Decompressive Craniectomy for Ischemic Stroke: Effect of Hemorrhagic Transformation on Outcome

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Background: Decompressive hemicraniectomy (DhC) is a life-saving surgical procedure being increasingly employed for malignant middle cerebral artery strokes. We examined the incidence of hemorrhagic transformation following DhC. *Methods:* We retrospectively reviewed the charts and radiological images of patients who underwent DhC for malignant middle cerebral artery strokes. We classified the hemorrhagic events and assessed the short-term 30-day outcome associated with these events. *Results:* A total of 23 DhCs were performed for supratentorial ischemic strokes in 22 patients. There were 16 males and 6 females with an average age of 47 years (21-69 years). Of the 22 patients, 13 (59%) developed a new hemorrhage following DhC. There were 3 mortalities (14%). Of the survivors, 6 (27%) were discharged home with a modified Rankin Scale (mRS) score of 2. The remaining 13 patients (59%) recovered to a degree wherein they were discharged to a rehabilitation center (mRS score 3-4). No patient persisted in a vegetative or semivegetative state (mRS score 5). *Conclusions:* In this study, the rate of hemorrhagic transformation following DhC for ischemic stroke was 59%. This is much higher than that reported in the stroke thrombolysis literature. The presence of any type of new hemorrhagic transformation in this patient population does not appear to alter the natural history of their ischemic strokes in terms of Glasgow outcome scores or destination of disposition. **Key Words:** Malignant middle cerebral artery stroke—decompressive craniectomy—hemorrhagic transformation—microbleeds—intracerebral hemorrhage—reperfusion injury—intracranial pressure monitoring.

Introduction

Acute ischemic hemispheric strokes are devastating neurological emergencies. Approximately 50% of stroke patients will survive with life-altering disabilities, requiring prolonged periods of rehabilitation.[1,2]

Delivery of intravenous (IV) thrombolysis has proven to be logistically challenging due the relatively short treatment opportunity window. A larger treatment opportunity window exists for intra-arterial stroke interventions.

Extensive, ischemia-related cytotoxic edema can lead to the infarct being referred to as a "malignant" stroke with elevated intracranial pressure (ICP) that can theoretically be proportional to the volume of the infarcted brain tissue. Despite early administration, patients receiving intravenous recombinant tissue plasminogen

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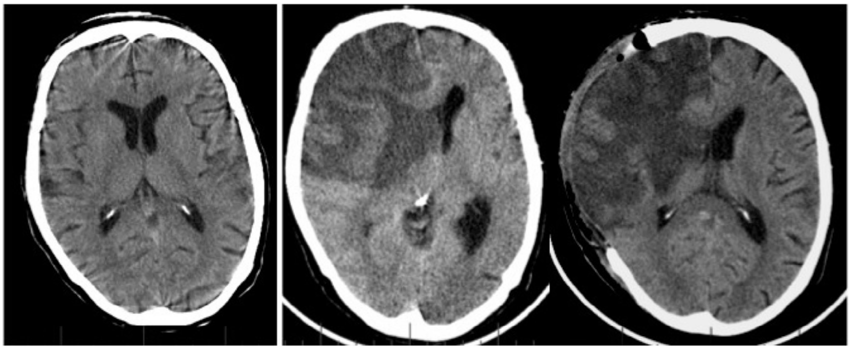

Figure 1. *Noncontrast enhanced computerized tomography scan images of a 54-year-old male who developed malignant middle cerebral artery infarction with midline shift. Note the resolution of the midline shift despite the persistent edema.*

activator will go on to develop infarcted brain tissue. Successful reperfusion of the ischemic/infarcted and swollen vessel walls can lead to extravasation of blood directly into the brain parenchyma. The extent and type of hemorrhagic transformation often predict the degree of clinical deterioration.[3,4] Occlusion of the middle cerebral artery (MCA) is most often associated with malignant infarction because of its potential for herniation syndromes and brainstem compression.

Decompressive hemicraniectomy (DhC) is a brain-space augmenting procedure that is garnering increased interest for use in patients who develop a "malignant" ischemic stroke.[5,6] It entails a large craniotomy similar to that of a trauma bone flap. The dura overlying the hemisphere is augmented, thereby reducing ICP. In extreme conditions, and to relieve the pressure of the herniating brain of the vital brainstem structures, an anterior–medial temporal lobectomy can be undertaken. An interval bone flap replacement is undertaken at a later date. The effect of decompressive procedures on the evolution of the malignant infarcted tissue, specifically hemorrhagic transformation; has not been well studied. We have examined the incidence of hemorrhagic transformation in patients who have undergone DhC for a malignant MCA infarction.

Materials and Methods

Research ethics board approval was obtained for a retrospective chart review of patients admitted to the Montreal Neurological Institute and Hospital between June 2007 and July 2010 with an acute ischemic stroke who underwent a DhC (with or without prior IV or intra-arterial thrombolysis). We examined the time to intervention and assessed the 30-day outcome using a modified Rankin Scale (mRS) score [7] and the Glasgow Outcome Scale (GOS) score.[8]

DhC

The anterior–posterior (AP) craniectomy diameter ranged from 12 to 15 cm and extended to the anterior temporal fossa floor. An augmenting duraplasty was performed on all patients. Infarcted brain was left in situ unless uncal herniation was imminent, in which case a partial or complete anterior temporal lobectomy was also performed.

The area of craniectomy (square centimeter) was calculated using the radii of the DhC as measured from the lateral scout X-ray of the postoperative computerized tomography (CT) scan (A [area, cm^2] $= D \times d \times \pi/4$)[9] (see Fig 1). The AP diameter of the DhC was calculated from lines projected from both the nasion anteriorly and the occipital protuberance posteriorly. We also calculated a ratio of the AP distance for the DhC to that of the AP of the skull on each individual patient. The vertical diameter of the DhC was calculated from the highest or most superior point of the defect of the DhC seen to the lowest or most inferior point of the DhC defect, including the temporal extension, as visualized on the lateral scout film.

Replacement of the bone flap occurred within 3 months in most patients.

Hemorrhagic Transformations

The term "hemorrhagic transformation" is used in general to refer to any new blood on the postdecompressive craniectomy CT scan. We used a 3-tier classification system as described in the European–Australasian Acute Stroke Study trial to better classify this event in our patients.[4] According to this system, hemorrhagic transformations are classified as (1) hemorrhagic infarction type 1 (HI-1), which refers to scattered heterogeneous petechiae found along the interface of the infarcted and perfused brain; (2) hemorrhagic infarction type 2 (HI-2), which is either heterogeneous petechiae within the infarcted area or a homogenous hematoma covering less than 30% of the infarcted area; (3) parenchymal hemorrhage type 1 (PH-1), which is defined as a hyperdense homogenous hematoma encompassing more than 30% of the ischemic lesion volume with no mass effect; and (4) parenchymal hemorrhage type 2 (PH-2), as blood clots in more than 30% of the infarcted area with a substantial space-occupying effect.

Statistical Analysis

Analyses were performed using Stata 12 software (Stata, College Station, TX). Hemorrhage means, medians, ranges, and frequencies (percent), along with independent patient