

MODIFIED “IN-WINDOW” TECHNIQUE FOR DECOMPRESSIVE CRANIOTOMY FOR SEVERE BRAIN INJURY

Momir J. Jovanović¹, Ljiljana Vujotić^{2,3}, Vesna Janošević², Ivan Soldatović⁴, Danilo Radulović^{2,3} and Vojislav Bogosavljević^{2,3}

¹Department of Neurosurgery, General Hospital of Čuprija, Serbia

²Neurosurgery Division, Clinical Center of Serbia, Belgrade, Serbia

³School of Medicine, University of Belgrade, Serbia

⁴Institute of Statistics, School of Medicine, University of Belgrade, Serbia

Abstract - Increased intracranial pressure and decreased cerebral perfusion in patients with severe traumatic brain injury are associated with cerebral ischemia and poor outcome. Lowering intracranial pressure is one of the goals of treatment. We analyzed the effects of decompressive craniotomy on intracranial pressure levels and outcome. In addition, we compared the results of decompressive craniotomy performed with our original technique (modified “in-window” technique, with no need for cranioplasty) with results of classic techniques. We formed two groups: 52 patients with TBI (GCS≤8), with monitored intracranial pressure, and the control: 45 patients without intracranial pressure monitoring. In the first group, malignant intracranial hypertension was treated by decompressive craniotomy, using a modified “in-window” technique. Results were analyzed using standard statistical methods. In the first group, with intracranial pressure monitoring, 17/52 had decompressive craniotomy, and significant reduction of intracranial pressure appeared in the early postoperative period (38.82 to 22.76 mmHg, mean), with significant decrease of intracranial pressure at the end of treatment, compared to the control group (mean=25.00, and 45.30 mmHg, respectively). Late complications were similar to results of other studies. Our results were 20% of epileptic seizures, 8% of hydrocephalus, 12% contusion/hematoma progression and 12% subdural hygroma. Outcome (measured with Glasgow Outcome Score-GOS) in the first group, at the time of discharge, was better with decompressive craniotomy than without decompressive craniotomy (GOS=2.47, and GOS=1.00, respectively). Modified “in-window” technique for decompressive craniotomy in severe traumatic brain injury is safe, promising and according to our experience offers a lower rate of complications with no need for additional cranioplastic surgery.

Key words: Decompressive craniotomy; intracranial pressure monitoring; “in-window” technique

Received March 11, 2014; **Accepted** November 26, 2014

INTRODUCTION

One of most frequently used definitions (Dawodu et al., 2007) of traumatic brain injury is that TBI is a nondegenerative, noncongenital insult to the brain from an external mechanical force, possibly leading to permanent or temporary impairment of cognitive, physical, and psychosocial functions, with an asso-

ciated diminished or altered state of consciousness. Intracranial pressure (ICP) is the result of the combined effects of atmospheric and hydrostatic tissue pressure. Content of the intracranial space is under constant pressure, which is equal to the pressure in the cortical veins, at 0-10 mm Hg. If elevated ICP has no tendency to return to the usual value, we talk of intracranial hypertension (ICH). Raised ICP is usu-

ally the consequence of brain damage, but extra cerebral causes cannot be ignored. Increased ICP and decreased cerebral perfusion (CBF – cerebral blood flow) are associated with cerebral ischemia and poor outcome in patients with severe head and brain injury (Glasgow Comma Scale (GCS) ≤ 8), (Chesnut et al., 1993; Olivecrona et al., 2007; Leonardo et al., 2012). Lowering the elevated ICP is one of the main goals in the treatment of patients with severe head and brain injury. In addition to conservative methods of treating ICH, decompressive craniotomy (DC) has lately been re-imposed as a possible solution for refractory intracranial hypertension, (Leonardo et al., 2012; Schmidt et al., 2007; Valenca et al., 2010). Increased ICP can be due to a rise in cerebrospinal fluid pressure that can also be caused by increased pressure within the brain matter, caused by a blood clot in the brain or fluid around the brain, or swelling within the brain matter itself. One of the most common pathological phenomena encountered by neurosurgeons is ICP and it has profound influence on the outcome of many intracranial problems, (Albanese et al., 2003). When elevated ICP is not recognized promptly and managed appropriately, there is always a considerable risk of secondary brain damage and long-term severe disability. Edema (swelling) of the brain can be characterized as increased content of fluid in the brain tissue. Brain edema results in an increased extracellular (more in the white matter) or intracellular (more in the grey matter) volume, it increases intracranial pressure and worsens the course of the primary disease. This occurs in many brain diseases. This process might be localized or generalized according to the causative agent. Following an initial trauma, the injured brain is vulnerable to secondary damage that may be exacerbated by secondary insults. The primary goals of intracranial pressure (ICP) monitoring are identification of intracranial pressure trends and evaluation of therapeutic interventions in order to minimize ischemic injury in the brain-injured patient. Intracranial hypertension (sustained ICP ≥ 15 mm Hg) occurs when the brain's protective mechanisms to shunt cerebrospinal fluid (CSF) to the subarachnoid space or to constrict cerebral arterioles, fail to maintain the ICP below 15 mm Hg. ICP compromises the relationship between

systemic blood pressure and the resistance to accomplish cerebral perfusion, (Kontopoulos et al., 2002). When cerebral perfusion pressure (CPP – the difference between ICP and mean arterial pressure) falls below 50 mm Hg, compromised CBF causes secondary brain ischemia, brain herniation, and ultimately, brain death occurs. ICP monitoring allows early detection of ICH and subsequent aggressive management. After severe traumatic brain injury, medical and surgical therapies are performed to minimize secondary brain injury. Increased intracranial pressure, which is typically caused by cerebral edema, is an important secondary insult, (Leonardo et al., 2012). Although few data regarding the monitoring of ICP are available from randomized, controlled trials, such monitoring is recommended by international clinical practice guidelines, and first-tier therapies are used to control intracranial pressure. However, many patients with severe traumatic brain injury have raised intracranial pressure that is refractory to first-tier therapies. In such cases, surgical decompressive craniotomy is performed in order to control intracranial pressure, (Cooper et al., 2011). Compared to developed countries, the possibilities for ICP monitoring are still not widely present in all neurosurgical ICUs in Serbia. Performing regular ICP monitoring and selecting patients for decompressive craniotomy, using modified technique is step forward to adequate treatment of severe TBI. Our decision whether to perform unilateral, bilateral, or frontal decompression was based on CT scan findings.

We performed a unilateral craniectomy in cases of unilateral edema, and in case of general brain swelling, a bilateral approach was used. To avoid herniation of the brain, we loosely bind a bone on the side where dura mater is opened, using modified “in-window” technique described by Valenca *et al.* (2010). These authors performed a large, almost rectangular craniotomy involving the frontal, temporal and parietal bones together with part of the occipital bone. The dura mater is opened and enlarged using a rectangular dural patch of the surgeon's choice in the form of a bridge between the anterior and posterior dural edges. With a vertical cut, the bone flap is

divided into 2 similarly sized pieces that function as "window lids." The outer frontal and occipital sides of the bone are tied to the skull border at 2 points to function as a hinge joint. The angle of the bone cut must be beveled outward (inclination $\sim 45^\circ$ of the bone drill or saw) to allow the bone flap to rest on the adjacent skull and prevent its slippage toward the intracranial cavity.

The purpose of our study is to show that early, timely and adequate therapy of elevated ICP can improve treatment outcome in patients with severe craniocerebral trauma. We wish to introduce DC as a standard for treatment of elevated ICP (ICP > 25 mmHg) if there is no other way for lowering elevated ICP, to determine the significance of monitoring ICP in patients with elevated ICP, as well as to introduce original surgical technique.

MATERIALS AND METHODS

In our study, we examined a group of 52 patients with severe craniocerebral trauma. Each patient had an ICP-monitoring system. The control group was formed of 45 patients who did not have an ICP-monitoring system. We compared the treatment outcome between the two groups of patients: those with malignant ICH treated by DC and those in whom DC was not performed. The statistical methodology used included a description of the parameters of interest and testing the differences between the factors of significance (χ^2 test, Fisher's test parameter or other non-parametric tests are applicable depending on the nature and quality of data).

RESULTS

The analysis was performed in two groups of patients. In the group of 52 patients, ICP-monitoring was performed. In the control group of 45 patients with severe head and brain injury there was no ICP-monitoring system. Indications for intracranial pressure monitoring were based on the modified Marshal scale. The gold standard for ICP measuring is the placement of an intraventricular catheter. We failed to place intraventricular catheter only in two



Fig. 1. Modified "in window" technique for decompressive craniotomy, position of the bones.

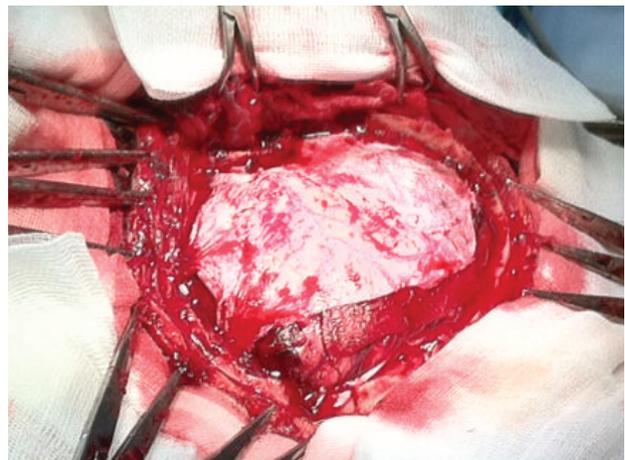


Fig. 2. Modified "in window" technique for decompressive craniotomy, position of the dura mater.

cases with small ventricles. We used an intraventricular catheter in therapeutic purposes as well, to evacuate CSF and reduce ICP.

Both groups consisted mostly of injured male patients. Comparing with other authors' results, we found no difference, because in other series patients with severe TBI were predominantly male and mostly young, between 20 to 44 years. During this period of life, people are more productive and a negative outcome of treatment has significant negative economic impact.

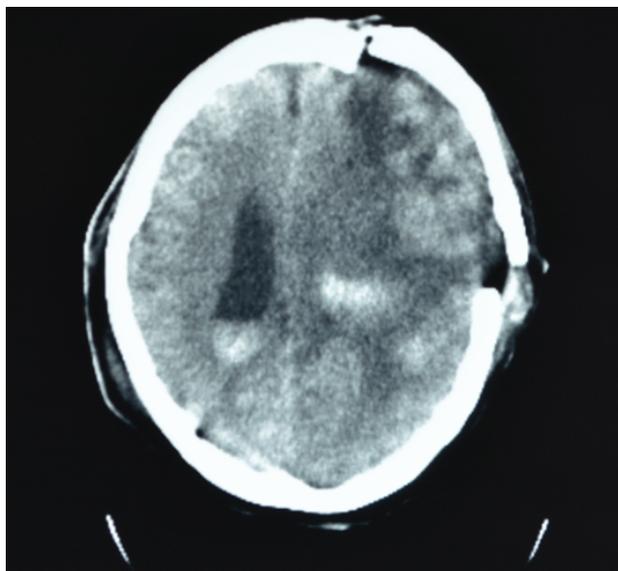


Fig. 3. CT scan of patient with severe head injury after decompression.

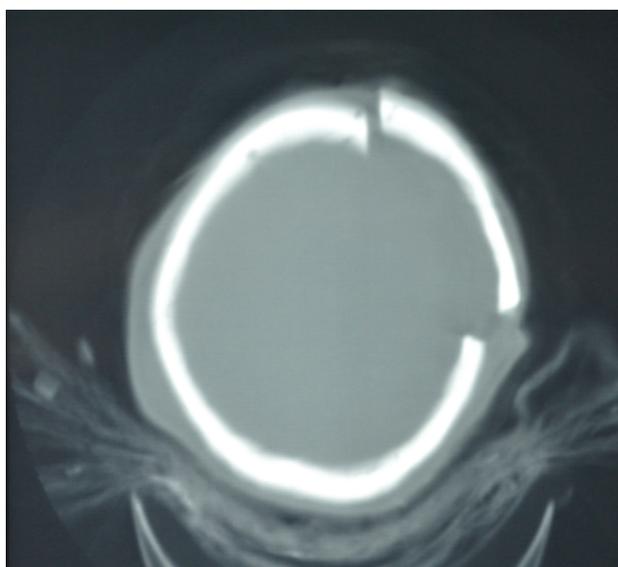


Fig. 4. CT scan bone window of the same patient after decompression, showing decompressive effect.

Patients in whom ICP was measured were significantly younger (AM=44, 48) than patients in the control group whose ICP was not measured (AM=56, 84). The youngest patient with measured ICP was 19 years; the oldest was 84 years. It can be concluded that younger people tend to have more severe head and brain injuries, probably due to the

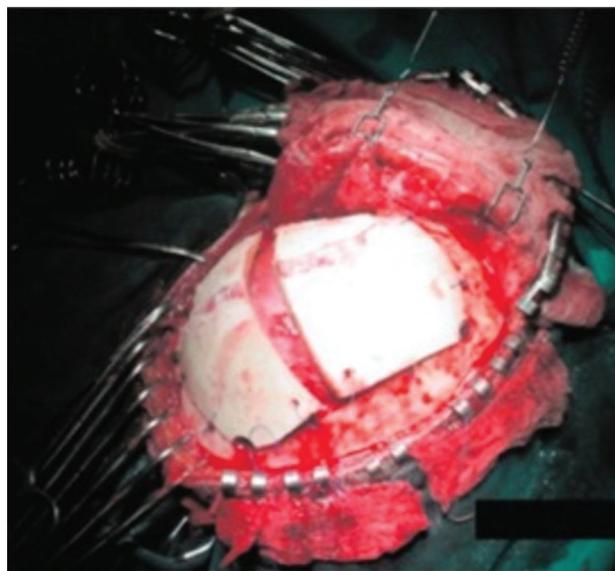


Fig. 5. Modified bifrontal "in window" technique for decompressive craniotomy, position of the bones.

predominant mechanism of injury, which is found to be traffic accidents.

The level of ICP at installation also confirms the previous results of our series, which show that the younger patients tend to have more severe head and brain injury. The average age of patients who had ICP > 25 mmHg, was 36.78 years, the average age of patients with ICP ≤ 25 mmHg was 52.80 years.

GOS was used for measurement the outcome of treatment of injured patients. It suggested a better outcome in the group of patients whose ICP was not measured. This was due to the fact that patients whose ICP was measured had significantly lower GCS (Glasgow Coma Score) on admission.

In patients in whom DC was performed, a significant reduction in ICP was noticed in the immediate postoperative period. The average value of ICP was 22.76 mm Hg. There was also a significant difference in the ICP value at the end of treatment: the average value of ICP at the end of treatment in patients with refractory ICP (>25 mmHg) with DC was 45.50 mmHg. In patients without DC, the average of ICP was 19.00 mmHg. Outcome was better in patients with DC compared to those without it. The average

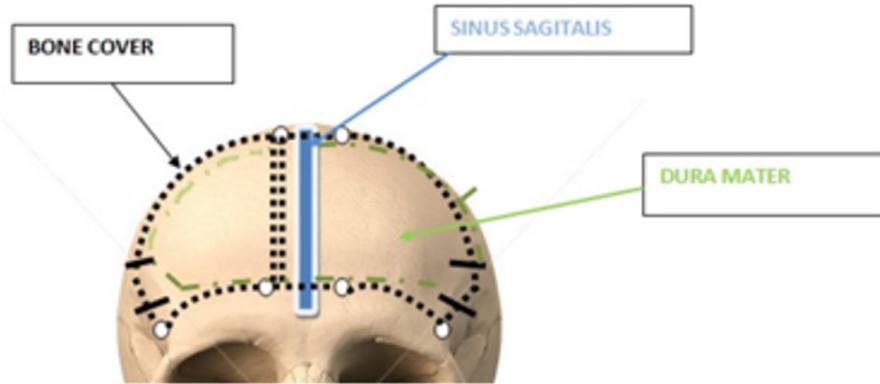


Fig. 6. Schematic view of a bifrontal modified “in window” technique for decompressive craniotomy.

Table 1. Installation of sensors for measuring ICP

	N	%	
No	45	46.4	
Yes	52	53.6	
In total	97	100.0	

Table 2. Installation of sensors for measuring ICP- distribution of patients by gender

			Gender		Total
			male	female	
Installation of sensors for measuring ICP	no	N	34	11	45
		%	75.6%	24.4%	100.0%
	yes	N	47	5	52
		%	90.4%	9.6%	100.0%
Total		N	81	16	97
		%	83.5%	16.5%	100.0%

Chi-square=3.851; p=0.050

Table 3. Installation of sensors for measuring ICP – Age

Installation of sensors for measuring ICP	N	Mean	SD	Median	Minimum	Maximum
no	45	56.84	19.888	61.00	17	88
yes	52	44.48	20.240	40.00	19	84
In total	97	50.22	20.913	56.00	17	88

Z=-2.870; p=0.004 Testing was done by Mann-Whitney U test

value of GCS in patients with DC at the end of treatment in the neurosurgical department was 2.47. No patient from the group without DC survived. This implies that patients with refractory ICP over 25 mm Hg have a very high percentage of mortality, despite the treatment. DC is an attempt to change the course of the disease and to improve patient survival.

DISCUSSION

Among adults with severe diffuse traumatic brain injury and refractory ICP in the intensive care unit (ICU), we found that DC decreases intracranial pressure. In addition, we found a better treatment outcome in a group of patients with refractory intracranial hypertension (ICP >25 mmHg) who had DC than in patients without DC. We concluded that it is necessary to implement ICP monitoring in patients with severe head injury. This allows us to make a timely decision on how to treat severely injured patients. The decision to incorporate monitoring of ICP is based on the modified Marshall scale for TBI. In order to prevent brain infarction during DC we recommend the way described below, DC and the next variation.

CONCLUSIONS

Patients with severe head and brain injuries are mostly young people, male, injured in traffic. ICP monitoring in patients with severe craniocerebral injury allows us adequate and timely treatment of patients with severe head and brain injury. Early DC in case of refractory ICH improves outcome. It is necessary to introduce ICP monitoring as a standard in severe craniocerebral injury and perform DC in patients with refractory ICH if it is not possible to lower the ICP by conservative methods of treatment. The modified window technique for DC in severe TBI is safe, promising and, according to our experience, with lower rate of complication. Additionally, with our technique there is no need for cranioplasty after recovery. Late complications were similar to the other studies' reports. Our results were 20% of epileptic seizures, 8% of hydrocephalus, 12% contusion/hematoma progression and 12% subdural hygroma.

Authors' contributions

Momir J. Jovanović, the author of the modified "in window" technique, is responsible for the surgical procedures, data collection and analysis. Ljiljana Vujić designed the study, selected patients and prepared the manuscript. Vesna Janošević, performed surgical procedures and collected the data. Ivan Soldatović performed the statistical analysis. Danilo Radulović designed the study design, selected the patients and prepared the manuscript. Vojislav Bogosavljević performed ICP monitoring and decision making.

Conflict of interest disclosure

The authors confirm that this manuscript is not sponsored directly or indirectly by a pharmaceutical company, equipment manufacturer, public relations firm, or any other commercial entity. Moreover, we certify that neither any immediate family member nor we currently have a financial interest in, or arrangement with, any organization that may have direct interest in the subject matter of this article.

REFERENCES

- Albanese, J., Leone, M., Alliez, J.R., Kaya, J.M., Antonini, F., Alliez, B. and C. Martin (2003) Decompressive craniectomy for severe traumatic brain injury: evaluation of the effects at one year. *Crit. Care Med.* **31**, 2535- 2538.
- Alexander, E., Ball, M.R. and D.W. Laster. (1987) Subtemporal decompression: radiological observations and current surgical experience. *Br. J. Neurosurg.* **1**, 427- 433.
- Chesnut, R.M., Marshall, L.F., Klauber, M.R., Blunt, B.A., Baldwin, N. and H.M. Eisenberg (1993) The role of secondary brain injury in determining outcome from severe head injury. *J. Trauma* **34**(2), 216-222.
- Cooper, D.J., Rosenfeld, J.V., Murray, L., Arabi, Y.M., Davies, A.R., D'Urso, P., and T. Kossmann et al. (2011) Decompressive Craniectomy in Diffuse Traumatic Brain Injury. *N. Engl. J. Med.* **365**(21): 2040.
- Dawodu et al. (2007) Traumatic Brain Injury: Definition, Epidemiology, Pathophysiology <http://www.emedicine.com/pmr/TOPIC212.HTM> (2007)
- Guerra, W.K., Gaab, M.R., Dietz, H., Mueller, J.U., Piek, J. and M.J. Fritsch (1999) Surgical decompression for traumatic

- brain swelling: indications and results. *J. Neurosurg.* **90**, 187- 196.
- Dunn, L.T. (2002). Raised intracranial pressure. *J. Neurol. Neurosurg. Psychiatry* **73** (Suppl I): I 23-i27.
- Kjellberg, R.N. and A. Jr. Prieto (1971) Bifrontal decompressive craniotomy for massive cerebral edema. *J. Neurosurg.* **34**, 488- 93.
- Kontopoulos, V., Foroglou, N., Patsalas, J., Magras, J., Foroglou, G., Yiannakou Pephtoulidou, M., Sofianos, E., Anastassiou, H. and G. Tsaoussi (2002) Decompressive craniectomy for the management of patients with refractory hypertension: should it be reconsidered? *Acta Neurochir. (Wien)* **144**, 791- 796.
- Leonardo, R.C. and R.W. Allen (2012) Closed Head Trauma Treatment & Management. *medscape*; Aug 13.
- Morgalla, M.H., Will, B.E., Roser, F. and M. Tatagiba (2008) Do long-term results justify decompressive craniectomy after severe traumatic brain injury? *J. Neurosurg.* **109**(4): 685-690.
- Olivecrona, M., Rodling-Wahistorm M., Naredi S. and L.O. Koskinen (2007) Effective ICP reduction by decompressive craniectomy in patients with severe traumatic brain injury treated by an ICP-targeted therapy. *J. Neurotrauma* **24**(6): 927-35.
- Rubiano, A.M., Villareal, W., Hakim, E.J., Aristizabal, J., Hakim, F., Diez, J.C., Pena, G. and experience. *Ulus Travma Acil. Cerrahi. Derg.* **15**(1), 28- 38.
- Schmidt, J.H.3rd., Reyes, B.J., Fisher, R. and S.K. Flaherty (2007) Use of hinge craniotomy for cerebral decompression. Technical note. *J. Neurosurg.* **107**(3): 678- 682.
- Stiver, S.I. (2009) Complications of decompressive craniectomy for traumatic brain injury. *Neurosurg Focus*; 26 (6): E7.
- Valenca, M.M., Martins, C. and J.C. Silva (2010) "In-window" craniotomy and "bridgelike" duraplasty: an alternative to decompressive hemicraniectomy. Technical note. *J. Neurosurg.* **113**(5): 982-9.