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Overdrainage after ventriculoperitoneal shunting in a patient with a wide depressed skull bone defect: The effect of atmospheric pressure gradient

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ABSTRACT

INTRODUCTION: In patients with traumatic brain injury, an effective approach for managing refractory intracranial hypertension is wide decompressive craniectomy. Postoperative hydrocephalus is a frequent complication requiring cerebrospinal fluid (CSF) diversion.

PRESENTATION OF CASE: A 50-year-old male who underwent decompressive craniectomy after traumatic brain injury. He developed hydrocephalus postoperatively, and accordingly we placed a ventriculoperitoneal shunt. However, an imbalance between the intra- and extra-cranial atmospheric pressures led to overdrainage, and he suffered cognitive disorders and extremity weakness. He remained supine for 5 days to avoid the effect of gravity on CSF diversion. After 20 days, we performed a cranioplasty using a titanium plate. The postoperative course was uneventful, and the patient achieved satisfactory recovery.

DISCUSSION: The gravitational effect and the atmospheric pressure gradient effect are two factors associated in the ventriculoperitoneal (VP) shunt treatment of hydrocephalus for the patient who had decompressive craniectomy. These effects can be eliminated by supine bed rest and cranioplasty.

CONCLUSION: We herein emphasize the efficacy of VP shunt, supine bed rest and cranioplasty in treating hydrocephalus patients who have undergone craniectomy. A flexible application of these procedures to change the gravitational effect and the atmospheric pressure gradient effect should promote a favorable outcome.

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1. Introduction

Decompressive craniectomy is an effective treatment for intractable intracranial hypertension caused by severe brain swelling or hematoma in patients suffering from serious head injury. Post-traumatic hydrocephalus (PTH) is a common complication that necessitates a ventriculoperitoneal (VP) shunt to divert the accumulated cerebrospinal fluid (CSF). 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 [1]. For patients with PTH and a concomitant wide depressed skull bone defect, the therapeutic strategy is quite challenging for neurosurgeons. Because there is the atmospheric pressure factor which effect on the decompressive skull bone defect [2]. Herein, we present an unusual case of traumatic brain injury with a wide decompressive skull bone defect due to

an overdrainage complication occurring after the VP shunting. Our report is in accordance with the SCARE criteria [3].

2. Case report

A 50-year-old man who was **transferred to our hospital** presented with a 1-month history of unsteady gait and urine incontinence.

One year prior to admission, he had suffered a traumatic brain injury in a traffic accident in which he was knocked down while riding a motorcycle and he fell into a coma immediately. The brain computed tomography (CT) revealed cerebral multiple contusion and subdural hematoma (Fig. 1). Under general anesthesia, an emergency hematoma and contusion cleaning procedure and left decompressive craniectomy was performed via a bilateral-supratentorial approach in our hospital. Postoperatively, the patient achieved favorable recovery, and there was no sensorimotor sequela. However, one month prior to the present admission to our hospital, he developed an unable to walk, and urine incontinence, and his cognitive function progressively degenerated. The brain CT revealed ventricular dilation.

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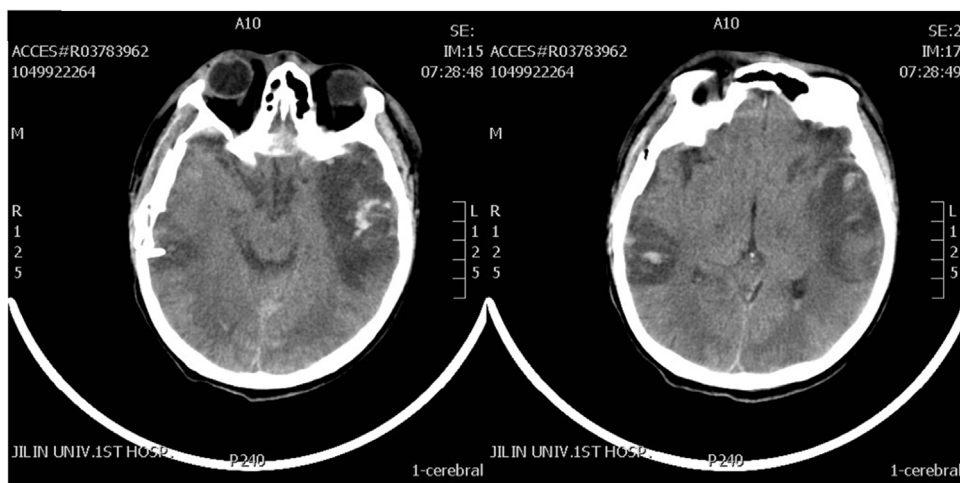


Fig. 1. Head CT showing cerebral multiple contusion and subdural hematoma.

At admission, upon physical examination the patient showed clear consciousness and could answer common questions. The pupils and relevant reflexes were normal. The surgical scar and skull defect were noted on the left temporal site. The power in the lower limbs according to Medical Research Council grading was 3/5. Bilateral Babinski signs were negative. The neurological function was scored 25 points, in accordance with the mini-mental state examination (MMSE) guide.

A repeated head CT in our department showed local bone defect in the left frontal-temporal-parietal region. The ventricular system was significantly dilated with patchy hypodensity in the anterior and posterior horns of the lateral ventricle; no midline shift was noted (Fig. 2).

We placed a VP shunt. On the second day after the procedure, the patient could walk with the support of relatives. The power in the lower limbs was 4/5. MMSE was scored 28 points.

Six days postoperatively, the condition exacerbated, and he was unable to walk. Examination showed that the patient was fully conscious and he could shake hands as requested. Nevertheless, he did not answer any questions, and the power in the lower limbs according to Medical Research Council grading was 2/5. A large skull defect with flaccid concavity was noted. Bilateral Babinski signs were negative. The MMSE scoring was 19 points.

The head CT showed bilateral ventricular reduction, with the drainage tube and its route clearly visible; the midline structures were shifted to the right (Fig. 3).

The patient was told to remain supine for 5 days, and his symptoms improved. A physical examination showed improvement in extremity muscle strength (grade 3/5), and the skull defect region had returned to a normal shape. The MMSE scoring was 26 points. A head CT showed an elimination of the space between the skull plate and the dura mater, and the appearance was normal (Fig. 4).

In order to maintain a relatively balanced state of the cerebrospinal fluid circulation and intracranial pressure, the patient was told to remain supine for another 9 days. Muscle strength was grade 3+/5. The MMSE scoring was 27 points. Twenty days after VP shunt, a cranioplasty using a titanium plate was performed. Seven days after cranioplasty, the patient was able to walk without external support, and the power in the lower limbs according to Medical Research Council grading was normal (grade 5/5). The MMSE scoring was 29 points. A repeated head CT showed the normal appearance for post-VP shunting (Fig. 5). During a follow-up period of 16 months, the patient's recovery was satisfactory. He could walk freely, complete simple work, and there is no urinary

problem. CT scan shows that the VP shunt works well and the brain ventricle is normal (Fig. 6).

3. Discussion

Traumatic brain injury is a severe condition, with a reported mortality rate of 20–30%. Among survivors, the rate of disability with neurologic sequelae is 80% [4,5]. Elevated intracranial pressure induced by brain injury can lead to cerebral ischemia and severe emergencies. For patients with traumatic brain injury, a wide decompressive craniectomy is an effective approach for managing refractory intracranial hypertension. However, PTH is a frequent complication of wide decompressive craniectomy [6].

The most widely accepted treatment for PTH is VP shunting combined with a subsequent cranioplasty, but the efficacy and potential risks associated with this strategy remain under debate [7,8]. Most scholars consider that intracranial excessive accumulation of CSF can lead to a regional cephalocele, supporting the rationale for cranioplasty, and recommend first-stage CSF diversion. Over drainage is an infrequent complication of a functioning CSF shunt, but the risk increases when the patient is upright [9]. Over drainage usually manifests as an orthostatic headache caused by intracranial hypotension, slit-like ventricle syndrome, hygroma, or subdural hematoma [10]. However, in hydrocephalus patients who have undergone a previous decompressive craniectomy, the incidence of overdrainage after CSF diversion increases significantly due to atmospheric pressure.

In patients who have undergone craniectomy, developed hydrocephalus, and been treated with VP shunting, abnormal CSF hemodynamics can be due to the atmospheric pressure gradient, intracranial ventricular pressure, gravity, anti-siphonage, and intraperitoneal pressure. Patients would have a higher risk of complications by undergoing two procedures simultaneously than by undergoing each procedure in staged operations [8].

In our present case, there was a wide depressed skull bone defect and hydrocephalus that made VP shunting the preferred treatment. However, on the fourth subsequent day the patient's condition exacerbated, with intracranial hypotension due to overdrainage suspected. This is because CSF diversion performed before cranioplasty in patients with a large cranial defect and hydrocephalus can result in a caving in of the craniectomy site due to the atmospheric gradient, which can also be aggravated by excessive diversion of CSF and change in the patient's position [2,6]. In our case, the sinking of the tissue led to a large flaccid concavity, mimicking a

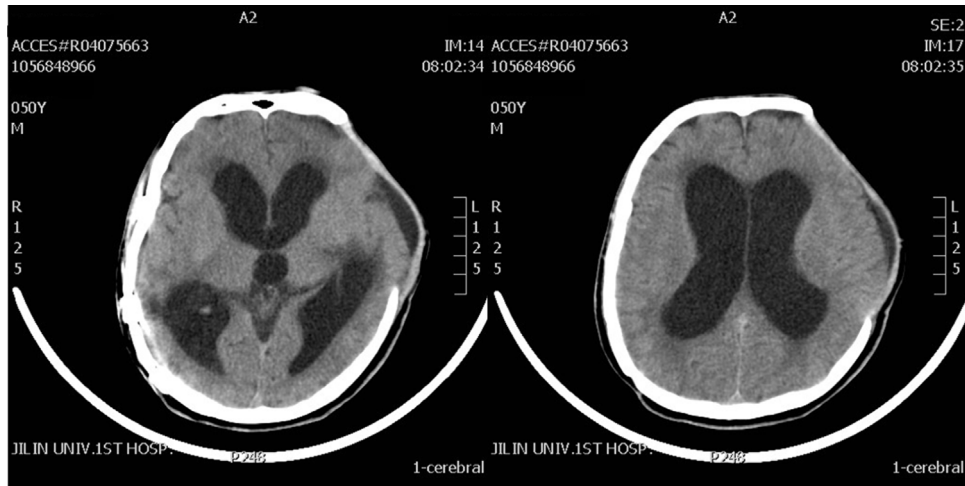


Fig. 2. Head CT showing local bone defect in the left frontal-temporal-parietal region. The ventricular system was significantly dilated with patchy hypodensity in the anterior and posterior horns of the lateral ventricle; no midline shift was noted.

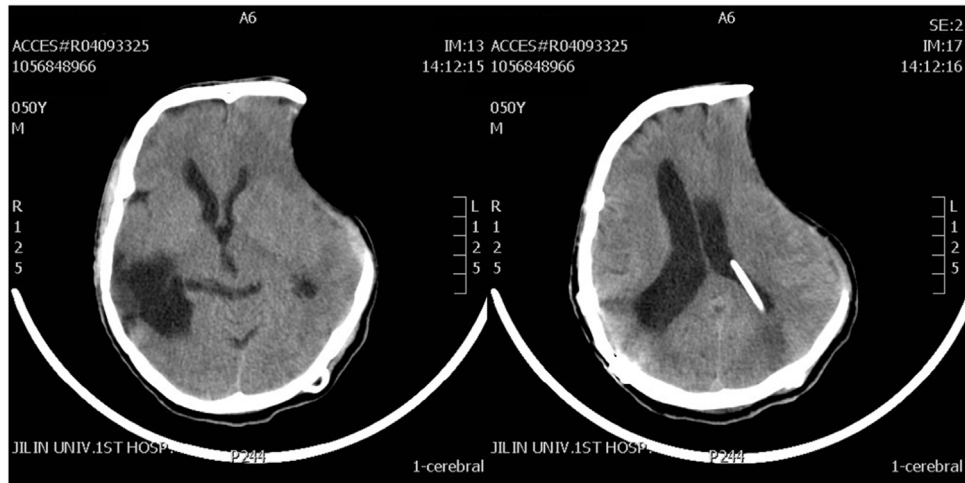


Fig. 3. Head CT showing bilateral ventricular dilation. The drainage tube and its route are clearly visible; the midline structures were shifted to the right.

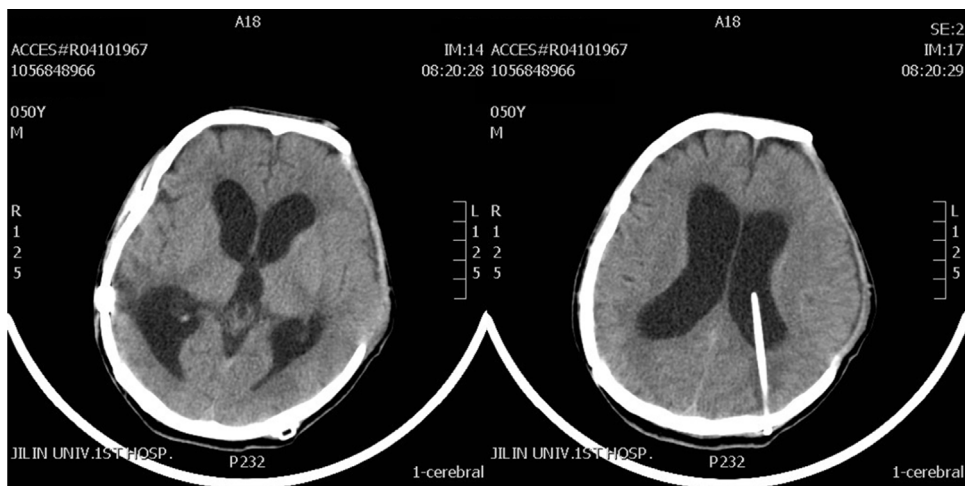


Fig. 4. Head CT showing the elimination of the space between the skull plate and the dura mater. The appearance is normal.

space-occupying lesion, which caused cerebral compression and a contralateral shift of the midline structure. Therefore, the patient's clinical symptoms, neurological function (MMSE scoring and mus-

cle strength), and cognitive function all worsened. Maintaining a supine position can withstand the effect of gravity on CSF diversion, and after a 5-day bed rest, the clinical symptoms and radiological

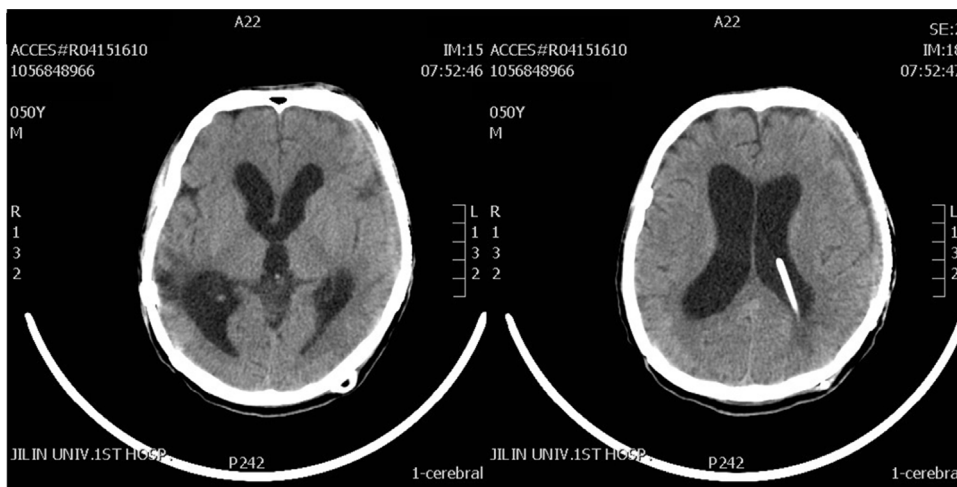


Fig. 5. Head CT showing a normal post-VP-shunting appearance with cranioplasty.

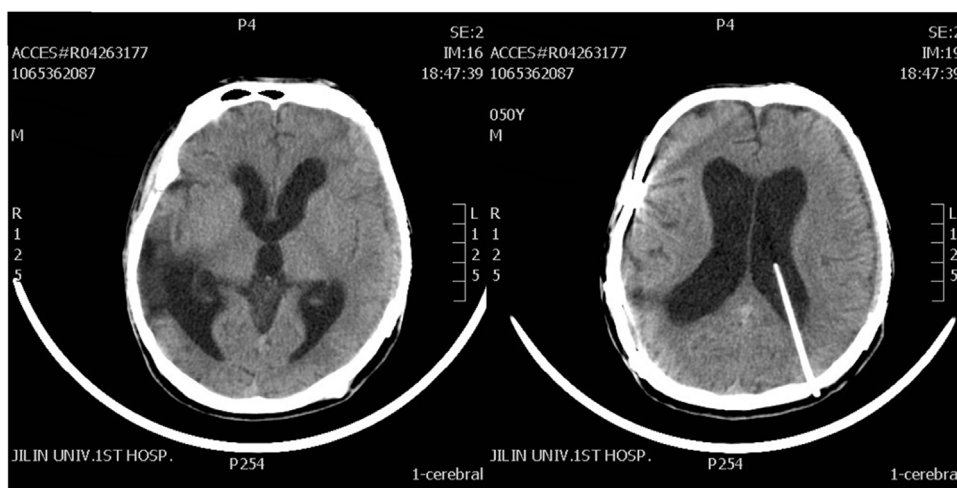


Fig. 6. Head CT showing the VP shunt works well and the brain ventricle is normal.

appearance of this patient significantly improved. In order to maintain a relatively balanced state of the cerebrospinal fluid circulation and intracranial pressure, the patient was told to remain supine for another 13 days. In these 13 days, there is nothing changed about the patient's syndrome and head CT scan. So we hypothesise the CSF dynamic got a relative balance state.

To maintain a stable intracranial pressure and avoid the effect of the atmospheric gradient, we performed a cranioplasty using a titanium plate. Eventually, the patient achieved a favorable recovery. Increase in the blood supply to the brain after the cranioplasty may also have contributed to the clinical improvement. The cranioplasty reduced the local compressive effect of atmospheric pressure, thereby improving brain autoregulation and enhancing cerebral hemodynamic status. This supports a previous study that cranioplasty is able to improve the neurological status of patients with a skull bone defect [11].

Patients would have a higher risk of complications by undergoing two procedures simultaneously than by undergoing each procedure in staged operations [8]. However, patients undergoing staged operations also are imposed with considerable complications, such as having more chances of undergoing general anesthesia and surgical procedure, higher cost of surgery, longer hospital stay, and adverse reactions of antibiotic prophylaxis. For patients who develop hydrocephalus after craniectomy and are treated with VP shunting, some scholars have recommended a tem-

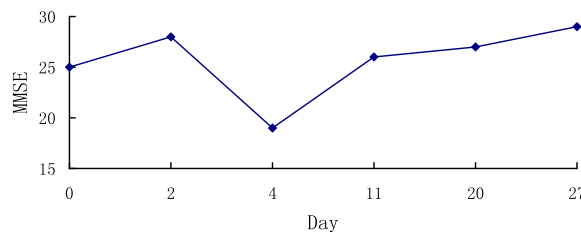


Fig. 7. Scoring of mini-mental state examination (MMSE) for each day after VP shunt.

porary occlusion of the distal shunt tube with an aneurysm clip to prevent severe sinking at the skull defect, and provide for good brain expansion before cranioplasty [6]. This procedure can effectively eliminate the empty space; nevertheless, the operation can increase the risk of intracranial infection.

In the present case, overdrainage occurred after the VP shunting procedure. The patient was instructed to remain supine to eliminate the gravitational effect on CSF diversion. After the CSF hemodynamic status was stable and good brain expansion was achieved, we performed a cranioplasty to eliminate the effect of atmospheric pressure. The patient's muscle strength (Fig. 8), cognitive function (Fig. 7), and brain CT showed corresponding changes in each period. Thus, we herein emphasize the efficacy of VP shunt-

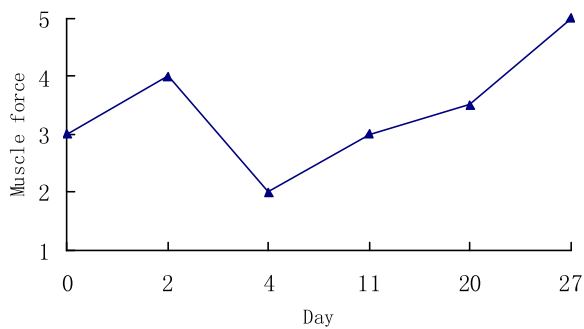


Fig. 8. Muscle force for each day after VP shunt.

ing and supine bed rest in treating hydrocephalus patients who have undergone craniectomy. A flexible application of these two procedures should promote a favorable outcome.

Our results in this case warrant a future multicenter randomized controlled trial to determine a standardized diagnostic and therapeutic strategy for post-craniectomy hydrocephalus. The timing of the cranioplasty should also be further discussed. More studies would be helpful to avoid over drainage, reduce surgical complications, and improve the efficacy and life quality of patients.

4. Conclusion

Here we report an unusual case of a patient who presented with a severe sinking skin flap after wide decompressive craniectomy and ventriculoperitoneal shunt due to traumatic brain injury. A flexible application of supine bed rest and cranioplasty to change the gravitational effect and the atmospheric pressure gradient effect should promote a favorable outcome. This case reminds surgeons to “never neglect the atmospheric pressure gradient effect and the gravitational effect on a brain with a skull defect”.

Author contribution

Lixiang Zhou, Yanwu Han: Surgeon performed the operation.

Jinlu Yu, Guangming Wang: writing and approving the manuscript.

Lichao Sun: collecting data and follow up.

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Ethical approval

Ethics committee approval was not required for this case report.

Conflict of interest

There is no conflict of interest to be declared.

Consent

Consent has been taken.

Guarantor

Guangming Wang.

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