# To Retain or Remove the Bone Flap During Evacuation of Acute Subdural Hematoma: Factors Associated with Perioperative Brain Edema

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■ BACKGROUND: **The fate of the bone flap is a significant decision during surgical treatment of acute subdural hematoma (SDH). A general guideline revolves around the surgeon's concern for brain edema. Limited studies, however, have focused on the factors that contribute to perioperative brain edema.**

■ METHODS: **From 2012 to 2015, 38 patients who underwent decompressive craniectomy for acute SDH were reviewed. Clinical data were extracted (age, sex, initial Glasgow Coma Scale (GCS) score, sodium level, hematocrit, and intraoperative blood loss). From the preoperative scan, SDH volume, midline shift (MLS), and volume within the skull (to estimate baseline brain volume) were measured. From the postoperative scan, brain volume (including any herniating regions) was measured. Δ% was defined as the percentage change in postoperative brain volume compared with preoperative volume. Evident contralateral injury, contusions, and intraventricular hemorrhage (IVH) were noted.**

■ RESULTS: **Fifteen patients demonstrated negative Δ%. Univariate analysis found significant correlations between Δ% and preoperative MLS, initial GCS, presence of IVH, and presence of contralateral injury ($P < 0.05$). A multiple regression for Δ% elicited a significant model ($F [3, 34] = 17.387$, $P < 0.01$) with R2 0.605, where $\Delta\% = 16.197 - 1.246*GCS - 0.986 * MLS + 3.292 * IVH$ (with 0 = no IVH, 1 = presence of IVH).**

■ CONCLUSIONS: **A high proportion of patients can exhibit negative Δ%, or relative brain compression after decompression of SDH. For these patients, replacement of the bone flap may be reasonable to avoid obligatory interval cranioplasty. Preoperative MLS, initial GCS, and presence of IVH can help predict whether overall brain volume will swell or compress within the normal confines of the skull. This can guide the decision to retain or remove the bone flap.**

## INTRODUCTION

The fate of the bone flap is a significant decision during surgical treatment of traumatic acute subdural hematoma (SDH). A general guideline revolves around the surgeon's concern for brain edema perioperatively. Retention of the bone flap confers a greater potential for intracranial hypertension but negates the risks associated with obligatory interval cranioplasty. Not uncommonly, a postoperative computed tomography (CT) of the head may demonstrate a relatively sunken cranial defect with persistent midline shift after decompressive craniectomy (DC). Previous studies have noted wide variation with this clinical decision among surgeons around the world.[1,2] Consequently, predictive preoperative factors to assess brain edema can help guide this clinical decision. As such, this study explored potential relationships between clinical factors and the extent of brain edema via analysis of perioperative imaging.

**Key words**
- Acute subdural hematoma
- Brain edema
- Trauma

**Abbreviations and Acronyms**
**Δ%**: Percentage change in postoperative brain volume compared with preoperative volume
**CR**: Craniotomy
**CT**: Computed tomography
**DC**: Decompressive craniectomy
**GCS**: Glasgow Coma Scale
**IVH**: Intraventricular hemorrhage
**MLS**: Midline shift
**SDH**: Subdural hematoma
**TBI**: Traumatic brain injury

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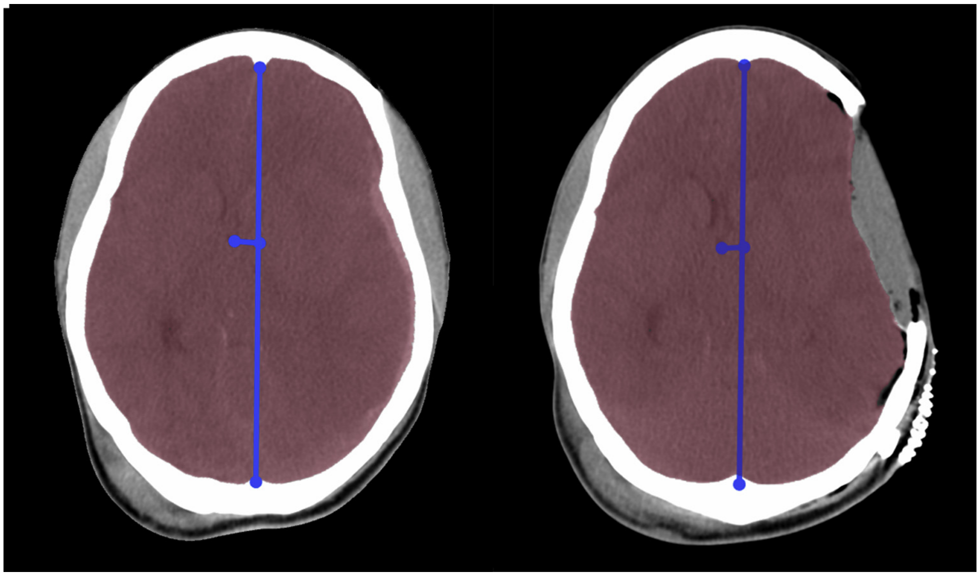

**Figure 1.** Example patient with negative percentage change in postoperative brain volume compared with preoperative volume (Δ%). Preoperative (*left*) and postoperative axial computed tomography of the head. *Red* demonstrates selection of brain volume region of interest, including any herniating regions. *Blue lines* demonstrate measurement of midline shift. Preoperative midline shift = 9.7 mm. Initial Glasgow Coma Scale score = 6. Δ% = −6.5.

We proposed that assessment of brain volume via CT imaging in patients without bone flaps is a reasonable model to study brain edema.

## METHODS

The approval of the institutional board review at our hospital was obtained before the study. From 2012 to 2015, 38 patients who underwent DC for traumatic acute SDH were reviewed. Clinical data were extracted (age, sex, initial Glasgow Coma Scale [GCS], sodium level, hematocrit, and intraoperative blood loss). CT imaging was loaded into OsiriX MD (Pixmeo, Bernex, Switzerland). From the preoperative scan, SDH volume, midline shift (MLS), and volume within the skull (to estimate baseline brain volume) were measured. From the postoperative scan, brain volume (including any herniating regions) was measured (Figures 1 and 2). Volume was obtained by a semiautomated protocol to select the region of interest through axial CT images. The extent of brain edema was defined as Δ%, or the percentage change in postoperative brain volume compared with preoperative volume. Other parameters (presence of contralateral injury, contusions, or intraventricular hemorrhage [IVH]) were noted.

Statistical analysis was performed with IBM SPSS, Version 22 (IBM Corp., Armonk, New York, USA). Descriptive statistics (mean, standard deviation, and/or percentage) were computed for all variables. To identify the best predictors of Δ%, a linear multiple regression model was computed. First, univariate analysis was completed with Δ% as the dependent variable and the other variables (age, sex, initial GCS, sodium level, hematocrit, intraoperative blood loss, presence of contralateral injury, presence of contusions, presence of IVH, preoperative MLS, preoperative brain volume, and preoperative SDH volume) as independent variables. Then, a backward, multiple linear regression computation was carried out to evaluate Δ%. The independent variables that entered into the model were those with a $P < 0.10$ in the univariate analysis.

## RESULTS

Table 1 summarizes the clinical factors. The mean age was 42.01 ± 13.65 years. There were 27 male and 11 female patients. Fifteen patients (39%) demonstrated negative Δ%. Univariate analysis found significant correlations between Δ% and the following: preoperative MLS, initial GCS, presence of IVH, and presence of contralateral injury (all $P < 0.05$).

A backward, multiple linear regression for Δ% that initially included all variables in which univariate analysis yielded $P < 0.1$ found a significant model that combined preoperative MLS, initial GCS, and IVH ($F$ [3, 34] = 17.387, $P < 0.01$) with $R^2$ 0.605, where $\Delta\% = 16.197 - 1.246 * GCS - 0.986 * MLS + 3.292 * IVH$ (with 0 = no IVH, 1 = presence of IVH) (Table 2). Δ% decreased by 1.246 % for each point in GCS, decreased by 0.986% for each millimeter in preoperative MLS, and the presence of IVH imparted 3.292% more volume. Consequently, a negative Δ% is possible with larger initial GCS, larger preoperative MLS, and absence of IVH.

## DISCUSSION

Traumatic acute SDH is a frequently occurring neurosurgical pathology. Recent analyses report mortality rates of 15%–17%