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Clinical Study

Addition of zygomatic arch resection in decompressive craniectomy

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ABSTRACT

Decompressive craniectomy (DC) is a surgical option in managing uncontrolled raised intracranial pressure refractory to medical therapy. The authors evaluate the addition of zygomatic arch (ZA) resection with standard DC and analyze the resulting increase in brain volume using three-dimensional volumetric CT scans. Measurements of brain expansion dimension morphometrics from CT images were also analyzed. Eighteen patients were selected and underwent DC with ZA resection. The pre- and post-operative CT images were analyzed for volume and dimensional changes. CT images of 29 patients previously operated on at the same center were retrieved from the picture archiving and communication system (PACS) and were similarly studied. The findings obtained from the two groups were compared and analyzed. Analysis from three-dimensional CT volumetric techniques revealed an significant increase of 27.97 ml (95% confidence interval [CI]: 39.98–180.36; $p = 0.048$) when compared with standard DC. Brain expansion analysis of maximum hemicraniectomy diameter revealed a mean difference of 0.82 cm (95% CI: 0.25–1.38; $p = 0.006$). Analysis of the ratio of maximum hemicraniectomy diameter to maximum anteroposterior diameter gave a mean difference of 0.04 (95% CI: 0.05–0.07; $p = 0.026$). The addition of ZA resection to standard DC may prove valuable in terms of absolute brain volume gain. This technique is comparable to other maneuvers used to provide maximum brain expansion in the immediate post-operative period.

1. Introduction

Decompressive craniectomy (DC), which involves the removal of a section of cranial bone to accommodate a swollen brain, still remains a useful salvage procedure in treating raised intracranial pressure refractory to medical therapy, in spite of recent claims [1] questioning its value in terms of overall outcome. Apart from traumatic brain injury, it is also used in severe brain swelling secondary to other conditions, including subarachnoid hemorrhage, spontaneous intracerebral hemorrhage and malignant infarction. Although there is a lack of well-designed randomized trials providing robust support for this procedure, it nevertheless has become an established technique which is widely employed [2].

Currently the Brain Trauma Foundation of the American Association of Neurological Surgeons [3] and The European Brain Injury Consortium [4] guidelines recommend DC as a second tier therapy for refractory intracranial hypertension, and to this end, the standard approach in cases requiring unilateral decompression consists of the removal of a wide frontotemporoparietal bone flap measuring at least 12 to 15 cm [2,5,6] in diameter. Technical modifications attempting to achieve adequate decompression have arisen since its inception in the beginning of the last century, all aiming to further reduce intracranial pressure [7]. Of these variations, a technique suggested by Park et al. [8] and Zhang et al. [9] involves, together with the standard procedure of DC, the resection of the temporalis muscle and its fascia. While theoretically attractive and technically feasible, post-operative morbidity contributed by the absence of the temporalis muscle remains a source of concern.

Applying skull base principles, we explored the possibility of adding a zygomatic osteotomy to DC, which permitted the preservation of the temporalis muscle and its fascia, and attempted to quantify the increase in overall volume of external brain expansion using three-dimensional CT volumetric analysis. The premise here is the possibility that since resecting the temporalis muscle afforded greater potential expansion of the underlying swollen brain as previously shown, the provision of a zygomatic osteotomy might provide a somewhat similar contribution in terms of potential space since it allows a larger outward excursion of the muscle and, theoretically, the underlying brain, without having to resort

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to the removal of the muscle itself. The replacement of the zygomatic arch (ZA) using plates and screws can then be performed together with cranioplasty at a later date.

2. Methods

The inclusion criteria for this study were (1) traumatic brain injury or cerebrovascular injury, (2) CT images with 1 mm slice thickness (sourced from the picture archiving and communications system [PACS] of Hospital Universiti Sains Malaysia [HUSM]) and (3) aged between 15 and 85 years.

Patients were placed into experimental and control groups at a ratio of 2:1. For the experimental group, patients who fulfilled the inclusion criteria were enrolled and underwent unilateral frontotemporoparietal DC with resection of the ZA between January and December 2012 at HUSM.

For the control group, patients who underwent a procedure for similar reasons (trauma or cerebrovascular injury) from 2007 to 2012 who fulfilled the inclusion criteria and had available brain CT scans in the HUSM PACS were included.

2.1. Experimental group

Concerning surgical decision making, the option to include the technique of ZA resection with the standard procedure of DC was left to the discretion of the attending neurosurgeon. All the surgeries were performed by a single surgeon (A.G.M.). Post-operative CT scans were taken, ranging from a few hours to 2 days, and these images, together with the pre-operative scans, were imported in Digital Imaging and Communications in Medicine (DICOM) format and the three-dimensional reconstruction images were analyzed using the Medical Imaging Interaction Toolkit 3M3 software (German Cancer Research Center) [10,11]. Both pre- and post-operative CT images were taken at 1 mm intervals. Measurements for morphometric parameters as described by Flint et al. [12] were also carried out using CT brain scans (Fig. 1) which were accessed via the hospital PACS and measurements were made using the cut taken at the level of the largest brain herniation. The parameters used were extracerebral herniation (ECH magnitude), maximum hemicraniectomy diameter (MHD), maximum anteroposterior diameter (MAP), MHD/MAP ratio, and ECH index (ECH/MHD) (Fig. 1). The scans that we acquired for analysis were all carried out within the first 2 post-operative days as per local protocols.

2.2. Control group

CT images of the control group were extracted from the PACS and analyzed for volume differences in the same manner as the experimental group. The method described by Flint et al. was also used to study the CT images from this group of patients, using the same parameters described above.

This study was conducted after obtaining Human Ethics Committee Approval (FWA #00007718; Institutional Review Board #00004494).

2.3. Surgical technique

2.3.1. Skin incision and cranial exposure

In agreement with most authors regarding the initial execution of a standard DC procedure [2,6,7,13] a reverse question-mark skin incision is performed, beginning 1 cm in front of the tragus and, additionally in this study, 1 cm below the ZA. This incision is extended upwards and arches posteriorly behind the ear to meet at approximately the posterior mastoid line and finally curving anteriorly to continue as a linear incision placed 2 cm lateral to the midline, ending at the widow's peak. The skin is lifted off to expose the frontotemporal keyhole and below to the ZA. Care is taken to maintain subfascial dissection so as to not injure the frontotemporal branch of the facial nerve. The temporalis muscle is then dissected off the squamous temporal bone as far as the root of the zygoma.

2.3.2. Craniectomy

Burrholes were suitably formed at the keyhole, temporal squama and over the convexity. Craniectomy was performed with the following margins: anteriorly, frontal to the midpupillary line; superiorly, 2 cm lateral to the superior sagittal sinus; posteriorly, at least 2 cm behind the external auditory meatus; and inferiorly,

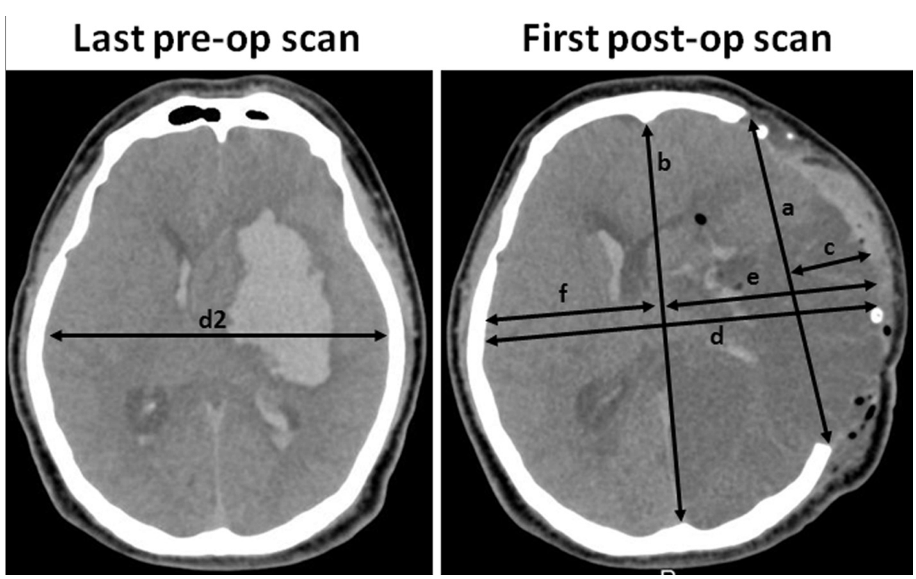

Fig. 1. Brain morphometric measurements using Flint's method on pre-operative (left) and post-operative (right) axial CT scans. Line a = maximum hemicraniectomy diameter. Line b = maximum anteroposterior diameter. Line b = midline. Line c = extracerebral herniation (extracerebral herniation index = Line c/Line a). Line d = maximum diameter taken at CT scan slice depicting the greatest brain excursion. Line e and Line f = distances from either surface of the brain to the midline. Line d2 = maximum diameter seen on pre-operative CT scan, taken at approximately the same level taken to measure Line d (Line d – Line d2 = lateral brain expansion).