Comparative Study of Cerebral Perfusion in Different Types of Decompressive Surgery for Traumatic Brain Injury

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Abstract

Introduction Computed tomography perfusion (CTP) brain usefulness in the treatment of traumatic brain injury (TBI) is still being investigated. Comparative research of CTP in the various forms of decompressive surgery has not yet been reported to our knowledge. Patients with TBI who underwent decompressive surgery were studied using pre- and postoperative CTP. CTP findings were compared with patient's outcome.

Materials and Methods This was a single-center, prospective cohort study. A prospective analysis of patients who were investigated with CTP from admission between 2019 and 2021 was undertaken. The patients in whom decompressive surgery was required for TBI, were included in our study after applying inclusion and exclusion criteria. CTP imaging was performed preoperatively and 5 days after decompressive surgery to measure cerebral perfusion. Numbers of cases included in the study were 75. Statistical analysis was done.

Results In our study, cerebral perfusion were improved postoperatively in the all types of decompressive surgery (p-value < 0.05). But association between type of surgery with improvement in cerebral perfusion, Glasgow Coma Scale at discharge, and Glasgow Outcome Scale-extended at 3 months were found to be statistically insignificant (p-value > 0.05).

Conclusion CTP brain may play a role as a prognostic tool in TBI patients undergoing decompressive surgery.

Keywords

- traumatic brain injury)
- brain CT perfusion
- cerebral perfusion
- decompressive surgery
- Glasgow Outcome Scale-extended (GOS-E)

Introduction

Traumatic brain injury (TBI) is the leading cause of death and disability worldwide.[1] It is the leading cause of incapacitation in young people around the world, particularly those under the age of 40.[2] In poor- and middle-income nations like India, the burden is borne by more than 90% of the population, especially the younger and more productive generations, with significant financial ramifications.[3] Traffic-related accidents account for between 45 and 60% of brain injuries in India, followed by falls (20–30%) with violence accounting for another 10 to 20%, depending on the research.[4]

Because of the risk of cerebral edema and intracranial hypertension (IH) that TBI patients face, treating them is a huge problem. A mass effect from cerebral hematomas, concussions, diffuse brain edema, or hydrocephalus can raise intracranial pressure (ICP) following TBI. By

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decreasing cerebral perfusion pressure, IH can cause brain ischemia.[5] A higher mortality rate following TBI is linked to IH.[6] In TBI patients, refractory ICP due to post-traumatic brain edema is a critical prognostic factor.[7] The first 48 hours of a patient's stay in the hospital are the most resource-intensive and also the most dangerous.[8] To avoid serious morbidity, it is critical to decrease ICP as soon as possible.[9] More than half of all patients who die after a TBI do so due to high ICP.[10]

Some patients' ICP will continue to rise despite the best medical therapy, according to the Monroe-Kelly doctrine.[9] Patients with increasing ICP fall into one of two categories from a surgical perspective: those for whom maximal medical therapy is no longer effective, and those for whom medical therapy must be supplemented with decompressive surgery. Early decisions should be based on frequent and close clinical reassessment and repeat neuroimaging.

The cranial decompression is a way to transform fixed volume and limited reserve cranium into an open system that can accommodate additional mass.[11] Most people agree that a decompressive craniectomy (DC) does not undo the effects of a primary brain injury.[12] TBI patients' ICP has been demonstrated to decrease when DC is administered.[13]

It is widely accepted that the opening of the dura is essential. Dura excision and duroplasty are time-consuming procedures that may have an adverse effect on the result in critically ill patients.[14]

Therefore, to decrease ICP, decompressive surgery may be in form of like DC with duraplasty (type I), DC without duraplasty (type II), DC with duraplasty (type III), and decompressive craniectomy without duraplasty (type IV).

Due to cerebral edema, decreased cerebral blood flow (CBF), and metabolic dysfunction, decompressive surgery for TBI has been associated with poor clinical results.[15] Patients having decompressive surgery have altered patterns of global and regional CBF, but these changes are not clearly defined.[16] There is a paucity of information on the effects of decompressive surgery on microvascular cerebral perfusion.[17] As a result of decompression surgery, further information is needed on the alterations in cerebral hemodynamics.

Brain noncontrast computed tomography (NCCT) is the gold standard diagnostic technique for TBI. NCCT may underestimate the magnitude of the lesion and provide little information on secondary ischemia damage.[18] Several modalities, including single-photon emission computed tomography (SPECT), positron emission tomography (PET), brain CT perfusion (CTP), and Xenon perfusion, have been employed over the years to provide information about TBI patients' injuries and prognosis.[19] CTP can be added to NCCT brain as an immediate and concurrent procedure, making it an excellent option for TBI patients.[20] There is no doubt that CTP provides timely data on cerebral perfusion. CTP may be useful in predicting long-term results in patients with severe TBI.[18]

A reference artery and venous region, as well as each scan pixel, are given time versus contrast concentration curves.[21] Color-coded maps and quantification of perfusion parameters such as CBF, cerebral blood volume (CBV), time to peak (TTP), and mean transit time (MTT) can be generated after data processing.[22] CBV/MTT is used to compute the CBF for each location. When calculating CBF, milliliters per 100 grams of tissue per minute is used. To find the CBV, divide the parenchymal pixel's area under the curve by the venous pixel's area under the curve. CBV is expressed as milliliters per 100 grams of tissue. Using the time concentration curve for each voxel and the arterial reference region, MTT is a measure of how long it takes blood to travel across the capillary network on average. Seconds are used to measure MTT.[21] When performing a perfusion study, the MTT, CBV, and CBF measurements for various brain regions can be used to identify areas of ischemia and aberrant perfusion using the CTP.

IH has been linked to decreased CBF in patients with severe TBI. Loss of cerebral autoregulation and abnormalities in CPP were shown to be associated with abnormalities on the CTP.[23] Mild and severe TBI patients' functional prognosis can be predicted using CTP.[18,24]

Hemodynamic alterations in the acute phases of head TBI are well-known. CTP can aid in the clarification of these changes and the determination of whether or not they have any predictive value for patients with TBI. Reduced CBF and CBV upon admission have been demonstrated in previous research to be predictive of outcome in severe brain injury when compared to the Glasgow Outcome Scale (GOS) at 3 months.[25]

CTP's usefulness in the treatment of TBI is still being investigated. Comparative research of CTP in the various modalities of cranial decompression has not yet been reported to our knowledge. Patients with TBI who underwent decompression surgery were studied using pre- and postoperative CTP.

It was our intention to see if using CTP to the decompressive surgery of TBI patients could turn it into something more than just an academic exercise. CTP scanning may also be useful in the management of TBI patients with respect to various decompressive surgical techniques.

Our study's goal is to compare CTP with various decompressive surgery procedures for TBI.

Materials and Methods

Study Design

An independent, prospective cohort study was conducted at Sawai Man Singh Medical College Jaipur and received ethics permission from the Ethics Committee (227/MC/EC/2021). The study was conducted between 2019 and 2021. The patient was enrolled in the study after receiving informed written agreement from a close relative or attendant.

Patients' Inclusion Criteria

All patients with head injuries who were scheduled to undergo decompressive surgery, were included in this study.

Patients' Exclusion Criteria

Pregnancy, a history of craniotomy or any serious chronic illness, respiratory or circulatory failures, any extracranial injury that could affect the outcome, diffuse axonal injury without the presence of intracranial hematoma, the absence of brain stem reflexes, hemodynamically instable, and any known contraindication to CT contrast agents (such as an allergy or anaphylactic reaction) were all considered exclusion criteria for this study.

Surgical Procedures

Based on the patient's clinical condition, radiographic evidence of midline shift on CT scan and/or increased ICP, and signs or symptoms of a refractory IH despite acceptable medical therapy, surgeons decided to proceed with decompressive surgery. Type of the decompressive surgery was decided on the basis of intraoperative findings. Postoperative patients were managed in the neurosurgical intensive care unit.

Radiological Evaluation

To carry out the CTP, a written informed permission was obtained following the decision to proceed with decompressive surgery. CTP imaging was conducted before surgery and 5 days (to evaluate the impact of cranial decompression on brain perfusion) after decompressive surgery to assess cerebral perfusion (►**Fig. 1**).

The CT scanner used was the Philips Ingenuity 128 slice CT scanner. NCCT brain was performed on all patients at 120 kV, 300 mA, and 5 mm per layer with a 5 mm layer gap as a baseline. A 30 mm section of brain parenchyma was sampled for the purpose of performing brain CTP on a specific area of interest. It was done at a voltage of 120 kV, an amperage according to body to body's weight and 1.25 mm thickness per slice. Injection of a nonionic contrast medium (iohexol 755 mg/mL, equivalent to 350 mg/L of iodine) was performed with a high-pressure syringe through the cubital vein (18G IV cannula) at a flow rate of 4.0 mL/s and dose of 100 mL using a power injector before the scan began. A saline flush (total 30 mL) was then performed at a rate of 3.0 mL/sec. After performing CTP, perfusion software was used to produce parametric maps from CTP raw data on a workstation. To record CBF, CBV, MTT, and TTP parameters, each region of interest (ROI) was inserted in the perilesional brain parenchymal area close to a contusion, subdural hemorrhage (SDH), or ICH or potential surgical side.

Postoperative CTP was done using the same technique and ROI pattern as the preoperative CTP. A comparison and correlation of the two CTP values was then performed, as well as surgical outcomes and an GOS-extended (GOS-E). For reasons like death before postoperative CTP or hypotension or renal insufficiency, some individuals were omitted from the study. As a result, there were 75 patients who participated in the research.

Statistical Analysis

Data was entered in Excel spreadsheets. Shapiro–Wilk test ($p > 0.05$) was used to check normality of data. Normal data was expressed in form of mean and standard deviation and was analyzed using Student's *t*-test and one-way analysis of variance test. Non-normal data was expressed in form of median and interquartile range and analyzed using Wilcoxon and Kruskal–Wallis test. Discrete data was summarized in form of proportions and difference in proportion was analyzed using chi-squared test. All statistical analyses were conducted with a 95% threshold of significance.

Results

In our study, half of the participants 37 (49.33%) were of the 20 to 34 years age group and least 3 (4%) were of 5 to 19 years and 65 to 79 years age group. Mean age of the participants was 38.62 ± 14.75 years. Most 63(84%) of the participants were male. Road traffic accident was the most common (78.67%, 59/75) cause of injury. Around half of the participants (37; 49.33%) had undergone type I surgery, followed by type III surgery (21; 28%), type II surgery (10; 13.33%) and least 7 (9.33%) participants undergone type IV surgery. Maximum 27 (36%) of the participants had SDH and contusion both, followed by contusion (18; 24%) and SDH (12; 16%).

Among participants who had undergone type I surgery, CBV and CBF improved postoperatively and improvement in CBF in affected area was statistically significant ($p < 0.05$). However, MTT and TTP decreased postoperatively and change in MTT and TTP postoperatively in affected area was statistically significant ($p < 0.05$). There was found to be statistically significant improvement in postoperative median Glasgow Coma Scale (GCS [motor]) from preoperative ($p < 0.05$; ►**Table 1**) median.

Among participants who had undergone type II surgery, CBV and CBF in affected area improved significantly postoperatively ($p < 0.05$). However, MTT and TTP decreased postoperatively and change in MTT and TTP postoperatively in affected area was statistically not significant ($p > 0.05$). Preoperative GCS (motor) among participants was 5 (5.25–5) and it increased to 5.5 (6–5) postoperatively, although this improvement in GCS (motor) was statistically not significant ($p > 0.05$; ►**Table 2**).

Among participants who had undergone type III surgery, CBV and CBF improved postoperatively and improvement in CBV in affected area was statistically significant ($p < 0.05$). However, postoperative MTT and TTP in affected area decreased significantly from preoperative values ($p < 0.05$). Preoperative GCS (motor) among participants was 5 (5-4) and it increased to 5 (6-5) postoperatively, and improvement in GCS (motor) was statistically significant ($p < 0.05$; ►**Table 3**).

Participants who had undergone type IV surgery showed improvement in CBV and CBF postoperatively, although this improvement in affected area was statistically not significant ($p > 0.05$). However, MTT and TTP decreased postoperatively and change in MTT and TTP in affected area was also not significant statistically ($p > 0.05$). Improvement in median GCS (motor) was also statistically not significant ($p > 0.05$; ►**Table 4**).

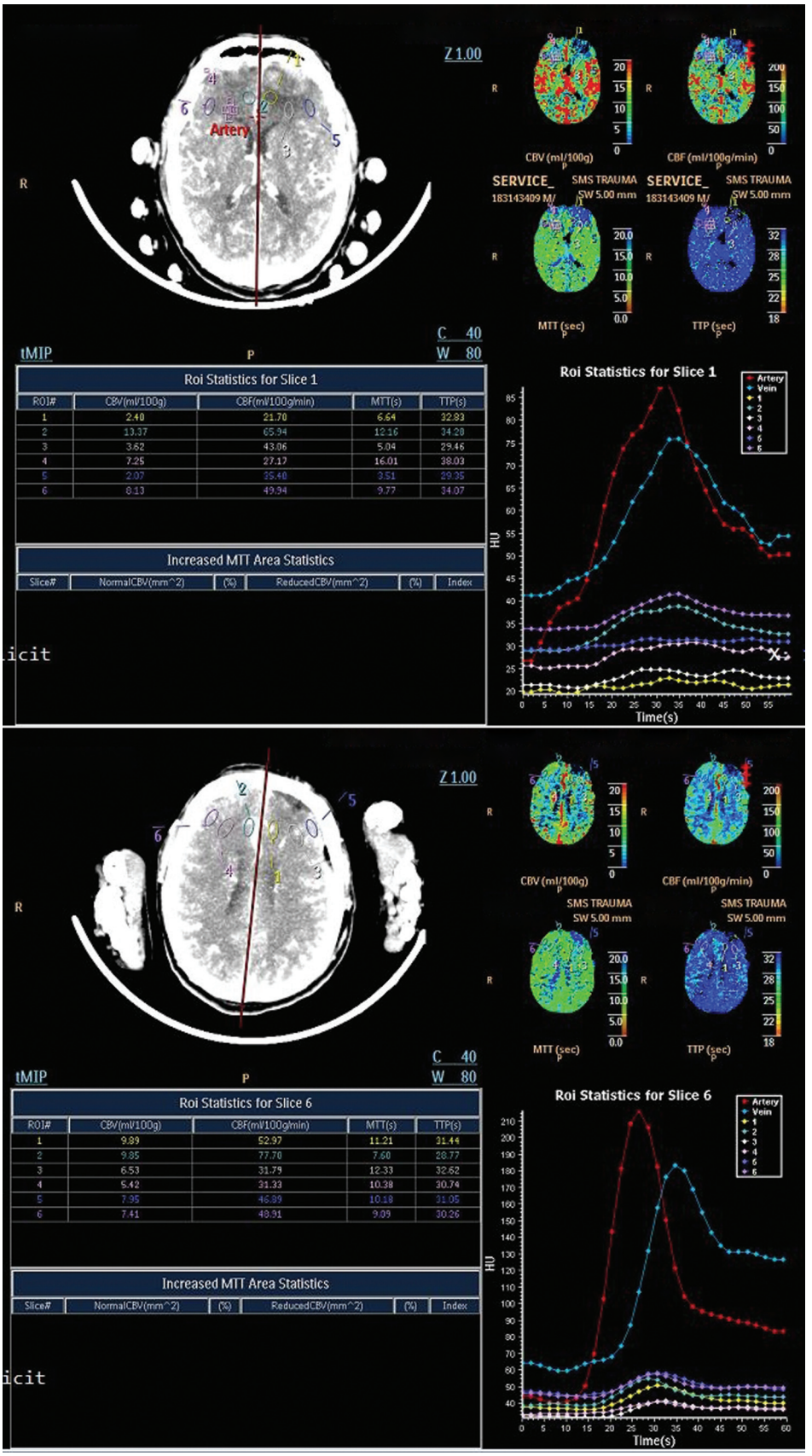

Fig. 1 Upper part of figure is preoperative computed tomography perfusion (CTP) and lower part of figure is postoperative day 5 CTP photo.

Table 1 Difference in pre- and postoperative CBV, CBF, MTT, TTP, GCS (motor) among patients undergone type I surgery

	Type I ($n = 37$)		
Variable	**Pre**	**Post**	***p*-Value**
CBV	3.88 ± 1.75	3.92 ± 1.31	$t = -0.116$, Df = 36, p-value = 0.909
CBF	32.75 ± 12.92	44.12 ± 16.55	$t = -4.378$, Df = 36, p-value < 0.001
MTT	7.49 ± 2.64	6.03 ± 2.81	$t = 3.507$, Df = 36, p-value = 0.001
TTP	31.45 ± 6.23	25.35 ± 5.05	$t = 5.819$, Df = 36, p-value < 0.001
GCS (motor)	5(6-5)	6(6-6)	Z value= 4.025, p-value < 0.001

Abbreviations: CBF, cerebral blood flow; CBV, cerebral blood volume; GCS, Glasgow Coma Score; MTT, mean transit time; TTP, time to peak.

Table 2 Difference in pre- and postoperative CBV, CBF, MTT, TTP, GCS (motor) among patients undergone type II surgery

	Type II ($n = 10$)		
Variable	**Pre**	**Post**	***p*-Value**
CBV	2.34 ± 0.66	2.95 ± 0.85	$t = -3.34$, Df = 9, p-value = 0.009
CBF	20.81 ± 10.37	29.39 ± 13.29	$t = -3.56$, Df = 9, p-value = 0.006
MTT	9.84 ± 9.19	6.97 ± 3.07	$t = 1.4$, Df = 9, p-value = 0.195
TTP	36.89 ± 6.63	33.36 ± 9.39	$t = 1.415$, Df = 9, p-value = 0.191
GCS (motor)	5(5.25-5)	5.5(6-5)	Z value= 1.890, p-value = 0.059

Abbreviations: CBF, cerebral blood flow; CBV, cerebral blood volume; GCS, Glasgow Coma Score; MTT, mean transit time; TTP, time to peak.

Table 3 Difference in pre- and postoperative CBV, CBF, MTT, TTP, GCS (motor) among patients undergone type III surgery

	Type III ($n = 21$)		
Variable	**Pre**	**Post**	***p*-Value**
CBV	3.43 ± 1.78	3.86 ± 1.45	$t = -1.576$, Df = 20, p-value = 0.131
CBF	26.0 ± 11.29	38.27 ± 14.52	$t = -5.377$, Df = 20, p-value < 0.001
MTT	8.26 ± 3.45	6.41 ± 2.12	$t = 2.476$, Df = 20, p-value = 0.022
TTP	34.67 ± 6.28	28.41 ± 8.51	$t = 3.164$, Df = 20, p-value = 0.005
GCS (motor)	5(5-4)	5(6-5)	Z value= 2.486, p-value = 0.013

Abbreviations: CBF, cerebral blood flow; CBV, cerebral blood volume; GCS, Glasgow Coma Score; MTT, mean transit time; TTP, time to peak.

Table 4 Difference in pre- and postoperative CBV, CBF, MTT, TTP, GCS (motor) among patients undergone type IV surgery

	Type IV ($n = 7$)		
Variable	**Pre**	**Post**	***p*-Value**
CBV	2.5 ± 0.70	3.09 ± 1.12	$t = -2.251$, Df = 6, p-value = 0.065
CBF	18.34 ± 11.2	30.93 ± 21.95	$t = -2.338$, Df = 6, p-value = 0.058
MTT	11.9 ± 10.6	8.49 ± 5.96	$t = 1.867$, Df = 6, p-value = 0.111
TTP	35.16 ± 6.8	30.41 ± 10.16	$t = 1.596$, Df = 6, p-value = 0.161
GCS (motor)	5(5-2)	5(6-3)	Z value= 1.890, p-value = 0.059

Abbreviations: CBF, cerebral blood flow; CBV, cerebral blood volume; GCS, Glasgow Coma Score; MTT, mean transit time; TTP, time to peak.

Among participants who had both SDH and contusion, maximum (40.74%, 11/27) participants had undergone type I surgery, followed by type III surgery (22.22%, 6/27), type II and type IV surgery each in (18.52%, 5/27) participants. Among participants who had contusion, two-third (66.67%, 12/18) of participants had undergone type I surgery and none of them undergone type II surgery. Association of type of injury with the surgery participants had undergone was statistically significant (p-value <0.05).

Among participants who had undergone type I, II, III, and IV surgery, median GOS-E score at 3 months after surgery was 7 (7-6), 5 (6-1.5), 3 (6-3), and 4 (5.5-2), respectively. And

Table 5 Association of improvement in variable with the type of surgery patients undergone

Variable	I ($n=37$)	II ($n=10$)	III ($n=21$)	IV ($n=21$)	Test of significance
Improvement in CBV	0.34(0.7–0.04)	0.50 (0.63-0.24)	0.31 (1.29-0.18)	0.27 (1.14-0.1)	p-Value= 0.712
Improvement in CBF	10.73(15.64–4.42)	6.06 (11.07-3.38)	11.14 (22.52-5.28)	4.53 (22.81-2.92)	p-Value = 0.677
Improvement in MTT	−1.12(−0.46–2.56)	−0.84 (−0.15–2.18)	−1.83 (−0.39–3.41)	−1.84 (−0.58–3.68)	p-Value= 0.833
Improvement in TTP	−6.05(−2.15–9.41)	−6.21 (3.64–10.01)	−5.68 (−3.36–8.1)	−6.64 (−4.24–8.36)	p-Value= 0.968
Improvement in GCS motor	0(1-0)	0 (1-0)	0 (1-0)	1 (1-0)	p-Value= 0.002
Trauma to operation time	43.32 ± 40.48	47.60 ± 68.76	25.67 ± 32.61	26.71 ± 21.77	F= 1.136, Df = 3, p-value = 0.341

Abbreviations: CBF, cerebral blood flow; CBV, cerebral blood volume; GCS, Glasgow Coma Score; MTT, mean transit time; TTP, time to peak.

difference in GOS-E score with type of surgeries participants had undergone was statistically significant (Kruskal–Wallis test 24.191, Df = 3, p-value < 0.001). Among participants who undergone type I surgery, most 22(59.5) of the participants had 7-8 GOS-E, none had 1-2 GOS-E at 3 months after the surgery. Among participants who undergone type III surgery, most 9(42.9) of the participants had 3-4 GOS-E and only 3(14.3) participants had 7-8 GOS-E. Association between type of surgery and GOS-E after 3 months was found to be statistically significant (X2 = 27.116, Df = 9, p-value= 0.001).

Maximum improvement in CBV was seen in cases of type II and least in cases of type IV surgery. Improvement in CBF was maximum among participants of type III surgery, while least among participants of type IV surgery. Improvement in GCS motor was maximum among type IV surgery participants. Association between type of surgery with improvement in CBV, CBF, MTT, TTP, and trauma to operation time was found to be statistically insignificant (p-value > 0.05) and association of GCS motor change with type of surgery was statistically significant (p-value < 0.05; ►**Table 5**).

There was positive correlation of GOS-E at 3 months with preoperative CBV ($\rho = 0.423$), preoperative CBF ($\rho = 0.531$) and this correlation was statistically significant (p-value < 0.05).

There was negative correlation of GOS-E at 3 months with preoperative MTT ($\rho = -0.155$) and preoperative TTP ($\rho = -0.234$), and correlation with preoperative TTP was significant (p-value < 0.05) and with preoperative MTT correlation was statistically insignificant (p-value > 0.05)

Discussion

CTP research in people with TBI has been ongoing for more than a decade; however, there are still few trials with sufficiently large sample sizes. Many researchers have examined the potential of CTP in assessing TBI's aberrant cerebral perfusion[26] as well as changes after treatment[27] and prognostication.[24] We wanted to see if there was any association between preoperative and postoperative CTP findings in different types of decompressive surgery. Our attempt was to reliably identify who will be vegetative versus who will be high functioning on the basis of preoperative CTP for better outcome for surgery in TBI patients.

In our study, road traffic accident (78.67%) was the most frequent reason, similar to the prior batch of reports (India).[28] Type I was performed most commonly (49.33%) followed by type III (28%). In our patients, most common finding on the NCCT was combined SDH and contusions (36%). Sinha et al found in their study that intracerebral contusions (65%) and SDHs (almost as common) were the most common radiological findings in TBI (63%).[28]

CBV and CBF values improved, whereas MTT and TTP values dropped in all types of surgeries, indicating an improvement in cerebral perfusion in all types of procedures. TBI patients with refractory high ICP have showed significant increases in CBF velocity after DC, indicating postdecompression CBF rise.[29] TBI patient after undergoing DC showed an approximately threefold increase in cerebral microvascular blood flow in contrast ultrasonography (USG).[30] There was transitory localized hyper perfusion in the decompressed brain that lasted at least 1 week after DC in five individuals studied by Yamakami and Yamaura.[31]

Heppner et al[30] conducted a pilot study on microvascular cerebral perfusion following DC using contrast USG, which included six patients. They reported increase in CBF and CBV 48 hours after surgery. Several investigations employing transcranial Doppler to quantify macrovascular flow have demonstrated increased flow velocities in both hemispheres.[29]

Soustiel et al[32] reported a considerable rise of roughly 4 mL/100 g/min in CBF in seven patients following DC. Daboussi et al[29] reported that CBF velocities in patients after DC were increased immediately and symmetrically.

Researchers observed that predecompression MTTs were about 8.2 seconds in both cerebral hemispheres, indicating

that brain was in distress before the procedure. To minimize MTT in the cerebral hemispheres, doctors performed a craniectomy.[27] Yamakami and Yamaura showed an increase in CBF after DC using PET in patients with ischemic stroke.[31]

Jaeger et al[33] stated an increase in oxygenation levels ipsilateral to the area of ischemia following DC. These researchers discovered a strong link between MTT and oxygenation levels in the brain. DC also resulted changes in cerebral perfusion pressure due to changes in ICP.[34] MTT and CBF were shown to be the Perfusion Computed Tomography (PCT) measures most responsive to even small changes in cerebral perfusion pressure.[35]

Type I and type IV had statistically insignificant improvements in CBV and changes in MTT and TTP postoperatively, suggesting cerebral perfusion autoregulation failure. Researchers observed that CBV is more closely linked to vasoconstriction and vasodilatation than other measures of cerebral autoregulation.[36] To understand why individuals with severe infarction may be less responsive to acute alterations following surgery, it is necessary to look at how their autoregulation is affected.[37]

But preoperative median GCS (motor) among all type of surgeries was improved postoperatively but statistically significant (p-value < 0.05) in type I and III and statistically not significant (p-value > 0.05) in type II and IV. Wintermark et al originally reported on the use of CTP in severe TBI patients that a normal brain perfusion and high CBV were related with a favorable outcome in a manner comparable to this.[18]

Our study revealed that most of patients had SDH with underlying contusion and only contusion undergone commonly type I and type III (statistically significant, p-value <0.05).

When comparing different types of surgery for improving cerebral perfusion, no statistically significant difference was found. This could be because cerebral perfusion is not solely dependent on surgery type, but also on other factors such as brain parenchyma injury, external trauma type, time from trauma to operation date, age, and many more. This may be why improvements in cerebral perfusion have been observed in all types of surgery. In other words, it shows that surgery does not repair the initial brain parenchyma damage. Findings like this were previously discovered in other studies, such as Wilberger et al[38] claimed that surgery did not affect fundamental brain damage, but can lessen major downstream effects, such as elevated ICP and cerebral displacements or distortions, by reducing the severity of these secondary lesions Previous research have sought to explain variations in CBV, which appear to be connected to the outcome, but this parameter is difficult to assess.[36,39] According to one study, the patterns of cerebral perfusion following DC did not improve in all individuals after a stroke in a uniform manner[40] and worse functional outcome in elderly patients.[41]

Association between type of surgery and GCS motor change was also found to be statistically significant (p-value < 0.05), when comparison done among types of surgeries. Amorim et al[27] and Martin et al[42] noted that CBF and BV rise does not necessarily mean improved hemodynamics because these increases can be induced by vasospasm or hyperemia, which can have detrimental effects on the brain.

Among participants who had undergone type I, II, III, and IV surgery, median GOS-E score at 3 months after surgery was 7 (7-6), 5(6-1.5), 3(6-3), and 4(5.5-2), respectively. Association between type of surgery and GOS-E after 3 months was found to be statistically significant ($X2 = 27.116$, $Df = 9$, p-value$= 0.001$).

Most (59.5%) patients who undergone type I surgery showed good recovery, that is, 7-8 GOS-E score. It reflects that type I surgery generally performed in the patients in which relatively less injured brain parenchyma was found. Patients who undergone type III and IV surgery were end up in the severe disability, persistent vegetative state or death. These findings also supported by previous studies like, Metting et al[43] suggested that a lower GOS was associated with decreased frontal lobe CBF and CBV. After a 6-month delay, the score is now extended. In SPECT, severe hypoperfusion was found to be related with a negative result, regardless of any other confounding circumstances.[44]

The single-center and nonrandomized study design of this study constituted a drawback of the current investigation. Many surgeons (of varying experience) have operated on the patients in this study. As a tertiary care referral hospital, the length of time after the injury occurred had a significant impact on our decision-making. Because the research was limited to a single facility, it is possible that the findings cannot be extrapolated to other settings. The study only followed up for 3 months, which may have been a restriction of our study, as a longer follow-up could have revealed changes in our findings and GOS-E. Another important limitation of our study is only one postoperative CTP (which was done on postoperative day 5); further studies may hope to remove these limitations.

Conclusion

Our findings imply that incorporating CTP data into the existing outcome predictors enhances the prognostic model's accuracy when used in conjunction with surgical treatments for TBI. Treatment decisions and therapeutic actions can be made based on the usage of these modalities. Patient outcome after TBI can be better predicted with CTP. Better prognostication may be possible if neurosurgeons are able to accurately distinguish patients who will go into vegetative and those who will go into high functioning. In TBI patients receiving decompressive surgery, CTP may be a useful predictive and prognostic tool.

Informed Consent

Individual consent from the study was obtained.

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Conflict of Interest

None declared.

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