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Four Quadrant Osteoplastic Decompressive Craniotomy as an Alternative to Decompressive Craniectomy

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Abstract: ***Introduction: Traumatic brain injury is major cause of death, disability and economic cost to our society. Decompressive craniectomy is proven surgical management of traumatic brain injury with raised intra cranial pressure. Decompressive craniectomy has certain complications like syndrome of trephined, development of post-operative hydrocephalus, CSF leakage. Secondary surgery to restore bone flap required in decompressive craniectomy which increase psychological and monetary burden over patients and increase patient load over health care facilities. An alternative option require for decompressive craniectomy that has advantages of decompressive craniectomy and avoid complication and disadvantages of decompressive craniectomy. Objective: To study Four Quadrant Osteoplastic Decompressive craniotomy (FQOD) as an alternative method for Decompressive craniectomy (DC) in terms of operative time, duration required for postoperative intensive care unit treatment, progression to decompressive craniectomy, postoperative complications, glasgow outcome scale at 3 months. Material and Methods: The study was conducted from April 2022 to May 2025 in the Department of Neurosurgery at Civil Hospital, Ahmedabad. Total 30 patients were included in the study as per selection criteria. Patients were randomized into undergoing the Decompressive craniectomy (DC) or Four Quadrant Osteoplastic Decompressive craniotomy (FQOD) procedures. All patients underwent routine preoperative investigations, and after obtaining informed written consent, they were taken up for the surgical procedure. All patients were treated with established head injury protocols and pre-operative and post-operative intensive care as required. Results: Total 30 patients included in this study. Majority patients undergone DC had acute subdural hematoma (SDH) while intracerebral hematoma (ICH) was primary reason in patients undergone FQOD. Majority patients had GCS between 9-12 in both group. Both group had comparable mid line shift in pre-operative scan (p=0.82). Mean operative time was 122.66 min for DC and 131.73 min for FQOD (p=0.019). Both group had comparable post-operative ICU stay (mean – 7 days) (p=0.29). 2 patient from decompressive craniectomy group required ventriculo-peritoneal shunt for development of post-operative hydrocephalus while 1 patient from FQOD group required removal of bone flap due to wound infection and 1 patient required ventriculo-peritoneal shunt for development of post-operative hydrocephalus. Majority of patients (56.67%) had Glasgow outcome scale score 4 at end of 3 months. 1(6.67%) patient could not survive post operatively in decompressive craniectomy group due to systemic complication. Conclusion: Four Quadrant Osteoplastic Decompressive craniotomy is probable alternative candidate for patients requiring decompressive craniectomy. FQOD reduces post-operative complications of decompressive craniectomy due to removal of bone flap like syndrome of trephined, hygroma, cosmetic deformity, secondary surgery, resorption of bone flap without added complications. It also reduce psychological and economic burden to patients for secondary surgery to restore bone flap and reduces patient load in high volume health care centre for the same in case of DC.***

Keywords: Decompressive craniectomy, Raised intracranial pressure, Four Quadrant Osteoplastic Decompressive craniotomy, Alterantive to decompressive craniectomy

1. Introduction

Traumatic brain injury (TBI) is the major cause of disability, death, and economic cost to our society.[1] Cranial decompression for the treatment of medically refractory intracranial hypertension was first reported by Kocher in 1901 and Cushing in 1908. In the century following its introduction, its role remained controversial. Recently, many have reported a significant reduction in ICP and even a positive effect on outcome using decompressive craniectomy (DC). Like any other surgical procedure, there is morbidity associated with DC. With a large bone defect, there is a potential risk to the exposed underlying brain, which may require the use of protective headgear. Known risks include edema, hematoma formation, infarction, lack of protection against further trauma, and strangulation of cerebral tissue at edge of bone flap. Other complications include hydrocephalus, syndrome of the trephined, and cerebrospinal fluid (CSF) leak. Delayed postoperative seizures have been reported in 37% and hydrocephalus in 40% of patients after DC. Neurological worsening has also been described after craniectomy with improvement following cranioplasty. In addition, as many as 17% of patients will have chronic, debilitating headaches that only improve with replacement of the cranial plate. Cranioplasty requires a second operation performed under general anesthesia and exposes the patient to additional potential complications. Cranioplasty has a significant infection risk with many patients requiring removal of the autologous cranial plate or prosthetic impalnt with subsequent revision. In addition, resorption of the bone plate can be a problem, especially in the pediatric population.[2] The ideal procedure for cranial decompression would be one that combines the effectiveness of DC but limits the aforementioned difficulties with which it is associated. A relatively novel and less well-utilised technique to achieve cerebral decompression in patients with brain swelling and/or raised ICP is the Four quadrant Osteoplastic Decompressive craniotomy (FQOD). In this technique bone flap cut in four quadrant with cutter and placed back. This technique fullfills requirement of reduction of intracranial pressure.[3]

2. Material and Methodology

The study was conducted as a parallel group randomized, controlled trial from April 2022 to May 2025 in the Department of Neurosurgery at Civil Hospital, Ahmedabad. Total 30 patients were included in the study as per selection criteria. Patients were randomized into undergoing the Decompressive craniectomy (DC) or the Four Quadrant Osteoplastic decompressive craniotomy (FQODC) procedures. All patients underwent routine preoperative investigations, and after providing informed written consent, they were taken up for the surgical procedure. All patients were treated with established head injury protocols and pre-operative and post-operative intensive care as required. All required data filled up in proforma and statistical analysis done with t-test where required,

Inclusion Criteria

- Patients requiring decompressive craniectomy
- GCS >= 7 at admission
- Patients or patient's relative who are willing to give informed consent
- Patient age >=12 years

Exclusion Criteria

- Patient age <12 years
- GCS at admission <7
- Patient requiring bilateral decompressive craniectomy, bifrontal decompressive craniectomy or posterior fossa decompressive craniectomy
- Patient having other associated injury.
- Patients or patient's relatives not willing to participate in study

3. Surgical Technique

Decompressive craniectomy

For unilateral DC, the patient was placed supine with a small rolled towel underneath the ipsilateral shoulder and the head turned toward the contralateral side. Once the site was prepped and draped, a large reverse mark incision was made starting at the level of zygoma and curving posteriorly above the ear, over the parieto-occipital region, then superiorly and anteriorly, approximately 2 cm lateral to the midline, and stopping just behind the hairline. The posterior extent of the incision was more than 15 cm behind the keyhole to allow for an adequate craniectomy flap. The superficial temporal artery was preserved and temporalis was dissected up to the zygoma to allow for maximal temporal decompression. The anteroposterior dimension was at least 15 cm and extended down to the floor of the temporal fossa. An adequate number of burr holes were made and underlying dura was separated using a Penfield No. 3 dissector. Cutter was used to make the craniectomy and temporal extent expanded till floor of middle cranial fossa using a rongeur. Hemostasis with the bone and epidural space was achieved using bone wax and dural tack up stitches, respectively, and the dura was opened carefully in a cruciate fashion. After evacuation of the hematoma, wound drain was placed and scalp closure was done in layers and bone flap sent for Ethylene Oxide (EtO) gas sterilization.[4]

Four Quadrant Osteoplastic Decompressive craniotomy

Patient positioned supine with lateral rotation of the head under general endotracheal anesthesia. A Fronto-temporo-parietal large trauma scalp flap was raised. Bone flap like the decompressive craniectomy flap is made keeping the temporal part attached to the muscle. The portion of the bone flap removed, and temporal craniectomy extends to the floor of the middle cranial fossa with rongeurs at the origin of the zygomatic arch. The dura is opened in a stellate fashion and a synthetic dural patch is kept tucked under the original dura over the brain to prevent the brain from bulging out. The bone flap is then divided into four quadrants with the periosteum in situ. Then, the periosteum of the free bone pieces are sutured with loose silk sutures to the other pieces so as to connect all the four bone pieces together by the periosteum and then connected to the periosteum of the calvaria under the galea. The bone flap is now in its place as four pieces sutured together with loose sutures and connected by the periosteum only. As the brain expands, the bone flaps float out in all four different directions giving space for the swollen brain. [5]

4. Result

Table 1: Summary of demographic data

Variables	FQOD	Decompressive craniectomy
No. of patients	15	15
Male: Female	10:5	13:2
Mean age (years)	47.86 ± 14.75	43.94 ± 13.72
Surgical indication		
ICH	7	3
SDH	6	7
Contusion	2	5
Side of surgery		
Right	9	9
Left	6	6

As per table 1 in this study patient randomly divided for FQOD and Decompressive craniectomy. Majority of patients undergone FQOD had ICH while acute SDH was major indication of Decompressive craniectomy.

Table 2: GCS at time of admission

Group	GCS <9	GCS 9-12	GCS 13-15
FQOD	3	11	1
Decompressive craniectomy	5	10	0

As shown in table 2 majority patient undergone surgical procedure had pre-operative GCS between 9 to 12. In both group no significant difference in pre operative GCS (p=0.59)

Table 3: Midline shift

Group	Mean midline shift (mm)
FQODC	10.4 ± 2.38
Decompressive craniectomy	10.2 ± 2.45

As indicated in table 3 both group had comparable midline shift in brain imaging (p=0.82).

Table 4: Operative time in both method

Group	Mean operative time (min)
FQOD	131.73
Decompressive craniectomy	122.66

As per table 4 operative time was slightly higher in FQOD group compared to decompressive cranieectomy group due to time required to divide bone in four quadrant and suturing periosteum. This difference is statistically significant. (p=0.019).

Table 5: Post-op. ICU stay

Group	Mean ICU stay (post op) (days)
FQOD	7.2 ± 1.18
Decompressive craniectomy	6.8 ± 1.24

As shown in table 5 in both group post-operative ICU stay was comparable (p=0.29). Average ICU stay was around 7 days in both group.

Table 6: Additional intervention required

Additional intervention	FQOD	Decompressive craniectomy
Ventriculo peritoneal shunt	1	2
Bone flap removal	1	NA

As indicated in table 6, 2 patient from decompressive craniectomy group required ventriculo-peritoneal shunt for development of post-operative hydrocephalus while 1 patient from FQOD group required removal of bone flap due to wound infection and 1 patient required ventriculo-peritoneal shunt for development of post-operative hydrocephalus.

Table 7: GCS at time of discharge

Group	GCS at time of discharge
FQOD	13.5
Decompressive craniectomy	12.92

As shown in table 7, both group patient had comparable GCS at time of discharge. (p=0.30)

Table 8: Mortality in both method

	FQOD	Decompressive craniectomy
Alive	15	14
Dead	0	1

As per table 8, 1 patient could not survive post operatively in decompressive craniectomy group due to systemic complication.

Table 9: GOS at 3 month[6]

GOS	FQOD	Decompressive craniectomy
1	0	3
2	1	0
3	2	2
4	9	8
5	3	1

As shown in table 9, 3 patients in decompressive craniectomy group could not survive upto 3 month. Probable cause was aspiration or cardiac event. Sudden neurological deterioration could be possible due to syndrome of trephined. No mortality recorded in FQOD group. No significant difference in both group (p=0.54)

5. Discussion

Peethambaran et. al presented a pilot study on a new technique called four quadrant osteoplastic decompressive craniotomy and found that this technique and DECRA were similar regarding survival and brain expansion on CT scan.[7]

Decompressive craniectomy is associated with a varied spectrum of complications because of absence of a bone flap.[8] The main complications that may occur following a DC include vulnerability of the underlying brain to direct injuries due to the loss of bone, the need for a second surgery to perform a cranioplasty, and a higher incidence of infection, hydrocephalus, syndrome of the trephined, intracerebral hematoma, delayed seizures, cerebrospinal fluid leak (3–5%), extra-axial collection (both epidural [20%], and subdural [5%]).[8,9,10] Studies have shown that many of these morbidities get reversed following replacement of the bone flap.[11,12] With regard to the timing of cranioplasty, studies have shown that patients with an early cranioplasty had a better functional outcome.[13,14] Hence, every effort should be made to reduce these specific complications associated with the absence of a large area of the bone flap. We believe that FQOD technique provided adequate compliance to the brain (as has been achieved in DC) and was also effective in reducing the above mentioned complications.

In our study total 30 patients included. Study results demonstrate both group are comparable. There is no significant difference in post-operative ICU stay, post-operative outcome and mortality in both group (table 1) which is comparable to study done by Peethambaran et al. [7]

In our study average ICU stay was 7 days (table 5) in both group which is comparable to each other (p=0.29) because in our institute limited availability of ICU bed and high patients load patients required to shift from ICU to general ward once they are stable. In similar study shows no significant difference in ICU stay.[7]

In our study there is no significant difference in glasgow outcome scale score at 3 month (p=0.54) (table 9) which is comparable to similar study done by Vankipuram S et al.[3] where comparable Glasgow outcome scale extended score at 6 month in both group.

One patient operated for four quadrant osteoplastic decompressive craniotomy required removal of bone flap due to wound infection while 2 patient (13.33%) operated for decompressive craniectomy and 1 (6.67%) patient in FQOD group required ventriculo peritoneal shunt for development of post op hydrocephalus (table 9). The mechanism of hydrocephalus is attributed to obstruction of the arachnoid granulations by surgical debris. Early cranioplasty would restore normal ICP dynamics and probably normalize the hydrocephalus.[7]

1 patient operated for decompressive craniectomy could not survive due to systemic complications (table 8).

6. Conclusion

Four Quadrant Osteoplastic Decompressive craniotomy is an alternative procedure for decompressive craniecotmy with comparable outcome. Patient operated for decompressive craniectomy requires second surgery for restoration of bone flap which can be avoided with Four Quadrant Osteoplastic

Decompressive craniotomy with similar post-operative outcomes. With help of Four Quadrant Osteoplastic Decompressive craniotomy, complications of decompressive craniectomy like syndrome of trephined[14], hygroma,[15] cosmetic deformity, secondary surgery, resorption of bone flap[16] can be reduced without any additional procedure to the patients. With help of Four Quadrant Osteoplastic Decompressive craniotomy patient's psychological and monetary burden for second surgery can be reduced. Patient burden for second surgery for cranioplasty can be reduced in high volume center by this method.

FQOD is as efficacious as decompressive craniectomy in improving the clinical outcome and producing adequate decompression. Furthermore, FQOD reduces late mortality due to acute neurologic deterioration from the absence of a bone flap and the morbidity of wound infection.

7. Limitation of Study

Limitations of our study is limited size, heterogeneous population, lack of long term follow up. In addition in our study ICP data is not available. As our institute is tertiary care hospital many patient came with brain imaging done outside so volumetric analysis cannot be done.

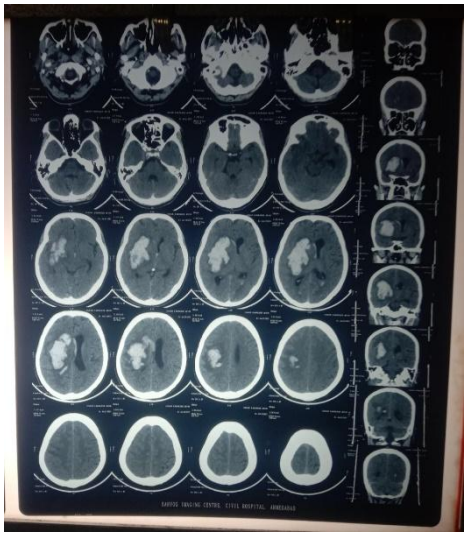

Image 1: Pre op image shows left side ganglio capsular ICH

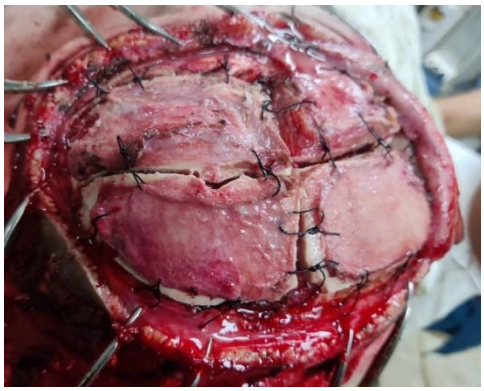

Image 2: intraop photograph showing bone flap divided in four quadrant and pericranium sutured with silk

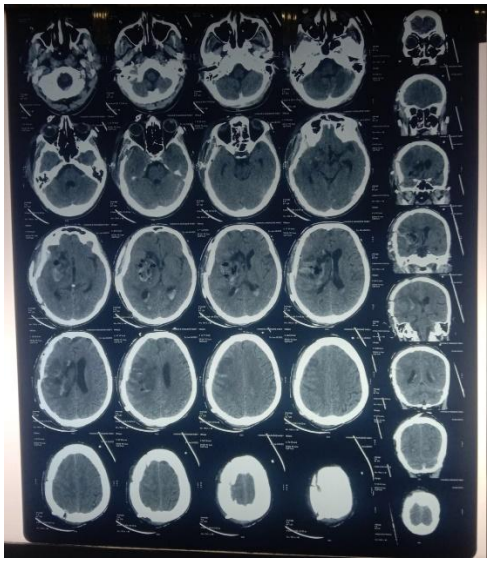

Image 3: Post op CT scan

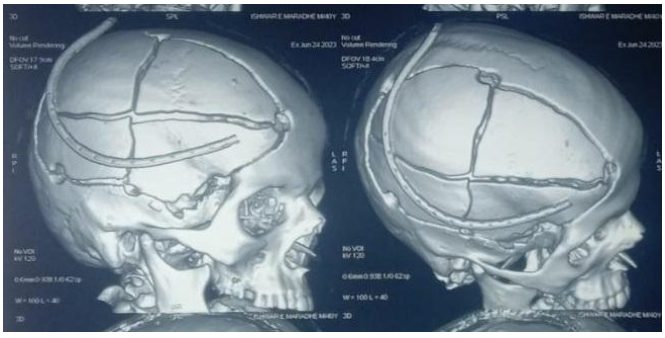

Image 4: 3D reconstruction of post op CT scan

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