Measurement of Bone Flap Surface Area and Midline Shift to Predict Overall Survival After Decompressive Craniectomy

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BACKGROUND: **There is uncertainty about the optimal method for measuring the decompressive craniectomy (DC) surface area and how large the DC should be.**

METHODS: **A radiological technique for measuring the surface area of removed bone flaps in a series of 73 DCs was developed. Preoperative and early postoperative computed tomography scans of each patient were evaluated. Midline shift (MLS) was considered the key factor for successful DC and was assigned to either normal (0–4 mm) or pathological (≥5 mm) ranges. The association between postoperative MLS and patient survival at 12 months was assessed.**

RESULTS: **Measurements of all removed bone flaps yielded a mean surface area of 7759 mm^2. The surface area of the removed bone flap did not influence survival (surviving 7643 mm^2 vs. deceased 7372 mm^2). The only factor associated with survival was reduced postoperative MLS ($P < 0.034$). Risk of death was 14.4 (3.0–70.1)-fold greater in patients with postoperative shift ≥5 mm ($P < 0.001$).**

CONCLUSION: **The ideal surface area for "large" square bone flaps should result in an MLS of <5 mm. Enlargement of the craniectomy edges should be considered for patients in whom MLS ≥5 mm persists according to early postoperative computed tomography scans.**

INTRODUCTION

"Large"decompressive craniectomy (DC) frequently is recommended to prevent or relieve brain swelling, and a better survival rate has been reported when a wide bone flap is removed.[1-4] A lack of data exists, however, concerning how wide the craniectomy should be in patients who are undergoing a cranial decompressive procedure. Bone flaps 12 × 15 cm,[2] 12 × 8 cm,[5] or 12 × 13 cm in size[6] or 12 cm in diameter[7] are considered "large" bone flaps. A too-large DC, however, is known to increase the risk of complications in the postoperative period.[8]

Uncertainty also exists about the optimal way to measure bone flaps after the removal of a portion of skull bone. Therefore, we developed a standard, reproducible radiological technique for measuring bone flaps in a series of DCs. Our aim was to establish the ideal surface area for "large" square bone flap removal with respect to survival.

METHODS

Institutional review board approval was obtained (Rif. 3793, Prot. 2458). From November 2012 to September 2014, 84 patients underwent DC with expansion duraplasty. Eleven patients were excluded because of bilateral DC or because the bone flap was unavailable for measurement. Seventy-three patients with unilateral DC (48 [65%] for hemorrhagic or ischemic stroke, 22 [30%] for brain injury and subdural hematoma, and 3 [4%] for infectious diseases) were eligible for measurement of the autologous bone flap, which was sterilized with ethylene oxide and hermetically sealed in a bag. Each bone flap was placed in a sagittal position on

Key words
- Brain
- Bone
- Computed tomography
- Craniectomy
- Flap
- Shift
- Ventricular system

Abbreviations and Acronyms
CT: Computed tomography
DC: decompressive craniectomy
MLS: Midline shift

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Figure 1. Acquisition image of an autologous bone flap that has been ethylene oxide sterilized and hermetically sealed in a bag. The bone flap was placed in a sagittal position on the scanner table, and a single scan yielded the image. The technician on the working desk used a mouse to draw a line over the inner edge of the bone flap (*white line*), obtaining a closed surface area. Computed tomography automatically determined the surface area to be 10,304.3 mm^2 (103 cm^2) (*arrow at lower left*).

the scanner table (Toshiba Aquilion TSX-101A, Tokyo, Japan), and an image was acquired (Figure 1). Afterwards, the technician on the working desk used a mouse to draw a line over the inner edge of the bone flap, thereby obtaining the closed surface area. The scanner automatically determined the surface area in square millimeters.

Guidelines for the treatment of acute subdural hematomas suggest that displacement of the septum pellucidum or midline shift (MLS) on the preoperative computed tomography (CT) are correlated with outcome and that patients with an MLS >5 mm should undergo surgical treatment regardless of the Glasgow coma score.[9] For this reason, we evaluated the preoperative and early postoperative (within 3 postoperative days) MLS on the axial CT slice at the level of the foramen of Monro (Figure 2) in all patients. Brain shift was considered to be within either normal (0–4 mm) or pathological (≥5 mm) ranges. Intracranial pressure monitoring data obtained in the intensive care units were not considered in this study. The surface area obtained from every square bone flap was analyzed for possible associations with patient survival at 1-year follow-up.

Statistical Analysis

Statistical analysis was performed with the Statistical Package for Social Science (SPSS), release 15.0 (SPSS Inc., Chicago, Illinois, USA). Continuous variables are expressed as mean ± standard deviation, and categorical variables are displayed as frequencies. Mann–Whitney U nonparametric or χ^2 tests were used to assess the significance of differences between subgroups. All of the tests were 2-sided, and statistical significance was set at $P < 0.05$.

RESULTS

Demographic and radiological characteristics of the patients are reported and stratified by primary outcome in Table 1. The mean

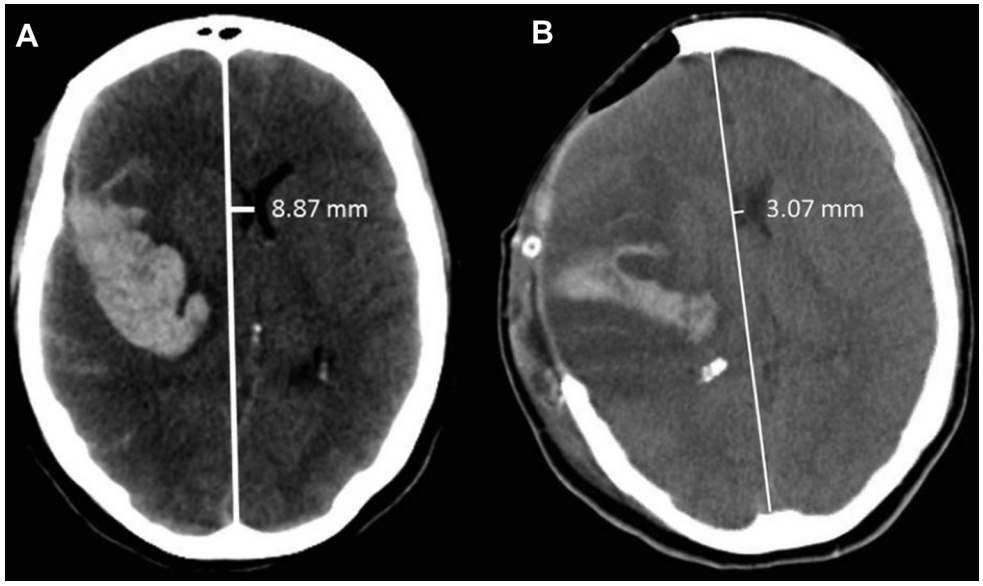

Figure 2. Computed tomography (CT) scans of a 39-year-old woman with rupture of a right middle cerebral artery aneurysm and intrasylvian hemorrhage. (**A**) Preoperative CT scan. Midline shift (MLS) was >5 mm. (**B**) Early postoperative CT scan after decompressive craniectomy and clipping revealed a reduction in the MLS (<5 mm). In this patient, the removed bone flap surface was 75 cm^2. The patient was still alive 1 year after surgery (Glasgow Outcome Scale Extended 7).