

Endoscopic-assisted Duraplasty with Collagen Matrix for Growing Skull Fracture: A Case Report

Yuki KOZAKI,¹ Masani NONAKA,¹ Koichi MIKI,¹ Hideaki TANAKA,¹
Hiroshi ABE,¹ and Tooru INOUE¹

¹*Department of Neurosurgery, Faculty of Medicine, Fukuoka University Hospital and School of Medicine, Fukuoka University, Fukuoka, Fukuoka, Japan*

Abstract

Growing skull fracture (GSF) is a rare complication of pediatric head injury. Early diagnosis and immediate surgical intervention are required for the prevention of irreversible brain damage. Surgical management involves water-tight closure of the dural defect and commonly uses autologous materials because of tissue compatibility; however, a large skin flap and craniotomy are necessary to harvest the autologous materials and repair the dural defect. We describe a successful case of endoscopic-assisted duraplasty using collagen matrix in a female infant suffering from early phase GSF. A 4-month-old female infant presented with a GSF. We surgically treated her because the fracture width progressively expanded 6 days post-injury. A zigzag skin incision was made, and the extent of the skull fracture and dural laceration was observed using an endoscope. Utilizing the collagen matrix, duraplasty was performed to completely seal the dural defect. Subsequently, cranioplasty was performed and the opposite sides of the fracture margins were drawn and bonded by nylon suture. Postoperatively, the patient did not develop any complication or experience recurrence. This is the first report of duraplasty using collagen matrix in GSF, and the collagen matrix can be used as a dural substitute. This novel technique was safe and a less invasive surgical approach for treating patients with GSF.

Keywords: growing skull fracture, collagen matrix, DuraGen, endoscopic surgery, pediatric neurosurgery

Introduction

Growing skull fracture (GSF) is a rare complication of pediatric head injury; it occurs in approximately 0.05–1.6% of cases, most commonly in infants and children younger than 3 years of age.^{1–4} The pathogenesis of GSF is understood to involve a skull fracture with dural laceration and subsequent entrapment of the arachnoid membrane or brain tissue within the fracture margin.^{1,2,5,6} The dura mater is in close contact with the bone in infancy and childhood; therefore, a major diastatic fracture of the vault is likely to cause tearing. Early diagnosis and immediate

surgical intervention are required for the prevention of progressive brain damage caused by GSF.^{2,5,6}

Dural closure can be challenging and requires water-tight closure of the dural defect and the pericranium, fascia lata, or artificial dura.^{2,5,6} Autologous materials are used to close the dural defect because of tissue compatibility; however, a large skin flap and craniotomy are necessary to harvest the sufficient autologous materials and repair the dural defect.^{2,5,6} In the current article, we present a case of a 4-month-old female infant, who was diagnosed with early phase GSF and was successfully treated with minimally invasive, endoscopic-assisted duraplasty using a collagen matrix.

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Case Report

A 4-month-old female infant fell from a baby sling wrapped around her mother and landed on a concrete

surface. On arrival to our department, her eyes were open, she was moving all extremities, and she had no focal neurological deficits. Although there was no open wound, a firm swelling of 10 × 8 cm in dimension was present in the parietal region. Besides confirming a cephalohematoma, computed tomography (CT) scan revealed an extensive skull fracture of the right parietal bone, from the lambdoid to coronal sutures, of roughly 10 cm and bone diastasis of 4 mm, without brain compression (Fig. 1A and 1B). The stability of the patient's neurological condition initially directed us to opt for conservative management of the condition, but the scalp swelling progressively worsened. Magnetic resonance imaging (MRI) performed 5 days after the injury detected a brain contusion and subcutaneous accumulation of fluid as dense as cerebrospinal fluid (CSF; Fig. 2).

We surgically treated her because the fracture width was unstable and greater than 6 mm on CT

at 6 days post-injury (Fig. 1C). The fracture line was identified by palpation at the margin of the scalp swelling, and a zigzag skin incision was made above the fracture line. The subcutaneous tissue was incised and the CSF was ejected. We observed the extent of skull fracture and dural laceration using a 4-mm, 0° rigid endoscope (KARL STORZ SE & Co. KG, Tuttlingen, Germany). The affected brain tissue bulged and herniated from the dural laceration, and it compressed the fracture margin while pulsating (Fig. 3B). There was no strict adhesion between dura mater and brain tissue and they could be separated without difficulty. Upon visualization, the edges of the dural defect did not appear to extend beyond the skull fracture (Fig. 3C). The CSF leak and dural laceration were not observed distally. Collagen matrix grafts (DuraGen; Integra LifeSciences, Princeton, NJ, USA) were cut at a larger size than the size of the dural defect. Through endoscopy, the collagen matrix graft was inserted in the subdural space as an inlay

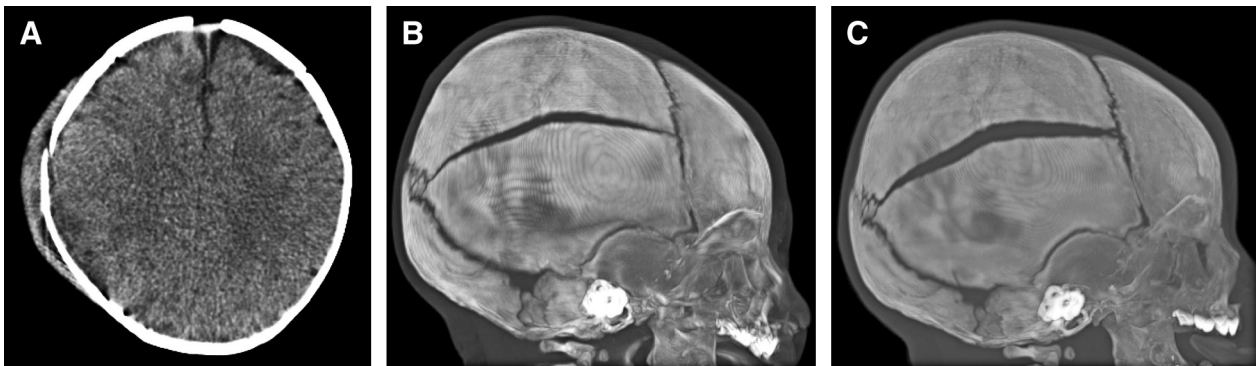


Fig. 1 (A, B) A CT scan showing a wide skull fracture of the right parietal bone, from the lambdoid to coronal sutures, measuring 10 cm at its superior portion and 4 mm at its inferior portion. (C) At 6 days post-injury, the fracture width had enlarged, and it was greater than 6 mm on CT scan. CT: computed tomography.

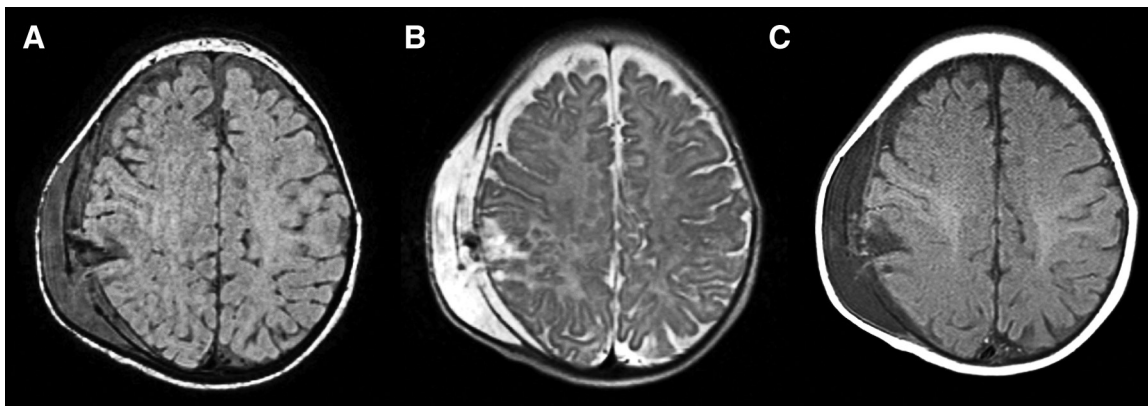


Fig. 2 Axial MRI showing the accumulation of subcutaneous fluid similar to cerebrospinal fluid, brain contusion, and herniated cortex at the right parietal lobe. (A) T1-, (B) T2-, and (C) fluid-attenuated inversion recovery-weighted images. MRI: magnetic resonance imaging.

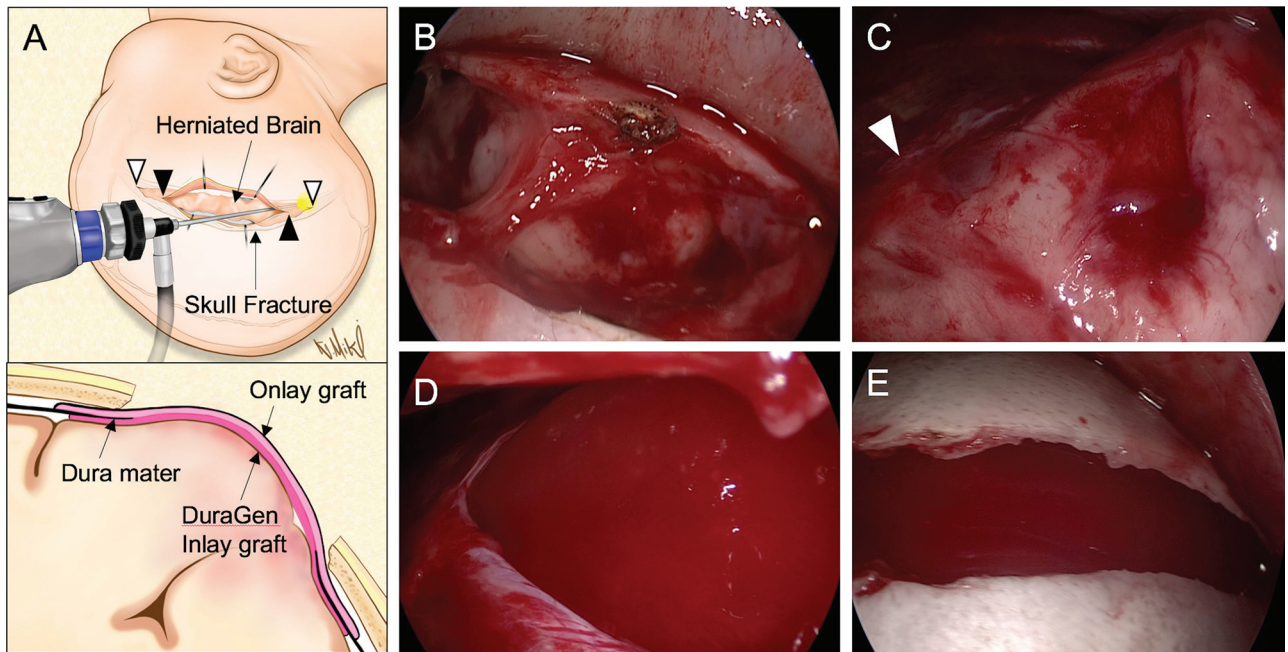


Fig. 3 Intraoperative photograph under visualization with an endoscope. (A) Upper row: Illustration showing the association between the edges of incision and dural laceration, and the approach with an endoscope for dural laceration (edges of incision [black arrowhead] and dural laceration [white arrowhead]). Lower row: illustration showing the duraplasty, using inlay and onlay grafts to close the dural defect. (B) The brain tissue with the contusion bulged and herniated from the dural laceration. Due to the pulsating, it compressed the fracture margin. (C) The edge of dural defect was visible (arrowhead). (D) The collagen matrix inserted in the subdural space as an inlay graft. (E) The overlapping dural defect surrounding the dural margins of the defect as an onlay graft.

graft. Subsequently, an onlay graft was placed over the dural defect, overlapping at the margins, and hydrated with physiological saline. (Fig. 3). Fibrin glue was not required during the surgery. Finally, the opposite sides of the fracture margins were drawn and bonded by 3-0 nylon suture before the incision was closed (Figs. 4A and 4B).

Postoperatively, the patient did not develop any complication and she was discharged after 9 days. The stitches were removed at an outpatient visit 2 weeks following surgery. The patient was healthy, with neither neurological deficits nor recurrence of the scalp swelling, and MRI did not demonstrate abnormal findings at 4-month follow-up (Figs. 4C–4E).

Discussion

Early diagnosis and prompt surgical intervention can prevent progressive brain damage and contribute to the improvement of neurological symptoms in cases of GSF.^{3,5} The water-tight closure of the dural defect is an essential step in the surgical management of GSF as it prevents progressive gliosis.^{5,6} Autologous pericranium and fascia lata or galea are preferentially used for dural repair owing to their tissue compatibility.⁶ Autologous materials are

commonly used in duraplasty because they are non-immunogenic, inexpensive, and have the lowest rate of complications, with decreased incidence of CSF leak and wound infection.⁷ However, conventional surgery requires a large skin flap and craniotomy to harvest sufficient autologous materials.^{8,9}

DuraGen is a safe and effective type I collagen matrix graft, manufactured from bovine Achilles tendon.^{10–12} Collagen matrix has an optimized pore size for fibroblast proliferation and enhances natural biological healing by its three-dimensional matrix structure, encouraging dural repair through the matrix instead of encapsulation, which can occur with synthetic grafts.¹³ Fibroblast proliferation begins 3–4 days post-surgery, becomes established at 14 days, and is completely resorbed over 6–8 weeks as the new dura mater is constituted.^{12,13} Interestingly, the collagen matrix can be used as a dural substitute, although this is the first report of duraplasty using collagen matrix in GSF. Our technique is advantageous since it does not require a large skin flap following the harvest of the autologous materials, similar to more conventional methods.

The pathophysiology of GSF remains controversial.^{1,5,6,14–16} A previous study described the formation of leptomenigeal cysts from the accumulation

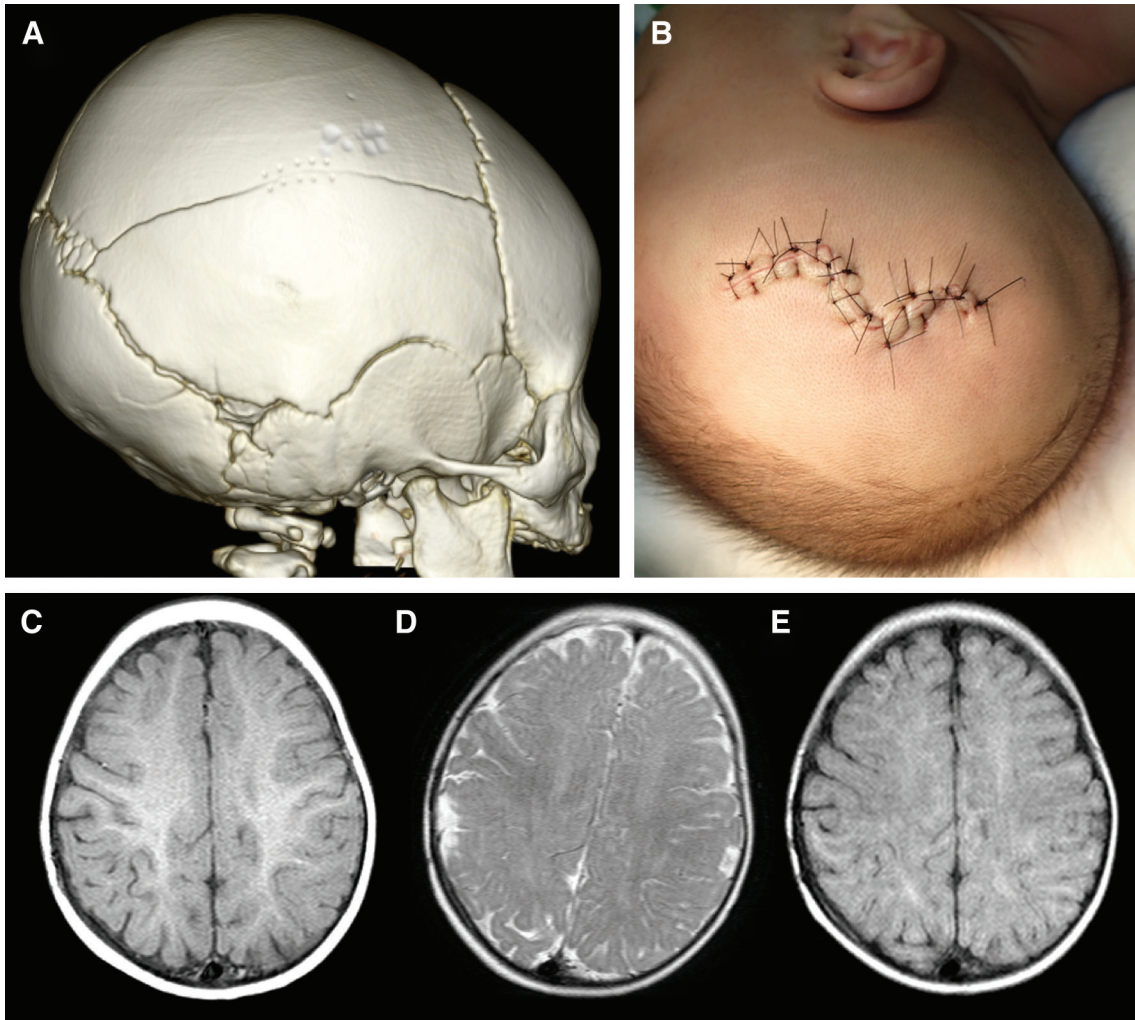


Fig. 4 Postoperative course. A postoperative 3D CT scan showing the bonded fracture margins. (A) A photograph immediately after performing skin closure. (B) Four months after surgery, the MRI shows neither recurrence nor abnormal findings. (C) T1-, (D) T2-, and (E) fluid-attenuated inversion recovery-weighted images. CT: computed tomography, MRI: magnetic resonance imaging.

of CSF in entrapped arachnoid tissue at the fracture site via a ball-valve mechanism, thereby causing the progressive enlargement of the fracture site.¹⁴ Alternatively, similar to our present case study, other reports have shown the enlargement of the skull fracture without associated cystic structures.^{15,16} It is more likely that the cysts, brain herniation, and the resulting pulsative compression of this herniated material contribute to the occurrence of GSF.^{1,6} In our current patient, the GSF appeared to result from brain herniation and the compression of the skull fracture through pulsations from the herniated brain.

Postoperative recurrence of GSF has been reported as a complication of surgery and found to be associated with incomplete dural closure of the defect.¹⁷ GSF continues to enlarge until the dura mater is

repaired, allowing it to counteract the stretching forces produced by the strong pressure of brain expansion.¹⁸ Several studies have reported good treatment results with DuraGen as an onlay graft in other neurosurgical cases.^{8,10,12} However, the graft may be displaced under high pressure of the CSF, resulting in an incomplete seal of the dural defect. We anticipated the bone edge to be highly pressured in this case, requiring generous cover of the dural defect by DuraGen. DuraGen attaches to the dural surface via surface tension.¹³ In our case, it was not easy to acquire sufficient overlap of the dura mater and onlay graft; therefore, we sandwiched the dural defect between two layers of the inlay and onlay grafts. The rise in surface tension between the dura mater and the grafts and between both the grafts might result in complete sealing of the dural defect.

The risk of postoperative wound infection is important following duraplasty and has been used as a “barometer” of the efficacy and safety of a dural graft. The collagen matrix is extensively used in neurosurgery as a dural substitute, and several reports have demonstrated low complication rates associated with this alternative.^{8,10–12,19)} The reported infection rate is similar to that of duraplasty performed with other materials (between 1.6 and 5.1%).^{1,7,8,11,20,21)} Postoperative CSF leaks and pseudomeningoceles occur in cases of 0–4.8% and 2.5–8.9%, respectively.^{8,10–12,19)} We did not observe these issues with our patient, suggesting that collagen matrix may be an effective dural graft.

Cranioplasty is also an important step following duraplasty. New bone growth results in no residual bone defect in the infant and young child. We performed cranioplasty by drawing and bonding using a suture, and a satisfactory bone fixation was achieved. However, our technique may be difficult in a GSF with a wide bone defect. In a patient with a wide bone defect, a bone flap may be used for cranioplasty. A rigid bone fixation is important, as pulsation will result in bone resorption. Early osteogenesis is induced by a vascularized flap with a periosteum.²²⁾ Although our case was that of an infant without the risk of fall, cranioplasty with an alternative fixation might be required in case of a risk of fall.

Endoscopy provides a large and clear visualization of deep lesions and has been increasingly utilized in pediatric neurosurgery,²³⁾ where working space is limited. It was able to assist in identifying the area of dural defect and maneuvering with minimal skin incisions in our case; however, dural defects may extend beyond the skull fracture in some patients, and enlargement of the skin incision may be necessary to visualize the defect.^{5,6)} Therefore, it may be difficult to identify the area of dural defect using this technique only. Finally, the procedure can be more challenging as the bone defect becomes larger and cystic structures arise, endoscopic success is enhanced in the early phases of GSF. Endoscopic duraplasty may not be appropriate to completely resect cystic structures and degenerated brain tissue, and the selection of conventional procedures may be necessary.

Conclusion

We report a case of GSF that was surgically managed through endoscopic-assisted duraplasty with collagen matrix as dural substitute. This novel technique may be a less invasive surgical approach for treating some patients with GSF, especially those in the

early phases of GSF; however, a conventional procedure would be more appropriate for GSF diagnosed in the late phase since further investigations are necessary to evaluate the safety and efficacy of endoscopic-assisted duraplasty.

Informed Consent

The patient has consented to submission of this case report to the journal.

Conflicts of Interest Disclosure

The authors declare that they have no conflicts of interest.

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Corresponding author: Koichi Miki, MD, PhD
Department of Neurosurgery, Fukuoka University,
7-45-1 Nanakuma, Jonan-ku, Fukuoka, Fukuoka
814-0180, Japan.
e-mail: em.koichi@gmail.com