New Technique of Decompressive Skinplasty With Artificial Dermis for Severe Brain Swelling
—Technical Note—

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Abstract
In cases of severe uncontrollable brain swelling, simple skin closure often increases intracranial pressure. This study examined the efficacy of a new technique of decompressive skinplasty to decrease intracranial pressure following decompressive craniectomy in cases of severe traumatic brain injury with uncontrollable brain swelling. In our technique, we use artificial dermis to avoid elevation of intracranial pressure. After performing decompressive craniectomy and duraplasty with artificial dura, decompressive skinplasty with artificial dermis was performed in 5 patients for whom simple skin closure caused the intracranial pressure to elevate under intracranial pressure monitoring. Artificial dermis was grafted onto the region to cover the skin defect and sutured to the skin with 4–0 nylon sutures. Two weeks after surgery, the silicone layer of the artificial dermis was removed and ointment treatment was continued until complete epithelialization was achieved. In all cases, decompressive skinplasty contributed dramatically to decreasing the intracranial pressure in patients with uncontrollable brain swelling. The technique of decompressive skinplasty with artificial dermis contributed to dramatically decreasing the intracranial pressure. More cases are required to investigate the indications for this technique.

Key words: artificial dermis, decompressive craniectomy, traumatic brain injury

Introduction
Intracranial pressure monitoring is a recommended standard procedure for the management of severe traumatic brain injury and first-tier therapies are used to control intracranial pressure. However, many patients with severe traumatic brain injury have elevated intracranial pressure that is refractory to these first-tier therapies, and decompressive craniectomy is often required to control the pressure. Although the efficacy of this procedure for improving patient outcome remains controversial, several reports have suggested it is efficacious for decreasing intracranial pressure. However, in cases of severe brain swelling, simple skin closure often increases intracranial pressure, so we use artificial dermis to avoid such elevation. We report here the usefulness of decompressive skinplasty with artificial dermis in decompressive craniectomy for the management of severe traumatic brain injury with uncontrollable brain swelling.

Methods
A total of 16 adults with severe traumatic brain injury underwent decompressive craniectomy at our institution, 5 of whom underwent decompressive skinplasty with artificial dermis (Pelnac®; Gunze Corp., Tokyo) due to uncontrollable brain swelling, between January 2010 and August 2011. A large bone flap was removed and the dura mater was opened in a stellate fashion. Artificial dura was then placed under the dura to cover the brain surface and the dura was sutured loosely. After completing the decompressive craniectomy and duraplasty with artificial dura, we performed decompressive skinplasty with Pelnac® for the 5 patients for whom simple skin closure caused the intracranial pressure to elevate under intracranial pressure monitoring. In this
procedure, Pelnac® was grafted onto the region to cover the skin defect and sutured to the skin with 4-0 nylon sutures. Pelnac® consists of an inner sponge layer of collagen and an outer layer of silicone. After dermis-like granulation tissue formed, usually within 2 to 3 weeks, the silicone layer was removed and ointment treatment was continued until complete epithelialization was achieved.

Results

The patients' characteristics are shown in Table 1. All 5 patients were male, and mean age was 61.6 years (range 28–81 years). The initial mean Glasgow Coma Scale (GCS) score was 7.4 (range 3–14). In terms of outcome, one patient died of circulatory failure and the other patients were severely disabled or in a vegetative state. Cases 3 and 5 underwent decompressive craniectomy, duraplasty, and skinplasty with Pelnac® simultaneously in a single operation, because simple skin closure caused elevation of intracranial pressure. The other patients underwent multiple surgeries: Case 1 underwent multiple decompressive craniectomy and internal decompression, and then only skinplasty with Pelnac® was performed in a final surgery; and Cases 2 and 4 underwent multiple decompressive craniectomy and internal decompression, and skinplasty with Pelnac® was performed with decompressive craniectomy and internal decompression simultaneously at the final surgery. Complications are shown in Table 2. Brain strangulation by bony edges was confirmed on postoperative brain computed tomography (CT) as low density areas along the bony edges.

Illustrative Cases

Case 1: A 64-year-old man presented with a head injury caused by a falling tree. GCS score was 8. Brain CT revealed multiple skull fractures and biparietal epidural hematoma. Initial surgery involved bilateral evacuation of the hematoma, decompressive craniectomy on the right, and placement of an intraparenchymal pressure probe in the left parietal lobe. One day later, intracranial pressure exceeded 30 mmHg and additional right temporal decompressive craniectomy and duraplasty were performed. Intracranial pressure decreased to less than 20 mmHg after this second surgery but increased again 4 days later. Additional right frontal decompressive craniectomy, evacuation of the right parietal lobe hematoma, and internal decompression of the right temporal tip were performed, which reduced in-

<table>
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<th>Case No.</th>
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<th>GCS score</th>
<th>CT finding</th>
<th>Number of surgeries</th>
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<td>8</td>
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<tr>
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<td>D</td>
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<td>4</td>
<td>68</td>
<td>M</td>
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<th>Additional graft</th>
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<td>—</td>
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<td>—</td>
<td>—</td>
<td>split-thickness skin grafting</td>
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*Pelnac® was applied onto the artificial dura in Cases 1 and 2 and onto the temporal muscle in the remaining 3 cases. +: present, —: absent.
tracranial pressure to less than 20 mmHg, although it increased to more than 40 mmHg the following day. In an emergency procedure, the fourth surgery, intracranial pressure decreased dramatically to less than 20 mmHg when the skin and dural sutures were cut. Decompressive skinplasty was performed with artificial dermis to maintain this low intracranial pressure (Figs. 1 and 2). After this surgery, intracranial pressure remained low, never exceeding 20 mmHg. Two weeks after the operation, the silicone layer was removed and ointment treatment was started. We applied artificial dermis onto the artificial dura and delayed wound healing was observed. We needed to graft the fascia lata over the artificial dura to promote epithelialization. Complete epithelialization was achieved 150 days after the fourth surgery.

Case 4:
A 68-year-old man riding a bicycle was involved in a traffic accident. GCS score was 6. CT revealed left supratentorial and subtentorial epidural hematomas, a right supratentorial subdural hematoma, and multiple contusions (Fig. 3). Bilateral evacuation of the hematomas, bilateral decompressive craniectomy, and placement of an intraparenchymal pressure probe in the right parietal lobe were performed. Seven hours later, intracranial pressure exceeded 30 mmHg (Fig. 4A) and additional right temporal internal decompression and duraplasty were performed. Intracranial pressure decreased to less than 20 mmHg after the second surgery but increased again the following day (Fig. 4B). Additional right frontal decompressive craniec-
Fig. 5 Case 4. Images of epithelialization and schematic drawing of skinplasty with artificial dermis. A: Pelnac® was grafted onto the temporal muscle (arrow). B: Schematic drawing of skinplasty with artificial dermis. C: At 2nd postoperative week, the silicone layer was removed. D: At 4th postoperative week, the skin defect was reducing in size. E: At 36th postoperative day, complete epithelialization was achieved.

Decompressive Skinplasty With Artificial Dermis

Decompressive skinplasty with artificial dermis. C: At 2nd postoperative week, the silicone layer was removed. D: At 4th postoperative week, the skin defect was reducing in size. E: At 36th postoperative day, complete epithelialization was achieved.

Discussion

High intracranial pressure is the most frequent cause of death or disability after severe traumatic brain injury, and decompressive craniectomy is frequently performed as a second-line therapy. Given that several reports have suggested the efficacy of decompressive craniectomy in decreasing intracranial pressure, we hypothesized that decompressive skinplasty with artificial dermis would also likely be effective. Indeed, decompressive skinplasty lowered intracranial pressure to less than 30 mmHg in all our patients. At the least, decompressive skinplasty under intracranial pressure monitoring is more likely to be effective in decreasing intracranial pressure. Forcible skin closure probably causes elevation of intracranial pressure and disturbances in skin blood flow in cases of severe brain swelling. Other second-tier options can be used to control intracranial pressure, including high-dose barbiturate therapy or mild hypothermia; however, the efficacy of these procedures remains controversial and the side effects are severe.5,9) Although estimating the efficacy of decompressive skinplasty is difficult, we suggest that decompressive skinplasty under intracranial pressure monitoring is safer and easier for managing a decrease in intracranial pressure than high-dose barbiturate therapy or mild hypothermia.

In our cases, this technique contributed to decreasing the intracranial pressure. Nonetheless, decreasing the intracranial pressure did not contribute to improvement of Glasgow Outcome Scale at discharge. One possible explanation is that most of our patients had severe diffuse brain injury and severe brain functional damages may have been present already at the time of injury. Another possible explanation is that decompressive craniectomy allowed expansion of the swollen brain and caused axonal stretch.9) Although the efficacy of decompressive surgery for improving prognosis of traumatic brain injury patients remains controversial, high intracranial pressure is obviously associated with poor prognosis. More cases are required to investigate the discrepancy between the intracranial pressure control and functional outcome in our patients.

Cranioplasty was not performed in all patients, because of their severe disability state. However, we suspect that artificial dermis only promotes epithelialization and probably does not obstruct cranioplasty. Artificial dermis has emerged as a medical material for healing deep skin defects, where it is gradually replaced by dermal-like granulation tissue, and has been used mainly in plastic surgery to date.10) We here describe the use of artificial dermis in decompressive skinplasty for the control of intracranial pressure to manage severe brain swelling. We applied Pelnac® onto the artificial dura in the first two cases and onto the temporal muscle in the latter 3 cases. Delayed wound healing was observed in both the first two cases and we subsequently needed to graft the fascia lata over the artificial dura to promote epithelialization. Therefore, we recommend applying Pelnac® onto vascularized tissue to avoid delayed wound healing. Vacuum-assisted closure and split-thickness skin grafting over Pelnac® reduced the period of hospitalization.7) We performed split-thickness skin grafting after the Pelnac® was removed for one patient who was malnourished and complete epithelialization was subsequently achieved. Split-thickness skin grafting was effective in accelerating epithelialization and it may be better to perform it routinely in cases with large

Neurol Med Chir (Tokyo) 53, January, 2013
skin defects.

In addition to delayed wound healing, the anticipated complications of this technique are cerebrospinal fluid leakage, infection, and brain strangulation by bony edges of the craniectomy. Cerebrospinal fluid leakage and infection caused by the skinplasty were not observed in any of the present cases, although cerebrospinal fluid leakage and infection not related to the skinplasty lesion was seen in Case 2 whose brain was exposed to the outside at the time of injury. However, clearly there are some risks of cerebrospinal fluid leakage and infection because tight skin closure with Pelnac® is impossible. Brain strangulation by the bony edges of the craniectomy was observed in 2 cases. Although this complication might not be unique to our skinplasty procedure, sufficient craniectomy is necessary to avoid brain strangulation. Our 5 patients all had very severe traumatic brain injury which might well have been difficult to rescue with only conventional therapy. Although some complications are expected with our new technique, it may be acceptable for the rescue of critical patients.

The present cases illustrate the usefulness of decompressive skinplasty with artificial dermis in decompressive craniectomy for severe traumatic brain injury with uncontrollable brain swelling. This technique contributed to decreasing the intracranial pressure dramatically. More cases are required to investigate the indications for this technique.

Conflicts of Interest Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices in the article. All authors who are members of The Japan Neurosurgical Society (JNS) have registered online Self-reported COI Disclosure Statement Forms through the website for JNS members.

References


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