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Original Article

Assessment of Predictive Accuracy of Glasgow Coma Scale Score and Computed Tomography in Acute Traumatic Head Injury

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ABSTRACT

Background- The incidence of acute traumatic head injury is increasing day by day and the most common cause in India is through RTA. These patients when arrive at the emergency department, the quick response of the team to assess the patient and plan further intervention plays a key role in the outcome of the patient.
Materials & Methods- It's an observational study in which all the patients coming to emergency department with acute traumatic head injury are assessed.
Results- The total patients presented to the emergency department were 150 among which 74% were males and 26% females. The patients presented are divided into 3 categories according to GCS - Mild (13-15), Moderate (9-13), Severe (3-8). The CT findings in all these patients is recorded. 30.7% of cases with severe head injury had prolonged hospital stay with surgical intervention, 24% of patients with moderate head injury recovered after the hospital stay and surgical intervention. 45.3% of patients with milder form of head injury did not require prolonged hospital stay or surgical intervention.
Conclusion- GCS is a very accurate scoring system which helps in early prediction of outcome of patient. CT scan has a crucial role in assessing the surgical outcome of the patient.

***Keywords**: GCS – Glasgow Coma Scale, CT – Computed Tomography, TBI – Traumatic Brain Injury.*

INTRODUCTION

Any structural skull injury caused due to trauma or external force may be mechanical, electrical or thermal heating, which leads to changes in cerebral physiology called as Traumatic brain injury (TBI).[1] Traumatic brain injury is one of most common cause of death in road traffic accidents.[4] In India more than 100,000 people die every year due to head injury with more than a million cases reported of serious head injury. Most common and important complication of traumatic head injury is the development of an increased intracranial pressure resulting in midline shift. The larger the amount of the midline shift on CT scan the poorer will be the outcome of traumatic head injury. [9 18] For the assessment of patient with acute brain injuries, 02 most common modalities are available i.e. 1. Glasgow coma scale (GCS) 2. Brain Imaging. The GCS score range between 03 and 15. It involves evaluation of 03 components eye, verbal, and motor response, final scoring is done by totalling all individual components. [10,11] Based on GCS Score, degree of head injury can be scored as mild (GCS score 13–15), moderate (GCS score 09–12), and severe (GCS score 08-03). GCS score has been widely used to predict prognosis of the patient in brain injuries. [10,11] Computed tomography (CT) is recommended for the initial assessment in the emergency services for trauma patients. The optimal point for performing Computed tomography (CT) scan for early detection of neurological lesions will be useful in achieving the positive clinical outcome and preventing the unwarranted. [3,14,15] The initial evaluation of TBI is essential in determining prognosis and guiding treatment decisions. Among the tools available for assessing brain injury severity, the Glasgow Coma Scale (GCS) and computed tomography (CT) imaging are central to clinical practice. The GCS provides a standardized approach to assess a patient's level of consciousness, while CT imaging delivers detailed anatomical views of intracranial pathology. While CT scans offer significant benefits, particularly in detecting brain lesions early in patients with head trauma, this imaging may not be available in all settings and can be contraindicated in certain conditions. Keeping this situation in mind, the present study is planned at tertiary care centre which aimed to assess the predictive accuracy of Glasgow Coma Scale score and Computed Tomography in acute traumatic head injury.

AIMS and OBJECTIVES:

AIM To assess the predictive accuracy of GCS score and CT in acute traumatic head injury OBJECTIVES 1. To assess the predictive accuracy of GCS score in acute traumatic head injury. 2. To assess the predictive accuracy of CT in acute traumatic head injury. 3. To compare predictive accuracy of GCS score and CT in acute traumatic head injury.

MATERIALS AND METHODS

The present study titled "Assessment of predictive accuracy of Glasgow Coma Scale score and Computed Tomography in acute traumatic head injury" was conducted as an observational study on patients with acute traumatic head injury at the Department of Surgery, People's College of Medical Sciences & Research centre and associated People's Hospital, Bhopal. Study Design: Observational study. Study Period: 1st May 2023 to 1st April 2025 Subject Recruitment period: 1st May 2023 to 31st Oct 2024 Source of Data: All head injury patients coming to the emergency department of People's College of Medical Sciences, Bhopal Sample Size: 150. Place of Study: People's Hospital associated with People's College of Medical Sciences & Research Centre, Bhopal. Inclusion Criteria: ¬ All traumatic head injury patient more than 12 years of age admitted in Department of Surgery ¬ All patients who had initial Computed Tomography (CT) scan after head injury. ¬ Patients who are willing to take part in the study and gave written consent.

Exclusion Criteria: ¬ Age less than 12 years ¬ Pregnancy, ¬ Patient having history of neurological deficit without trauma, and ¬ Patients who are non-willing to take part in the study CONSENT- Written consent was obtained from all the study participants in a consent sheet after explaining them the purpose and details of the study using participant information sheet. After taking written consent from the patient, the detailed information about each patient including name, age, sex, address, presenting complaints, duration of traumatic injury, general examination, local examination, stating site, size and other characteristics of head injury were retrieved from records and noted in a prescribed proforma. Patients were subjected to regular clinical examination, local examination, assessment of unconscious patient, GCS, CT scan finding. Statistical Analysis: Data was compiled using Ms Excel and analysis was done with the help of IBM-SPSS (Statistical Package for the Social Sciences) PC-version. 20. Categorical data was expressed as frequency and proportion whereas continuous data was expressed as mean and standard deviation. Statistical differences between the proportions were tested by Chi square test or Fisher's exact test. 67 Spearman's correlation coefficient was used to see the correlation between GCS score, duration of hospitalization, and outcome. p' value < 0.05 was taken as statistically significant.

Figure

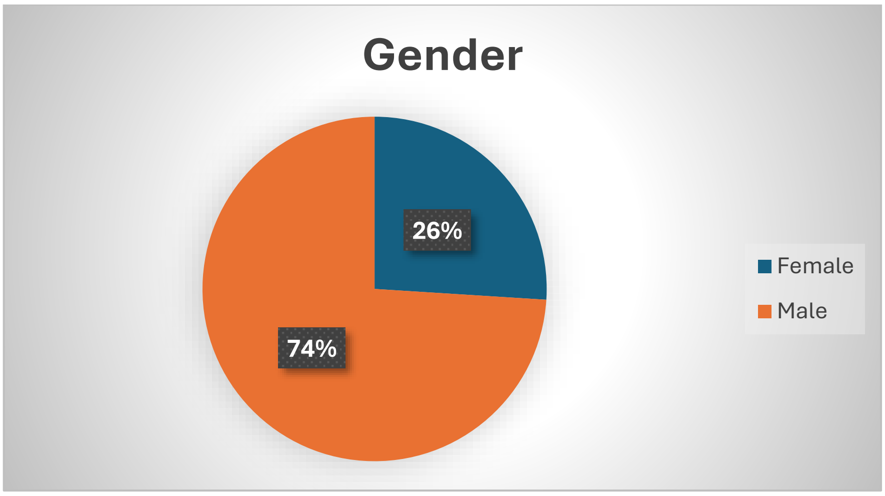


Fig.1 Distribution of Gender of the Participants: In our study, 39 (26%) participants were female while 111 (74%) were male.

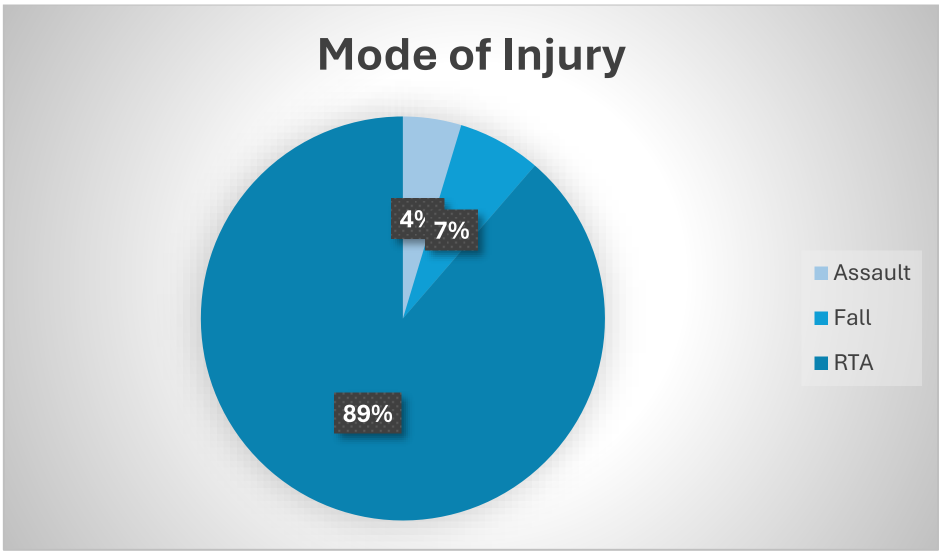


Fig.2 Distribution of Mode of Injury: Maximum participants had a history of Road Traffic Accident 133 (88.7%) , followed by Fall from height (6.7%) and assault 7 (4.7%).

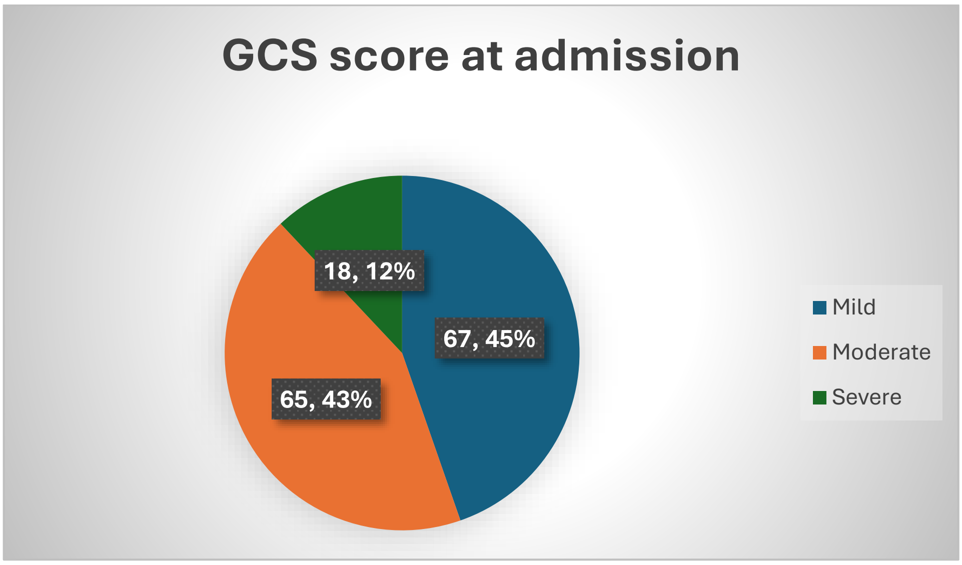


Fig. 3 Distribution of GCS Score at the time of admission: Mean GSC Score at the time of admission was found to be 7.13±2.570 (3-15). 67 (44.7%) patients having mild GCS score (13 -15) while 18 having severe GCS score (08 -03).

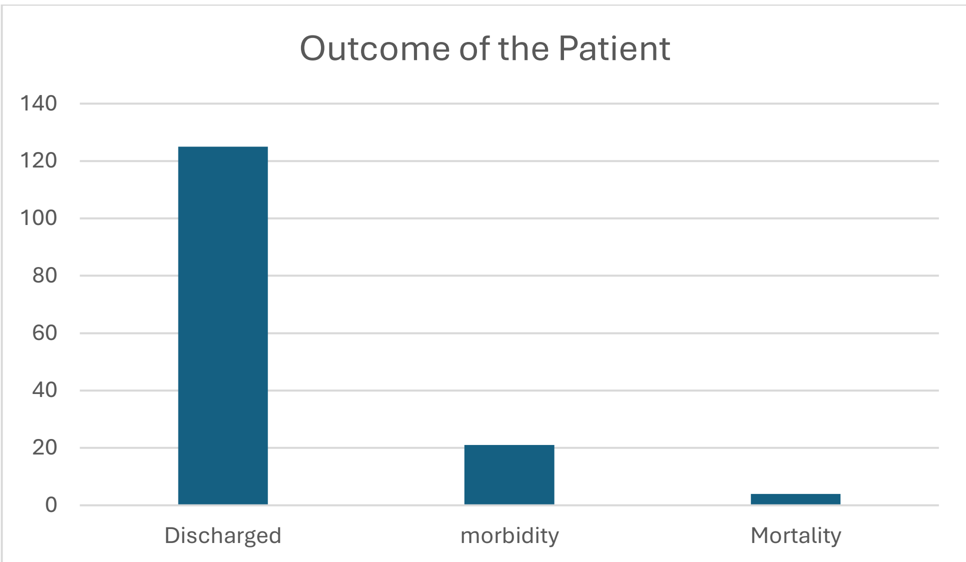


Fig.4 Distribution of Outcome of the Patients: 125 (83.3%) patients were discharged while 4 (2.7%) patients died during treatment.

Tables

1 Table 1. Association between Severity of GCS Score and outcome of the patient: There is a strong association between the severity of GCS score and patient outcomes. Mild GCS patients have the best recovery rates, while severe GCS patients have the highest morbidity and mortality. Patients having moderate GCS scores had mixed outcomes, with some experiencing morbidity but no deaths. These differences are statistically significant (p = 0.001), indicating that severity of GCS score is good predictor of patient outcomes. ($\chi 2$ = 84.080, p= 0.001).

S.NO	Severity of GCS Score	Outcome of the patients			
		Discharged	Morbidity	Mortality	χ^2 = 84.080, p= 0.001 df = 04
1	Mild	67	0	0	
2	Moderate	58	07	00	
3	Severe	0	14	4	
		125	21	04	

2. Table 2 Association between Severity of CT Scan and

S.NO	Severity of CT Scan	Days of Admission					
		00-05 Days	06-10 Days	11-15 days	16-20 days	More than 20 days	
1	Mild	57	9	1	1	0	χ^2 = 67.949, p= 0.001 df= 08
2	Moderate	19	15	2	0	0	
3	Severe	9	11	9	12	5	
Total		85	35	12	13	5	

Duration of hospitalization:

Patients with mild injuries had the shortest hospital stays, with 57 out of 68 (83.8%) discharged within 5 days. Moderate cases had slightly longer hospitalizations, with 15 out of 36 (41.7%) staying 6-10 days. Severe cases had the longest hospitalizations. 17 out of 46 (37%) stayed more than 10 days and 5 (11%) patients required over 20 days of hospitalization. This difference is found to be statistically significant. (χ^2 = 67.949, p= 0.001).

3. Table 3. Corelation Between GCS score at admission, Outcome of the patient, Severity of GCS score, severity of CT scan and Days of Hospitalisation

S. No.		GCS score at admission	Severity of GCS score	Severity on CT scan	Outcome	Days of hospitalization
1	GCS score at admission	1	r = -0.909 p = 0.001	r = -0.710 p = 0.001	r = -0.815, p = 0.001	r = -0.700 p = 0.001
2	Severity of GCS score	r = -0.909 , p = 0.001	1	r = -0.661, p = 0.001	r = - 0.676 p = 0.001	r = 0.665 p = 0.001
3	Severity on CT scan	r = - 0.710 p = 0.001	r = - 0.661 p = 0.001	1	r = - 0.564 p = 0.001	r = 0.659 p = 0.001
4	Outcome	r = - 0.815 p = 0.001	r = -0.676 p = 0.001	r = - 0.564 p = 0.001	1	r = 0.505 p = 0.001
5	Days of hospitalization	r = -0.700, p = 0.001	r = 0.697 p = 0.001	r = 0.659 p = 0.001	r = 0.505 p = 0.001	1

Lower GCS scores at admission predict more severe brain injury (r = -0.909, p = 0.001), worse outcomes (r = -0.815, p = 0.001) and longer duration of hospital stay. (r = -0.700, p = 0.001). Findings on CT scans also correlate with the outcome of the patient and duration of hospitalization. These relationships are statistically significant (p = 0.001), suggesting strong evidence for this correlation.

Table 4: Predictive Accuracy of CT Scan And GCS Scores:

S.NO	GSC Severity	CT scan			Total
		Mild	moderate	Severe	
1	Mild GCS	51	12	04	67
2	Moderate GCS	17	24	24	65
3	Severe GCS	0	0	18	18
Total		68	36	46	150

For Severe head injury, GCS ≤8 and considering Severe CT findings as True value of Positive, and mild and moderate considered as negative finding.

So,

- True positive = 18
- False Negative = 00 (where Severe GCS was misclassified as Mild or Moderate CT.)
- False Positive = 4+24 =28 (Mild or Moderate GCS were incorrectly classified as Severe CT.)
- True Negative = 104 (Mild or Moderate GCS were correctly classified as Mild or Moderate CT.)

Sensitivity (True Positive Rate) = TP÷(TP+FN)*100
= 18 ÷(18+00)
= 100%

Specificity (True Negative Rate) = TN÷(TN+FP)*100
= 104 ÷ (104 + 28) *100
= 78.78%

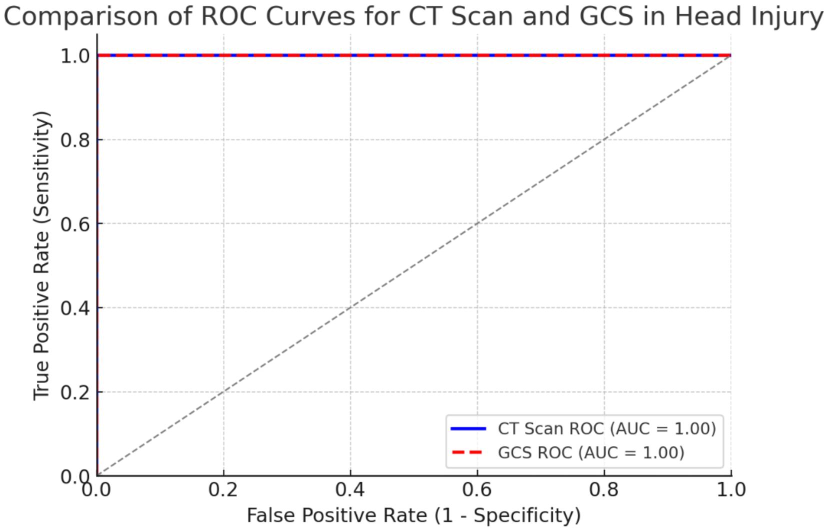
Positive Predictive Value = TP÷(TP+FP)*100
= 18 ÷(18+28)
= 39.13%

Negative Predictive Value = TN ÷ (TN+FN)*100
= 104 ÷(104+0)
= 100%

Accuracy = (TP+TN) ÷ (TP+FP+TN+FN)*100
= (18+104) ÷ (18+28+104+00) *100
= 81.33%

CT scan correctly detects all severe cases. Severe GCS cases correctly identified as Severe CT. All non-severe CT cases were truly non-severe, meaning CT never misses a severe case . CT correctly classifies head injuries in 81.3% of cases. CT scan correctly identifies non-severe cases 78.8% of the time, but some false positives exist. Only 39.1% of cases classified as Severe CT were actually severe (GCS≤ 8) . This indicates a high false positive rate, meaning CT inclines to overestimate severity.

Table.5 ROC Curve for GCS Score and CT Scan in Acute Head Injury :



CT Scan has an AUC of 0.81 while GCS has an AUC of 0.87. Mean AUC difference ~0.0 showing nearly identical predictive accuracy with p= 0.004 (statistically significant at $p < 0.05$).

GCS have slightly higher accuracy that CT scan (higher AUC), slightly better at predicting severe head injury However, the absolute difference is negligible, meaning both methods are comparable in predictive ability.

DISCUSSION

Demographic Profile: In the present study, the mean age of the participants is 34.34 ±14.593 years (14-75 years). Similar findings were reported by Similar findings were reported by Maas et al.59, Tagliaferri et al. 60, Roozenbeek et al. 62, and

Andriessen et al. 61 where mean age is between 30 to 45 years showing adult population is mostly affected by brain injury. In our study, 39 (26%) participants were female while 111 (74%) were male.fig.1. It has male predominance with 74% male having acute brain injury. Similar findings were reported by Similar findings were reported by Maas et al.59, Tagliaferri et al. 60, Roozenbeek et al. 62 , A.K.Chaurasia, et.al.4 and Andriessen et al. 61 reflecting association between risk taking behaviour of male and acute brain injuries. Mode of Injury: In our study, maximum participants had a history of Road Traffic Accident 133 (88.7%) , followed by Fall from height (6.7%) and assault 7 (4.7%). fig.2. Fall from height is very less as compared to findings of Tagliaferri et al.60 where fall is leading cause of acute brain injury. RTA as most common cause for acute brain injury was also reported by Maas et al. 59 (60%) , Myburgh et al. 63 (54%) , Peeters et al. (45%) where RTA is most prevalent cause of acute brain injury. Our study has highest number of RTAs i.e. 88.7%, indicating selection 89 bias as our study centre is tertiary care trauma centre and situated in urban area. Findings of the CT Scan: Cerebral contusion was the most common finding on CT scan in our study as reported by many studies such as Maas et al.59 (40%) Gentry et al. 65 (43%) , Raj et al.66 (35%)., Kumar S et.al 5 (50%). These findings are consistent with the findings of our study. Presence of Extra dural haemorrhage and Sub Dural Haemorrhage on CT Scan in our study was similar to findings of Gentry et al.65 , Maas et al.59 and Raj et al. 66 but Raj et al. 66 and Kumar S et.al 5 reported higher percentage of SDH 25% and 22% respectively. Presence of midline shift is almost similar to the findings of the other studies such as Marshall et al.48 and Raj et al. 66 but not as compared to the A.K.Chaurasia, et.al.4 who reported 76 % patients with no midline shift. Severe injury like Diffuse Axonal Injury was present in 10 (6.7%), which was lower as compared to Maas et al. 59 (15%) and Gentry et al. 65 (19%). This difference is might be due to difference in the sensitivity of the imaging. GCS Scores :fig.3. Hossein Nayebaghayee, et.al 3 reported 80.25% having mild GCS scores . Mild GCS in our study is in accordance with the findings of Maas et al. 59 where 40% cases having mild GCS score . 90 Mean GCS score of our study is 7.13±2.570 indicating moderate to severe cohort but it has only 18 (12%) patients with severe GCS score , which is similar to the findings of Hossein Nayebaghayee, et.al 3 (9% had GCS>8) This contrast the findings of many studies such as Maas et al. 59 (30%), Teasdale et al. 67 (30%) , Hukkelhoven et al.68 (35%) and Myburgh et al. 63 (40%). The difference is might be due to smaller sample size and selection bias. Management of the patient : Conservative management of the patient was the most common 112 (74.7%) in our study. Similar results were reported by Patel et al. 69(70%) Myburgh et al. 63 (74%) , Stocchetti et al. 70 (60%) . This similarity is due to large number of mild head injuries. Craniotomy was performed in 21.3% of cases , similar to Maas et al. 59 (20%), Patel et al.69 (18%) and Myburgh et.al. 63 (25%). It aligns with severe CT findings in our study. VP Shunting is not usually done as trauma surgery but in our study , there was one case with intra cranial bleed sub arachnoid haemorrhage and enlarged lateral ventricles, due to which VP shunting was performed. Outcome of the patients : In our study, 125 (83.3%) patients were discharged while 4 (2.7%) patients died during treatment.fig.4. Death rate in our study is remarkably lower as compared to other studies Maas et al. 59 (15%) 91 Tagliaferri et al. 60 (19%) , Hukkelhoven et al. 68 (26%), Myburgh et al.63 (17%). This difference in death rate is suggesting better outcome possibly due to effective management and more number of mild to moderate cases of head injury . The severity of GCS score and CT scan can predict the outcome of the patient and it is statistically significant as reported in present study. (χ^2 = 84.080, p=0.001), and χ^2 =62.101, p=0.001). Similar strong correlation and associations (p=0.001) were reported by Maas et al. 59 , Teasdale et al. 67 Hukkelhoven et al. 68 and Raj et al. 66. Days of hospitalization: Mean days of hospitalization was found to be 7.13±5472 days in our study. It indicates large number of milder injuries and higher discharge rates. Stocchetti et al. 70 and Peeters et al. 64 also reported similar stay at hospital 10 days and 09 days respectively reflecting milder cases of head injury. Raj et al. 66 and Andriessen et al. 61 had higher mean of days of hospitalization as they have more number of severe cases while our study has only 12% of severe cases. That explains the difference in mean days of hospitalization. Predictive Accuracy : The present study reported AUC for GCS 0.87 is slightly higher than CT 0.81, with very small but significant difference (p=0.004). These results are similar to findings of Maas et al.59 (AUC 0.75–0.85 92) Yuh et al. 57 (AUC = 0.80) , Raj et al. 66 (CT AUC = 0.83, GCS AUC = 0.86.) Mata-Mbemba et al. 52 reported contrasting finding to our study. (CT AUC 0.78) Sensitivity (100%) reported in our study is better than Yuh et al. 57 (90%) while specificity of both study is almost similar at 80%.

CONCLUSION

This study provide a comprehensive analysis of the demographic, clinical, and radiological profiles of patients with acute head injuries. The result of the study showed that majority of the affected population are young male adults with mean age of 34 .34 years. Male are more susceptibility to head injury. Road traffic accidents (88.7%) are the predominant cause of injury highlighting the serious need for improved road safety measures and public awareness initiatives to prevent traumatic brain injuries (TBI). On radiological assessment of the patients using CT scan show that that cerebral contusion and oedema are the most frequently observed findings (30.7%), while extra-dural hematomas (EDH) and sub-dural hematomas (SDH) account for 17.3% each. Severe forms of injury like Diffuse axonal injury (6.7%),also observed. 45.3% of patients having mild injury , while 30.7% present with severe injuries. Mild CT findings correspond to better prognoses, whereas severe CT findings are linked to higher morbidity and mortality rates. GCS scores indicate that 44.7% of patients suffer from mild TBI, 43.3% from moderate TBI, and 12% from severe TBI. There is strong statistical association (p = 0.001) between GCS severity, days of hospitalization and patient outcomes which affirms the reliability of GCS as a prognostic tool for head injuries. 95 Conservative management is the preferred modality (74.7%), followed by craniotomies (21.3%) and tracheostomies (2.7%) for more severe cases. Patient outcomes show that 83.3% of individuals recover and are discharged, while morbidity and mortality rates stand at 14% and 2.7%, respectively. These results emphasize the efficacy of appropriate medical and surgical interventions in improving patient survival and minimizing complications. ROC curve analysis shows that both GCS and CT scans serve as effective predictive tools for severe head injuries. While CT scans exhibit an accuracy of 81.3%, they tend to overestimate severity, with a 100% sensitivity rate ensuring that no severe cases go undetected. In conclusion, this study highlights the vital role of early assessment using GCS and CT scans in predicting patient outcomes accurately. The strong correlation between injury severity and clinical prognosis reinforces the importance of timely medical intervention. Preventive measures, including enhanced road safety regulations, public education on accident prevention, and immediate medical response, are essential in mitigating the impact of traumatic brain injuries. Future research should focus on refining predictive models, identifying additional diagnostic markers, and improving treatment protocols to optimize patient care and recovery.

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REFERENCES

1. Rincon-Guio C. The role of computed tomography as a prognostic tool in traumatic brain trauma. Hospital. 1971 Oct.
2. Roy CW, Pentland B, Miller JD. The causes and consequences of minor head injury in the elderly. Injury. 1986;17:220-3.
3. Nayebaghayee H, Afsharian T. Correlation between Glasgow Coma Scale and brain computed tomography scan findings in head trauma patients. Asian J Neurosurg. 2016;11:46-9.
4. Chaurasia AK, et al. Int Surg J. 2021;8(10):3075-80.
5. Kumar S, Kardam NK, Gahlot K Babu, Maharia MS. A study on correlation of degree of midline shift on CT scan and Glasgow Coma Scale in patients of acute traumatic head injury. Int J Med Biomed Stud [Internet]. 2020 Aug 27.
6. Available from: https://emedicine.medscape.com/article/433855 overview#a4
7. Byass P, de Courten M, Graham WJ, et al. Reflections on the global burden of disease 2010 estimates. PLoS Med. 2013;10:1477.
8. Stein SC, Narayan RK, Wilberger JE, Povlishock JT. Classification of head injury. In: Neurotrauma. New York: McGraw-Hill; 1996. p. 31 41.
9. Azian AA, Nurulazman AA, Shuaib L, Mahayidin M, Ariff AR, Naing NN, et al. Computed tomography of the brain in predicting outcome of traumatic intracranial haemorrhage in Malaysian patients. Acta Neurochir (Wien). 2001;143(7):711-20. 100
10. Kumar VA, Bhandarkar P, Roy N, Kumar V, Kamble J, Agrawal A. Predictive value of Glasgow Coma Score and its components in interpreting outcome in trauma patients. J Datta Meghe Inst Med Sci Univ. 2019;14:94-8.
11. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet. 1974;2:81-4.
12. Hassan Z, Smith M, Littlewood S, et al. Head injuries: A study evaluating the impact of the NICE head injury guidelines. Emerg Med J. 2005;22:845-9.
13. Metting Z, Rödiger LA, De Keyser J, et al. Structural and functional neuroimaging in mild to moderate head injury. Lancet Neurol. 2007;6:699-710. a. Bricolo AP, Pasut LM. Extradural hematoma: Toward zero mortality. A prospective study. Neurosurgery. 1984;14:8-12.
14. Teasdale G, Galbraith S, Murray L, Ward P, Gentleman D, McKean M. Management of traumatic intracranial haematoma. Br Med J (Clin Res Ed). 1982;285:1695-7.
15. Snell RS. Snell's Clinical Neuroanatomy. South Asian ed. New Delhi: Wolters Kluwer; 2021. p. 9-482.
16. Marshall LF, Gautille T, Klauber MR, Koepfler S, Frankowski RF, Luerssen TG, et al. The outcome of severe closed head injury. J Neurosurg. 1992;75(Suppl):S28-36.
17. Maas AIR, Hukkelhoven CW, Marshall LF, Steyerberg EW. Prognostic value of the Rotterdam CT score in traumatic brain injury. Neurosurgery. 2005;57(6):1173-82.
18. Maas AIR, Marmarou A, Murray GD, Teasdale SG, Steyerberg EW. IMPACT recommendations for improving outcome prediction in traumatic brain injury. Acta Neurochir (Wien). 2007;149(10):1027 35.
19. Mata-Mbemba D, Mugikura S, Nakagawa A, Murata T, Kato Y, Tatewaki Y, et al. CT predictors of outcome in traumatic brain injury: Comparison of Marshall and Rotterdam CT scoring systems in a university hospital in Japan. AJR Am J Roentgenol. 2018;211(3):678-85.
20. Firsching R, Woischneck D, Diedrich M, Döhring W, Behrens Baumann W, Skalej M. Early CT findings in predicting outcome in traumatic brain injury. Acta Neurochir (Wien). 2001;143(10):1037 41. 105
21. Chieregato A, Fainardi E, Servadei F, Tanfani G, Targa L, Taylor GS, et al. Normal computed tomography scans in severe head injury: A marker of occult pathology? Crit Care. 2016;20(1):123.
22. Lee B, Newberg A. Neuroimaging of traumatic brain injury. Am J Neuroradiol. 2015;36(6):1164-9.
23. Brenner DJ, Hall EJ. Computed tomography—An increasing source of radiation exposure. N Engl J Med. 2007;357(22):2277-84.
24. Yuh EL, Mukherjee P, Lingsma HF, Yue JK, Ferguson AR, Gordon WA, et al. Magnetic resonance imaging improves detection of traumatic brain injury missed by computed tomography. Ann Neurol. 2013;73(2):224-35.

25. Servadei F, Teasdale G, Merry G. Defining the evolving brain lesion after head trauma. Neurosurgery. 2001;48(4):699-706.
26. Maas, A. I., Hukkelhoven, C. W., Marshall, L. F., & Steyerberg, E. W. (2007). Prediction of outcome in traumatic brain injury with computed tomographic characteristics: A comparison of the Marshall and Rotterdam classifications. The Lancet Neurology, 6(5), 413–422. DOI:10.1016/S1474-4422(07)70089-8
27. Tagliaferri, F., Compagnone, C., Korsic, M., Servadei, F., & Kraus, J. (2006). A systematic review of brain injury epidemiology in Europe. 106 Journal of Neurology, Neurosurgery & Psychiatry, 77(3), 323–330. DOI:10.1136/jnnp.2005.071944
28. Andriessen, T. M., Horn, J., Franschman, G., van der Naalt, J., Haitsma, I., Jacobs, B., ... & Vos, P. E. (2011). Epidemiology, severity classification, and outcome of moderate and severe traumatic brain injury: A prospective multicenter study. Journal of Neurotrauma, 28(10), 2019–2031. DOI: 10.1089/neu.2011.2034
29. Roozenbeek, B., Maas, A. I., & Menon, D. K. (2013). Changing patterns in the epidemiology of traumatic brain injury. Critical Care Medicine, 41(9), 2057–2063. DOI: 10.1097/CCM.0b013e3182a0e473
30. Myburgh, J. A., Cooper, D. J., Finfer, S. R., Venkatesh, B., Jones, D., Higgins, A., ... & Bellomo, R. (2008). Epidemiology and 12-month outcomes from traumatic brain injury in Australia and New Zealand. Critical Care Medicine, 36(4), 1070–1077. DOI: 10.1097/CCM.0b013e3181684cd4
31. Peeters, W., van den Brande, R., Polinder, S., Brazinova, A., Steyerberg, E. W., Lingsma, H. F., & Maas, A. I. (2015). Epidemiology of traumatic brain injury in Europe. Journal of Neurotrauma, 32(20), 1579–1587. DOI: 10.1089/neu.2014.3814 107
32. Gentry, L. R., Godersky, J. C., & Thompson, B. (1988). MR imaging of head trauma: Review of the distribution and radiologic features of traumatic lesions. American Journal of Roentgenology, 150(3), 663–672. DOI: 10.2214/ajr.150.3.663
33. Raj, R., Siironen, J., Skrifvars, M. B., Hernesniemi, J., & Kivisaari, R. (2014). Predicting outcome in traumatic brain injury: Development of a novel computerized tomography classification system (Helsinki CT score). Neurosurgery, 75(6), 632–646. DOI:10.1227/NEU.0000000000000521
34. Teasdale, G., Maas, A., Lecky, F., Manley, G., Stocchetti, N., & Murray, G. (2014). The Glasgow Coma Scale at 40 years: Standing the test of time. The Lancet Neurology, 13(8), 844–854. DOI: 10.1016/S1474-4422(14)70120-6
35. Hukkelhoven, C. W., Steyerberg, E. W., Rampen, A. J., Farace, E., Habbema, J. D., Marshall, L. F., ... & Maas, A. I. (2005). Patient age and outcome following severe traumatic brain injury: An analysis of 5,600 patients. Journal of Neurosurgery, 102(3), 424–433. DOI:10.3171/jns.2005.102.3.0424 108
36. Patel, H. C., Bouamra, O., Woodford, M., King, A. T., Yates, D. W., & Lecky, F. E. (2005). Trends in head injury outcome from 1989 to 2003 and the effect of neurosurgical care: An observational study. The Lancet, 366(9496), 1538–1544. DOI: 10.1016/S0140-6736(05)67626-X
37. Stocchetti, N., Furlan, A., & Volta, F. (2007). Hypoxemia and arterial hypotension at the accident scene in head injury. Critical Care Medicine, 35(4), 1041–1047. DOI: 10.1097/01.CCM.0000259528.10429.5B