Utilizing real-time pressure and tissue oxygenation monitoring to assess the adequacy of hinge craniotomy

Alexander Riccio, Victoria Villescas, Constantine Plakas, John Dalfino

**Abstract**

Hinge craniotomy has been described as a feasible option for certain patients in need of decompression as a result of a mass lesion. The technique of hinging the bone flap alleviates the need to return to the operating room for cranioplasty as is the case with a traditional decompressive craniectomy. Intracranial pressure and brain tissue oxygenation monitoring can be utilized for intraoperative guidance to assess adequacy of hinge craniotomy. We report a case where intraoperative monitoring helped guide surgical decision making for a 23 year old male patient with a left traumatic subdural hematoma. The patient had a Licox monitor placed in the right frontal region, showing elevated intracranial pressure and decreased brain tissue oxygenation. The patient underwent hinge craniotomy, which initially lowered his intracranial pressure from 54 to 11 cm H2O and allowed his brain tissue oxygenation to rise to a normal value of 20.5 mm Hg. However, upon closure of the skin, the patient’s intracranial pressure increased to 24 cm H2O and brain tissue oxygenation decreased to 7.8 mm Hg. As a result, the patient underwent decompressive craniecetomy and the intracranial pressure and brain tissue oxygenation values normalized postoperatively. Intracranial pressure and brain tissue oxygenation can be helpful intraoperative guides in determining whether hinge craniotomy is adequate.

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1. Introduction

Decompressive hinge craniotomy has been presented by our group [3] as a potential alternative to the traditional decompressive craniectomy for the treatment of refractory intracranial hypertension. Once the craniotomy is performed the bone flap is plated and attached superiorly to the existing skull, allowing the inferior aspect to “hinge” and accommodate a swelling brain if necessary [3]. Retrospective data suggest that the hinge craniotomy can provide adequate control of intracranial pressure (ICP) without the need for additional reconstructive surgery [3]. At the population level, the data suggest that the hinge craniotomy provides adequate ICP control for most patients [4]. In practice, however, some patients do require conversion to a decompressive craniectomy if the ICP remains high after a hinge craniotomy.

The decision to perform a hinge craniotomy rather than a decompressive craniectomy often relies on the subjective biases and anecdotal experience of the operating surgeon rather than on objective data. This case report supports the use of objective data via ICP and brain tissue oxygenation (PbO2) monitoring to assist the neurosurgical team in decision-making and operative planning in real time. The utility of this type of data in guiding the type or extent of craniectomy has not been published previously. We describe the effect of each step of a decompressive hinge craniotomy on ICP and PbO2. In this particular case, hinging the bone plate did not adequately control ICP or PbO2. Intraoperative monitoring resulted in modification of the operative plan from a hinge craniotomy to a standard craniectomy for improved control of ICP.

2. Case report

2.1. Preoperative course

The patient was a 23-year-old unhelmeted male, under the influence of alcohol, who was riding his bicycle downhill when he struck a parked car. Upon arrival to the emergency department (ED), the patient was combative and vomiting but did not have any focal neurological deficits. His initial Glasgow Coma Scale score was 8. His pupils were equal, and he was hemodynamically stable. He was intubated for airway protection and to facilitate imaging studies.

Initial computed tomography (CT) imaging of the brain revealed a small left frontal subdural hematoma with 6 mm of midline shift toward the right (Fig. 1A), scattered subarachnoid hemorrhage, and a right occipital skull fracture extending into the temporal and sphenoid bones. There was effacement of the basal cisterns (Fig. 1B) but no evidence of significant parenchymal injury. Laboratory results showed the
Fig. 1. Preoperative noncontrast computed tomography (CT) of the brain. There is a small left convexity subdural hematoma with 8 mm of midline shift toward the right side (A) and effacement of the basal cisterns (B). Postoperative CT shows improvement in the midline shift following a decompressive craniectomy with dural augmentation (C).

Fig. 2. Operative intracranial pressure (ICP) and brain tissue oxygen (PbtO2) monitoring (A) and postoperative PbtO2, ICP, and cerebral perfusion pressure (CPP) following surgical decompression (B).
hematocrit, blood chemistries, and coagulation panel to be within normal limits. CT scans of the chest, abdomen, and pelvis were unremarkable except for small pulmonary contusions. CT scans of the cervical, thoracic, and lumbar spine were normal.

ICP and $P_{\text{BTO2}}$ monitors (Licox, Integra) were inserted into the right frontal lobe in the ED. Initial ICP measurements were between 45 and 50 cm H$_2$O. The patient also became increasingly hypertensive and bradycardic. Pupils were equal, round, and reactive. Seventy-five grams of intravenous mannitol were administered, and within a few minutes the ICP decreased to 25 cm H$_2$O. The decision was made to perform an emergent decompressive hinge hemicraniotomy to control the ICP.

### 2.2. Surgical procedure

The patient was brought to the operating room and prepared for a left-sided frontotemporoparietal hinge craniotomy with dural augmentation. The Licox monitors that had previously been inserted in the right frontal lobe remained in place for continuous monitoring throughout the procedure. ICP and $P_{\text{BTO2}}$ measurements were recorded at each step of the surgery (Fig. 2A). Just before skin incision, the ICP measured 54 cm H$_2$O at the level of the tragus and the $P_{\text{BTO2}}$ was 6.3 mm Hg. Immediately after dural opening, the ICP dropped to 11 cm H$_2$O and the $P_{\text{BTO2}}$ rose to 20.5 mm Hg. Initially a hinge craniotomy was planned, but at the start of skin closure the ICP climbed back up to 24 cm H$_2$O and the $P_{\text{BTO2}}$ fell to 7.8 mm Hg. With the availability of real-time ICP and $P_{\text{BTO2}}$ monitoring, the hinge craniotomy was able to be converted to a standard craniectomy. This intraoperative modification resulted in reduction of the ICP to 16 cm H$_2$O, although the $P_{\text{BTO2}}$ remained low for an extended period of time (Fig. 2B).

### 2.3. Postoperative recovery

The ICP remained less than 20 cm H$_2$O after surgery, and the $P_{\text{BTO2}}$ returned to normal limits within a few hours (Fig. 2B). A routine postoperative head CT demonstrated resolution of the midline shift (Fig. 1C). The patient’s neurological status improved significantly, and he was extubated on postoperative day 4 (POD4). At the time of discharge from the hospital on POD9, the patient had no focal neurological deficits and was following commands, although he did continue to experience periods of agitation.

### 2.4. Cranioplasty

A left-sided cranioplasty was performed 3 months after the craniectomy. There were no complications; however, an external ventricular drain (EVD) was inserted due to intraoperative cerebral edema. Examination showed the patient was stable after reversal of anesthesia and extubation. The EVD was discontinued on POD1. A noncontrast head CT on POD2 revealed no hydrocephalus or hemorrhage. The patient was discharged from the hospital in stable condition on POD3 with no new neurological deficits.

### 3. Discussion

The goals of decompressive craniotomy are a) to remove mass lesions such as subdural hematomas and intraparenchymal hemorrhages and b) to expand the volume of the skull to allow for brain swelling in order to lower ICP and prevent cerebral hypoperfusion. There is robust evidence that surgical decompression is helpful in lowering ICP [1] and that keeping the ICP lower than 20 cm H$_2$O improves outcome [5]. Similar, albeit less robust, evidence has established that failing to maintain $P_{\text{BTO2}}$ above 5–15 mm Hg is associated with poor clinical outcomes [2].

Hinge frontotemporoparietal craniotomy has been proposed as a reasonable alternative to the traditional craniectomy for the management of intracranial hypertension [3]. There is little doubt that replacement of the bone plate after a craniotomy, even in a hinged fashion, results in less expansion of the cranial vault than when the bone plate is removed entirely. If one agrees that control of ICP and maintenance of adequate $P_{\text{BTO2}}$ are important to prevent secondary brain injury, then monitoring of these parameters during interventions, including surgical decompression, is logical. This case report demonstrates that invasive monitoring of ICP and $P_{\text{BTO2}}$ in the opposite hemisphere during decompressive craniectomy provides immediate feedback as to the adequacy of the decompression.

### 4. Conclusions

The adequacy of hinge craniotomy can be assessed in real-time by continuous ICP and $P_{\text{BTO2}}$ monitors in the contralateral hemisphere. The results of this case study suggest that a prospective randomized trial for TBI patients, who are candidates for decompressive craniectomy versus hinge craniotomy, would be helpful in further delineating the role of intraoperative monitoring of ICP and $P_{\text{BTO2}}$. The intraoperative data could be correlated to patient outcome postoperatively, as well.

### References


