

# Simple, Quick, and Safe Dural Incision Technique for Patients with Expected Brain Bulging during Decompressive Craniectomy: “Crank-shaped Dural Incisions”

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## Abstract

Brain bulging is an unfavorable outcome in patients with brain swelling who require decompressive craniectomy (DC) to control elevated intracranial pressure (ICP). Although several previous studies have described methods for reducing the operation time during DC in these patients, few have proposed a technique for controlling brain protrusion. Here we describe an effective and simple method for external reduction of ICP and discuss its suitability for patients at risk of brain bulging during DC. After craniectomy, crank-shaped lines extending from a central square dural canopy are all marked on the dura. As the incisions are made, pressure from the swelling brain opens the lines and the protruding cortical surface forms dural windows. The square canopy gradually rotates as it stretches, and along with the remaining dura, functions to gently support and compress the cortex. In the case of insufficient decompression, the incision lines can be extended to further reduce ICP. As the parenchyma is accessible to the surgeon, hematoma removal can be performed through the dural windows. In initial experience of four patients who underwent this technique, ICP was controlled in all cases after surgery and no adverse events occurred. The crank-shaped dural incision method is a simple, quick, and effective technique for external reduction of ICP in patients at risk of brain bulging that is intuitive in the emergency situation and thus can be performed even by relatively inexperienced neurosurgeons.

Keywords: decompressive craniectomy, dural incision, duralplasty, cranioplasty

## Introduction

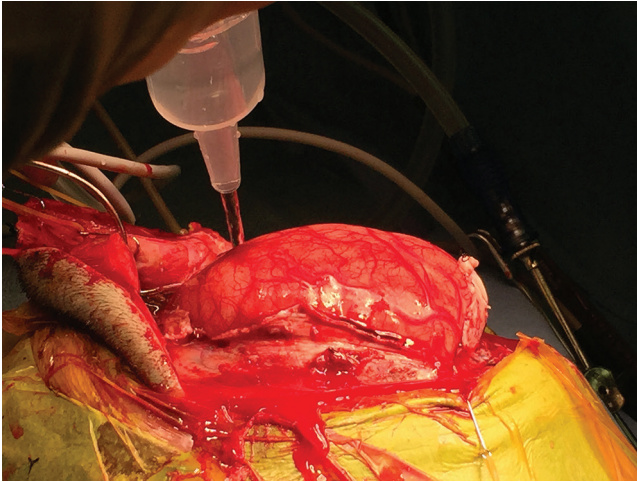
The temporary removal of a wide section of cranium, termed decompressive craniectomy (DC), is sometimes performed in neurosurgery to control elevated intracranial pressure (ICP) due to brain swelling caused by severe traumatic brain injury or major vessel occlusion. The goal of DC is to decrease ICP and return brain metabolism to within the normal range. However, great care must be

taken with this procedure as patient outcome is unfavorable in the situation of brain bulging during DC.<sup>1)</sup> Basically, as wide as possible craniectomy is performed for DC, with simultaneous dural incisions. As the dural incisions are made from the center of the craniectomy toward the corners, the brain surface can protrude from the bone edge if ICP is elevated (Fig. 1). If there is significant brain protrusion and development of malignant circulation, the neurosurgeon is faced with a very unpleasant reality and regrets having opened such a wide dural window. The authors propose a new dural incision method for DC in patients in whom brain bulging is expected during the procedure. The key feature of this proposed method is that crank-shaped dural incisions are made in such a

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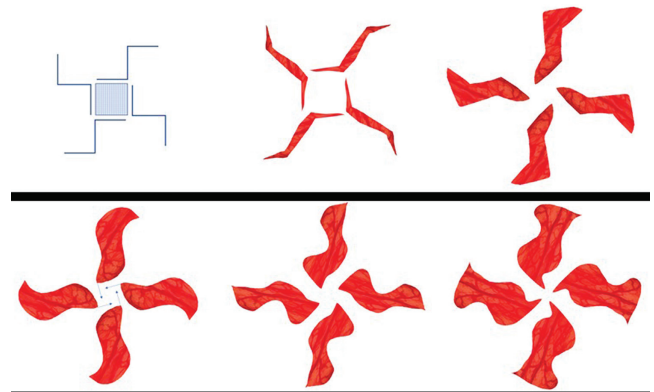


**Fig. 1** An example of brain bulging during DC. Protrusion of brain parenchyma beyond the inner table of the skull during surgery indicates brain swelling as well as elevated ICP. On this basis, the decision was made to perform additional craniotomy with dural incision, the dura covered the parenchyma in a rough fashion (not watertight closure), and the scalp was removed. Usually, this type of brain bulging is induced by a craniectomy that is too small to release elevated ICP and causes compression of venous circulation at the bone edge.

way as to retain a central square section of dura that acts as a canopy (canopy: a covering that serves as a roof to shelter an area over the swollen hemisphere) to control the protrusion of swollen brain. Because DC is an emergency procedure, intuitive judgement is required and the operation design must be simple enough to be performed even by less experienced surgeons. The proposed method is simple, requires minimal operation time, avoids cortical injury, and can be performed by less experienced surgeons.

### Surgical technique

Suitable candidates for this surgical procedure are those suspected preoperatively to have brain bulging, particularly patients with diffuse brain swelling from severe brain injury or large territory vessel occlusion who require emergency DC. Figure 2 shows the stepwise process. Basically, as wide as possible craniectomy is performed, after which the outline of the dural incision is drawn on the surface of the dura mater. The square outline of the canopy of dura mater to be retained is drawn in the center of the surgical field, and crank-shaped lines are extended from the square toward each corner of the surgical field. After the design is marked on the dura matter, incisions are then made

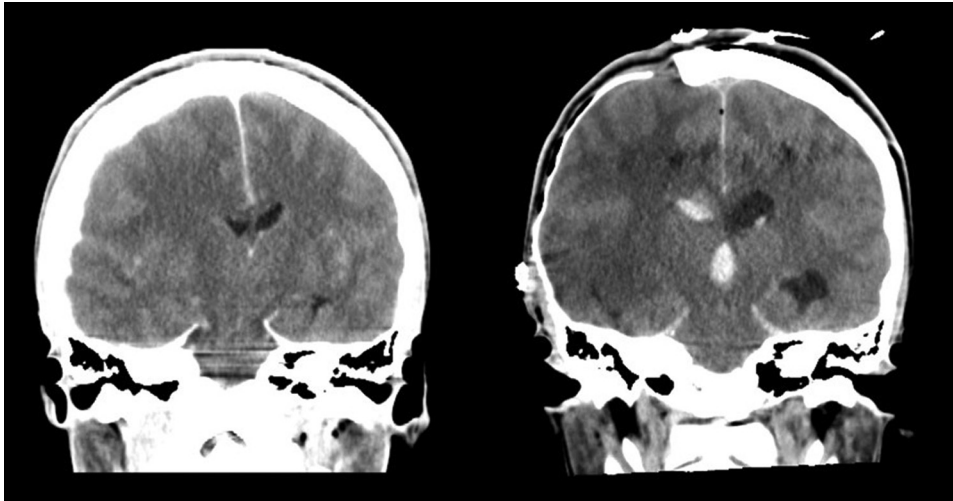


**Fig. 2** Diagrams showing the steps in the proposed crank-shaped dural incision technique. After crank-shaped dural incisions are made around a square canopy of retained dura mater, protruding brain parenchyma lifts the canopy in centroclinal fashion and the dural incisions gradually open as they are pushed away from the center.

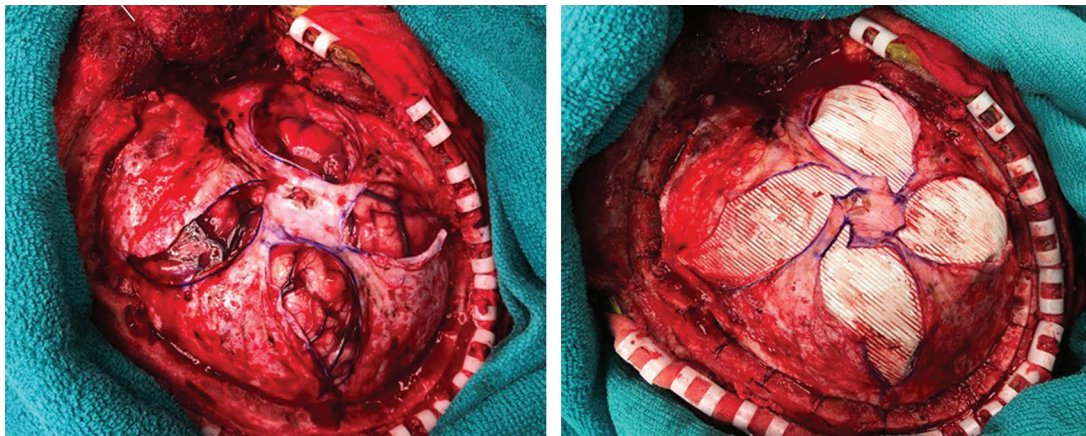
along the crank-shaped lines at once and without hesitation, and in no particular order. As the incisions are made, these lines are stretched by pressure from the protruding cortical surface, and the square canopy of dura mater is lifted and gradually rotated. In the process of pushing and stretching, the dural incision lines open, and the cortical surface can be seen through these dural windows. If the surgeon considers that decompression is insufficient, additional dural incisions can be made around the remaining square canopy of dura mater. In this case, the remaining square canopy of dura mater is elevated in centroclinal fashion and becomes smaller than previously designed, and the dural windows continuously stretch and widen. In this way, the elevated ICP is released externally. If intraparenchymal hematoma detected by intraoperative ultrasound imaging or subdural hematoma can be identified by direct observation, the surgeon can then perform hematoma removal through the dural windows. To achieve additional decompression, artificial dura can be inserted beneath the remaining dura mater through the dural windows. It is not necessary to suture the artificial dura to the remaining dura mater. The skin is closed in the usual fashion.

### Illustrative case and initial experience

A 16-year-old boy injured in a road traffic accident presented with a Glasgow Coma Scale of 9 (E2V2M5). CT of the head showed marked swelling of the right hemisphere, a subdural hematoma, and a small volume of traumatic intracerebral hematoma (Fig. 3, left). We performed as wide as possible



**Fig. 3** CT images of an illustrative case. Left: Preoperative CT shows marked swelling in the right hemisphere combined with thin acute subdural hematoma, and shift of midline structures toward the left. Right: Postoperative CT shows moderately increased ventricular size due to intraventricular hemorrhage. The swollen right hemisphere pushes the dura and stretched scalp toward the outside.



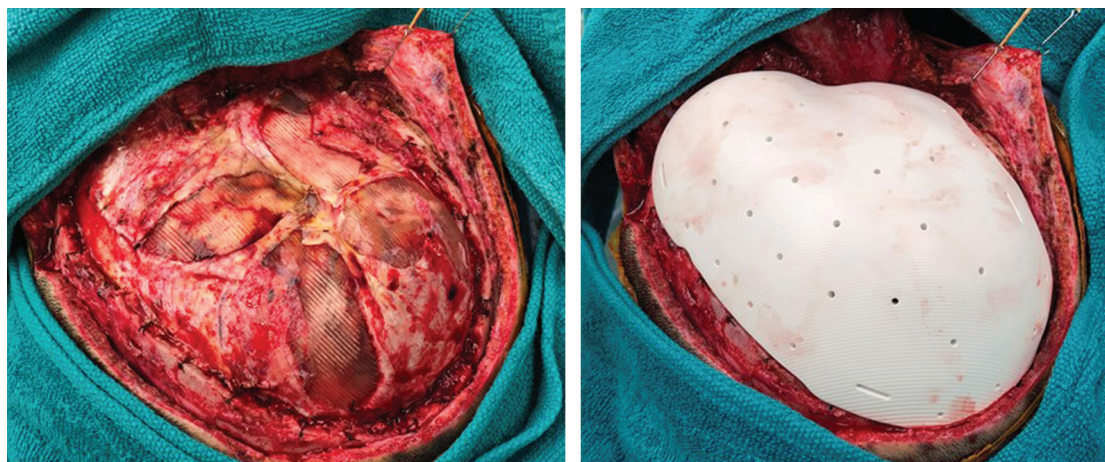
**Fig. 4** Operative view of an illustrative case of elevated ICP at the time of decompressive craniectomy. Left: Crank-shaped incisions in the dura are shown to form windows that reduced ICP to some degree, but ICP remained elevated. Right: After the intraoperative decision to lengthen the dural incisions around the square canopy of dura mater, a further reduction in ICP was achieved. Note that the canopy became smaller and showed rotation compared with the initial position. Artificial dura was then placed to cover each dural window.

frontotemporal DC with crank-shaped dural incisions. The incisions enabled protrusion of swollen brain through the dural windows coming off the central square of dura mater (Fig. 4, left). To further release tension on the remaining dura, the surgeon extended the dural incisions at the center of the surgical field to obtain satisfactory decompression and reduce the size of the central square of dura mater (Fig. 4, right). The dural windows were then covered with artificial dura. The ICP was well controlled after the DC and CT showed satisfactory surgical results (Fig. 3, right). Twenty-six days after the initial DC

to control ICP, there was limited adhesion between the scalp and dura matter that could be easily dissected, the cortical surface was successfully covered with autologous dura mater and artificial dura, and cranioplasty was performed in the usual fashion (Fig. 5).

In all four patients who underwent DC at our institution using the technique of crank-shaped dural incisions, ICP was controlled following surgery. There was no difficulty closing the scalp after the crank-shaped dural incisions with craniectomy.





**Fig. 5** Operative view of an illustrative case during cranioplasty. Left: With the scalp peeled back, the cerebral parenchyma was successfully covered with autologous dura mater and dural substitute. Right: Cranioplasty was completed in the usual fashion using artificial bone (hydroxyapatite plus tricalcium phosphate).

## Discussion

The proposed crank-shaped dural incision method is a simple, quick, and safe surgical procedure in patients at risk of brain bulging during DC. This method has the advantages that it avoids fully opening the dura mater, retains some dura mater that opposes the force of bulging brain, and gently supports the cortical surface with uniform pressure. The dural incisions can be lengthened if necessary, to further reduce ICP during the procedure. Moreover, artificial dura can easily be inserted beneath the remaining dura mater through the open windows. In addition, after ICP is controlled, the dura and scalp can be separated without cortical injury at the time of cranioplasty.

Accepted guidelines for treatment of severe head injury<sup>2)</sup> or stroke<sup>3)</sup> recommend that DC is performed for carefully selected patients with elevated ICP, and that DC should be mastered by all neurosurgeons. It is performed using the basic surgical principle that a large frontotemporoparietal DC (not less than  $12 \times 15$  cm, or diameter 15 cm) is recommended over a small frontotemporoparietal DC to reduce mortality and improve the neurologic outcomes of patients with severe head injury.<sup>2)</sup>

Numerous studies have reported techniques for reducing operation time in the emergency situation. Bhat et al. performed multiple-dural stabs without dural reconstruction,<sup>4)</sup> and Burger et al. performed multiple straight parallel durotomies without dural reconstruction or suturing.<sup>5)</sup> Güresir et al. opened the dura widely in a stellate pattern without suturing the dura.<sup>6)</sup> Nagai et al. have proposed methods for DC that include pentagonal incision<sup>7)</sup> and performed

geometrical analysis to determine the shortest incision that could be made in the dura mater.<sup>8)</sup> In 2020, they described a spiral dural incision technique for DC in which the incision design was analyzed geometrically and then verified in a simulation generated by a physics engine. They first planned the dural incisions based on geometrical logic, using a silk thread to design the dural incisions before making four to five spiral dural incisions, and lifted up the dura mater to transform it into a centroclinal form.<sup>9)</sup> However, according to the figure legends in that study,<sup>9)</sup> they retained a maximum amount of autologous dura mater and created a minimum area of dural windows, which does not appear to be the most effective method for reducing elevated ICP. Moreover, the spiral incision technique is well designed with respect to geometrical theory, but is not intuitive in the emergency situation. In contrast, the principle of our proposed method is easy to understand regardless of surgical experience, and additionally allows for extension of the dural incisions in the case that the surgeon wishes to further reduce ICP.

## Conflicts of Interest Disclosure

The authors declare that no conflicts of interest exist.

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