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Efficacy of the Decompressive Craniectomy for Acute Cerebral Infarction : Timing of Surgical Intervention and Clinical Prognostic Factors

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Objective : Acute cerebral infarction is often accompanied by transtentorial herniation which can be fatal. The aim of this study is to determine the timing of surgical intervention and prognostic factors in patients who present with acute cerebral infarction.
Methods : We reviewed retrospectively 23 patients with acute cerebral infarction, who received decompressive craniectomy or conservative treatment from January 2002 to December 2004. We divided patients into two groups according to the treatment modalities (Group 1 : conservative treatment, Group 2 : decompressive craniectomy). In all patients, the outcome was quantified with Glasgow Outcome Scale and Barthel Index.
Results : Of the 23 patients, 11 underwent decompressive craniectomy. With decompressive craniectomy at the time of loss of pupillary light reflex, we were able to prevent death secondary to severe brain edema in all cases. Preoperative Glasgow Coma Scale and loss of pupillary light reflex were significant to the clinical outcome statistically. With conservative treatment, 9 of the 12 patients died secondary to transtentorial herniation. The clinical outcomes of remaining 3 patients were poor.
Conclusion : This study confirms the value of life-saving procedure of decompressive craniectomy after acute cerebral infarction. We propose that the loss of pupillary light reflex should be considered one of the most important factors to determine the timing of the decompressive craniectomy.

KEY WORDS : Acute cerebral infarction · Decompressive craniectomy · Pupillary light reflex.

Introduction

Life-threatening middle cerebral artery(MCA) infarction occurs in up to 10% of all stroke patients[8,14,21,22,25]. It may be accompanied by severe postischemic brain swelling due to cytotoxic vasogenic edema. The progressive mass effect may prove fatal, owing to increased intracranial pressure and herniation[18]. Progressive deterioration of clinical status due to massive hemispheric edema occurs in up to 10% of patients and is described as the "malignant middle cerebral artery syndrome"[13]. A large space occupying MCA infarction is reported to lead to a mortality rate of up to 80% even with aggressive medical treatment[8,21,25].

Decompressive craniectomy has been described in a growing number of reports as a life-saving measure for many of these patients, and good functional outcomes can be achieved[5]. Recent studies have shown that early decompressive hemicraniectomy decreased mortality to 16~42%[23]. However, the timing of surgical decompression is still controversial and has not been clearly determined.

The proposals of this study were to compare the prognosis between conservative and surgical treatment and to determine the timing of surgical intervention and prognostic factors.

Materials and Methods

This study investigated 23 patients (12 men and 11 women) in whom decompressive craniectomy or medical therapy alone was performed due to acute cerebral infarction in our clinic between January 2002 and December 2004. The patients with deteriorating conscious level from acute massive cerebral infarction and secondary edema were reviewed retro-

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spectively and then classified into two groups : Group 1 (n=12) underwent conservative treatment and Group 2 (n=11) included patients who received decompressive craniectomy.

The initial inclusion criteria consisted of the followings : patients with clinical and computed tomographic(CT) evidence of acute, complete cerebral infarction which consisted of an early, large parenchymal hypodensity and local brain swelling, such as effacement of the sulci and compression of the lateral ventricle; on follow-up CT, complete space-occupying cerebral infarction with midline shift and obliteration of the basal cisterns and/or further neurological deterioration compared with the baseline clinical status on admission.

In all patients the decision to perform craniectomy was made after consultation with the patient and/or the patient's family. We performed decompressive craniectomy at a time of loss of pupillary light reflex, only for the patients who signed full written informed consent. In Group 1, all patients received oxygen supply via nasal probe or mechanical ventilation. Normoglycemia, normothermia and high perfusion pressure were obtained. To reduce elevated intracranial pressure, mannitol and furosemide were given as well as a 30° head elevation in all patients. Barbiturate was not used in this treatment regimen.

In Group 2, surgery consisted of a large question mark incision made from the midline to include the frontal, parietal, and temporal regions on the ipsilateral side of the stroke. Then, large fronto-temporo-parietal craniectomy with maximum diameter of more than 12cm was created. After dura was incised on half-moon shape, duroplasty with lyophilized cadaver dura or homologous temporal fascia was done to gain additional intradural space and the wound was closed. In all patients, immediate post-operative CT scans were obtained.

We reviewed and compared the demographic profile of patients, interval between symptom onset and operation, Glasgow Outcome Scale(GOS) and anisocoria with loss of pupillary light reflex. All patients were assessed three months after admission and the outcome was quantified on GOS and Barthel Index(BI). Statistical analysis was performed using Mann-Whitney U non-parametric tests, Chi-squared tests, and Fisher's exact test. The statistical significance was assigned to *P* value of <0.05.

Results

Group 1 consisted of 5 men and 7 women. The average age was 69.9 years and their ages ranged from 49 to 85 years. Group 2 consisted of 7 men and 4 women. The average age was 62.8 years and the age range was from 42 to 75 years. The mean follow-up period was 9 months (range 3 days-32 months) in all patients. In Group 2, during the follow-up period, one patient was dropped out because his family wanted him to be transferred to other hospital. Among all patients, 19 patients had an ischemic infarction restricted to the MCA territory, 2 patients had additional posterior cerebral artery (PCA) infarction and 2 patients had total internal carotid artery(ICA) infarction. In Group 1, during the follow-up period, 9 out of 12 patients died secondary to transtentorial herniation from increased intracranial pressure. The remaining 3 patients were severely disabled. In Group 2, we were able to prevent death secondary to severe brain edema in all cases. Three patients died during the follow-up period because of non-neurological causes such as adult respiratory distress syndrome(ARDS), chronic renal failure and heart failure. Seven patients experienced long-term survival for a mean follow-up period of 17.2 months (range 8-32 months). Five patients were mildly to moderately disabled (Fig. 1) and 2 patients were severely disabled (Fig. 2)(Table 1).

Fig. 1. Case 6. Preoperative computerized tomography(CT) scan of 49-year-old man. CT scan shows right middle cerebral artery infarction and posterior cerebral artery infarction with brain swelling. Preoperative Glasgow Coma Scale was nine. Operation was done 25 hours after the onset of symptom. He has mild disability at 18 months after operation.

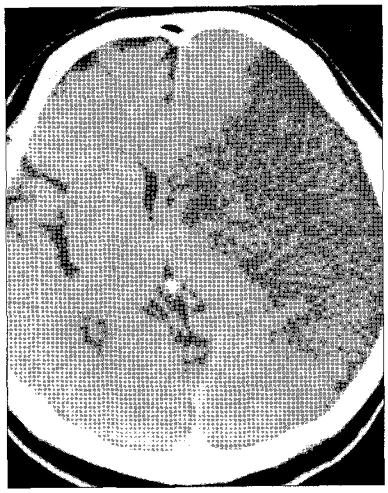

Fig. 2. Case 10. Preoperative computerized tomography(CT) scan of 74-year-old woman. CT scan shows left middle cerebral artery infarction with brain swelling and involvement of basal ganglia. Preoperative Glasgow Coma Scale was six. Operation was performed 28 hours after the onset of symptom. She has severe disability at 12 months after operation.

In Group 1, the mean Glasgow Coma Scale(GCS) score on admission was 8.3 (range 7-10). Six patients had pupillary light reflex and six patients did not have it (Table 2). In Group 2, the mean GCS on admission was 12.4 (range 10-13), having deteriorated to mean GCS of 8.5 (range 6~11) before surgery. The mean of time interval between symptom onset and op-

Table 1. Comparison of demographics and outcome between the conservative treatment group (Group 1) and the decompressive craniectomy group (Group 2)

Demographics and outcome		Group 1 (n=12)	Group 2 (n=11)
Mean age		69.9 years (49−85 years)	62.8 years (42−75 years)
Sex ratio (M:F)		5:7	7:4
Extent of infarct	MCA	11	8
	ICA	1	1
	MCA+PCA	0	2
Outcome			
mild to moderate		0	5
severe		3	2
death		9	3*
loss†		−	1

ICA : internal carotid artery, MCA : middle cerebral artery, PCA : posterior cerebral artery, *Patients died due to non−neurological causes, †Patient's family want to transfer to other hospital

Table 2. Twelve patients undergoing medical treatment for acute cerebral infarction : Patient characteristics and treatment information

Patient No.	Sex/Age	Site	GCS at admission	Pupillary light reflex	Follow−up period	GOS	Barthel Index
1	M/49	Rt MCA	8	+	30 months	2	10
2	F/85	Rt MCA	10	+	26 months	3	45
3	M/71	Rt MCA	8	+	21 days	1	0
4	M/68	Lt MCA	7	−	3 days	1	0
5	F/70	Rt MCA	9	−	1 months	1	0
6	F/74	Lt MCA	8	+	14 days	1	0
7	M/69	Rt ICA	9	−	19 days	1	0
8	F/67	Lt MCA	7	−	5 days	1	0
9	F/72	Lt MCA	9	−	15 months	2	15
10	M/75	Rt MCA	9	+	24 days	1	0
11	F/66	Lt MCA	8	+	19 days	1	0
12	F/73	Lt MCA	7	−	7 days	1	0

GCS : Glasgow Coma Scale, GOS : Glasgow Outcome Scale, MCA : middle cerebral artery, ICA : internal carotid artery

Table 3. Eleven patients undergoing decompressive craniectomy for acute cerebral infarction : Patient characteristics and treatment information

Patient No.	Sex/ Age	Site	Time* (hr)	GCS at admission	GCS at operation	Anisocoria with loss of pupillary light reflex	Follow−up period	GOS	Barthel Index
1	M/49	Rt MCA	23	13	11	−	32 months	5	90
2	M/65	Lt MCA	29	13	9	−	26 months	4	75
3	F/74	Rt MCA+PCA	14	12	6	+	42 days	1	0
4	F/59	Lt MCA	32	13	11	−	13 months	4	80
5	M/71	Rt MCA	27	13	11	−	14 months	4	80
6	M/49	Rt MCA+PCA	25	13	9	−	18 months	4	80
7	M/42	Lt MCA	15	12	8	+	25 days	1	0
8	F/75	Lt MCA	34	11	6	+	17 days	1	0
9	M/62	Rt MCA	31	13	9	+	8 months	3	55
10	F/74	Lt MCA	28	13	6	+	12 months	3	40
11	M/71	Rt ICA	21	10	8	+	Loss	−	−

GCS : Glasgow Coma Scale, GOS : Glasgow Outcome Scale, MCA : middle cerebral artery, PCA : posterior cerebral artery, ICA : internal carotid artery, *Time : time interval between symptom onset and operation

eration was 25.4 hours (range 14~34 hours). Five patients did not have pupillary dilatation at surgery, and 6 patients had it (Table 3). All five patients who didn't have anisocoria with loss of pupillary light reflex showed good recovery with only moderate disa-bilities in 3 months after operation. However, among 6 patients who had anisocoria with loss of pupillary light reflex, 2 patients were severely disabled.

In Group 2, we compared the patients according to the Barthel Index (Table 4). In the group that the patients had Barthel Index above 50 (n=6), mean preoperative GCS was 10.0 and 5 patients did not have anisocoria with loss of pupillary light reflex. But in the patients that had Barthel Index below 50 (n=4), the mean preoperative GCS was 6.5 and all patients had anisocoria with loss of pupillry light reflex. All (100%) among 6 patients with preoperative GCS score 9 or above survived, in contrast with only 1 (25%) survivor among 4 patients with lower than 9 (Fisher's exact test, $P<0.05$). Only 2 (40%) out of 5 patients who had anisocoria with loss of pupillary light reflex survived. Meanwhile, all patients who did not have anisocoria with loss of pupillary light reflex survived (Fisher's exact test, $P<0.05$).

Discussion

According to literatures about the acute massive cerebral infarction, the patients clinically presenting with severe hemispheric stroke syndrome, including hemiplegia, forced eye and head deviation, and progressive deterioration of consciousness within the first two days have poor prognosis with the mortality rate as high as 80%[8,21,25]. But most previous hemicraniectomy series reduced mortality to approximately 20%[4,5,12,16,24]. Rieke et al. collected historical data of 79 patients who had undergone hemicraniectomy after malignant MCA infarction and found that their mortality rate was 30.4%[17]. Of survival patients, 34.5% were severely disabled (patients dependent upon others for daily support due to mental or physical disability or both) and 65.5% moderately disabled (patients independent, as far as daily life is concerned, with disabilities including varying degrees of dysphasia, hemiparesis, or ataxia, as well as intellectual and memory deficits and personality changes) or independent[10,12,17,20,23]. Schwab presented data of 46 surviving patients (73%) after hem-

Table 4. Comparison of clinical factors in 10 patients undergoing decompressive craniectomy ||

	Barthel Index>50 (n=6)	Barthel Index<50 (n=4)	P-value
Age †	59.2 (49-71)	66.3 (42-75)	NS
Sex (M:F)*	5:1	2:2	NS
Patients No. of anisocoria with loss of pupillary light reflex ‡	1	4	0.004
Time§ (hr)	27.8	22.8	NS
Preoperative GCS †	10.0 (9-11)	6.5 (6-8)	0.003

*Significance value were calculated by using the Chi-square test, † Significance value were calculated by using the Mann-Whitney U non-parameter test, ‡ Significance value were calculated by using the Fisher's exact test, §Time : between symptom onset and operation, GCS : Glasgow coma scale, || One patient was dropped out during follow-up period because his family wanted to transfer to other hospital

icraniectomy : All patients were able to walk and had a mean Barthel Index of 68.8[11,21,23]. Holtkamp et al. found poor functional outcome in elderly patients with malignant MCA infarction; mortality differed between conservatively and operatively treated patients (66% versus 17%)[9]. Sakai and Carter have reported mortality rate of 33% and 0% respectively for operatively treated patients from neurological cause[4,20].

Despite the fact that the decompressive craniectomy in malignant acute cerebral infarction is an effective treatment, there is no guideline on the optimal timing of decompressive craniectomy. In deciding the timing of surgery, it is important to know that in general, clinical signs precede critically increased intracranial pressure(ICP)[21]. Ropper et al. suggested that drowsiness is major clinical symptom of developing edema; thus ICP monitoring of this condition might be helpful in guiding further therapy[19]. However, Frank has demonstrated that elevated ICP is not a common cause of initial neurological deterioration from large hemispheric stroke[7]. He presented that cerebral edema contributed to the gradual build-up of a mass, displacing the brain stem rather than globally increasing ICP. Carter et al. suggested a better outcome of patients treated with early rather than delayed hemicraniectomy[4]. They discussed that a delay in performing the surgery has caused a more severe neurological deficit than might have been expected if earlier surgery had been performed. However, Holtkamp et al. presented that no inverse correlation between time to surgery and the outcome was detected[9].

In our study, the time interval between symptom onset and surgery may not have correlation with clinical outcome. The mean time interval from symptom onset to surgery was 27.8 hours in the patients that had a Barthel index of 50 or better, but the other patients had 22.8 hours. Furthermore, the number of patients who had good functional outcome and did not have anisocoria with loss of pupillary light reflex were greater than that of the patient who had poor functional outcome (5 patients vs. 1 patient). So we suggest that the clinical signs of anisocoria with loss of pupillary light reflex is more important guidance for surgical timing.

There have been many studies to investigate the clinically important prognostic factors in acute cerebral infarction[2,6,8,11,15,25]. According to the previous studies, age, preoperative GCS score, the side of infarction, time interval between symptom onset and surgery, and extent of infarction may be associated with survival rate and functional outcome in the patients who had decompressive craniectomy after malignant acute cerebral infarction[5,9,13,21,23,25]. Barber et al. identified that CT images of anteroseptal shift greater than 5mm, pineal shift greater than 2mm, temporal lobe infarction, hydrocephalus, and other vascular territory infarction if present were predictive of fatal outcome after large MCA infarction[3]. Andre et al. presented the CT findings associated with increased mortality as follows; midline shift more than 4mm, large lesion volume (more than 50cc), infarction of a whole hemisphere, or infarction in the distribution of the anterior, middle, or posterior cerebral arteries which are massive (more than 90% expected area) or submassive (more than 50% expected area), or with extension into adjacent vascular territories[1,11].

Conclusion

Decompressive craniectomy confers a clear survival benefit in patients who present with neurologic deterioration from massive cerebral infarction and secondary edema. Decompressive craniectomy may save patients life with preserving a reasonable quality of life satisfactory to both family and patients. We propose that the good preoperative GCS and the surgery before pupillary dilatation should be considered as important factors which are related with better functional outcome and longer survival.

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Commentary

The authors retrospectively analysed 23 cases of acute cerebral infarction, and confirmed the efficacy of decompressive craniectomy and proposed the loss of light reflex as one of the most important factors to determine the timing of the surgery.

But, the initial GCS of non-surgical group appeared worse than the surgical group. And there was no data about the degree of infarction such as volume of infarction and the severity of midline shifting, etc. If these factors are considered in prospective further study, we can get more convincing results.

I think there is no more debate about the benefits of decompressive craniectomy for acute massive cerebral infarction with conservatively uncontrollable intracranial pressure. But, it still be debateful what kinds of surgery should be done. In some literatures, agressive surgical decompression(large craniectomy, anterior temporal lobectomy, resection of infarcted tissue, and duroplasty) was also proposed as a better management strategy than hemicraniectomy and dural augmentation alone.

I appreaciate the authors' excellent work and think that if appropriate decompressive surgery is done before the loss of pupillary lighr reflex, we can get better outcome in acute massive cerebral infarction.

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