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Clinical Article

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# Clinical Factors for the Development of Posttraumatic Hydrocephalus after Decompressive Craniectomy

**Objective :** Earlier reports have revealed that the incidence of posttraumatic hydrocephalus (PTH) is higher among patients who underwent decompressive craniectomy (DC). The aim of this study was to determine the influencing factors for the development of PTH after DC.
**Methods :** A total of 693 head trauma patients admitted in our hospital between March 2004 and May 2007 were reviewed. Among thee, we analyzed 55 patients with severe traumatic brain injury who underwent DC. We excluded patients who had confounding variables. The 33 patients were finally enrolled in the study and data were collected retrospectively for these patients. The patients were divided into two groups: non-hydrocephalus group (Group I) and hydrocephalus group (Group II). Related factors assessed were individual Glasgow Coma Score (GCS), age, sex, radiological findings, type of operation, re-operation and outcome.
**Results :** Of the 693 patients with head trauma, 28 (4.0%) developed PTH. Fifty-five patients underwent DC and 13 (23.6%) developed PTH. Eleven of the 33 study patients (30.3%) who had no confounding factors were diagnosed with PTH. Significant differences in the type of craniectomy and re-operation were found between Group I and II.
**Conclusion :** It is suggested that the size of DC and repeated operation may promote posttraumatic hydrocephalus in severe head trauma patients who underwent DC.

**KEY WORDS :** Hydrocephalus · Craniotomy · Craniocerebral trauma.

## INTRODUCTION

Posttraumatic hydrocephalus is an active and progressive process of excessive cerebrospinal fluid (CSF) accumulation due to liquorodynamic disturbances following craniocerebral injury[13]. The incidence of PTH ranges from 0.7-86%[3,8,9,18]. Differences in diagnostic criteria and classification have contributed to the variation in reported incidence. Longer duration of coma, increased age, decompressive craniectomy (DC), and subarachnoid hemorrhage have been reported to increase the risk of developing PTH[10,15]. Among these risk factors, DC can be performed therapeutically in head trauma cases with progressively increasing intracranial pressure (ICP) that were refractory to medical management. This procedure has been shown to improve survival in carefully selected cases[11,16,20,25]. However improvements in long-term functional outcomes and quality of life, when compared with standard medical therapies, have been tangible[5,24]. Therefore, we have speculated that any factors that might have associated with DC could affect the development of PTH. The aim of this study was to assess influencing factors for posttraumatic hydrocephalus in patients who underwent DC.

## MATERIALS AND METHODS

From March 2004 to May 2007, a total of 693 patients were treated for head trauma in our hospital. Data were collected retrospectively on 55 patients with severe traumatic brain injury who underwent DC. We excluded patients who had confounding variables known to independently contribute to the development of hydrocephalus, including thick subarachnoid hemorrhage, intraventricular hemorrhage, infection or bifrontal decompression. Patients who died or were lost early in their follow up period were also excluded. Thirty-three patients were eventually included. All patients had sustained intracranial hypertension. The ICP (intracranial pressure) was above 21 mmHg or brain herniation was proven by clinical

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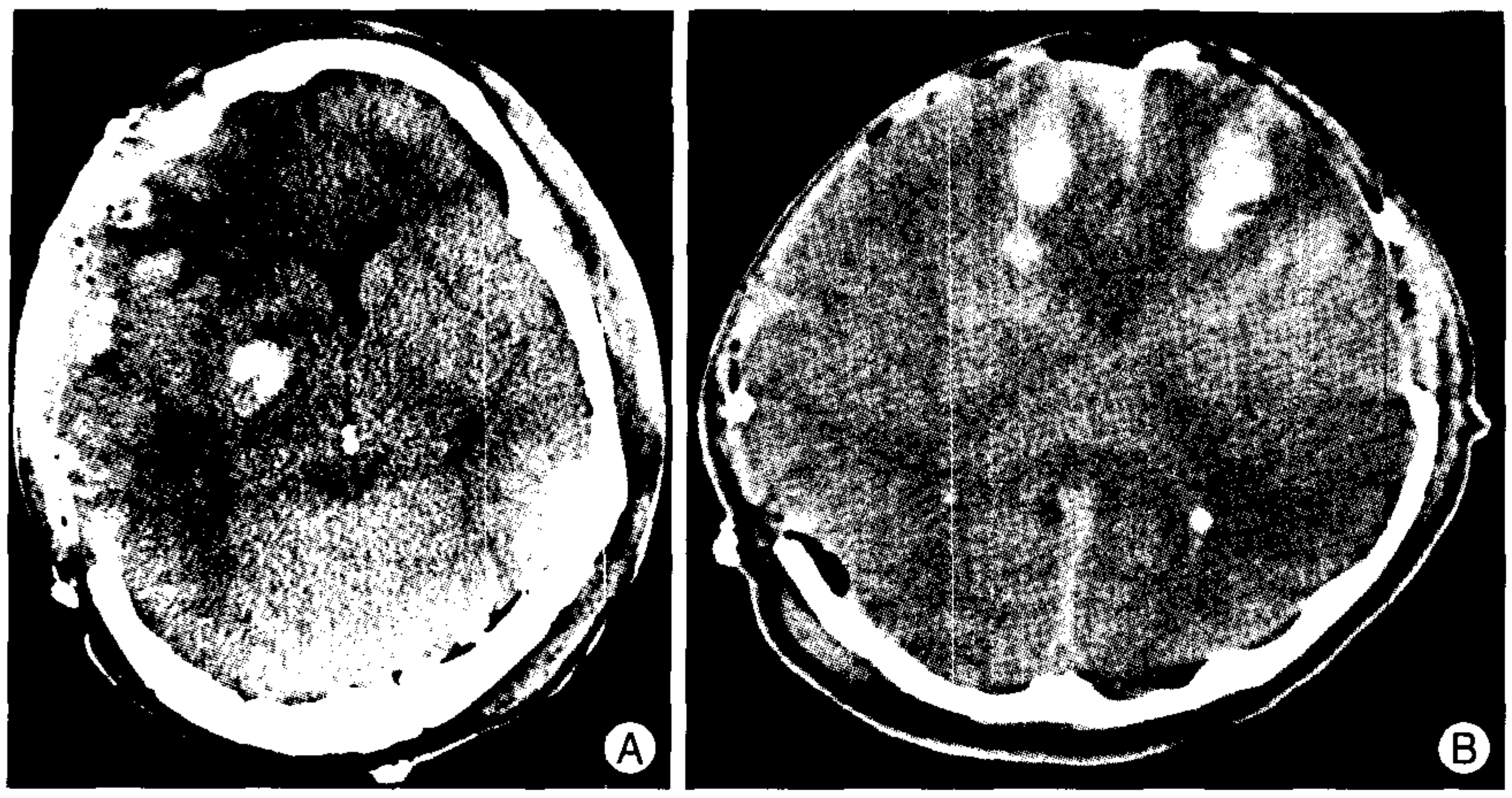


**Fig. 1.** Computerized tomography findings of patients with decompressive craniectomy. A : Standard craniectomy with unilateral free frontotemporoparietal bone flap (12x15 cm) being removed. B : Extended craniectomy with unilateral free frontotemoporoparietal bone flap and contralateral frontal bone flap being removed.

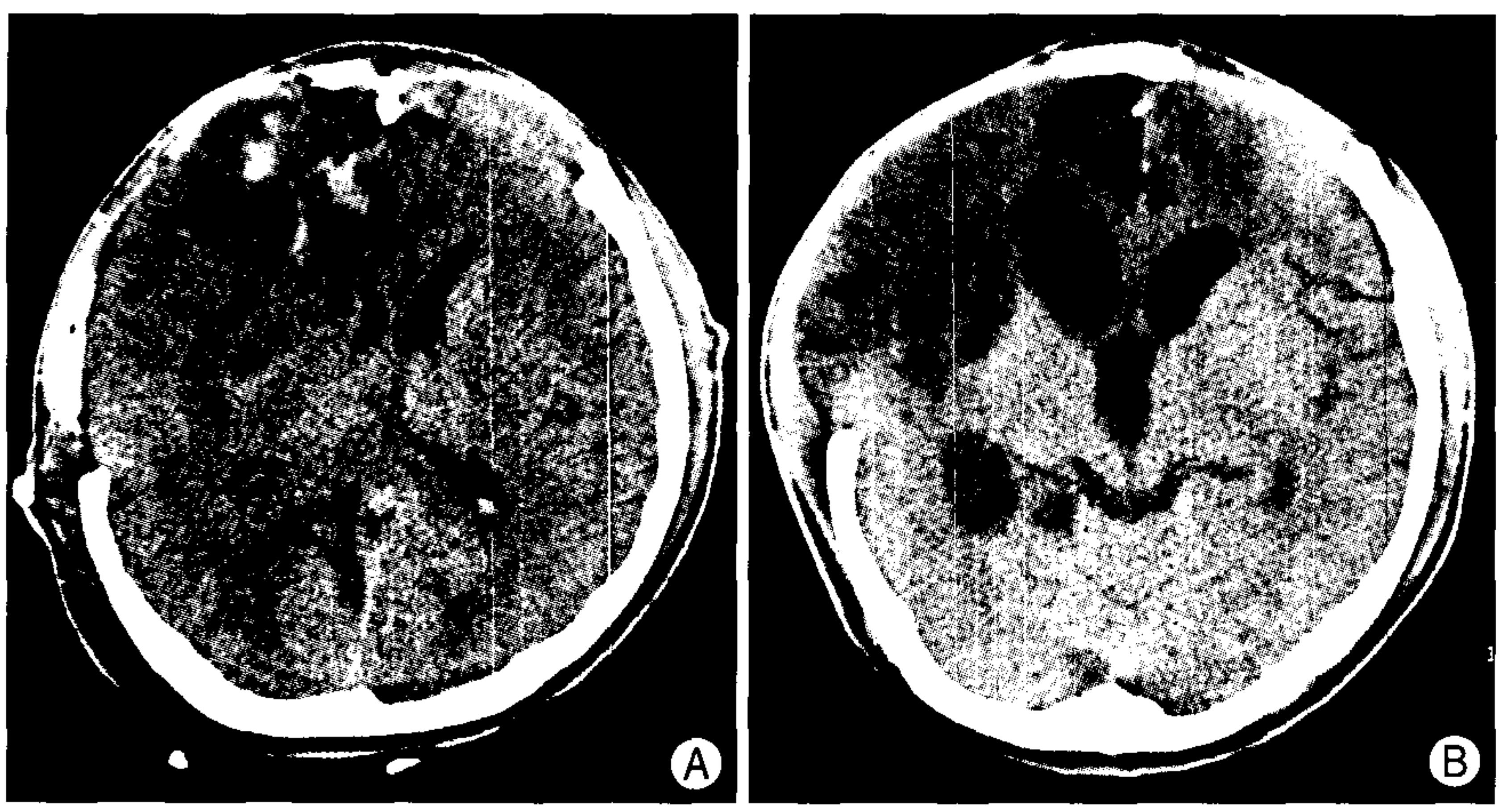


**Fig. 2.** Serial computerized tomography findings from a 39-year-old male with hydrocephalus after decompressive craniectomy. A : Scan taken 2 weeks after extended decompressive craniectomy. B: Computerized tomography showing development of posttraumatic hydrocephalus in the same patient whose clinical condition deteriorated after 2 months.

examination and imaging study. DC was done by two methods. One was done via unilateral standard craniectomy, wherein unilateral free frontotemporoparietal bone flap (12 × 15 cm) and duroplasty was done (Fig. 1). The other was through extended craniectomy, wherein unilateral free frontotemoporoparietal bone and contralateral frontal bone flap were removed and duroplasty was done (Fig. 1). PTH was diagnosed when there was radiographic evidence of ventricular dilatation on serial CT images in a patient whose clinical condition was deteriorating (Fig. 2). For patients with poor baseline neurologic function, metrizamide CT was performed to estimate the dynamics of the CSF. PTH was diagnosed if metrizamide CT revealed early ventricular reflux and delayed wash out (Fig. 3).

The 33 patients were divided into two groups; hydrocephalus group (Group I) and non-hydrocephalus group (Group II). Related factors assessed were broadly divided into clinical factors, radiologic factors and operative factors. Clinical factors analyzed were the sex, age, preoperative Glasgow coma scale (GCS) and the time interval between trauma and operation. Preoperative CT findings of mid line shifting more than 5 mm, subdural hematoma (SDH) more than 5 mm and intracranial hematoma (ICH) more than 10 mm were comparatively analyzed for the radiologic factors. Type of DC was divided into standard and extended type for analysis of operative factors. Repeat operation was also investigated. Glasgow outcome scale (GOS) at discharge was used to assess the clinical outcome. All patients were divided into two groups based on GOS scores : favorable (good recovery or moderate disability) and unfavorable (severe disability, persistent vegetative state or death).

Statistical analysis was done using Mann-Whitney test and Fisher's Exact test. Statistical significance was determined when $p$ value was less than 0.05.

## RESULTS

A total of 693 patients visited to our institution following head trauma during the study period were included. Of these, 28 patients (4.0%) developed PTH. In non decompressive group of 638 patients who received conservative treatment mostly, PTH occurred in 15 patients (2.4%). Among the 55 patients who received DC, 13 patients (23.6%) developed PTH (Table 1). Of the 13 patients, one showed thick subarachnoid hemorrhage, and another underwent bifrontal craniectomy. These two patients were considered as having confounding factors. Therefore, only 11 patients (30.3%) with PTH after DC having no confounding factors were included in the study (Table 2).

### Clinical factors

The 22 patients included in the no hydrocephalus group (Group I) consisted of 19 males and 3 females with a mean age of 49 years (range 31-68). The 11 patients included in the hydrocephalus group (Group II) consisted of 9 males and 2 females with an average age of 54 years

Fig. 3. Computerized tomography findings from a 61-year-old male, mute state. A : Scan showed ventricle size increasing at 4 months post-op. B : Metrizamide computerized tomography demonstrating ventricular reflux and remaining dye in ventricle.

Table 1. Incidence of posttraumatic hydrocephalus after head trauma

| Decompression | Non-PTH (%) | PTH (%) | Total |
|---|---|---|---|
| Yes | 42 (76.4%) | 13 (23.6%) | 55 |
| No | 621 (97.6%) | 15 (2.4%) | 638 |
| Total | 665 (95.9%) | 28 (4.0%) | 693 |

PTH : posttraumatic hydrocephalus

(40-68). The preoperative mean GCS score for each group was 9.5±3.6 and 8.5±3.7 respectively. The interval between the head trauma and the start of operation was 10.1±6.1 hours in Group I and 8.8±6.2 hours in Group II. Sex, age, preoperative GCS score, time interval between trauma and operation did not show statistical significance between groups (Table 3).

### Radiological factors

The preoperative CT findings in Group I showed that midline shifting length was more than 5 mm in 16 patients (72.7%), maximal diameter of SDH was greater than 5 mm in 13 patients (59.1%) and maximal diameter of ICH was longer than 10 mm in 9 patients (21%). In Group II, midline shifting length, maximal diameter of SDH and maximal diameter of ICH were above 5 mm in 6 patients (27.3%), above 5 mm in 8 patients (72.7%) and above 10 mm in 2 patients (18%), respectively. Preoperative CT findings between the two groups did not show statistically significant difference (Table 4).

### Operative factors

Among 22 patients in Group I, 3 patients (13.6%) received extended craniectomy and 19 patients (86.4%) underwent standard craniectomy. In Group II, extended craniectomy was done in 6 patients (54.5%) and standard craniectomy was performed in 5 patients (45.4%). Reoperation was done in 4 patients (18%) and 6 patients (55%) for Group I and II, respectively. There were statistically significant differences between the two groups for the type of DC and reoperation ($p$=0.033, $p$=0.049) (Table 4).

### Outcome

In Group I, 12 patient had favorable outcome (54.5%) and 10 patients unfavorable (45.5%). In Group II, only two (18.2%) patients showed favorable outcome and 9 patients (81.8%) were unfavorable. Group I had better outcome. There was no statistically significant difference between the two groups ($p$=0.067) (Table 4).

## DISCUSSION

PTH has been recognized since Dandy's report in 1914[4]. The incidence of symptomatic PTH ranges from 0.7%-29%[3,9]. However, if the CT criteria of ventriculomegaly was used, the incidence has been reported to range from 30%-86%[8,18]. A wide variety of clinical and radiological diagnostic criteria have been suggested for PTH[9,12]. Differences in diagnostic criteria and classification have contributed to the variations in reported incidences. The accuracy of CT scan in determining the underlying cause of post traumatic ventriculomegaly, namely atrophy and/or hydrocephalus, has been uncertain. The diagnosis of hydrocephalus requires the demonstration of large ventricles without sulci enlargement and the development of any associated clinical symptoms, impaired consciousness, no neurologic improvement, dementia and incontinence. PTH must also be differentiated from ventricular enlargement secondary to posttraumatic cerebral atrophy[1,19]. Although selection of patients for surgery can be defined principally on clinical grounds, several studies such as CT, magnetic resonance imaging (MRI), single photon emission computed tomography (SPECT), temporary lumbar drainage and CSF dynamics studies may be helpful in differentiating ventricular enlargement due to cortical atrophy from hydrocephalus[14,15]. It should be noted that the diagnosis of PTH in patients with head trauma may be inaccurate. In this study, we diagnosed PTH by serial brain CT images in patients with clinical deterioration and we used metrizamide CT in patients with poor baseline neurological state.

The management of ventricular dilation following severe head injury has been controversial because it has been difficult to determine whether ventriculomegaly is related to an atrophic process or to a true hydrocephalus with

CSF absorptive deficit. As a result, the response of patients with PTH to CSF shunting procedures has been difficult to predict, and generally the results of CSF diversion in these patients have not been encouraging[3]. Therefore, there is no consensus on an appropriate treatment for post traumatic ventriculomegaly. In clinical practice, even if the incidence of PTH is relatively high, only 1-4% of these patients eventually require shunt operation[2].

The treatment of PTH in patients who undergo DC is a difficult problem to solve. Shunt operation with or without cranioplasty may be done simultaneously with aims to correct the underlying problems. The former may result in neurological deficits known as 'the syndrome of the sinking skin flap' or 'the symptom of the trephine' due to midline shifting and CSF overdrainge at atmospheric pressure[21]. The latter procedure is associated with a higher risk of developing brain edema and infection due to early operation. The treatment of PTH in patient who underwent DC was CSF shunting and cranioplasty in our case, but the results have been poor. In our study, poor outcome was observed in 82% of patients and this was due to the complications associated with the surgical procedures. Therefore, it is important to prevent the PTH for the good outcomes of the patients with DC.

Previous studies suggested that factors such as altered intracranial pressure dynamics, mechanical blockage or inflammation of the arachnoid granulations by postsurgical debris may induce PTH[6,7,17,23]. Waziri et al[23] suggested that DC may play a role in the "flattening" of the normally dicrotic ICP waveform in patients having the procedure, due to the transmission of the pressure pulse out through the open cranium. Because the arachnoid granulations function as pressure-dependent one-way valves from the subarachnoid space to the draining venous sinuses, it is possible that disruption of pulsatile ICP dynamics secondary to opening the cranial vault results in decreased CSF outflow[22]. If this is the case, early cranioplasty should lead to restoration of normal

**Table 2.** Clinical features of 11 patients with posttraumatic hydrocephalus

| Case No. | Sex/Age | Cause of reoperation | Time interval btw trauma & PTH (month) | Clinical Sx change by PTH | Symptom after shunt op | Complication | Outcome |
|---|---|---|---|---|---|---|---|
| 1 | M/71 | Hematoma | 2 | Yes | Improve | Infection | Unfavorable |
| 2 | M/39 | Hematoma | 1 | Yes | Improve | None | Favorable |
| 3 | M/52 | None | 5 | Yes | Improve | None | Favorable |
| 4 | M/56 | Hematoma | 2 | Yes | Not improv | None | Unfavorable |
| 5 | F/57 | Hematoma | 4 | No | Not improv | None | Unfavorable |
| 6 | M/75 | None | 2 | Yes | Not improv | None | Unfavorable |
| 7 | M/61 | Brain swelling | 4 | No | Not improv | None | Unfavorable |
| 8 | M/39 | None | 1 | Yes | Improve | Infection | Unfavorable |
| 9 | M/54 | None | 2 | No | Not improv | None | Unfavorable |
| 10 | M/29 | None | 3 | No | Not improv | None | Unfavorable |
| 11 | F/61 | Brain swelling | 3 | No | Not improv | None | Unfavorable |

PTH : posttraumatic hydrocephalus

**Table 3.** Comparison of clinical factors between non-hydrocephalic group and hydrocephalic group

| Variable | No. of patients (%) | | *p-value* |
|---|---|---|---|
| | Non-hydrocephalus | Hydrocephalus | |
| No. of patients | 22 | 11 | |
| Mean age (years) | 49.3±18.5 | 54.0±13.9 | 0.56 |
| Male/female | 19/3 | 9/2 | 1.00 |
| Preoperative GCS score | 9.5±3.6 | 8.5±3.7 | 0.64 |
| Interval between trauma & operation | 10.1±6.1 | 8.8±6.2 | 0.098 |

GCS : Glasgow coma scale

**Table 4.** Comparison of radiological, operative factors and out-come between non-hydrocephalic group and hydrocephalic group

| Variable | | No. of patients (%) | | *p-value* |
|---|---|---|---|---|
| | | Non-hydrocephalus | Hydrocephalus | |
| No. of patients | | 22 | 11 | |
| Preoperative CT findings | | | | |
| Midline shift | > 5 mm | 16 (72.7) | 6 (55) | 0.44 |
| | < 5 mm | 6 (27.3) | 5 (45) | |
| SDH | > 5 mm | 13 (59.1) | 8 (72.7) | 0.70 |
| | < 5 mm | 9 (40.9) | 3 (27) | |
| ICH | > 10 mm | 9 (41) | 2 (17) | 0.55 |
| | < 10 mm | 13 (59) | 9 (83) | |
| Craniectomy | | | | |
| Bilateral | | 3 (13.6) | 6 (54.5) | 0.033 |
| Unilateral | | 19 (86.3) | 5 (45.5) | |
| Reoperation | | | | |
| Yes | | 4 (18) | 6 (55) | 0.049 |
| No | | 18 (82) | 5 (45) | |
| Outcome | | | | |
| Favorable | | 12 (54.5) | 2 (18.2) | 0.067 |
| Unfavorable | | 10 (45.5) | 9 (81.8) | |

SDH : subdural hematoma, ICH : intracerebral hematoma intracranial pressure dynamics and spontaneous resolution of hydrocephalus as witnessed.

Also, it was reported that in cases of subarachnoid hemorrhage and traumatic intracranial hematoma, mechanical blockage or inflammation of the arachnoid granulations may promote hydrocephalus. Foroglou[7] described obliteration of subarachnoid spaces with fibrous thickening of the leptomeninges, particularly in the sulci of the convexities and the base of the brain, in PTH and suggested that the obstruction around the convexities can result in hydrocephalus[6,7,17].

An important finding in our study is that the incidence of PTH was higher in patients receiving extended craniectomy and reoperation. These results are in agreement with those of above studies. We believe that the greater CSF dynamic changes, the more postoperative surgical debris associated with a larger craniectomy and the repeat operation may be important factors for the development of PTH.

Finally, it is important to note that this study has the limitations of the inexact nature of PTH diagnosis, the small sample size and the retrospective study design used.

## CONCLUSION

Extended craniectomy and repeat operation may play a role in the development of PTH in patients receiving DC. Future studies are required to ascertain CSF flow changes in patients who had DC by CSF dynamic study.

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