

## Clinical Article

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# Surgical Treatment for Acute, Severe Brain Infarction

**Objective :** Stroke is the most prevalent disease involving the central nervous system. Since medical modalities are sometimes ineffective for the acute edema following massive infarction, surgical decompression may be an effective option when medical treatments fail. The present study was undertaken to assess the outcome and prognostic factors of decompressive surgery in life threatening acute, severe, brain infarction.

**Methods :** We retrospectively analyzed twenty-six patients (17 males and 9 females; average age, 49.7yrs) who underwent decompressive surgery for severe cerebral or cerebellar infarction from January 2003 to December 2006. Surgical indication was based on the clinical signs such as neurological deterioration, pupillary reflex, and radiological findings. Clinical outcome was assessed by Glasgow Outcome Scale (GOS).

**Results :** Of the 26 patients, 5 (19.2%) showed good recovery, 5 (19.2%) showed moderate disability, 2 (7.7%) severe disability, 6 (23.1%) persistent experienced vegetative state, and 8 (30.8%) death. In this study, the surgical decompression improved outcome for cerebellar infarction, but decompressive surgery did not show a good result for MCA infarction (30.8% overall mortality vs 100% mortality). The dominant-hemisphere infarcts showed worse prognosis, compared with nondominant-hemisphere infarcts (54.5% vs 70%). Poor prognostic factors were diabetes mellitus, dominant-hemisphere infarcts and low preoperative Glasgow Coma Scale (GCS) score.

**Conclusion :** The patients who exhibit clinical deterioration despite aggressive medical management following severe cerebral infarction should be considered for decompressive surgery. For better outcome, prompt surgical treatment is mandatory. We recommend that patients with severe cerebral infarction should be referred to neurosurgical department primarily in emergency setting or as early as possible for such prompt surgical treatment.

**KEY WORDS :** Cerebral infarct · Brain edema · Decompression · Surgery · Craniectomy.

## INTRODUCTION

Ischemic cerebrovascular disease is the most frequent disease of the brain and may lead to death in about 15% of all patients. Acute ischemia in the territory of the middle cerebral artery (MCA) can lead to massive cerebral edema with raised intracranial pressure and progression to coma and death. This phenomenon, known as "malignant MCA infarction" has been well documented in clinical settings and in autopsy studies<sup>(4)</sup>. The main cause of death encountered in these patients is severe postischemic brain edema leading to arise intracranial pressure (ICP)<sup>(6,7)</sup>. Although experimental evaluation of artificial ventilation, various antiedema agents, such as osmotic diuretics, barbiturates, or Tris buffer, has indicated their beneficial effects in the treatment of ischemia-induced brain edema, no treatment has been shown to be consistently effective in the clinical setting<sup>(6,13,16)</sup>. Medical therapy in such cases is limited to osmotic agents to reduce edema and mechanical ventilation to control the ICP. The outcome in malignant MCA infarction with the best medical management alone is generally poor—only 20 to 40% survival at best and shows a high degree of functional dependence in the survivors<sup>(7,12)</sup>. Also, cerebellar infarction constitute 1.5-4.2% of cases in clinicopathological series and 1.9-10.5% of those in clinical series of patients with cerebral infarctions<sup>(8,14)</sup>. Many patients are in a responsive state early after stroke and deteriorate secondarily after various periods of time (24-168 hours; median time, 72 hours)<sup>(3)</sup>.

Because of the limitations of medical therapies, there have been proposals for decompressive surgery in patients with elevated ICP for a variety of neurological disorders, such as head trauma, space-occupying hemispheric infarction<sup>(2,3,5,8)</sup>. The surgical management of intracranial hypertension is directed toward improving cerebral perfusion and preventing ischemic damage

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and mechanical compression of the brain against the rigid intracranial structures, such as the falx, tentorium, and the sphenoid ridge.

We report our experience and result of the management of 26 patients with severe cerebral or cerebellar infarction during past four years.

## MATERIALS AND METHODS

### Selection and preoperative management

The twenty-six patients, who presented with acute severe cerebral or cerebellar infarction to our institute, were considered for enrollment in this study during the period between January 2003 and December 2006. All patients who experienced spontaneous acute and severe infarction were admitted to the neurological or neurosurgical department. Stroke was diagnosed by clinical history, physical examination, brain computed tomography (CT), and diffusion magnetic resonance imaging (MRI). The patients diagnosed with stroke were initially treated with adequate medical supportive methods. When necessary, they were observed in neurological intensive care units. Usually, 300 mg aspirin was given daily. In all cases, the decision to perform surgery was based on further neurological deterioration despite aggressive medical managements, antiedemic agents, such as mannitol, furosemide, steroids, and hyperventilation. Emergency brain CT or diffusion MRI was used repeatedly for clinical evaluation. When the clinical judgment of the physicians was that medical therapy was ineffective and a fatal outcome was imminent, then emergency surgical decompression was decided.

### Surgical technique

In cerebral infarction, decompressive hemicraniectomy was performed using a large frontoparietotemporal curvilinear incision. A large hemicraniectomy bone flap, including the frontal, parietal, and temporal squamous bone, was removed. The temporal squama was removed to the middle cranial fossa floor to reduce the chance of subsequent uncal herniation. A curvilinear dural incision was used with radial cuts following major sulcal vessels to prevent kinking at the dural margin by edematous brain. Brain parenchyma was not resected. A lax duraplasty was performed using artificial dura.

In cerebellar infarction, a paramedian or median skin incision was made, depending on the location of the lesions. Unilateral or bilateral suboccipital craniectomy with opening of the foramen magnum was performed. The upper and lateral margin of craniectomy was extended to the transverse and lateral sinuses. The dura was opened in a large cruciate incision. A lax duraplasty was performed using artificial dura.

If marked hydrocephalus was evident, a unilateral external ventricular draining was prepared before or after craniectomy.

### Outcome analysis

Patients were evaluated by the Glasgow Coma Scale (GCS) and by neurological examinations before and after surgery. When there was a deterioration of neurological status, all patients underwent imaging study (CT or MRI) immediately. They were transferred for rehabilitation if the clinical conditions became stable. After discharge from the hospital, patients were also evaluated for functional independence by the Glasgow Outcome Scale (GOS). The outcome result was analyzed by the length of interval time to operation. Patients were also regularly followed up in other departments for the management of underlying diseases.

### Data analysis

All values were expressed as mean  $\pm$  SD. The physiological measurements within groups were analyzed by the student's t-test for paired data. To compare both treatment groups, Mann-Whitney rank sum test was used; a probability value of less than 0.05 was considered to be significant.

## RESULTS

### Study population

The twenty six patients with severe infarction (17 males and 9 females; average age, 49.7 yrs) who exhibited neuroclinical deterioration despite aggressive medical managements, underwent decompressive surgery. The median time from ictus to surgery was 74.2 hours. The mean age of male patients was 47.5 years (range 19-66 years), and female patients was 53.9 years (range 35-72 years) with a normal distribution. Some of these patients had various medical conditions (hypertension : 9, diabetes mellitus : 7, cardiovascular disease : 3, moyamoya disease : 1, unruptured aneurysm : 2) Seven patients were heavy smoker (> 1 pack/d). Mean preoperative GCS score was 5.84. All patients were confirmed of acute infarction (6 MCA, 12 cerebellar, 1 ACA, 2 PCA, 2 ICA, 5 mixed territory) by image study (CT or diffusion MRI).

### Outcome measures

We evaluated the outcome at the time of discharge according to the Glasgow Outcome Scale, i.e., 5 : good recovery, 4 : moderate disability (disabled but independent), 3 : severe disability (conscious but disabled), 2 : persistent vegetative state (unconscious, unable to follow commands), 1 : death. The results were separated by favorable outcome (GOS scores 4 and 5) and unfavorable outcome (GOS score 1, 2 and 3). Of the 26 patients, 5 patients showed good recovery, 5

**Table 1.** The Glasgow outcome scale (GOS) scores at discharge

GOS	No. Patients	Outcome
GOS 5	5	38% (favorable outcome)
GOS 4	5	
GOS 3	6	62% (unfavorable outcome)
GOS 2	2	
GOS 1	8	

**Table 2.** Summary of statistical correlations (26 patients)

	Favorable (GOS 5,4)	Unfavorable (GOS 3,2,1)	p value
Age (mean)	47.6 yrs	50.7 yrs	0.66
SEX (M/F)	7/3	10/6	0.5
Preoperative GCS			<0.05*
Territory of Infarctions			
Cbl†	8	4	<0.05*
MCA‡	0	6	<0.05*
ICA§	0	1	–
Others	1 (ACA)	1 (PCA)	–
Mixed	1	3	0.29
Hemisphere (Rt/Lt/bilateral)	5/3/2	6/7/3	<0.05*
Time to operation	2.6 days	3.4 days	<0.01*

†Cbl : cerebellum, ‡MCA : middle cerebral artery, §ICA : internal carotid artery

**Table 3.** Statistical correlations between underlying medical conditions and outcome

Underlying Conditions	Favorable (GOS 5,4)	Unfavorable (GOS 3,2,1)	p value
Hypertension	4	5	0.94
Diabetes mellitus	2	5	<0.05*
Cardiovascular disease	1	2	–
Smoking	3	4	0.21

moderate disability, 2 severe disability, 6 persistent experienced vegetative state, and 8 death. The overall mortality rate was 30.8%. According to the GOS score at discharge, 38% of patients showed favorable outcome (GOS Scores 4 and 5) and 62% unfavorable outcome (GOS score 1, 2 and 3) (Table 1).

**Statistical correlations**

A statistically significant negative correlation existed between patient age, sex and outcome. There was statistically significant association between the time from ictus to surgery and the outcome measures (GOS) at discharge on either bivariate analysis (*p* value <0.01). There was a similar correlation between preoperative GCS score and the outcome measures (GOS) at discharge (*p* value <0.05). Regarding the infarction territory, cerebellar and MCA infarctions showed statistically positive correlation (*p* value <0.05). The surgical decompression was shown to be effective in cerebellar infarction. However, decompressive surgery did not show a good result in MCA infarction. The dominant-hemisphere infarcts showed worse prognosis, compared with nondominant-hemisphere infarcts (*p* value <0.05), (Table 2).

Among the 10 patients with favorable outcome, only two

had preexisting diabetes mellitus, whereas five of sixteen with unfavorable outcome had underlying diabetes mellitus (*p* value <0.05). However, other underlying circumstances, such as hypertension and smoking, showed negative correlation (Table 3).

**DISCUSSION**

The brain swelling following infarction results from cytotoxic and vasogenic edema<sup>10</sup>. Severe brain ischemia initially produces cytotoxic edema without apparent disruption of the blood-brain barrier. Early ischemia disturbs the regulatory mechanism within the cell membrane and results in accumulation of intracellular fluid. The brain tissue affected by ischemic necrosis usually undergoes edematous swelling. Not uncommonly, reflow of blood into damaged vessels following fragmentation and movement of embolus or via collateral circulation may accelerate the enlargement of the mass effect by promoting tissue swelling. Severe brain edema causes a regional increase in ICP, further reducing the regional cerebral perfusion pressure and cerebral blood flow, which may potentiate further infarction and thus create a vicious cycle. Decompressive surgery probably helps to break this cycle. Over the past years, several studies have shown that decompressive surgery is a possible treatment strategy for otherwise uncontrollable increased ICP after severe hemispheric stroke<sup>2,5,9,11,15</sup>. Surgical decompression was shown to be effective in lowering increased ICP and preventing brain herniation. The studies in several cohorts of patients with large MCA infarction have shown that decompressive surgery can reduce mortality to less than 50%<sup>2,5,9,11</sup>. Also, surgical decompression has previously been shown effective in selected cases of cerebellar infarction<sup>3,8,14</sup>.

According to our result, decompressive surgery did not show a good result in MCA infarction, unlike to our expectation. In our patients, preoperative GCS scores were lower and time to operation was longer than other studies; preoperative GCS 5-7 (others 7-8), time to operation 2-3 day (others 1-2 days)<sup>2,5,9,11,15</sup>. Decompressive surgery should be considered based on timely identification of patients who will benefit from this intervention. Several other investigators reporting poor results seemed either to utilize decompressive surgery as a salvage therapy in patients at end stages of herniation or operate on an older population. A higher chance of vegetative outcome when surgery is performed in the late stages of herniation has been reported<sup>11</sup>. In our hospital, almost all patients with severe stroke were referred from emergency room via department of neurology to neurosurgery. During referring period, neurological signs and herniation syndrome became aggravated. Also, the study was limited

in this respect given its small number of patients. However, as seen in our study results, it should be recommended that patient with severe infarction should be referred to neurosurgical department primarily in emergency setting or as early as possible.

With regards to poor prognostic factors, diabetes mellitus, dominant-hemisphere infarcts and low preoperative GCS score were found in our study.

## CONCLUSION

The patients who exhibit clinical deterioration despite aggressive medical management following severe cerebral infarction should be considered for decompressive surgery. For better outcome, prompt surgical treatment is mandatory. We recommend that patients with severe cerebral infarction should be referred to neurosurgical department primarily in emergency settings or as early as possible for such prompt surgical treatment.

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## COMMENTARY

I read this paper about Surgical Treatment for Acute, Severe, Brain Infarction with great interest. In our clinical setting, decompressive surgery for massive cerebral infarctions which have severe edema and already compromised auto-regulatory function of brain is not optimistic at all. In the authors' study, this awful and gloomy result proved as 100% mortality especially in the MCA territory infarctions. But this article also contributes additional evidence in some patients of massive infarction about the benefits of craniectomy and dural expansion.

Several surgical methods to improve the operative outcome have been used including hemicraniectomy, temporal lobectomy, resection of infarcted brain in the parietal & frontal lobule, and duroplasty, etc. Among them removal of the infarcted cerebral tissue, a main source of further brain swelling by lasting and aggravating cytotoxic edema, was the main theme to discuss for improving patients' outcome after surgery<sup>1-3</sup>. Personally I performed partial temporal and frontal lobectomy in every cases of massive MCA infarctions and then the patients were managed with barbiturate coma therapy under the monitoring of ICP. The outcomes were not so good but not so bad. The authors used conventional decompressive surgery without removing infarcted tissue, without coma therapy, without ICP monitoring. More aggressive salvage therapy for massive cerebral infarction can often result in improved outcomes in this unfortunate group.

Another important feeling I got after reading of this article came from the end of your discussion. The authors pointed out that "most of patients with massive cerebral infarction transferred from specific department (neurology) and the operative result was bad because of delaying.....". I'm afraid that this opinion would make an incorrect nuance for specific group who participates in everyday stroke management.

Finally I recommend that further larger multicenter study should be needed to compare the result between conventional and more aggressive salvage operation for Acute, Severe, Brain Infarction. I hope that it could reveal some benefits surely with the assistance of aggressive medical therapy and intensive monitoring.

Once again I thank the authors for this interesting article.

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