

# Never neglect the atmospheric pressure effect on a brain with a skull defect

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**Abstract:** Herein, we report an unusual case of a patient who presented with a severe, sinking skin flap after a decompressive craniectomy and ventriculoperitoneal shunt surgery due to a traumatic brain injury. After cranioplasty, the patient's neurological deficiency improved and was confirmed by transcranial Doppler sonography. In addition to discussing the pathogenesis of the sinking skin flap, we emphasize the importance of cranioplasty for neurological improvement and remind the surgeon to "never neglect the atmospheric pressure effect on a brain with a skull defect".

**Keywords:** traumatic brain injury, decompressive craniectomy, hydrocephalus, cranioplasty

## Introduction

Decompressive craniectomy is a common practice and considered to be a life-saving procedure in patients with severe traumatic brain injury.<sup>1</sup> Post-traumatic hydrocephalus is a complication needing a ventriculoperitoneal shunt to divert cerebrospinal fluid.<sup>2</sup> A sinking scalp flap occasionally develops after decompressive craniectomy and could be aggravated by a ventriculoperitoneal shunt.<sup>3-5</sup> In such cases, the purpose of cranioplasty at the craniectomy site is to eliminate atmospheric pressure, restore the cerebrospinal fluid, and improve neurological status.<sup>6-10</sup> Here we present an unusual case of a severe sinking scalp flap after decompressive craniectomy and ventriculoperitoneal shunt.

## Case report

A 65-year-old male patient was transferred to our hospital with a large, right-sided skull defect and severe scalp depression. He had suffered a traumatic brain injury 5 months earlier and undergone decompressive craniectomy and removal of an intracranial hemorrhage at that time. Hydrocephalus developed one month after the operation and he received a ventriculoperitoneal shunt. However, his level of consciousness progressively deteriorated thereafter. On neurological examination, he was drowsy with a Glasgow Coma Scale score of E1V1M4 and profound left hemiplegia. A computed tomography (CT) brain scan revealed marked concavity of the brain at the craniectomy site associated with midline shift to the left (Figure 1). Transcranial Doppler sonography (Multi-Dop® X2, DWL; Elektronische Systeme GmbH, Schlotheim, Germany) was unable to detect the wave pattern of the blood flow in the middle cerebral artery of the concave brain. The impression was of sinking skin flap syndrome, so cranioplasty with bone cement was performed. Postoperatively, the patient was treated with hydration and bed

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**Figure 1** Computed tomography scan of the axial brain showing sinking at the craniectomy site with extensive midline shift and the proximal tube of the ventricular peritoneal shunt.

rest for 3 days. Four days after his cranioplasty, follow-up CT images showed reversal of the midline shift with no significant complications in the underlying brain (Figure 2). Follow-up transcranial Doppler revealed a mean velocity of 30 cm per second in the right middle cerebral artery. After the surgery, the patient's mentality gradually improved to an



**Figure 2** Computed tomography scan showing reversal of the sunken brain contour and the midline shift after an autologous cranioplasty repair of the skull defect.

alert state and he was discharged with a Glasgow Coma Scale score of E34V1M5–6 one month after cranioplasty.

## Discussion

Decompressive craniectomy is widely used as a life-saving measure to treat intracranial hypertension following traumatic brain injury.<sup>1</sup> However, it has been identified as a risk factor for changes in cerebrospinal fluid and development of post-traumatic hydrocephalus, for which a ventriculoperitoneal shunt may be necessary for diversion of cerebrospinal fluid.<sup>2</sup>

Mean atmospheric pressure is 1,033 cm H<sub>2</sub>O of water and equivalent to 14.7 psi.<sup>2</sup> A ventriculoperitoneal shunt for hydrocephalus in patients with a skull defect may lead to excessive sinking at the craniectomy site as a result of the atmospheric pressure gradient, which could be aggravated by diversion of cerebrospinal fluid and change in position, especially when there is post-traumatic brain parenchymal atrophy or loss, as in our case.<sup>3,4</sup> Thus, the goal of treatment in a patient with a sinking skin flap is to eliminate atmospheric pressure at the craniectomy site via cranioplasty.

However, performing a cranioplasty on a patient with a severe concave scalp flap at the craniectomy site does increase the risks of accumulation of fluid and formation of hematoma.<sup>5</sup> To relieve the pressure gradient between the atmosphere and the intracranial space and to reverse the scalp depression and midline shift, temporary occlusion of the shunt device<sup>5</sup> or reprogramming of the ventriculoperitoneal shunt to a higher valve pressure before cranioplasty<sup>6</sup> have been recommended. However, our patient underwent cranioplasty without temporary occlusion or shunt reprogramming, but rather hydration and postoperative bedrest for 3 days. Follow-up CT of the brain showed good brain expansion with no formation of hematoma. Nevertheless, we recommend early combined cranioplasty and programmable shunts for patients with skull bone defects to avoid sunken skin in accordance with the suggestion of Carvi et al.<sup>7</sup>

In our case, the possible reason for decreasing cerebral blood flow in a brain with a skull defect can be explained as impairment of brain autoregulation (due to insult of previous traumatic brain injury) and the local compression effect of atmospheric pressure. Several important principles have been described with regard to intracranial dynamics in relation to the conventional physiological regulatory mechanism of cerebral blood flow, including pressure autoregulation, regulation of CO<sub>2</sub>, and regulation of metabolism.<sup>8</sup> In an experiment by Schaller et al, cats that underwent hemispheric craniectomy showed decreased cerebral blood flow in normal brain tissue that

lasted for at least one day.<sup>9</sup> We thought it might be related to a local compression effect by atmospheric pressure; however, the normal brain without traumatic injury is able to restore cerebral blood flow in a few days. Therefore, cranioplasty is able to improve neurological status in patients with a skull bone defect.<sup>10</sup> It reduces the local compression effect of atmospheric pressure, thereby improving brain autoregulation and enhancing cerebral hemodynamic status.<sup>9-10</sup> This result is consistent with our previous study about neurological improvement after cranioplasty, increasing velocity of cerebral blood flow can be seen on transcranial Doppler.<sup>11</sup>

We report here an unusual case of a patient who presented with a severe sinking skin flap after decompressive craniectomy and ventriculoperitoneal shunt due to traumatic brain injury. This case underscores the importance of cranioplasty and reminds surgeons to “never neglect the atmospheric pressure effect on a brain with a skull defect”.

## Disclosure

The authors report no conflicts of interest in this work.

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