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Original Article

Decompressive hemicraniectomy in supra-tentorial malignant infarcts

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Abstract

Background: Decompressive hemicraniectomy not only reduces the intracranial pressure but has been demonstrated to increase survival and decrease the morbidity in patients with supratentorial malignant brain infarcts (STMBI). The aim of this study was to assess the efficacy of surgical decompression to decrease the mortality and morbidity in patients with STMBI refractory to medical therapy and to compare the results with those of the medically managed patients.

Methods: All the 24 consecutive patients with clinical and radiological diagnosis of STMBI, refractory to medical management in 2 years, were included. Option of surgical decompression after explaining the outcome, risk and benefits of the procedure was given to the attendants/relatives of all patients who were fulfilling the inclusion criteria. The patient group, whose attendants/relatives were not willing to undergo surgery, were subjected to the same medical therapy and they were taken as the "control group."

Results: Supratentorial malignant infarcts were more common in the age group of 41–60 years. Mean age of presentation was 42.16 ± 16.2 years and the mean GCS on admission was 7.83 ± 2.1. Mortality was 16.7% in the surgically and 25.0% in the medically managed group. Patients operated early (<48 h), age ≤60 years, midline shift <5 mm and size of infarct less than 2/3rd of the vascular territory involved showed good prognosis. The functional outcome revealed by modified Rankin Score (mRS) and Glasgow Outcome Score (GOS) was better in surgically managed patients. Results of the Zung Self-Rating Depression Score were better in surgically managed patients at 1 year. Barthal Index in the surgically managed group showed statistically significant results.

Conclusions: Decompressive hemicraniectomy with duroplasty if performed early in STMBI not only decreases the mortality but also increases the functional outcome when compared with patients who were managed conservatively with medical therapy only.

Key Words: Brain infarct, decompressive hemicraniectomy, mortality, outcome

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INTRODUCTION

The tradition definition of stroke, devised by the World Health Organization in the 1970s, is a "Neurological deficit of cerebrovascular cause that persisits beyond 24 hours or is interrupted by death within 24 hours." Eighty-five percent of all stroke cases are due to infarction, and only 15% are due to hemorrhage.[24,41]

Stroke is the third most common cause of death throughout the world, after cancer and ischemic heart disease. The annual incidence of stroke in the over 45 years age group in the United Kingdom is about 350 per lakh population.[2] In the United States, it is estimated that 2 lac persons die each year as a result of stroke.[34] Among the Asians, the number who died from stroke was more than three-times that for CAD[50-52] Stroke represents 1.2% of the total deaths in India.[3]

Acute ischemic stroke in the carotid artery distribution can lead to massive cerebral edema with raised intracranial pressure (ICP), uncal, singulate or tonsillar herniation, and progression to coma or death.[34] In ischemic stroke, the patient sustains both cytotoxic and vasogenic edema. Malignant brain edema is a state of severe, progressive and diffuse cerebral edema that causes rapid clinical deterioration, which does not respond to aggressive treatment.

For most complicated strokes, therapy consists of medical supportive care, prevention of systemic complications and rehabilitation. In cases in which medical therapy fails to control life-threatening increase in ICP, emergent surgical hemicraniectomy can be performed to provide immediate decompression. Following a period of pessimism regarding the role of decompressive hemicraniectomy in acute stroke management, there has been a resurgence of interest in the past decade.[12,19,30]

The concept of wide bone removal for the treatment of intracranial hypertension has been recognized since the 19th century. Different types of decompressive craniectomy have been described, including unilateral or bilateral frontal and subtemporal decompression, and circumferential hemicraniectomy.[9,11] Decompressive craniotomy was initially described by Miyazaki in 1966 and popularized by Kjellberg and Prieto in 1971.[20,26]

Timing of the surgical decompression is critical. In clinical studies, surgery performed on an average of 21 h post ictus resulted in a decreased mortality rate compared with surgery performed on an average of 39 h post ictal.[39,40] Without surgical decompression, typical medical measures aimed toward lowering ICP yield a mortality rate of approximately 80% for malignant infarcts.[15] Most hemicraniectomy series reduce mortality to approximately 20%.[8,21] Decompressive surgery, if performed early in patients with rapidly declining neurological status secondary to brain swelling from infarction, can reduce mortality and result in a favorable outcome.[15,39]

MATERIALS AND METHODS

All patients in this prospective study were managed according to the standardized protocol, which included initial history taking, clinical assessment using Glasgow Coma Scale (GCS) and assessment by localizing signs like pupillary size and pulse rate. A computed tomography (CT) scan of the head was done in all the patients to look for the side, vascular territory involved, midline shift and approximate volume of infarct. Instructions of mild head elevation, osmotic therapy using mannitol, glycerol, furosemide, etc. and intubation followed by elective ventilation in patients with GCS less than 7 were given. Decision of surgical decompression has to be made according to the inclusion criteria laid down by the stroke management unit of this Institute, which consists of neurologists, neurosurgeons and the intensive care team.

Following were the inclusion and exclusion criteria for decompressive hemicraniectomy laid by the stroke management unit of SKIMS:

Inclusion criteria

A. Clinical criteria
   1. Age of the patient up to 60 years.
   2. Falling GCS even after extensive medical therapy.
   3. Motor response M_5, M_4 and M_3 or (GCS between 5 and 13)
   4. Hemodynamically stable patient.
   5. <48 h after signs of tentorial herniation.

B. Radiological criteria
   1. CT head evidence of major vessel infarct.
   2. Midline shift >2 mm.
   3. >50% of vascular territory involved.

Exclusion Criteria

A. Clinical criteria
   1. Age of patient >60 years.
   2. GCS improving with medical therapy.
   3. Motor response M_6, M_2 and M_1 (GCS <5 and >13).
   4. Hemodynamically unstable patient.
   5. >48 h after signs of tentorial herniation.

B. Radiological Criteria
   1. CT brain evidence of small infarcts/lacunar infarcts.
   2. Midline shift <2 mm.
   3. <50% of vascular territory involved.

Option of surgical decompression after explaining the risks, outcome and benefits of the procedure was given to the attendants/relatives of all patients who are fulfilling the inclusion criteria. An informed consent was taken before shifting the patient for the procedure. The patient group whose attendants/relatives refuse to undergo

surgery were subjected to the same medical therapy and were taken as the "control group."

A large decompressive hemicraniectomy involving the frontal, temporal and parietal bones and duroplasty consisting of pericranium and commercially available dural substitute was used in all surgically managed patients. The bone flaps were stored in the anterior abdominal wall in few and deep freezer in others till they were reimplanted back after 6 months. In a few patients, even methyl meth-acrylate was used for cranioplasty.

Outcome of the surgical decompression was assessed using the Glasgow Outcome Scale (GOS), Barthal Index (BI), modified Rankin Scale (mRS) and Zung Self-Rating Depression Scale and was compared with the control group.

Data was described as mean ± SD and percentages. Intergroup comparison was carried out by non-parametric tests (Mann–Whitney U-test and Fisher's exact test). A *P*-value of <0.05 was considered significant. Software used for statistical analysis was SPSS, Minitab and Java Stat.

RESULTS

Twenty-four patients were included in this prospective study, and a majority (70.8%) of the patients were in the age group of 41–60 years. Mean age of presentation was 42.16 ± 16.2 years. The male to female ratio was 1.18:1. Twelve (50%) patients underwent surgical decompression, whereas the rest of the 12 (50%) were managed on medical lines of treatment. 70.2% patients were admitted within 24 h, whereas 20.8% were admitted after 24 h of ictus. The GCS on admission in both the groups was 7.83 ± 2.1.

Hypertension, smoking and diabetes mellitus were the main associated factors in our patients in both medically and surgically managed patients. Overall, right-sided (66.7%) infarcts were more common than left-sided (33.3%) infarcts in our study. The most commonly involved vascular territory was the middle cerebral artery (75.0%), followed by anterior cerebral artery (12.5%) and internal carotid artery (12.5%) infarct on CT scan head. A second CT scan of the head was done in all of the surgically managed patients, and it was done in <48 h in 83.3% of the patients.

The aim of conducting the second CT head was to look for the midline shift and size of infarcts, as the infarcts usually takes some time to evolve fully. Midline shift in 62.5% patients was less than 5 mm and in 37.5% of the patients, it was more than 5 mm. Size of the infarct calculated was equal or more than 50% of the vascular territory involved in 29.2% and less than 50% in 70.8% of the patients.

Of 12 operated patients, 10 (83.3%) were operated within 48 h of ictus, whereas the rest of the 12 (16.7%) were operated after 48 h of ictus. Both of the patients operated after 48 h of ictus died in the postoperative period, which has revealed that patients with malignant infarcts if operated early (<48 h) will show a better outcome.

Of the 12 operated patients, 10 (83.3%) survived, and they were followed for 1 year. This data was compared with the medically managed group of 12 patients, in which nine, i.e. 75.0%, survived. Comparison of GOS between surgically and medically managed groups showed statistically significant results ($P = 0.035$) [Figure 1].

Fifty percent of the patients in the surgically managed group showed modified Rankin Scale mRS from 1 to 3, which reflects good outcome, whereas only 22.2% patients in medically managed group showed good outcome after 1 year of follow-up ($P = 0.19$).

Of 10 patients who survived after decompressive hemicraniectomy, eight (80%) were having a Zung Self-Rating Depression Score (ZSRDS) of 70–90, which was considered normal, whereas only two (20%) patients were having a score less than 70, which was in favor of depression. In the medically managed group of 12 patients, nine (75%) survived, and when these patients were followed for 1 year, only four4 (44.4%) patients were normal and five (55.6%) were having ZSRDS less than 70 [Figure 2], Fisher's exact test ($P = 0.17$, OR = 0.13).

BI of 19 patients who survived 1 year of follow-up has shown statistically significant results between surgically and medically managed group of patients ($P = 0.025$). BI >60 is associated with good functional outcome, and <60 means that the patient is dependent after 1 year of follow-up [Figure 3]. Dependence ratio was statistically significant ($P = 0.001$).

DISCUSSION

Of the 24 consecutive patients included in our study for a period of 2 years, 12 were managed conservatively and another 12 underwent surgical intervention in the form of decompressive hemicraniectomy and duroplasty. Mean age of presentation was 42.16 ± 16.2 years. These results were comparable with those available in the literature, as the mean age of presentation in studies by Curry and Pillai *et al.* was 46.8 years and 48.4 years, respectively.[12,30]

We have kept the upper age limit as 60 years because many of the studies have shown poor outcome of decompressive hemicraniectomy in old age. Holtkamp *et al.*[17] studied outcomes after hemicraniectomy in patients between the ages of 55 and 75 years, and concluded that although survival was achieved, physical disability was severe and did not differ from that in the surviving medically treated patients. Similar findings were

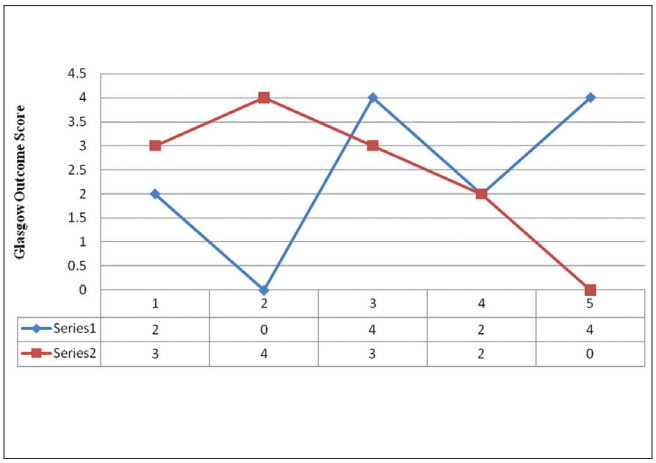

Figure 1: Glasgow outcome scale at 1 year follow-up (Series 1 – surgically managed group; Series 2 – medically managed group

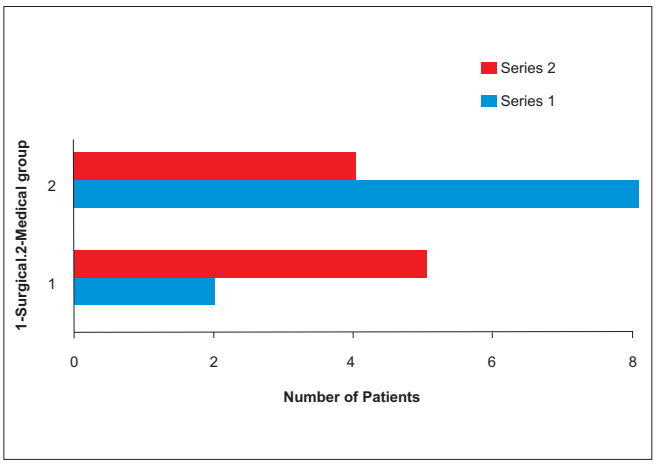

Figure 2: Zung Self-Rating Depression Score of patients at 1 year follow-up

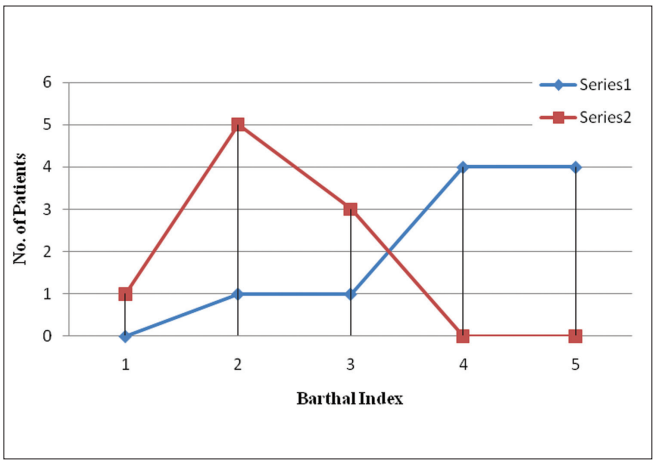

Figure 3: Barthal Index of all the patients at 1 year of follow-up (Series 1 – surgically managed group; Series 2 – medically managed group)

obtained by Pranesh *et al.*,[31] in a review of 19 patients and by Leonhardt *et al.*,[23] who determined that age was an independent predictor of outcome (concluding that "older patients do not seem to benefit from decompressive hemicraniectomy"). Stroke is common in the male gender.[12,30] Even in our study, male (54.2%) patients outnumbered female (45.8%) patients. The male to female ratio was 1.18:1.

Pooled analysis of three randomised trials (DECIMAL, DESTINY, HAMLET) confirms suggestions from nonrandomised studies that decompressive surgery undertaken within 48 h of stroke onset reduces mortality and increases the number of patients with a favorable functional outcome after malignant hemispheric infarction.[46] Nineteen (79.2%) patients in our study were admitted within 24 h, whereas five (20.8%) were admitted after 24 h of ictus. All of the 12 operated patients were admitted within 24 h.

Falling GCS even after medical therapy, motor response M3-M5 and GCS of 5–13 were included in the inclusion criteria, as most of the authors feel that motor response is a more important component of GCS assessment.[44,45] Mean GCS in our study group was 7.83 ± 2.1. These results were comparable with the results available in the literature.[12,30,37]

Hypertension is the most common associate risk factor in stroke patients.[10,49] Other modifiable risk factors include high blood cholesterol levels, diabetes, cigarette smoking[16,48] (active and passive), heavy alcohol consumption[35] and drug use,[43] lack of physical activity, obesity and unhealthy diet. The most common comorbid condition in both our groups was hypertension. Therefore, before taking the patients for surgical decompression, control of hypertension and blood sugar was performed in all our patients.

Overall, right-sided (66.7%) infarcts were more common in our patients. One of the recent studies[3] has shown that of 26 patients included, 14 (53.8%) had non-dominant (right) hemispheric infarct and the rest of the 12 (46.2%) had dominant (left) hemispheric infarcts. The most commonly involved vascular territory was the middle cerebral artery (75.0%), followed by the anterior cerebral artery (12.5%) and internal carotid artery (12.5%) infarcts on CT scan head. Even review of the literature revealed that MCA infarcts were the most common.[4,30,37]

Davalos *et al.*,[13] found some common characteristics in patients who develop severe brain swelling, which included younger age, nausea/vomiting during the first 24 h, early hypodensity on initial brain CT scan and cerebral infarcts involving 35–50% of the MCA territory. The larger the infarcted area, the greater is the risk of developing fatal brain swelling.[12,26,27,36,37]

Although an early hypodensity involving more than 50% of the MCA territory on baseline CT is a major predictor of malignant brain infarct,[22] we did a second CT scan

in all the patients. The aim of doing a second CT scan was to look for the midline shift and size of infarcts as the evolution of infarcts takes time.[28,36,39] In 16 (66.7%) patients, the second CT scan was performed in less than 48 h, whereas in eight (33.3%) it was done after 48 h of hospital stay. In 10 (83.3%) patients of the surgically managed group, the second CT scan was performed within 48 h, and all of these patients survived. When this was compared with the medically managed group in which the second CT scan was done in six (50.0%) patients, three patients expired. Barber *et al.*,[4] found that CT findings are of value in stroke patients, and they can be used to predict a malignant or fatal course.

Out of five patients who died in our study, two (16.6%) were in the surgically managed group and three (25.0%) were in the conservatively managed group. All the five patients were having midline shift more than 5 mm and infarct size greater than 2/3rd of the vascular territory involved. We used CT scan as an easily available freehand technique for the assessment of midline shift and infarct size was used by Curry *et al.*[12] In a recent study, Barber *et al.*,[4] identified CT demonstration of anteroseptal shift greater than 5 mm, pineal shift greater than 2 mm, temporal lobe infarction, hydrocephalus and other vascular territory infarction as predictive of fatal outcome after large MCA infarction.

In the setting of ischemic stroke, patients sustain both cytotoxic and vasogenic edema. Cytotoxic edema is the major mechanism leading to fatal intraparenchymal swelling and mass effect. The time course of cytotoxic edema is slightly variable, but begins within hours after the initial onset of the stroke to even about 3–5 days after infarction. The first 24–48 h after a large MCA infarction is the period during which patients are at the greatest risk of developing fatal brain swelling.[6,7,15] Admission to the hospital and close monitoring of a patient's neurological condition are mandatory during this critical period. Out of 12 operated patients in our study, 10 (83.3%) were operated within 48 h of the ictus, whereas the remaining two (16.7%) were operated after 48 h of the ictus. Both the patients operated after 48 h of ictus died in the postoperative period, which had revealed that patients with malignant infarcts if operated early (within 48 h) will show a better outcome than those operated late.

A comparison of initial study data published by Rieke *et al.*,[36] with that by Schwab *et al.*,[39] supports the notion that outcome is worse when surgery is performed during the stages of herniation. A higher chance of a vegetative outcome when surgery is performed in the late stages of herniation has been reported.[33]

Decompressive surgery in our patients consisted of creation of a large bone flap and duroplasty. In summary, a large (reversed) skin incision in the shape of a question mark based at the ear was made. A bone flap with a diameter of at least 12 cm (always including the frontal, temporal and parietal bones) was removed, as was done in many of the previous trials.[46] Additional temporal bone was removed so that the floor of the middle cerebral fossa could be reached. The dura was opened and a dural patch, consisting of pericranium or a commercially available dura substitute, was inserted and secured to enlarge the intradural space. To prevent epidural bleeding, dural tacking sutures were used when considered necessary. The temporal muscle and the skin flap were then reapproximated and sutured. In surviving patients, cranioplasty was undertaken after at least 6 months with the stored bone flap or acrylate. After surgery, patients were transferred to an intensive care unit, but antiedema treatment was give to few patients only. In the conservative group, patients received best medical treatment on the basis of published guidelines for the management of acute ischemic stroke and space-occupying brain edema.[1,5,29] Of the 12 operated patients in our study, three (25%) patients had immediate and early postoperative complications in the form of acute Respiratory Distress Syndrome (ARDS), hospital-acquired pneumonia and abdominal wall hematoma secondary to the deposited bone flap. The first two patients with the diagnosis of ARDS and hospital-acquired pneumonia were on ventilator after surgery for 3 and 5 days, respectively, and later both of them expired. The third patient developed abdominal wall hematoma on the second postoperative day, which was drained on the same day and the bone flap was removed.

Two patients (16.66%) had delayed complications, one had local wound infection probably due to artificial dural patch and the other presented with sinking skin flap syndrome. The first patient presented with local wound infection after 1 month of decompressive craniectomy. He was managed by drainage of the subgaleal collection and putting the patient on antibiotics as per the culture sensitivity report. The second patient came after 6 months with a clinical feature in favor of sinking skin flap syndrome.[38] He underwent cranioplasty and his clinical condition improved in the postoperative period. The survival rate in the surgically managed group was 83.3% as 10 out of 12 patients in our study survived on 1 year follow-up. The survival rate is comparable with that of the previous reports.[12,30,46] Six patients (50.0%) in the surgically managed group showed moderate to good recovery, whereas only two (16.7%) patients showed moderate to good recovery in the medically managed patients when GOS[18] was compared between the two groups. GOS has shown statistically significant results between the two groups ($P = 0.035$). This means that decompressive hemicraniectomy not only improves survival rate but also improves the functional outcome when compared with those managed conservatively, as has been concluded by many of the studies.[8,12,30,40,46] The

modified Rankin Scale (mRS) is a commonly used scale for measuring the degree of disability or dependence in the daily activities of people who have suffered a stroke, and it has become the most widely used clinical outcome measure for stroke clinical trials. It was originally introduced in 1957 by Rankin,[32] and first modified to its currently accepted form by Prof. C. Warlow's group at the Western General Hospital in Edinburgh for use in the UK-TIA study in the late 1980s.[14] The first publication of the current modified Rankin Scale was in 1988 by van Swieten *et al.*, who also published the first interobserver agreement analysis of the modified Rankin Scale.[47] In our study, 50% of the patients in the surgically managed group showed mRS from 1 to 3, which means good outcome, whereas only 22.2% of the patients in the medically managed group showed good outcome with mRS 1–3. Although not statistically significant (P = 0.19), a score on the mRS of ≤3 is generally accepted as a favorable outcome in stroke research as per Vahedi *et al*.[46] The ZSRDS was designed by the Duke University psychiatrist, Dr. William W. K. Zung, to assess the level of depression for patients diagnosed with depressive disorder.[53] Eight out of 10 (80%) who survived after decompressive hemicraniectomy had a ZSRDS of 70–90, which is considered normal, whereas only two (20%) had features in favor of depression. This data when compared with the medically managed group of 12 patients in which nine (75.0%) survived and when they were followed for 1 year, only four (44.4%) patients were normal and the remaining five (55.6%) were diagnosed as having depression as per the ZSRDS, Fisher exact test (P = 0.17, OR = 0.13). This revealed that, clinically, depression was more common (55.6%) in surgically managed patients than in the medically managed (20%) group on 1 year of follow-up. Our results were almost similar to that of Curry *et al*.[12] The BI was first introduced by Mahoney and Barthel in 1965,[25] and is now extensively used in rehabilitation. It was initially developed to measure functional ability before and after treatment and to assess the amount of nursing care needed. Initially, it was designed for use with long-stay hospitalised patients with neuromuscular or musculoskeletal problems.[25] According to Sinoff and Ore,[42] scoring on the BI can be interpreted as follows: score of 80–100, independent; score of 60–79, needs minimal help with ADL; score of 40–59, partially dependent; score of 20–39, very dependent; score of <20, totally dependent. BI of the 19 patients in our study who survived on 1 year follow-up has shown statistically significant results between the surgically and medically managed groups (P = 0.025). Eight out of 10 (80.0%) operated patients had BI of more than 60 at 1 year, whereas none of the patient in the conservative group showed BI of more than 60.

CONCLUSION

This study had shown that the decompressive hemicraniectomy with duroplasty if done early (<48 h) in patients less than 60 years of age improves survival when compared with the medically managed patients. This not only improves the survival but also the functional outcome assessed by GOS, mRS, Zung Depression Score and BI was better in patients who underwent surgical decompression.

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