outcome was evaluated with the Barthel index (BI) and the Glasgow outcome scale (GOS) during the follow-up period of 12 months.

Results: Mortality was 20% (12 patients) during 30 days and 26.6% during 12 months' follow-up. The factors associated with higher mortality were age ≥ 60 years, involvement of more than 1 vascular territory, clinical herniation signs before surgery and treatment after 24 hours of ictus. Mean GOS was 3.3 ± 1.7 during the 12-month follow-up period. Mean BI was 65.1 ± 40.1. Twenty-nine (65.9%) patients had favorable outcome (BI ≥ 60). The factors associated with favorable outcome were age < 60 years, dominant hemisphere infarction, regaining of consciousness within 7 days after operation, being without respiratory failure and treatment within 24 hours of ictus before clinical signs of herniation.

Conclusion: Decompressive hemicraniectomy may be a useful procedure in patients with malignant MCA infarction. Age, clinical signs of herniation and timing of surgery were the prognostic factors associated with mortality and functional outcome. [*J Chin Med Assoc* 2007;70(2):56–60]

Key Words: decompressive surgery, infarction, outcome

Introduction

Life-threatening cerebral infarction of the middle cerebral artery (MCA) is found in 10–15% of all stroke patients.[1,2] Patients show severe neurologic deficits including hemiplegia, head and gaze deviation towards the side of infarction and deterioration of consciousness. Subsequent brain edema may be associated with transtentorial brain herniation and death. A number of clinical trials have reported that survival rates of patients with malignant MCA infarction treated with decompressive hemicraniectomy range from 67% to 84% compared with a 20–30% survival rate in conservatively treated patients.[3–17] However, the effects of decompressive hemicraniectomy on functional outcome are still controversial. Since young patients are especially affected by malignant MCA infarction,[16] in addition to reducing the death rate, lowering morbidity and improving quality of life are essential goals of decompressive hemicraniectomy. Thus, the aims of this study were: (1) to determine survival, prognosis and functional outcome; and (2) to determine factors associated with survival rates and functional outcome within a series of consecutive patients who underwent decompressive hemicraniectomy for treatment of malignant MCA infarction.

*Correspondence to: Dr Der-Yang Cho, Department of Neurosurgery, China Medical University Hospital, 2, Yu-Der Road, Taichung 404, Taiwan, R.O.C.
E-mail: d5057@www.cmuh.org.tw • Received: February 23, 2006 • Accepted: January 10, 2007

Methods

Patient selection

The decompressive surgical inclusion criteria were:

1. An initial infarction > 2/3 of the MCA territory as defined by computed tomography (CT); clinical deterioration of consciousness; follow-up CT study demonstrating brain swelling and a midline shift > 5 mm.
2. The patient was alert, but diffusion-weighted MRI (DWI) demonstrated MCA or internal carotid artery total infarction.

Patients with a history of disabling neurologic disease, stroke, coma, terminal illness, bleeding tendency or secondary parenchymal hemorrhage were excluded.

Operative methods

All patients in the study underwent a large ipsilateral craniectomy and a large duroplasty for decompression. Intracranial pressure (ICP) was monitored by intraparenchymal insertion with Codman's fiberoptic sensor. If postoperative ICP was > 30 mmHg with medical treatment, further anterior temporal lobectomy was performed to reduce ICP. The bone flap was frozen and stored until reimplantation 12 weeks postsurgery.

Patient evaluation

Clinical status was recorded on admission and preoperatively using the Glasgow coma scale (GCS) score. Levels of consciousness of all patients were evaluated on the 7th postoperative day. Time spent in the ICU was also recorded. Surgical mortality was defined as death of the patient within 30 days after surgery. Functional outcome was evaluated by the Barthel index (BI) and the Glasgow outcome scale (GOS) during 12 months of follow-up. A favorable outcome was defined as BI ≥ 60 (moderate disability to good recovery), and a poor outcome was defined as BI < 60 (severe disability).

Statistical analysis

All numerical data are given as mean ± standard deviation (SD). The following variables were considered for prognostic evaluation: age, sex, timing of surgery, extension of infarction (MCA territory only *vs.* more than the MCA territory), laterality of the infarction, regaining of consciousness within 7 days after operation, clinical signs of herniation, time spent in the ICU, respiratory failure and infection after operation. Univariate analysis was done first. Continuous data were analyzed using the Mann-Whitney U test and categorical data were evaluated using the χ^2 test. A p value ≤ 0.05 was considered to be significant. Logistic regression analysis was used to analyze the prognostic impact of pretreatment factors on BI. A BI < 60 was classified as an unfavorable outcome; otherwise, a favorable outcome was assumed.

Results

Patient characteristics

From January 2000 to December 2003, 60 patients (39 men, 21 women) with a mean age of 62.7 ± 13.9 years (range, 19–89 years) were included in this study. The demographic data of patients are presented in Table 1. In 41 patients, only the MCA territory was affected, whereas in 19 patients, the anterior cerebral artery and MCA territories were involved. The mean preoperative GCS score was 8.4 ± 2.5. The mean time from onset of symptoms to decompressive hemicraniectomy

Table 1. Baseline characteristics of variables in 60 patients who underwent surgical decompression to treat malignant MCA infarction

Mean age, yr	62.7 ± 13.9
Mean GCS	8.4 ± 2.5
Sex (F/M), *n*	21/39
Affected side (L/R), *n*	22/38
Mean time to op, hr (range)	41.3 ± 47.8 (1–216)
Involvement of ipsilateral vascular territories, *n* (%)	
MCA	41 (68.3)
MCA + ACA (ICA)	19 (31.7)
Etiologies of infarction, *n* (%)	
Large-vessel atherosclerosis	21 (37.8)
Cardioembolic	21 (37.3)
ICA dissection	6 (8.3)
Other/unknown	12 (16.6)
Clinical sign of herniation*, *n* (%)	
Positive	20 (33.3)
Mean postoperative ICU stay, d (range)	15.5 ± 11.0 (4–60)
Mean BI during 12-mo follow-up (*n* = 60)	65.1 ± 40.1
BI ≥ 60, *n* (%)	29 (48.3)
Mean GOS during 12-mo follow-up (*n* = 60)	3.3 ± 1.7
GOS ≥ 4, *n* (%)	29 (48.3)

**Asymmetric pupil size. GCS = Glasgow coma scale; op = operation; MCA = middle cerebral artery; ACA = anterior cerebral artery; ICA = internal carotid artery; ICU = intensive care unit; BI = Barthel index; GOS = Glasgow outcome scale.*

was 41.3 ± 47.8 hours; 31 patients were treated within 24 hours, and 29 patients were treated after 24 hours of ictus. Twenty (33.3%) patients presented with asymmetric pupil size (clinical sign of herniation) before treatment.

Survival rates and prognostic factors

Forty-eight (80%) out of 60 patients survived after operative treatment of malignant MCA infarction. The mortality was 20% (12 patients) during the first 30 days after treatment and 26.6% during the 12 months of follow-up. Thirty-four (56.7%) patients regained consciousness within 7 days after operation. The mean ICU stay was 15.5 ± 11.0 days. Univariate analysis revealed that involvement of more than 1 vascular territory (p = 0.0036) and clinical signs of herniation before operation (p = 0.0013) were risk factors of mortality. Although univariate analysis indicated that there were no statistical differences in timing of surgery and age (dichotomized: ≥ 60 years), logistic regression analysis found that treatment after 24 hours of ictus (p = 0.0362) and age > 60 years (p = 0.0008) were indicative of a higher mortality rate. There were no statistical differences in sex, initial GCS, side of infarction and duration of ICU care.

Functional outcome and prognostic factors

The mean follow-up of patients who survived (n = 44) was 12 months. Mean GOS score was 3.3 ± 1.7. Mean BI was 65.1 ± 40.1. Twenty-nine (65.9%) patients had a favorable outcome (BI ≥ 60). The variables associated with an unfavorable outcome were: age ≥ 60 years (p = 0.0002), right-side infarction (p = 0.0202), no regaining of consciousness within 7 days after operation (p < 0.0001), signs of herniation before treatment (p = 0.0019), and respiratory failure (p < 0.0001) (Table 2). Logistic regression analysis revealed that age > 60 years (p = 0.0085) and treatment after 24 hours of ictus (p = 0.0477) were risk factors for poor functional outcome (BI < 60) (Table 3).

Discussion

The management of patients with malignant MCA infarction remains a challenge. Decompressive hemicraniectomy can relieve the mass effect due to infarcted brain tissue, thereby preventing brain herniation and death. Several studies have shown that decompressive surgery can reduce the mortality rate from 80% to 30%.[3–17] One study suggested that the mortality rate could be further reduced to 10% when decompression is undertaken within 24 hours of ictus.[7] Although decompressive surgery can reduce the mortality rate associated with malignant MCA infarction, it is unclear which groups of patients benefit most from the procedure. Life quality of survival after hemicraniectomy remains a key factor in the choice of therapy for malignant MCA infarction. The main reason why many neurosurgeons do not treat malignant MCA infarction by decompressive hemicraniectomy is not a concern over survival, but rather a concern over the life quality of survival.[13] Our aim in the current study was not only to calculate mortality rates and functional outcome scores over time for patients, but also to investigate whether there were prognostic factors independent of treatment for malignant MCA infarction.

In our series, the mortality rates after surgery were 20% during the first postoperative month and 26.6% at 12-month follow-up. The estimated mortality rate was in the range of those previously reported, 10–30%.[7,10,11] The factors associated with higher mortality were age ≥ 60 years, involvement of more than 1 vascular territory, clinical herniation signs before surgery and treatment after 24 hours of ictus.

The BI is the most common scale for evaluating physical disability in stroke patients. It assesses the performance of specific tasks related to self-care and mobility. Although the index is limited to assessment of language function and mental and psychologic status, its simplicity and widely accepted use allow for cross-comparison analysis of data from different studies. In this index, the maximal score is 100; a score > 60 implies moderate to good functional outcome. In our series, 65.9% of patients had favorable outcome. The factors associated with favorable outcome were age < 60 years, dominant hemisphere infarction, regaining of consciousness within 7 days after operation, being without respiratory failure and treatment within 24 hours of ictus before clinical signs of herniation.

The impact of age on outcome of treatment for malignant MCA infarction has not been well studied. Several reports have indicated poor functional outcome and increased mortality in older patients who undergo hemicraniectomy.[3,4,8–10,16] Age has been reported to be the most important pretreatment prognostic factor.[4,8,9] Our study confirmed that age is a crucial factor for mortality and functional outcome; 10 of 39 patients (25.6%) ≥ 60 years old died despite having undergone surgery, compared with 2 of 21 patients (9.5%) < 60 years of age. Furthermore, 12 of 26 patients (46.2%) ≥ 60 years old had BI ≥ 60, compared with 17 of 18 patients (94.4%) < 60 years who had BI ≥ 60. Therefore, age may be the most important factor in deciding which patients should undergo hemicraniectomy.

Timing of surgery is another crucial factor for hemicraniectomy in malignant MCA infarction. Animal and

Table 2. Comparison of variables in 60 patients who underwent decompressive hemicraniectomy: Barthel index (BI) results

	BI < 60 (*n* = 31)	BI ≥ 60 (*n* = 29)	*p*
Age (yr)	68.8 ± 10.1	56.2 ± 14.5	0.0002
< 60, *n* (%)	4 (19.1)	17 (80.9)	0.0002
≥ 60, *n* (%)	27 (69.2)	12 (30.8)	
Sex, *n* (%)			0.2442
Female	13 (61.9)	8 (38.1)	
Male	18 (46.1)	21 (53.9)	
Time to op (hr)	49.1 ± 52.8	32.9 ± 40.9	0.1907
≤ 24 hr, *n* (%)	14 (45.2)	17 (54.8)	0.2972
> 24 hr, *n* (%)	17 (58.6)	12 (41.4)	
Disease type, *n* (%)			0.0711
MCA	17 (41.5)	24 (58.5)	
MCA + ACA	14 (73.7)	5 (26.3)	
Affected side, *n* (%)			0.0202
Left	8 (36.4)	14 (63.6)	
Right	23 (60.5)	15 (39.5)	
Return of consciousness within 7 d after op, *n* (%)			< 0.0001
Yes	7 (20.6)	27 (79.4)	
No	24 (92.6)	2 (7.4)	
Signs of herniation*, *n* (%)			0.0019
Positive	16 (80.0)	4 (20.0)	
Negative	15 (37.5)	25 (62.5)	
ICU stay (d)	17.0 ± 11.1	13.8 ± 10.9	0.2739
Respiratory failure, *n* (%)			< 0.0001
Yes	30 (90.9)	3 (9.1)	
No	1 (4.1)	26 (95.9)	
Infection, *n* (%)			0.9450
Yes	2 (50.0)	2 (50.0)	
No	29 (51.8)	27 (48.2)	

**Asymmetric pupil size. op = operation; MCA = middle cerebral artery; ACA = anterior cerebral artery; ICU = intensive care unit.*

Table 3. Logistic regression analysis of functional outcome (Barthel index < 60 model, sample size *n* = 60)

	OR	95% CI	*p*
Age (≥ 60 yr)	35.66	2.49–511.44	0.0085
Involvement of > 1 vascular territories (ICA)	1.84	0.20–16.84	0.5891
Time to op (> 24 hr)	0.04	0.00–0.97	0.0477
Right-side infarction	3.36	0.40–28.7	0.2634
Herniation (positive)	18.10	0.95–346.18	0.0545

OR = odds ratio; CI = confidence interval; ICA = internal carotid artery; op = operation.

clinical studies have provided evidence for a benefit of early surgery.[7,11,19] However, Foerch et al reported that neither mortality rate nor functional outcome were associated with timing of surgery.[9] In our study, decompression within 24 hours had a significant good influence on mortality rate and functional outcome.

Some reports have shown that clinical signs of herniation were not associated with functional outcome in malignant MCA infarction patients who underwent hemicraniectomy.[9,13] In our series, poor functional outcome was associated with clinical signs of herniation before treatment. It is logical that patients with

anisocoria before treatment will have mesencephalic ischemia and poor prognosis. Better outcome would be expected if patients were treated before clinical signs of herniation developed.

Patients with internal carotid artery infarction involving more than 1 vascular territory and dominant hemisphere infarction have a poor prognosis and are unfavorable candidates for decompressive surgery; but our study showed that right side infarction had a poor prognosis after operation. This apparent contradiction could be resolved by further prospective and controlled studies.

In conclusion, decompressive hemicraniectomy may be a useful procedure in patients with malignant MCA infarction. Age, clinical signs of herniation and timing of surgery were the prognostic factors associated with mortality and functional outcome.

References

1. Ng LK, Nimmannitya J. Massive cerebral infarction with severe brain swelling: a clinocopathologic study. *Stroke* 1970;1:158–63.
2. Kasner SE, Demchuk AM, Berrosuchot J, Schmutzhard E, Harms L, Verro P, Chalela JA, et al. Predictors of total brain edema in massive hemispheric ischemic stroke. *Stroke* 2001;32: 2117–23.
3. Carter BS, Ogilvy CS, Candia GJ, Rosas HD, Buonanno F. One-year outcome after decompressive surgery for massive nondominant hemispheric infarction. *Neurosurgery* 1997;40:1168–76.
4. Holtkamp M, Buchheim K, Unterberg A, Hoffmann O, Schielke E, Weber JR, Masuhr F. Hemicraniectomy in elderly patients with space occupying media infarction: improved survival but poor functional outcome. *J Neurol Neurosurg Psychiatry* 2001;70:226–8.
5. Leonhardt G, Wilhelm H, Doerfler A, Ehrenfeld CE, Schoch B, Raulhut F, Hufnagel A, et al. Clinical outcome and neuropsychological deficits after right decompressive hemicraniectomy in MCA infarction. *J Neurol* 1997;42:164–70.
6. Mori K, Aoki A, Yamamoto T, Horinaka N, Maeda M. Aggressive decompressive surgery in patients with massive hemispheric embolic cerebral infarction associated with severe brain swelling. *Acta Neurochir* 2001;143:483–92.
7. Schwab S, Steiner T, Aschoff A, Schwarz S, Steiner HH, Jansen O. Early hemicraniectomy in patients with complete middle cerebral artery infarction. *Stroke* 1998;29:1888–93.
8. Walz B, Zimmemann C, Bottger S, Haberl RL. Prognosis of patients after hemicraniectomy in malignant middle cerebral artery infarction. *J Neurol* 2002;249:1183–90.
9. Foerch C, Lang JM, Jochen K, Raabe A, Sitzer M, Seifert V, Steinmetz H, et al. Functional impairment, disability, and quality of life outcome after decompressive hemicraniectomy in malignant middle cerebral artery infarction. *J Neurosurg* 2004;101: 248–54.
10. Koh MS, Goh KYC, Ung MYY, Chan C. Is decompressive craniectomy for acute cerebral infarction of any benefit? *Surg Neurol* 2000;53:225–30.
11. Cho DY, Chen CC, Lee HC. Ultra-early decompressive craniectomy for malignant middle cerebral artery infarction. *Surg Neurol* 2003;60:227–32.
12. Pranesh MB, Nayak SD, Mathew V, Prakash B, Natarajan M, Raimohan V, Murali R, et al. Hemicraniectomy for large middle cerebral artery territory infarction: outcome in 19 patients. *J Neurol Neurosurg Psychiatry* 2003;74:800–3.
13. Uhl E, Kreth FW, Elias B, Goldammer A, Hempelmann RG, Liefner M, Nowak G, et al. Outcome and prognostic factors of hemicraniectomy for space-occupying cerebral infarction. *J Neurol Neurosurg Psychiatry* 2004;75:270–4.
14. Robertson SC, Lennarson P, Hasan DM, Traynelis VC. Clinical course and surgical management of massive cerebral infarction. *Neurosurgery* 2004;55:55–62.
15. Gupta R, Connolly ES, Mayer S, Elkind MSV. Hemicraniectomy for massive middle cerebral artery territory infarction. *Stroke* 2004;35:539–43.
16. Nakayama H, Jorgensen HS, Raaschou HO, Limburg M, Bottger S. The influence of age on stroke outcome: the Copenhagen stroke study. *Stroke* 1994;25:808–13.
17. Ying KS, Pang KK, Huang JK, Lin JC. Early CT findings of acute cerebral infarction in the middle cerebral artery territory. *J Chin Med Assoc* 1992;49:223–30.
18. Shen WC, Lee CC. Computerized tomographic angiography in the evaluation of cerebral infarction. *J Chin Med Assoc* 1999; 62:255–60.
19. Forsting M, Reith W, Schabitz WR, Heiland S, von Kummer R, Hacke W, Sartor K. Decompressive craniectomy for cerebral infarction: an experimental study in rats. *Stroke* 1995;26: 259–64.