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Original Research Article

Evaluation of Changes in Cerebral Hemodynamics in Cranioplasty Patients Using Magnetic Resonance Perfusion

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ABSTRACT

Cranioplasty is the surgical repair of a residual calvarial bone defect secondary to decompressive craniectomy performed to relieve intractable intracranial hypertension. Although primary aim of cranioplasty is cosmetic rehabilitation and to provide mechanical protection to the brain, marked improvements in the neurological status after cranioplasty have been reported in several studies. The improvement might be secondary to a reduction of local cerebral compression effects by atmospheric pressure post cranioplasty leading to improved cerebral hemodynamics. This increased cerebral blood flow might result in the overall improvement in the neurologic parameters. Literature lacunae exist in correlating clinical symptoms with cerebral hemodynamics in cranioplasty patients using various imaging modalities. To overcome the radiation hazard drawbacks in conventional imaging modalities, evaluation of cerebral hemodynamics using "Magnetic Resonance Perfusion Imaging" has emerged as a feasible alternative with comparable results. Therefore, this prospective comparative study was undertaken to evaluate the changes in cerebral hemodynamics viz. cerebral blood flow, cerebral blood volume and mean transit time in cranioplasty patients using Magnetic resonance perfusion. The neurologic parameters were evaluated using global disability parameters namely Barthel index and Modified Rankin scale. The study emphasized to establish a correlation between the improved cerebrohemodynamic status and the neurologic improvement post cranioplasty.

Key words: Cranioplasty, Cerebral hemodynamics, Magnetic resonance perfusion.

INTRODUCTION

Management of intractable intracranial hypertension following a severe traumatic brain injury often poses a challenge for the treating surgeon. The acutely raised intracranial pressure (ICP) can overwhelm the autoregulatory mechanism of the cerebral blood flow of the brain with the resultant cerebral ischaemia often leading to diminished neurologic function or death. Decompressive craniectomy (DC) is an emergency treatment option for refractory intracranial hypertension allowing for intracranial volume expansion, thereby relieving the hypertension. Owing to the urbanization and its consequences on the human lifestyle, there has been a substantial increase in the number of patients receiving decompressive craniectomies over the past decade.

Patients managed with decompressive craniectomy have a residual calvarial defect which requires restoration by cranioplasty. The primary aim of cranioplasty is to give mechanical support to the brain as well as for cosmetic rehabilitation. Marked improvements in the neurologic status in terms of daily physical activities post cranioplasty has been reported in the literature. This improvement can be attributed to the reduction in cerebral compression due to atmospheric pressure. [1, 2] Elimination of the atmospheric pressure effects results in an increase in the cerebral blood flow, thus leading to neurologic improvement. [3]

Literature review reveals very few studies in cranioplasty patients correlating changes in cerebral hemodynamics with neurologic status using imaging modalities. [4-8] To overcome the issue of radiation hazard associated with traditional imaging modalities like Computed Tomography Perfusion, evaluation of cerebral hemodynamics using “Dynamic Magnetic Resonance Perfusion Imaging” has emerged as a non –invasive, multiplanar imaging modality with better soft tissue resolution. Therefore, the present study is undertaken with the aim to evaluate the changes in cerebral hemodynamics in patients undergoing cranioplasty using Magnetic Resonance (MR) Perfusion. The secondary objective is to establish a correlation between changes in neurologic status measured via global disability parameters and cerebral hemodynamics post cranioplasty.

MATERIALS AND METHODS

The prospective study was conducted over a duration of 2 years (Jun 2015 to May 2017) on thirty patients (23 males and 07 females) aged between 18-65 years (mean 42.6 years) reporting to the Department Of Oral And Maxillofacial Surgery, Army Dental Centre (Research and Referral), Delhi for cranioplasty post decompressive craniectomy secondary to severe head injury following trauma. Patients with decompressive craniectomies owing to cerebrovascular, cardiovascular or peripheral vascular disorders, advanced stages of malignancies accompanying primary pathology were excluded from the study.

The cranioplasty was performed using autologous graft in six cases and alloplastic with polymethylmethacrylate acrylic plate in twenty four cases. All the patients had undergone unilateral cranioplasties for fronto-temporo-parietal (FTP) defects. The mean time interval between craniotomy and cranioplasty was six months with a range from three months to eight months.

The protocol for the study was duly approved by the institutional ethical committee and written informed consent was taken from all the patients. Neurologic assessment was done preoperatively by global disability parameters namely Barthel index and Modified Rankin Scale. Both the indices measure the extent to which somebody can function independently and has mobility in their activities of daily living i.e. feeding, bathing, grooming, dressing, bowel control, bladder control, toileting, chair transfer, ambulation and stair climbing. The index also indicates the need for assistance in care. The Barthel Index yields a total score out of 100 – the higher the score, the greater the degree of functional independence. [9] The Modified Rankin scale runs from 0 - 6, running from perfect health without symptoms to death. [10]

Cerebral hemodynamics was studied by MR perfusion imaging using the parameters of cerebral blood flow, cerebral blood volume and mean transit time. Perfusion maps were calculated from regions of interest drawn from over frontal, parietal and occipital lobes of each hemispheres for each side **(Figure 1)**. For comparison of perfusion parameters, cerebral blood flow (CBF), cerebral blood volume (CBV) and mean transit time (MTT) of both the cerebral hemispheres were obtained. With cerebellum as the reference base line, ratio of cerebral blood flow (rCBF), cerebral blood volume (rCBV) and mean transit time (rMTT) was calculated for each lobe of either hemisphere. All the parameters were evaluated four weeks after the procedure and compared to establish a correlation between the cerebral hemodynamics, its possible impact on neurological outcome and as a prognostic factor.

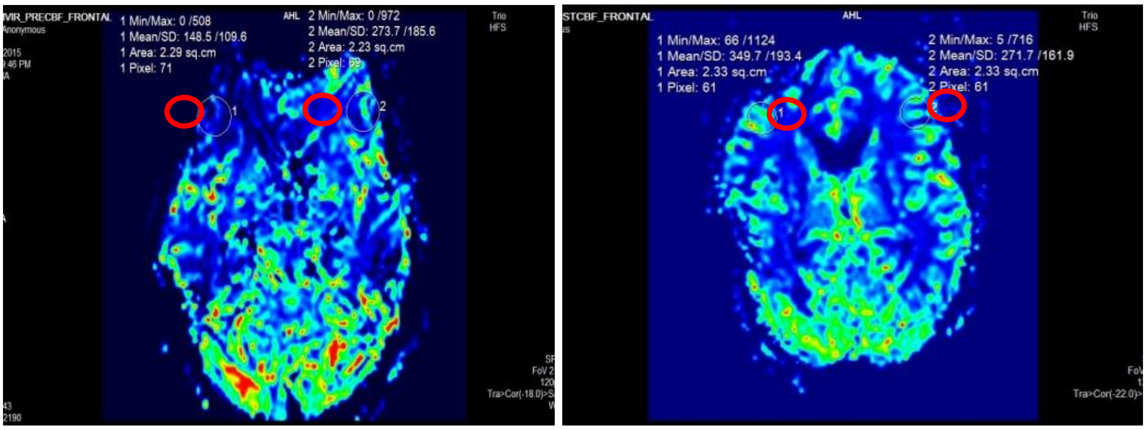

Figure 1: CBF perfusion map of frontal lobe – Preop (left) and Postop (right)

Statistical Analysis:

The data was subjected to statistical evaluation by paired t-test using the software SPSS Version 17.0 with values less than 0.05 considered statistically significant for the parameter.

RESULTS

Out of the total sample of thirty patients, comparative evaluations of twenty nine patients were carried out with one patient suffering fatality due to suspected reperfusion injury following cranioplasty.

Neurologic status –

None of the patients experienced total recovery after cranioplasty. However, there was statistically significant improvement in the neurologic status postoperatively as defined by the global disability parameters **(Figure 2).**

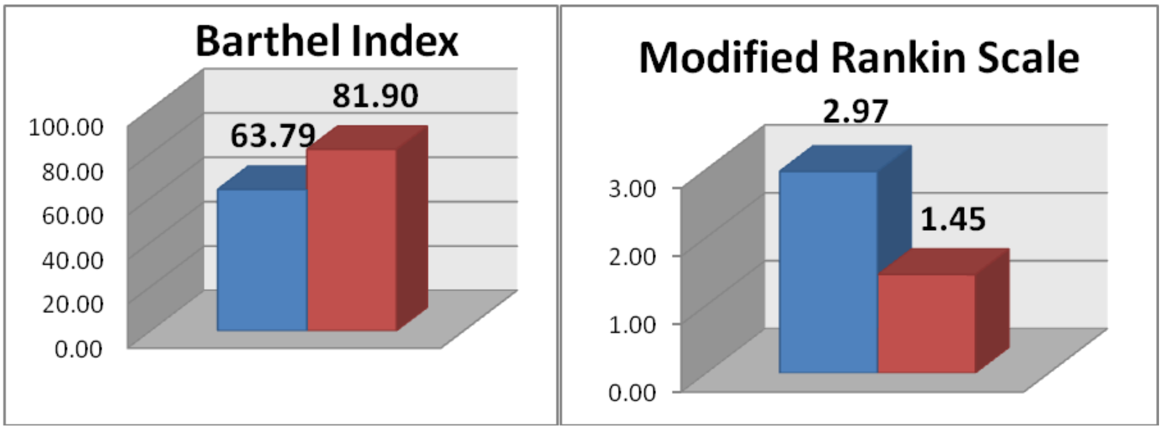

Figure 2 : Global disability parameters - Preop Postop

Cerebral perfusion status –

rCBF -

There was overall improvement in the cerebral blood flow post operatively in both ipsilateral and contralateral hemisphere. The paired t-test revealed the results were statistically significant ($p<0.05$) only in the ipsilateral frontal lobe ($p=0.004$) **(Table 1)**

Table 1: Cerebral Blood Flow (rCBF)

rCBF cerebral lobe		Mean	Std. Deviation	p-value
Ipsilat Frontal	Pre Op	0.68	0.180	**0.004**
	Post Op	0.81	0.214	
Ipsilat Parietal	Pre Op	0.84	0.332	0.092
	Post Op	0.94	0.350	
Ipsilat Occipital	Pre Op	1.16	0.537	0.219
	Post Op	1.29	0.335	
Contra Frontal	Pre Op	0.89	0.464	0.336
	Post Op	0.96	0.356	
Contra Parietal	Pre Op	0.91	0.594	0.097
	Post Op	1.12	0.389	
Contra Occipital	Pre Op	1.26	0.627	0.067
	Post Op	1.36	0.545	

rCBV -

There was minimal improvement in mean cerebral blood volume in both the hemispheres with statistically significant difference noted in the contralateral parietal lobe (p=0.024). (**Table 2)**

Table 2: Cerebral Blood Volume (rCBV)

rCBV cerebral lobe		Mean	Std. Deviation	p-value
Ipsilat Frontal	Pre Op	0.874	0.49	0.64
	Post Op	0.8969	0.47	
Ipsilat Parietal	Pre Op	0.9173	0.36	**0.024**
	Post Op	1.0033	0.40	
Ipsilat Occipital	Pre Op	1.172	0.53	0.575
	Post Op	1.2039	0.44	
Contra Frontal	Pre Op	0.941	0.51	0.776
	Post Op	0.964	0.41	
Contra Parietal	Pre Op	0.9223	0.41	0.062
	Post Op	1.0641	0.45	
Contra Occipital	Pre Op	1.313	0.66	0.805
	Post Op	1.3319	0.61	

rMTT -

For MTT parameter, there was a minimal overall reduction in the post operative phase commensurating with the other two hemodynamic parameters. The values attained statistical significance only in the contralateral frontal lobe (p<0.001) **(Table 3)**

Table 4 : Mean Transit Time (rMTT)

rMTT cerebral lobe		Mean	Std. Deviation	p-value
Ipsilat Frontal	Pre Op	0.8851	0.245	0.627
	Post Op	0.8258	0.712	
Ipsilat Parietal	Pre Op	0.9569	0.294	0.493
	Post Op	0.8944	0.566	
Ipsilat Occipital	Pre Op	1.114	0.830	0.037
	Post Op	0.9741	0.618	
Contra Frontal	Pre Op	0.8618	0.206	**<0.001**
	Post Op	0.7245	0.228	
Contra Parietal	Pre Op	0.8376	0.211	0.008
	Post Op	0.7381	0.218	
Contra Occipital	Pre Op	1.253	1.245	0.138
	Post Op	0.9421	0.301	

DISCUSSION

Conservative approaches such as hypermolar dehydration, hyperventilation and barbiturate coma have been used as first line measures to combat intractable intracranial hypertension following traumatic brain injuries. However, 10-15% patients do not respond to the medical management and require decompressive craniectomy to lower the intracranial pressure. [11]

To restore the residual calvarial defect, cranioplasty is usually performed as a secondary procedure in patients undergoing decompressive craniectomy. In addition to its primary role of cerebral protection and cosmesis, it has been hypothesized that cranioplasty may have a therapeutic role in improving the neurologic status of the patient. Its role in protecting the brain from cerebral seizures, to relieve the "Motor Trephine Syndrome", to protect the brain from atmospheric pressure effects and to correct the shift of central structures has been reported in various literatures. [12, 13]

Restoration of cerebral hemodynamics as an explanation for neurological recovery after cranioplasty was proposed by Richaud et al (1985). [14] Suzuki et al (1993) investigated the cerebral blood flow with dynamic CT scanning in patients who underwent cranioplasty. They suggested that an increase in the bilateral cerebral blood flow after cranioplasty might play a role in the patients' neurological recovery. [4] Yoshida et al (1996) studied cerebral blood flow and metabolism in 7 patients with stable 133Xe Computed Tomography (CT) and 31P Magnetic Resonance Spectroscopy and demonstrated the increase of cerebral blood flow and the decrease of neurological deficits. [5]

Winkler et al (2000) proposed improvement in postural blood flow regulation, cerebrovascular reserve capacity and cerebral glucose metabolism post cranioplasty with improvement in brain perfusion and hemodynamics. [15] Various studies using other imaging modalities revealed that cranioplasty can improve the cerebral blood flow by increasing blood flow velocities of the ipsilateral middle cerebral and internal carotid arteries, as well as, improve the cardiovascular functions. [6, 16]

To overcome the disadvantages of radiation hazard associated with the gold standard CT perfusion, evaluation of cerebral hemodynamics using "Dynamic Magnetic Resonance Perfusion Imaging" has been suggested as a suitable alternative modality with comparable results. Other modalities like Transcranial cranial dopplersonography do not provide the soft tissue details as with Magnetic resonance perfusion. Importantly, MRI-based perfusion measurements are minimally invasive overall and do not use any radiation and radioisotope; providing superior soft tissue details.

Sakamoto's study on CT Perfusion noted an improvement in CBF not only on the symptomatic side but also on the contralateral side. [17] Similar results were reported by Decaminda et al, where they reported neurological improvement as well as improvement in cranial perfusion even though the data was not statistically significant. [7] Our study showed a statistically significant improvement only in CBF in ipsilateral frontal lobe. For the remainder we found an overall improvement in clinical and cerebral perfusion parameters from the first to the last examination with significant improvement in CBV in ipsilateral parietal lobe and MTT in contralateral frontal lobe. This improved cerebral hemodynamics is in sync with the improvement in neurologic status as measured by the global disability parameters suggesting a definite correlation between the two factors. The neurological improvement after cranioplasty may be due to the increase in CBF velocities at all vessels including the ipsilateral and contralateral side resulting from elimination of the effects of atmospheric pressure on the brain. [3,5,8,15]

CONCLUSION

The inference of our study is in concurrence with various previous literature reports based on CBF changes after cranioplasty showing a definite correlation between the clinical and neurologic parameters with changes in the cerebral hemodynamics in the cranioplasty patients. However, further studies are required to establish the exact magnitude of the correlation between the two parameters.

Hence, we propose to reemphasize the theory that cranioplasty is carried out not only for restoring normal appearance and physical barrier but should also be performed with a purpose for improving the neurologic status of the patient. Moreover the study utilized Magnetic resonance perfusion imaging which is a noninvasive, radiation hazard free imaging modality unlike the established gold standards.

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