Original Research Article

Intraoperative Hyperglycemia in Patients Undergoing Emergency Craniotomy for Traumatic Brain Injury

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ABSTRACT

INTRODUCTION

Hyperglycemia following TBI is linked to poor outcomes. But studies on intraoperative hyperglycemia in adult TBI (Traumatic Brain Injury) were fewer in number. In this study, conducted at Govt. Medical College, Thrissur, we examined blood glucose value variability and risk factors for hyperglycemia during craniotomy in persons with TBI.

OBJECTIVES

The primary objective was to study the prevalence of intraoperative hyperglycemia during an emergency craniotomy for traumatic brain injury. The secondary objective was to identify the risk factors for intraoperative hyperglycemia during an emergency craniotomy for traumatic brain injury.

METHODS

This was a prospective observational study conducted in the Department of Anaesthesiology, Government Medical College, Thrissur for an 18-month period after approval from the Institutional Ethics Committee on 214 patients meeting the inclusion criteria who had provided consent and were undergoing emergency craniotomies for traumatic brain injury. The sampling method was continuous sampling. Hyperglycemia was defined as a GRBS (General Random Blood Sugar) value >140 mg/dl (preoperative or intraoperative first hour or second hour GRBS value). Hyperglycemia was treated with either an insulin bolus or an infusion when the GRBS value exceeded 180–190 mg/dl.

RESULTS
Intraoperative hyperglycemia was common in our study population. It was observed that the prevalence of intraoperative hyperglycemia was higher in older adults, aged 65 years and older. The prevalence of intraoperative hyperglycemia was higher in the diabetic population. There was no significant association between intraoperative hyperglycemia and EDH. The prevalence of intraoperative hyperglycemia was high in patients with SDH. There was no significant association between intraoperative hyperglycemia and SAH. Both preoperative GCS and GCS at discharge from the ICU were lower in patients who had intraoperative hyperglycemia. Patients with preoperative hyperglycemia had a higher chance of developing intraoperative hyperglycemia. The following were independent risk factors for intraoperative hyperglycemia: age ≥ 65 years, SDH, preoperative GCS ≤ 9, and preoperative hyperglycemia.

CONCLUSION
Intraoperative hyperglycemia was common during an emergency craniotomy for a traumatic brain injury. The following were independent risk factors for intraoperative hyperglycemia: age ≥ 65 years, SDH, preoperative GCS ≤ 9, and preoperative hyperglycemia.

KEYWORDS
Traumatic Brain Injury, Craniotomy, Intraoperative Hyperglycemia, GCS.

INTRODUCTION

In India and across the globe, the burden of diabetes has steadily increased over the past 25 years, with India contributing a major part of the global burden. The number of people with diabetes in India rose from 26 million in 1990 to 65 million in 2016. The prevalence of diabetes in adults aged 20 years or older in India increased from 5.5% in 1990 to 7.7% in 2016, with an increase in every state of India. This prevalence was highest in the more developed states, such as Tamil Nadu and Kerala.[1]

Traumatic brain injury, defined as an alteration in brain function or other evidence of brain pathology, caused by an external force, is a leading cause of death among adults.[2]

TBI induces a variety of basic and functional changes that exacerbate the patient's condition. Associated injuries produce remarkably varied outcomes. Individuals seem to react differently to the stress caused by trauma. Since there is little that medical professionals can do to ameliorate the symptoms of a primary brain injury, the main focus of head injury treatment is on preventing further injuries.[3]

A retrospective cohort study conducted in 185 patients >18 years old at Harborview Medical Centre, who underwent emergency craniotomy for traumatic brain injury showed that intraoperative hyperglycemia was common and in-hospital mortality was higher in patients with intraoperative hyperglycemia.[4]

Aims and Objectives

To study the prevalence of intraoperative hyperglycemia during emergency craniotomy for traumatic brain injury and to identify the risk factors for intraoperative hyperglycemia during emergency craniotomy for traumatic brain injury.

MATERIALS AND METHODS

It was a prospective observational study done at the department of anesthesiology at Government Medical College Hospital, Thrissur. Adults > 18 years old undergoing emergency craniotomy for traumatic brain injury at Govt. Medical College, Thrissur, who are consenting

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to be part of the study. Patients not consenting to be part of the study, age <18 years, pregnant patients, repeat craniotomies, and patients on steroids were excluded.

Study Procedure

After obtaining ethical committee clearance, 240 patients who presented with TBI for emergency craniotomy in the EOT were screened, out of which 26 patients were excluded from the study based on the exclusion criteria. The study was then conducted on 214 patients undergoing emergency craniotomies for traumatic brain injuries. After explaining the anesthetic procedure, written informed consent for participation in the study was obtained from the caregivers of the patients, since the majority of the study population had poor GCS scores with which they couldn't provide consent. A preanaesthetic evaluation was done, and a detailed history and physical examination were conducted. Pre-operative GCS and pre-operative blood glucose values were noted.

The first- and second-hour intraoperative capillary blood glucose values were obtained. Hyperglycemia was defined as a GRBS value >140 mg/dl (preoperative/intraoperative first hour or second hour GRBS value). Hyperglycemia was treated with either an insulin bolus or an infusion when the GRBS value exceeded 180–190 mg/dl. All cases were managed intraoperatively as per the institutional treatment protocol. The decision to treat hyperglycemia. (i.e., the level of intraoperative glucose to give insulin, whether to give a bolus injection of insulin or an insulin infusion, and the amount of insulin given) was made by the attending anesthesiologist in charge of the table and was observed by the principal investigator. The patient was prospectively followed up, i.e., the length of stay in the ICU and GCS at the time of discharge from the ICU to the ward were noted. The data procured was analyzed using appropriate statistical methods.

Statistical Analysis

Data are presented as mean and standard deviation for continuous variables and as frequency for categorical variables. Analysis was carried out using the Student's *t*-test, $\chi 2$ test, or Fisher's exact test. A univariate analysis of factors associated with mortality and ICU length of stay was carried out using logistic regression analysis. Interaction and confounding were assessed through stratification and relevant expansion covariates. Factors with a p-value <.20 in the univariate analysis were entered in a multivariable logistic regression analysis. *P*-values of ≤.05 were considered statistically significant.

RESULTS

A total of 240 patients who presented to the EOT with TBI for emergency craniotomies were enrolled. 214 patients who fulfilled the inclusion criteria and consented to be part of the study were included. 26 patients were excluded based on the exclusion criteria.

		Frequency	**Percent**
Age Group	Young adults (18-25)	38	17.8
	Adults (26-64)	129	60.3
	Older adults (65 and above)	47	22.0
Gender	Male	161	75.2
	Female	53	24.8
Presence of DM	No	182	85.0
	Yes	32	15.0

Treatment of DM	Diet control	1	3.125
	Insulin	8	25
	OHA	23	71.875
GCS score	Severe TBI:≤ 8	117	54.7
	Moderate TBI: 912	91	42.5
	Mild TBI:13-15	6	2.8
	Total	214	100.0
GCS score on discharge	**GCS Score**	**Frequency**	**Percent**
	≤ 8	0	0
	9-12	47	22.7
	13-15	160	77.3
	Total	207	100.0

Table 1: Age, Sex, Presence of Diabetes Mellitus and Treatment, Pre-Operative GCS Score, GCS Score on Discharge

Patients in the age group 26–64 years (adults) contributed to 60.3% of the study population. 22% of the patients were in the age group 65 years and older (older adults), and young adults (18–25 years) constituted 17.8% of the study population.

15% of the study population were those with diagnosed diabetes mellitus, while the majority were nondiabetic (85%). In the diabetic individuals of the study population (32 out of 214), 71.875% were on treatment with OHA, 25% were on insulin, and 3.125% were on diet control.

Distribution Based on Mode of TBI Sustained

Injury	Frequency	Percent
EDH	78	36.4
SDH	73	34.1
SAH	1	.5
EDH, SDH	57	26.6
SDH, EDH, SAH	1	.5
Total	214	100.0

Table 2: Mode of Traumatic Brain Injury

In the study population, the most common injury sustained was EDH (36.4%), followed by SDH (34.1%). 26.6% of the study population had sustained a combination of EDH and SDH. 0.5% of the study population had SAH and a combination injury of SDH, EDH, and SAH each. 54.7% of the study population had a preoperative GCS of ≤ 8. For 42.5% of individuals, preoperative GCS was in the range of 9-12. 2.8% of the study population had a preoperative GCS of 13-15**.**

After surgery, the mortality rate was 3.3%. Out of 214 study participants, 7 expired after surgery.

Time	N	Minimum	Maximum	Mean	Std. Deviation
Pre-operative	214	3	13	8.52	2.06
At ICU discharge	207	11	15	13.78	1.30
Length of ICU stay	214	1	14	3.18	2.10

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GRBS Values					
Before start of surgery	214	85	412	182.60	63.06
First hour intra operative	214	102	385	183.36	61.86
Second hour intra operative	214	109	358	170.78	48.06
Before start of surgery	214	85	412	182.60	63.06

Table 3. Descriptive Statistics Regarding GCS before Start of the Surgery and at ICU Discharge

In Table 4, the mean preoperative GCS of the study population was 8.52 with a standard deviation of 2.06. The mean GCS at discharge from the ICU to the ward was 13.78, with a standard deviation of 1.3**.** In the study population, the minimum length of ICU stay was one day, and the maximum length of stay in ICU was 14. The mean length of stay in the ICU was 3.18, and the standard deviation was 2.1. Intraoperative hyperglycemia was common in our study population. Out of the 214 study participants, 171 had a GRBS value >140 mg/dl in either the first or second hour (79.9%). The GRBS value was less than 140 mg/dl in both the first and second hours in 43 participants (20.09%).

In the study population, the minimum preoperative GRBS value noted was 85 mg/dl, and the maximum was 412 mg/dl. The mean preoperative GRBS was 182.6, and the standard deviation was 63.06. The minimum first-hour GRBS value noted was 102 mg/dl; the maximum value was 385 mg/dl. The mean first hour GRBS was 183.36, and the standard deviation was 61.86. The minimum second-hour GRBS value noted was 109 mg/dl; the maximum value was 358 mg/dl. The mean second-hour GRBS was 170.78, and the standard deviation was 48.06.
In the study population, 69.6% had preoperative GRBS >140 mg/dl. 72% had first-hour GRBS >140 mg/dl. And 64.5% had a second-hour GRBS >140 mg/dl.

Age Group	**No Hyperglycaemia**		**Hyperglycaemia**		**Total**
	Freq.	**Percent**	**Freq.**	**Percent**	
Young adults (18-25)	21	55.3	17	44.7	38
Adults (26-64)	27	20.9	102	79.1	129
Older adults (65 and above)	1	2.1	46	97.9	47
Total	49	22.9	165	77.1	214
χ^2 value = 34.315**; P-value <0.001					
Gender	**No Hyperglycaemia**		**Hyperglycaemia**		**Total**
	Freq.	**Percent**	**Freq.**	**Percent**	
Male	43	26.7	118	73.3	161
Female	6	11.3	47	88.7	53
Total	49	22.9	165	77.1	214
χ^2 value = 5.348*; P-value = 0.021					
History of DM	**No Hyperglycaemia**		**Hyperglycaemia**		**Total**
	Freq.	**Percent**	**Freq.**	**Percent**	
No	49	26.9	133	73.1	182
Yes	0	0	32	100	32
Total	49	22.9	165	77.1	214
χ^2 value = 11.174**; P-value = 0.001					
EDH	**No Hyperglycaemia**		**Hyperglycaemia**		**Total**
	Freq.	**Percent**	**Freq.**	**Percent**	

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No	15	19.2	63	80.8	78
Yes	34	25.9	102	75.0	136
Total	49	22.9	165	77.1	214
χ^2 value = 0.935^{ns}; P-value = 0.334					
SDH	**No Hyperglycaemia**		**Hyperglycaemia**		**Total**
	Freq.	**Percent**	**Freq.**	**Percent**	
No	28	33.7	55	66.3	83
Yes	21	16.0	110	84.0	131
Total	49	22.9	165	77.1	214
χ^2 value = 9.021**; P-value = 0.003					

Table 4. Association of Intraoperative Hyperglycemia with Age, Gender, History of DM, EH and SDH of the Patients

** Significant at 0.01 level

A significant chi-square value indicates that intraoperative hyperglycemia is significantly associated with increasing age. Percentage analysis shows that among the young adults, 44.7% had intraoperative hyperglycemia. Among the adult population, it was 79.1%, and among older adults, the chance of having intraoperative hyperglycemia was 97.9%. Thus, it was observed that the prevalence of intraoperative hyperglycemia was higher in older adults, aged 65 years and older.

Percentage analysis shows that in females with TBI, 88.7% had intraoperative hyperglycemia. Among males, it was 73.3%. Thus, it was observed that the prevalence of intraoperative hyperglycemia was higher in females.

Intraoperative hyperglycemia is strongly associated with the presence of diabetes mellitus. Percentage analysis shows that in diabetic individuals, 100% had intraoperative hyperglycemia. It was observed that the prevalence of intraoperative hyperglycemia was higher in the diabetic population.

Here the p-value was 0.334, hence the chi square value was found to be nonsignificant. This indicates that there is no significant association between intraoperative hyperglycemia and EDH.

Intraoperative hyperglycemia is significantly associated with SDH. Percentage analysis shows that 84% of the patients who sustained SDH had intraoperative hyperglycemia. Thus, the prevalence of intraoperative hyperglycemia is high in patients with SDH. There is no significant association between intraoperative hyperglycemia and SAH.

GCS Score	**No Hyperglycaemia**		**Hyperglycaemia**		**Z-Value**	**P-Value**
	Median	**Range**	**Median**	**Range**		
Pre-operative	9	7-13	8	5-13	4.154**	<0.001
At ICU discharge	15	13-15	13	11-15	4.295**	<0.001
Variable	**No Hyperglycaemia**		**Hyperglycaemia**		**T-Value**	**P-Value**
	Mean	**SD**	**Mean**	**SD**		
Pre-operative GRBS	131.51	14.67	197.77	63.96	7.185**	<0.001

Table 5. Comparison of GCS among Patients with and without Intraoperative Hyperglycemia

When preoperative GRBS was compared in patients with and without intraoperative hyperglycemia, it was observed that patients with preoperative hyperglycemia had a higher

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chance of developing intraoperative hyperglycemia. A comparison of the GCS score among patients with and without intraoperative hyperglycemia was done using the Mann-Whitney U test. A comparison of the preoperative GRBS value among patients with and without intraoperative hyperglycemia was done using an independent t-test.

Factors	Odds Ratio	95% CL	P-Value
Age ≥ 65	18.555	2.49 - 138.38	0.004
SDH	2.667	1.39-5.12	0.003
Pre GCS ≤ 9	2.903	1.497-5.629	0.002
Pre-operative hyperglycemia	17.657	8.032-38.814	<0.001

Table 6: Odds Ratio for the Independent Risk Factors

Binary linear logistic regression was fitted with each risk factor as an independent variable to find out the odds ratio corresponding to each risk factor.

Thus, it was observed that the following were independent risk factors for intraoperative hyperglycemia: age ≥ 65; BMI ≥ 25; SDH; preoperative GCS ≤ 9; preoperative hyperglycemia.

DISCUSSION

It is estimated that by 2025, India will be the world's "diabetes capital," with 69.9 million diabetics. Diabetes is more severe in low- and middle-income countries.[4]

In our study, the age of the patients ranges from 18 to 76 years, with a mean age of 45.27 and a standard deviation of 17.443. Patients in the age group 26–64 years (adults) contributed to 60.3% of the study population. 22% of the patients were in the age group 65 years and older (older adults), and young adults (18–25 years) constituted 17.8% of the study population.

In our study population, 75% were males and 25% were females. In a cross-sectional longitudinal study by Joseph J. J. et al. at Trivandrum Medical College, out of the 658 patients included in the study, the majority of the subjects belonged to the age group of 30–60 years. About 80% of the subjects were males.[5] In a prospective observational study by Bhattacharjee et al. on the perioperative glycemic status of adult TBI patients undergoing a craniotomy, the mean age of the included patients was 33.9 ± 8.6 years (n = 200), with a male-to-female ratio of 9:2.[6] The age and gender distribution of our study population is consistent with other published data.[5,6,7]

Fifteen percent of the study population were those with diagnosed diabetes mellitus, while the majority were nondiabetic (85%). In the diabetic individuals of the study population, (32 out of 214), 71.875% were on treatment with OHA, 25% were on insulin, and 3.125% were on diet control. Studies from developed nations showed a slightly lower incidence of diagnosed diabetes mellitus. In a retrospective review study in a level 1 trauma center at the University of Alabama at Birmingham, 7.2% of the total patient population had diabetes, which approximates the estimates seen by Kerby et al. when evaluating trauma patients (8.7% of the study population) and the estimates of DM in the United States (9.3% of the population) from the Center for Disease Control and Prevention.[8,9,10]

In our study population, the most common injury sustained was EDH (36.4%), followed by SDH (34.1%). In our study population, 26.6% had sustained a combination of EDH and SDH. 0.5% of the study population had SAH and a combination injury of SDH, EDH, and SAH each. In a prospective observational study by Bhattacharjee et al., extradural hemorrhage had

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the highest frequency (44%), followed by an equal incidence of intracerebral hemorrhage and acute subdural hemorrhage (28% each).[5]

More than half of the study population (54.7%) had a preoperative GCS of ≤ 8. For 42.5% of individuals, preoperative GCS was in the range of 9–12. 2.8% of the study population had a preoperative GCS of 13–15.

After surgery, the mortality rate was 3.3%. Out of 214 study participants, seven expired after surgery. During discharge from the ICU to the ward, the GCS score of 77.3% of live patients was in the range of 13–15. The GCS score of 22.7% of live patients was in the range of 9–12.

The mean preoperative GCS of the study population was 8.52, with a standard deviation of 2.06. The mean GCS at discharge from the ICU to the ward was 13.78, with a standard deviation of 1.3. In a cross-sectional, non-interventional manuscript study of the “Pennsylvania Trauma Outcome Study Database” by Chalouhi N. et al., the proportion of patients who had a GCS score of 3 to 5 (vs. a GCS of 6-8) was significantly higher in level I trauma centers (78.7%, n = 2021) than level II trauma centers (74.4%, n = 1051, p = 0.002). The mean GCS score on admission was significantly lower in level I (3.9±1.6) than in level II centers (4.2±1.7).[11]

In a retrospective cohort study by Herou E. et al., surgically treated patients: median age was 76 years', and their 30-day overall mortality rate was 36%. Higher mortality was seen with a lower level of consciousness, high energy trauma, one pupil fixed and dilated, and more extensive intracranial pathology. Mortality for patients with GCS (Glasgow Coma Scale) 10–15 was 6%, GCS 6–9 67%, and GCS 3–5 100%.[12]

In the study population, the minimum length of ICU stay was one day, and the maximum length of stay in ICU was 14. The mean length of stay in the ICU was 3.18, and the standard deviation was 2.1. In a retrospective multicenter cohort study by P.A. Tardif et al., the average length of the ICU and total hospital stay were 9.1 and 15.8 days, respectively. The median GCS at 24 hours was 10, with 67% improving to GCS 15 by the time of discharge.[13]

Intraoperative hyperglycemia was common in our study population. Out of the 214 study participants, 171 had a GRBS value > 140 mg/dl in either the first or second hour (79.9%). The GRBS value was less than 140 mg/dl in both the first and second hours in 43 participants (20.09%).

In the study population, the minimum preoperative GRBS value noted was 85 mg/dl, and the maximum was 412 mg/dl. The mean preoperative GRBS was 182.6, and the standard deviation was 63.06. The minimum first-hour GRBS value noted was 102 mg/dl; the maximum value was 385 mg/dl. The mean first hour GRBS was 1183.36, and the standard deviation was 61.86. The minimum second-hour GRBS value noted was 109 mg/dl; the maximum value was 358 mg/dl. The mean second-hour GRBS was 170.78, and the standard deviation was 48.06.

In our study population, 69.6% had preoperative GRBS >140 mg/dl. 72% had first-hour GRBS >140 mg/dl. And 64.5% had second-hour GRBS >140 mg/dl. In the study by Bhattacharjee et al. on the perioperative glycemic status of adult TBI patients undergoing a craniotomy, the preoperative capillary blood glucose value was 136.8±11.9 mg/dL, and the one-hour postoperative value was 166.7±11.4 mg/dL.[5]

In our study, we observed that the prevalence of intraoperative hyperglycemia was higher in older adults, aged 65 years and older. It was observed that the prevalence of intraoperative hyperglycemia was higher in the diabetic population. It was also observed from our study that the prevalence of intraoperative hyperglycemia was high in patients with SDH. There was no significant association between intraoperative hyperglycemia and EDH.

There was no significant association between intraoperative hyperglycemia and SAH. It was observed that both preoperative GCS and GCS at discharge from the ICU were lower in

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patients who had intraoperative hyperglycemia. It was observed from our study that patients with preoperative hyperglycemia had a higher chance of developing intraoperative hyperglycemia. These observations were in concurrence with the retrospective cohort study by Travis Pecha et al.[14]

CONCLUSION

The study concluded that intraoperative hyperglycemia was common during emergency craniotomies for traumatic brain injuries. These were independent risk factors for intraoperative hyperglycemia: age ≥ 65 years, SDH, preoperative GCS ≤ 9, pre-operative hyperglycemia.

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