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Case Report

Cranial distraction osteogenesis for craniosynostosis associated with osteopetrosis: A case report

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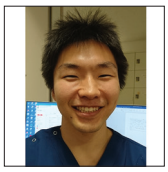

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ABSTRACT

Background: Osteopetrosis is a rare disease characterized by systemic osteosclerosis and hematopoietic disturbances. Childhood-onset cases are often accompanied by hydrocephalus and craniosynostosis; however, there have been no established treatments. We performed cranial distraction in a child with osteopetrosis who presented with craniosynostosis and intracranial hypertension.

Case Description: The patient was a 4-year-1-month-old boy. His pregnancy and birth were normal, but at 4 months of age, he was diagnosed with osteopetrosis based on generalized osteosclerosis and family history. A computed tomography scan of the head revealed early sagittal suture fusion and ventricular enlargement. A ventriculoperitoneal shunt was placed for intracranial hypertension; however, slit ventricle syndrome ensued and pansynostosis developed. To improve uncontrolled high intracranial pressure, cranial distraction was performed for intracranial volume expansion. No perioperative hemorrhagic or infectious complications were observed. After the start of distraction, the intracranial pressure gradually decreased, and clinical findings such as disturbance of consciousness and bradycardia disappeared. Bone regeneration in the defect site was good, and the extension device was removed 6 months after the operation.

Conclusion: For osteopetrosis with poorly controlled intracranial hypertension, cranial distraction was considered to be an effective treatment.

Keywords: Cranial distraction osteogenesis, Craniosynostosis, Intracranial hypertension, Osteopetrosis

INTRODUCTION

Osteopetrosis is a rare disease characterized by systemic osteosclerosis, hematopoietic dysfunction, and fragility. Based on clinical findings, it is classified into early-onset and late-onset forms. The early-onset type develops at birth or in infancy and causes hardening and deformation of the skull, impaired vision and hearing, and impaired mental development. The early-onset type entails a poor prognosis. The late-onset type is found incidentally on X-rays, and central nervous system disorders are rare. In addition, an intermediate type and a disease type accompanied by renal tubular acidosis are reported.[24] Autosomal recessive inheritance and sex-linked recessive inheritance are prevalent in the early-onset type, and autosomal dominant inheritance is prevalent in the late-onset type. The severe, infantile, and autosomal recessive osteopetrosis are called malignant infantile osteopetrosis. The incidence is about 1/250,000. The incidence is higher in certain areas such as Brazil, Costa Rica, and the Middle East.[8,17]

As for the genetic abnormality, more than half of the children with autosomal recessive infantile osteopetrosis have variants in the *TCIRG1* gene.[9,15] Other causative genes reported include *CLCN7, SNX10, OSTM1, TNFRSF11A, TNFSF11*, and *PLEKHM1*.[3,19,20]

CASE DESCRIPTION

The patient was a 4-year-1-month-old boy. He was born at 40 weeks 0 days gestation weighing 3262 g. When he was 4 months old, severe atrophy of bilateral optic nerves was found due to his inability to pursue. The X-ray showed sclerosis of the whole-body bone. He was diagnosed with osteopetrosis because of a family history of his maternal grandmother's brother dying of osteopetrosis at the age of five. The computed tomography (CT) scan showed early sagittal suture synostosis and ventricular enlargement [Figure 1]. When he was 6 months old, he underwent endoscopic third ventriculostomy (ETV) and cerebrospinal fluid (CSF) reservoir placement. After the operation, intracranial hypertension recurred. The intracranial pressure by reservoir puncture was over 30 cmH_2O and the ventriculoperitoneal (VP) shunt was placed at the age of 1 year and 3 months. Postoperatively, he developed slit ventricle syndrome, with frequent episodes of hospitalization with vomiting, bradycardia, and consciousness disturbance. Meanwhile, he developed pansynostosis on a CT scan [Figures 2a and b]. At the age of 4 years, we performed CSF reservoir placement on the contralateral side of the shunt [Figures 2c and d]. Even with CSF tap from the reservoir and administration of osmotic diuretics in addition to the VP shunt, it was insufficient to improve symptoms of intracranial hypertension. The reservoir puncture pressure was >30 cmH_2O. The head circumference was at the 90th percentile, although the body weight and height were at around the 10th percentile. Craniocerebral disproportion due to craniosynostosis was considered to be the main contributor to intracranial hypertension. Whereas impaired venous perfusion due to jugular foramen stenosis may have also contributed to the symptoms, we decided to proceed to cranial distraction surgery considering the possibility of improvement in his symptoms and the risk of bleeding during the surgery.

The surgical procedure was performed through the coronal skin incision. In this case, because there was a possibility of bleeding that was difficult to control during the surgery, we started a transfusion of red blood cells and fresh frozen plasma at the beginning of the surgery in preparation for intraoperative bleeding.

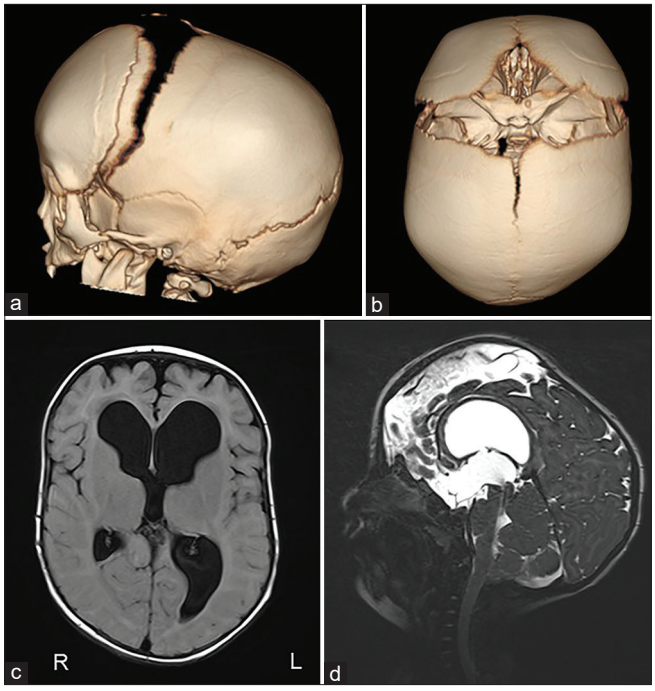

Figure 1: Image findings at first visit. (a and b) Computed tomography showed early sagittal suture synostosis. (c and d) Magnetic resonance imaging revealed ventricular enlargement and ballooning of the base of the third ventricle.

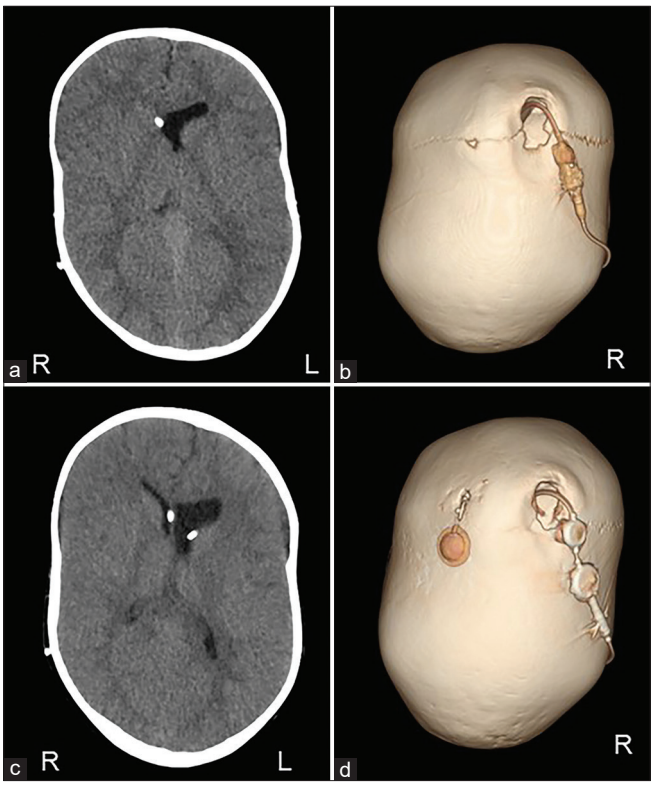

Figure 2: (a and b) Computed tomography (CT) post ventriculoperitoneal shunt. He developed slit ventricle syndrome (SVS). (c and d) CT after reservoir placement through the left anterior horn. The right ventricle enlarged and SVS improved after daily reservoir puncture.

The scalp was reflected and the calvarial surface was exposed. A bilateral circumferential parieto-occipital osteotomy was performed. The osteotomy line was decided using neuronavigation. The cortical bone was very hard and thick, while the cancellous bone was relatively thin. The dura was fragile and strongly adhered to the bone. To prevent sinus injury, the osteotomy above and close to the superior sagittal sinus was performed gently using Kerrison rongeur. The osteotomy line was kept rostral to the transverse sinus. Four cranial distractors were fixed to the cranial bone. The sites of the distractors were decided so as not to interfere with the existing shunt and reservoir [Figure 3]. To minimize the amount of bleeding during the surgery, we stopped even small bleeding at every step from the skin incision to the wound closure. The operating time was 5 h 24 min, and the blood loss was 10 mL.

No perioperative hemorrhagic complications or infections were observed. Cranial distraction was started on the 6th postoperative day and extended to a total of 25 mm (1 mm/day). The extension of the lateral distractor on the right side was terminated at 9 mm not to interfere with the shunt [Figure 4]. Antibiotic administration was continued during the extension period. After the start of distraction, intracranial pressure gradually decreased to 4–6 cmH_2O, and symptoms such as disturbance of consciousness and bradycardia resolved. The patient was discharged 33 days after the operation and no recurrence of symptoms has been observed. Bone regeneration in the defect site was good, and the extension device was removed 6 months after the operation [Figure 5].

DISCUSSION

In this report, we performed cranial distraction osteogenesis for a child with osteopetrosis who presented with uncontrolled intracranial hypertension and obtained a favorable outcome.

Surgical treatment for osteopetrosis

In osteopetrosis, the dysfunction of osteoclasts leads to high bone density but susceptibility to fracture.[5] In the treatment of fractures, conservative treatment is generally considered to heal without delay. Surgical treatment is often difficult due to osteosclerosis and the reduction of cancellous bone. Intraoperative bleeding and postoperative infection due to hematopoietic disorders associated with osteopetrosis can also be problems.[23] Considering that infections are the leading cause of death in children with severe osteopetrosis, prevention of perioperative infections is essential.[10] Some reports suggest that ETV should be given priority over VP shunts in the treatment of osteopetrosis patients with hydrocephalus, considering the risk of shunt infection.[1] In our case, to prevent a dural tear and CSF leak, meticulous osteotomy using Kerrison rongeur was performed where

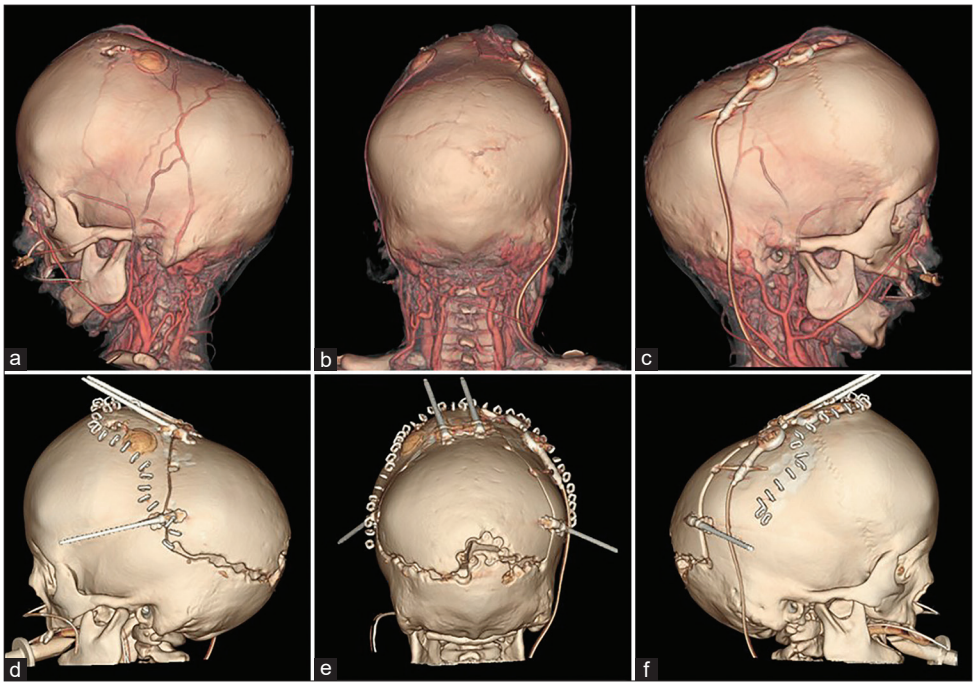

Figure 3: (a-c) Preoperative and (d-f) postoperative computed tomography. The osteotomy line was designed so as not to interfere with existing shunts and reservoirs. Furthermore, the emissary vein was preserved as much as possible. The osteotomy line was kept rostral to the transverse sinus because the adhesion between the bone and the dura mater was particularly strong near the sinus confluence.

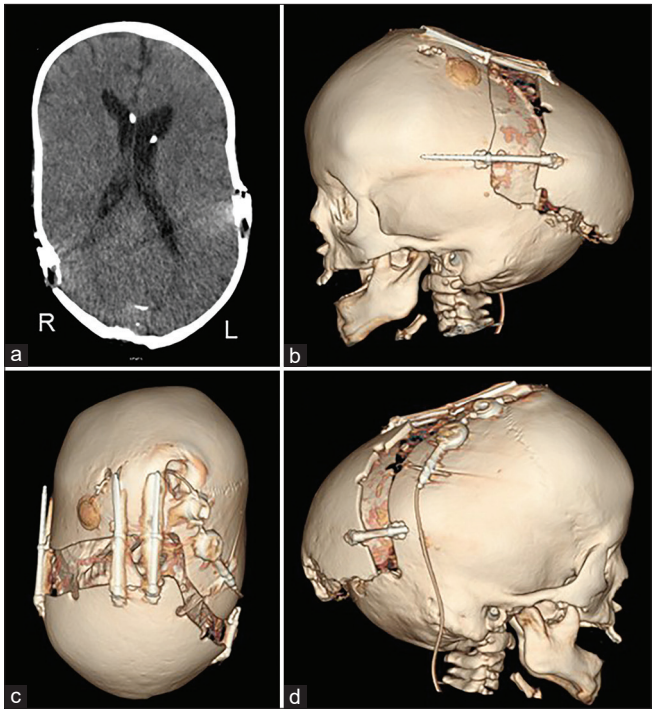

Figure 4: (a) Computed tomography at the end of cranial expansion. Slit ventricle syndrome resolved. (b-d) We extended the distractor to a total of 25 mm. The extension of the lateral distractor on the right side was terminated at 9 mm not to interfere with the shunt.

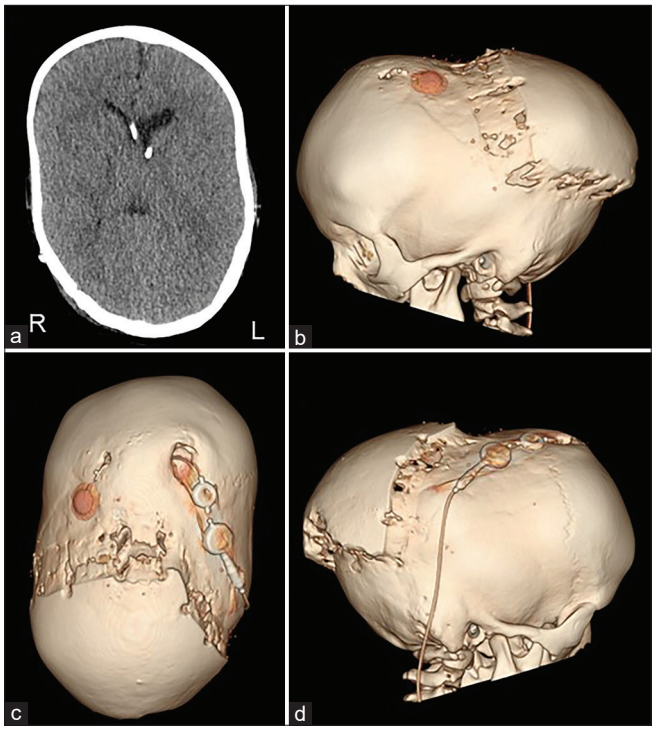

Figure 5: (a) Computed tomography after the removal of the extension device. The ventricle was not slit. (b-d) Bone formation in the bone defect was good 6 months after the distraction osteogenesis.

adhesion between the dura and the bone was strong. Administration of antibiotics was continued during cranial distraction, and no infectious complications were observed. Bleeding tendency due to hematopoietic dysfunction can be a problem in children with severe osteopetrosis.[21] In the present case, although preoperative bleeding tendency was not found, perioperative blood transfusion was performed, and no bleeding complications ensued.

Cranial expansion for osteopetrosis

In craniosynostosis associated with osteopetrosis, multiple factors are thought to contribute to intracranial hypertension. The increased thickness of the calvarium and the decrease in the cranial capacity are the causes of increased intracranial pressure.[12] Acquired Chiari malformation also contributes to intracranial hypertension. Poor venous perfusion due to cranial foramen stenosis and inadequate CSF circulation is thought to cause hydrocephalus.[2,6] When impaired venous perfusion was the cause of intracranial hypertension, treatment options could include jugular foramen decompression, venous bypass, and stent placement.[11,18] However, in this case, emissary veins, which were collateral blood circulation routes, had already developed, and surgical procedures on the posterior fossa were considered to have a high risk of bleeding due to the developed emissary vein. In addition, the antithrombotic therapy required for stent placement was considered to be high risk for the patient.[14] It is suggested that cranial expansion surgery can be a curative treatment for children with osteopetrosis. To the best of our knowledge, there have been four reports of pediatric osteopetrosis patients undergoing intracranial volume expansion surgery.[7,13,16,22] Only one case reported to have undergone distraction osteogenesis.[7] The remaining three cases underwent cranial expansion including craniotomy.

Necessity of gradual cranial distraction

Jamjoom *et al.* reported the case of a 4-year-old boy with osteopetrosis who had a cardiac arrest during one-stage cranial enlargement. They considered hypotension associated with sudden intracranial pressure drop, complication of Chiari malformation, and intraoperative bleeding as causes of cardiac arrest.[13] As one-stage cranial enlargement may have a higher surgical risk including bleeding complications, Dowlati *et al.* recommended gradual enlargement using a distractor.[7]

Preservation of emissary veins

In osteopetrosis, venous outflow stenosis is considered to be one of the causes of hydrocephalus and increased intracranial pressure.[2,6] There is also a report that venous perfusion failure causes perioperative cerebral hemorrhage, and it is considered important to preserve the emissary veins, which

are collateral channels of venous perfusion.[23] In our case, the skin incision and osteotomy area were determined to preserve the emissary veins [Figure 3], and no complications of exacerbating intracranial pressure or hemorrhage ensued.

Determination of craniotomy range and surgical technique

In cranial distraction surgery, a large bone flap that includes the caudal side of the torcula is often created to simultaneously decompress the venous sinuses.[4] However, when performing surgery on a patient with osteopetrosis, it may be difficult to control bleeding when the sinus is injured. Thus, we designed a bone flap that does not include the area above the sinus. Moreover, in this case, thinning of the dura mater and strong adhesion to the bone were observed during operation. Because, the bone adhesion was particularly strong near the superior sagittal sinus, creating a bone flap across the sinus was considered to be risky.

Meticulous detachment using Kerrison rongeur was effective to preserve the dura during the osteotomy and no bleeding from the sinus and postoperative CSF leakage occurred. Considering the fragility of the dura mater, it was considered necessary to delay the start timing of distraction. We delayed the start of distraction to the 6th postoperative day and no CSF leakage due to dural injury was observed throughout the course of distraction.

Treatment timing

It is difficult to judge when to perform cranial expansion surgery in the case of osteopetrosis-associated craniosynostosis and hydrocephalus. We usually perform a posterior vault expansion for craniosynostosis before considering drainage techniques such as VP shunt surgery. However, in patients with osteopetrosis, we should decide on the surgical method considering that they have a high risk of bleeding in surgery with bone manipulations. In this case, we performed a VP shunt before cranial expansion against intracranial hypertension that was poorly controlled by ETV and regular puncture drainage. We suggested that considering the risk of cranial distraction surgery, the VP shunt surgery and/or ETV was performed first, and the cranial distraction surgery may better be delayed until high intracranial pressure becomes uncontrollable even with the VP shunt.

CONCLUSION

We successfully performed cranial distraction osteogenesis for the patient with osteopetrosis associated with hydrocephalus and craniosynostosis. Cranial distraction osteogenesis is considered an effective treatment for uncontrolled intracranial hypertension with osteopetrosis.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The author(s) confirms that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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