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Research Article

Intracranial Haemorrhage After Decompressive Craniectomies for Trauma: Role of the Skull Clamp

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Abstract

Background: High Intracranial Pressure (ICP) is the most frequent cause of death and disability after severe Traumatic Brain Injury (TBI); in Europe, 33% of patients with TBI require neurosurgical intervention. Decompressive Craniectomy (DC) represents the extreme surgical treatment; although it is regarded as a relatively simple surgical procedure, it is often accompanied by many complications, including Extradural Hematoma (EDH) associated with an overlying fracture on the contralateral side. It presents an incidence of 5-12%, but Singh et al., analysing 2108 DC performed without the skull clump, estimate it to be about 0.48%. Any authors have indicated the relationship between EDH after DC for trauma in patients showing skull fractures and the use of this Head Immobilisation Device (HID).

Materials and methods: We have retrospectively analysed all patients who underwent frontotemporoparietal DC and bifrontal DC after TBI at Venice Angel Hospital during a 5-year and six-month period (January 2017-June, 2022). All patients showed skull bone fractures at CT brain scan, associated with clinical and neuroradiological signs of increasing ICP. For each patient, we analysed: age and sex, neurological status: GCS at the moment of trauma and before surgery, pupillary size and form before and after surgery; neuroimaging evolution; the timing and DC. DORO© Mayfield skull clump was used in all cases.

Results: Our surgical cohort counts 20 patients with M/F 3:2 and an average age of 47±17. 16 patients underwent urgent surgery (primary DC), and 4 were operated on after an overage of 50 hours of observation (secondary DC): 90% of patients experienced frontotemporoparietal DC and 10% bifrontal DC. Postoperative CT brain scan showed enlargement of brain contusion in 4 patients (20%); EDH in 4 patients: 2 in the side of skull fracture contralateral at DC, 1 contralateral at DC and skull fracture, 1 occipital in the side of fracture homolateral at DC; SDH in 2 cases, both homolateral at DC. For 3 patients, surgical treatment of EDH was necessary following DC.

Conclusion: Our patients showed a higher probability of developing remote-site EDH; other typical complications presented the same or slightly higher frequency of occurrence. Considering the high risk-benefit ratio of skull bone application, we suggest adopting safer HID, such as surgical adhesive tape or a horseshoe headrest.

Introduction

Traumatic Brain Injury (TBI) constitutes significant rising health and socio-economic problem worldwide [1-3]; it prevails in low- and high-income countries, impacting people of all ages. In Europe, the annual incidence of head injury is 2.3 per 1000 person-years [4-6], and 33% require neurosurgical intervention [4].

Decompressive Craniectomy (DC) represents the extreme surgical treatment of medically refractory Intracranial Hypertension (ICP) after TBI; it is often executed as urgent surgery (primary DC), but it may follow an intracranial pressure monitoring period (secondary DC).

Development of Extradural Hematoma (EDH) associated with an overlying fracture on the contralateral side of DC is a rare but potentially devastating complication with an incidence of 5-12% [9-11]. Causes are not defined but are thought to be caused by the loss of the tamponing effect of increased Intra-Cranial Pressure (ICP) after a DC [10-12].

The Mayfield© skull clamp is the most common head immobilisation device (HID) [7] and is used routinely in neurosurgical procedures worldwide. Guidelines on the correct application of this HID are lacking [7]; indication and position are often empirical. Complications related to using the skull clamp are rare and usually avoidable: most are skull fractures with or without epidural hematomas [8].

To the best of our knowledge, any authors have indicated the relationship between EDH after DC for trauma in patients showing skull fractures and intraoperative application of skull clamp. This article aims to clarify if this HID is a valid intraoperative support for neurosurgeons or revest a crucial role in raising this devastating complication [10,11].

Materials and methods

We have retrospectively analysed all patients who underwent surgery after TBI at Venice Angel Hospital during a 5-year and six-month period (January 2017-June 2022).

Inclusive criteria considered were:

-Suspecting increasing ICP (considering trauma dynamics, clinical and neuroradiological signs) associated with brain contusions, subarachnoid haemorrhage (ESA), acute Subdural Hematoma (SDH) and/or Extradural Hematoma (EDH) after TBI

-Presence of skull fractures

-Frontotemporoparietal decompressive craniectomy and bifrontal decompressive craniectomy

We decided not to consider patients who underwent suboccipital decompressive craniectomy because studies have shown significant differences between supratentorial and infra-tentorial ICP [13-15]: posterior fossa post-traumatic hematomas may not be a source of modifications in supratentorial ICP [14,15].

Clinical and radiological data: For each patient, we analysed: age and sex, neurological status: GCS at the moment of trauma and before surgery, pupillary size and form before and after surgery; neuroimaging evolution; the timing and DC. Every patient was admitted to Intensive Operative Care for case care; daily Intracranial Pressure (ICP) monitoring was performed. These patients neither had any associated coagulopathy or thrombocytopenia nor were on anticoagulant/antiplatelet medications. Furthermore, they did not carry any other comorbidity with bleeding diathesis.

Surgical data: DORO© Mayfield skull clump was used in all cases. The operative records of patients were analysed for the presence of any significant brain bulge during surgery. All craniectomies were associated with duraplasty, and the size of the bone flap respects all surgical guidelines. We routinely performed postoperative CT brain scans.

Results

26 patients underwent DC after TBI: 4 cases did not present any skull fractures, and 2 were treated with suboccipital DC; 20 patients respected inclusive criteria with M/F 3:2 and an average age of 47±17 years.

At the moment of first aid, GCS was on average 7±4:13 patients were intubated in place; in 7 cases, GCS decreased on overage 8±2 before intubation. Pupils were bilaterally isochoric, isocyclic and light-reagent in 11 patients: in 10 cases they were unchanged, and in 1 case they rapidly became anisocorics; 1 patient was rescued and treated when he was anisocoric, 1 patient was recovered anisocoric then rapidly became bilaterally mydriatic; pupils were mydriatic in 5 patients and miotic in 2 cases before surgery.

CT brain scan showed EDH associated with bilateral SDH and brain contusions in 1 case, 14 patients presented SDH: 80% were frontotemporoparietal and 60% were associated with important brain contusions, 45% presented ESA. 7 patients showed a frontal bone fracture, in 4 cases interesting also the parietal bone, in 3 the temporal bone and 1 the occipital bone; 6 patients reported a temporal bone fracture, in 2 cases interesting also the parietal bone, 1 the skull base and 1 the occipital bone; 6 patients showed an occipital bone fracture, in 1 case interesting also the temporal bone, in 1 case the parietal bone and the skull base.

16 patients underwent urgent surgery (primary DC), and 4 patients were initially clinically monitored; behind evaluating ICP refractory to maximal medical management and decreasing GCS, they were operated on after an overage of 50 hours of observation (secondary DC): 90% of patients experienced frontotemporoparietal DC and 10% bifrontal DC. The operative records of patients showed a significant brain bulge during surgery in all cases.

Postoperative CT brain scan showed enlargement of brain contusion in 4 patients (20%); EDH in 4 patients: 2 in the side of skull fracture contralateral at DC, 1 contralateral at DC and skull fracture, 1 occipital in the side of fracture homolateral at DC; SDH in 2 cases, both homolateral at DC. For 3 patients, surgical treatment of EDH was necessary following DC.

Discussion

Traumatic Brain Injury (TBI) represents rising critical health and socio-economic problem throughout the world [1,2]; it impacts people of all ages in low- and high-income countries, and it is a significant cause of death and disability in people younger

Table 1: Patients neurological statement.

Age	GCS I	GCS II	Pupillary form
53	11	7	Iso
48	14	11	Iso
55	10	10	Iso
29	4	Tube	Mio
42	4	Tube	Iso
55	8	8	Iso
62	13	3	Iso->ani
68	6	Tube	Iso
60	4	Tube	Myd R
20	3	Tube	Myd Bil
30	3	Tube	Myd Bil
58	6	Tube	Ani
19	3	Tube	Iso
17	10	6	Ani->myd
57	8	Tube	Mio
67	3	Tube	Myd
29	4	Tube	Myd->ani
56	3	Tube	Iso
73	3	Tube	Iso
48	14	9	Iso

GCS I: At the moment of the first aid; GCS II: Before surgery. Iso: Isocyclic; Mio: Miotic; Ani: Anisocoric; Myd: Mydriatic.

than age 45 [12]. Data presented in the literature suggest underestimation of the actual incidence, and society is often unaware of the impact; the mortality is decreasing, with an average rate of 10.5/100,000 [4,5], and the incidence is increasing, especially in the least years, in the elderly [6]. In Europe, the annual incidence of head injury is 2.3 per 1000 person-years [4-6], and 33% require neurosurgical intervention [4].

Decompressive Craniectomy (DC) represents the decisive surgical strategy in the management of medically intractable Intracranial Hypertension (ICP), often sustained, following TBI, by intracerebral haemorrhage, subarachnoid haemorrhage (ESA), acute Subdural Hematoma (SDH), Extradural Hematoma (EDH), and others [16-18]. After major trauma, DC is often performed as urgent surgery (primary DC); however, considering different clinical elements (age, comorbidity, trauma dynamics, neuroimaging, clinical signs), it may follow an intracranial pressure monitoring period (secondary DC). Although DC is regarded as a relatively simple surgical procedure, it is often accompanied by many complications [19]: contusion expansion is reported in 12.6-14% [10,19,20], and extracerebral hematomas showed a reported incidence of 10.2% [21,22], they more frequently occur ipsilaterally to the performed decompression. The most common is subgaleal hematoma; SDH is less frequent, mostly a residue of primary bleeding rather than its recurrence [10]. EDH contralateral to the surgical site is often associated with skull fractures, and it presents reported incidence in the range of 5-12% [10-12,23,24]. The causes are not defined but are thought to be due to loss of the tamponing effect of increased ICP after DC [10-12]; the patient outcome is usually adverse.

The Mayfield© skull clamp is the most common head immobilisation device (HID) [7]; it is used worldwide in cranial and

Table 2: Radiological findings

Preoperative CT finding	Skull fracture involvement	DC	Control CT finding
SDH F-T-P L, SDH F R, ESA, Contusion F-T R	F-P L	FTP L	-
ESA tentorial and falx, Contusion F bil and T L	O-T Bil	Bif	-
SDH F L, SDH and EDH F R, Contusion F L	T Dx	FTP R	-
Multiple contusions	Base	FTP R	-
SDH F-T-P L, Contusion F-T Bil	F-P-O L, O-P R	FTP L	-
ESA, Contusion F Bil	F R	Bif	-
ESA, Contusion F-T Bil	O R	FTP R	-
SDH F L, ESA Base, Contusion T L	T R	FTP L	-
SDH F-T-P Bil and Falx L, Contusion T Bil	F-T L	FTP L	-
SDH F-T-P L, Contusions F L and T-P R	O R	FTP L	-
SDH F R	F-T R	FTP R	-
SDH T R, Contusions F-T R	T R	FTP R	Contusion F Bil
SDH Falx, ESA Silv, Contusions F-T-P L	O R	FTP L	SDH FTP L
SDH F-T-P R	T-P L	FTP R	EDH T-P L
SDH F-T-P R, Multiple Contusions	O R	FTP R	EDH O R
SDH F-T-P R, ESA Silv, Contusion P R	T-P R	FTP L	Contusion P R
SDH F-T-P R	Base and P-O L	FTP R	EDH T-P-O L and O R
SDH Bilat	P R	FTP L	-
SDH F-T-P L, ESA Silv, Contusion F	F-T-P L	FTP L	SDH F L, Contusion F
SDH F-T-P R, ESA Pan, Contusion F-T	F-P R	FTP R	EDH T-P L, Contusion F-T R

SDH: Subdural Hematoma; ESA: Subarachnoid Haemorrhage; EDH: Extradural Hematoma; F: Frontal; P: Parietal; T: Temporal; O: Occipital; L: Left; R: Right.

selective cervical neurosurgical procedures. Guidelines of this HID are missing [7,25]: indication, application and pins placement are often empirical. Only a few authors analysed complications related to its use; they are rare and usually avoidable (skull fractures with or without EDH) [7,8,26,27]. To the best of our knowledge, any authors, data, study or guidelines exclude the use of skull clump in major trauma patients presenting skull fractures; in this case, it is mandatory to confirm the integrity of the skull with a CT brain scan to not place pins in or in the vicinity of fractures avoiding penetration, displacement of a fractured fragment [8,28], enlargement fracture line [7,8], or insufficient stabilisation [7,29].

Different studies have analysed acute complications of DC [11,20,30-32]: many did not report the use of skull clump in their surgical practice [20,24,32]; Singh et al. [11] performed 2108 DC between 2015 and 2019 without the use of HID, he signalled a total of 9 remote side EDH (0.4%) at various sites predominantly without any associated fracture, and suggested that increased mass effect and brain bulge during surgery can predict such a complication.

As far as we know, nobody has indicated the relationship between EDH after DC associated with fractures post-trauma and application of skull clamp.

We have retrospectively analysed 20 patients who underwent craniectomy decompressive after TBI between January 2017 and June 2022. At the moment of first aid, 14 patients presented GCS≤8, on average 7±4; in 7 cases, GCS decreased on overage 8±2.5 before intubation. First TC brain scan revealed EDH associated with bilateral SDH and brain contusion in 1 case, 5 patients showed important brain contusions, 14 patients presented SDH: 80% were frontotemporoparietal and 60% associated with significant brain contusions; all patients presented skull fractures (Table 1). 16 patients underwent urgent surgery (primary DC), and 4 patients were initially clinically monitored; evaluating ICP refractory to maximal medical management and decreased GCS, they were operated on after an overage of 50 hours of observation (secondary DC): 90% of patients experienced frontotemporal DC and 10% bifrontal DC; the operative records of patients showed significant brain bulge during surgery in all case. We routinely performed postoperative CT scans (Table 2): we reported enlargement of brain contusion in 4 patients, SDH in 2 cases both homolateral at DC, EDH in 4 patients and, for 3 of which a new surgical treatment was necessary. A decision to operate upon the postoperative EDH depended on its size and the mass effect produced; the patient who did not require an immediate clot evacuation was followed-up with serial scans and close observation of their clinical status. Other postoperative complications were managed conservatively.

Patient 1: Severe head injury. At the moment of first aid, GCS was 10; during transport, GCS decreased to 6, pupils became anisocoric, and she was intubated. An urgent TC brain scan showed a right frontotemporoparietal SDH and a left temporoparietal fracture. An urgent primary right DC was performed: skull clump was positioned (single pin on the left forehead, two pins on right occipital), SDH was evacuated (Figure 1a), and we observed a significant brain bulge; duraplasty was executed, and bone flap was not replaced. At the end of the procedure, after the skull clump removal, pupils were mydriatic; TC brain scan reported a voluminous left temporoparietal EDH (Figure 1b), and then, at 9 hours for trauma, it was evacuated. After almost a year, the bone flap was repositioned and is moderately disabled (GOS 4).

Patient 2: Severe head injury. At the moment of first aid, GCS was 4, pupils were mydriatics, and all reflexes were absent except the carinal reflex; she was intubated. An urgent TC brain scan reported a right frontotemporoparietal SDH (Figure 2a) and a left occipitalparietal fracture extended to the skull base. An urgent primary right DC was performed: skull clump was positioned (single pin on the left forehead, two pins on left occipital), SDH was evacuated, and we observed a significant brain bulge; duraplasty was executed, and bone flap was not replaced. At the end of the procedure, pupils became anisocoric after the skull clump removal (right>left). TC brain scan showed a voluminous left temporoparietaloccipital EDH (Figure 2b); it was evacuated. After almost a year, the bone flap was repositioned, and she is unaware of herself and her environment (GOS 2).

Patient 3: Apparent Mild-Moderate head injury, major dynamics. At the moment of first aid, GCS was 14; during transport, GCS decreased quickly to 9, and he was intubated. Pupils were isochoric-isocyclic; an urgent TC brain scan reported a right frontotemporoparietal SDH, diffuse ESA and frontotemporal brain contusions associated with a right frontoparietal fracture. An urgent primary right DC was performed: skull clump was positioned (single pin on the left forehead, two pins on right occipital), SDH was evacuated, then we observed a moderate brain bulge; duraplasty was executed, and bone flap was not replaced. At the end of the procedure, pupils persisted isochoric-isocyclic after the skull clump removal. TC brain scan showed a left temporoparietal EDH; it was evacuated at 7 hours to trauma. The bone flap was repositioned, and after 2 years, he is moderately disabled (GOS 4).

Considering data shown in the Results, 20% of our patients reported EDH following DC contralateral to the surgical site associated with skull fractures; this percentual result is significantly higher than data reported in the literature (5-12%) [10-12,23,24] and dramatically higher than those affirmed by Singh et al. (0.4%) [11]. Considering the high frequency of these surgical procedures and the devastating effect of this complication, it seems clear how the use of skull clamps shows a high risk-benefit ratio. To explain the rising of complications, we accepted the theories about the loss of the tamponing effect of increased ICP after a craniectomy decompressive [10-12], and we think that pin placement (sudden increase in blood pressure, venous congestion by clamping of epicranial veins) and sudden remotion may play an important role. In fact, veins of the scalp drain the blood from the scalp muscles via the internal and external jugular veins and the superior vena cava, and they are connected to intracranial venous sinuses and diploic veins of the skull through valveless emissary veins [33]. According to this aetiology, the skull clump would appear to be a risk factor for all patients undergoing DC with contralateral skull fracture: if the fracture were homolateral to the DC, at the time of bone flap removal, by eliminating the tamponing effect, it would be possible to see the onset of any haemorrhage and to arrest it by coagulating the vessel. Until this theory is verified or denied, we suggest adopting other HID (surgical adhesive tape, horseshoe headrest) for DC after TBI associated with bone fractures.

Limitations and future directions: The study shows several limitations: the number of patients is restricted, the data were collected retrospectively, and there are no authors to support or deny our theory; nevertheless, this preliminary study represents a valuable topic of daily surgical practice and may be considered a starting point for future research. In the future, we hope to expand our case series by considering patients undergoing DC without a history of trauma and skull fractures.

Conclusion

Our patients who underwent DC adopting skull clump after TBI presenting skull bone fractures showed a higher probability of developing remote-site EDH. Other complications associated with this surgical procedure presented the same or slightly higher frequency of occurrence than reported in the literature. Considering the high risk-benefit ratio of skull bone application in these cases, despite the restricted number of patients analysed, we suggest adopting safer HID, such as surgical adhesive tape or a horseshoe headrest, until this observation is confirmed or denied.

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