Validity of Glasgow Coma Scale - Pupil Age Charts in Predicting The Outcome for Patients with Traumatic Brain Injury

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ABSTRACT

Context: Glasgow Coma Scale (GCS) is considered a cornerstone of neurological assessment to distinguish the prognosis of traumatic brain injury patients.

Aim: This study aimed to examine the validity of the Glasgow coma scale - Pupil Age charts in predicting outcomes for patients with traumatic brain injury.

Methods: Descriptive exploratory research design was utilized to conduct this study at El-Fayoum University Hospitals and EL-Nabawi Mohandas General hospital in the Neurosurgical intensive care unit and neurosurgical inpatients ward. This research included a purposive sample of 100 adult patients with Traumatic Brain Injury using three tools for assessment. They were the patient's profile data form, the Glasgow Coma Scale - Pupil Age Charts, and the Glasgow outcome scale. Criterion validity with its two types of predictive validity and concurrent validity was used to validate GCS-Pupil Age charts.

Results: The study shows that the Glasgow Coma Scale-Pupil Age Chart is valid in predicting outcomes in patients with traumatic brain injury patient with the best cut-off value of $\le$10.50, a sensitivity of 91.5%, and a specificity of 98.1%, while the Glasgow Coma Scale with the best cut off value $\le$9.50, sensitivity 87.2%, and specificity of 94.3%. Glasgow Coma Scale-Pupil Age Charts and Computed tomography findings are valid in predicting outcomes following traumatic brain injury.

Conclusion**:** Glasgow Coma Scale-Pupil Age Charts and computed tomography finding chart are valid in predicting outcomes following traumatic brain injury. The current study recommended developing an educational program for nurses working in intensive care units about GCS and GCS- PA charts to assess traumatic brain injured patients. Besides, encouraging the use of GCS- PA charts in the emergency unit and neurosurgical intensive care unit to predict patient outcomes and plan the care for traumatic brain injury patients. Designing the clinical pathway for traumatic brain-injured patients from admission until discharge considering age, pupil reactivity response, and CT findings.

Keywords: Validation, traumatic brain injury, Glasgow coma scale - pupil age, prediction

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1. Introduction

Traumatic brain injury (TBI) is a unique problem within the medical, social, and economic communities, with different challenges in the developing world. The burden of TBI is extremely large, with an incidence among around 10 million persons worldwide, 13 million in Europe and North America alone, and up to 14,000 trauma deaths per day *(Wells et al., 2021).*

The incidence of TBI is estimated to be 939 in 100,000 worldwide, with the major causes being falls, vehicle accidents, wars, and sports. The mortality rate of TBI worldwide is estimated to be between 7% and 23%, with 90% of TBI-related deaths occurring in developing countries. Additionally, TBI imposes an economic burden where its annual global cost reaches 400 billion dollars *(Ismail et al., 2020).*

Traumatic brain injury continues to be a major cause of mortality and morbidity worldwide. Sixty-nine million individuals worldwide are estimated to sustain a TBI from all causes yearly, with a disproportionate burden in low- and middle-income countries. Moreover, 60 percent of patients with severe TBI either die or survive with severe disability *(Ginalis et al., 2022).*

The World Health Organization estimates that there were 1.35 million deaths from road traffic accidents in 2016 and that the number is increasing yearly *(Taylor et al., 2019).*

The Glasgow Coma Scale (GCS) is the most widely used scale for assessing neurological status in patients with traumatic brain injury. The GCS was introduced in 1974 by Teasdale and Jennett; it has three aspects of behavioral response to external stimulation: Eye-opening, motor reaction, and verbal response *(Majdan et al., 2015).*

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The Glasgow coma scale is the cornerstone tool for the neurological assessment of patients used by nursing and medical staff. The GCS establishes and provides a patient's baseline information on traumatic head injuries. Reporting that assessment of consciousness was part of the daily routine for the nurses working in clinical settings, with an estimated median frequency of six times per shift *(Ehwarieme et al., 2021).*

Besides the GCS, assessment of pupils' reactivity is another standard procedure of neurological evaluation. Acute pupil dilatation in head-injured patients indicates a neurological emergency. Traditionally was thought to be caused by uncal herniation due to brain edema or a mass lesion that led to pupil dilatation or due to a decrease of the blood flow to the brain stem and resulting in brain stem ischemia *(Majdan et al., 2015).*

The GCS Pupils Age prognostic charts provide a simple graphical presentation of the probabilities of outcome following traumatic brain injury based on GCS, pupil reactivity, age, and computed tomography (CT) scan findings. They were developed by Gordon Murray, Paul Brennan, and Graham Teasdale *(Murray et al., 2018).*

Intracranial lesions can be detected aided by computed tomography scanning even before appearing clinical manifestations for early detection of neurological lesions that achieve the appropriate clinical outcome and prevent unnecessary interventional treatments *(Nayebaghayee & Afsharian, 2016).*

Nurses play an important role in providing care to patients with a head injury, beginning with the assessment and monitoring that require using the GCS correctly from the time of admission to discharge, which includes assessing the level of consciousness with the help of the Glasgow Coma Scale, monitoring of vital signs and signs of increased intracranial pressure; the provided care demands specialized skills and knowledge to effectively perform the GCS observations *(Kumar, 2015).*

2. Significance of the study

Traumatic brain injury is one of the causes of death worldwide. It is estimated that one and a half million people die due to TBI each year, and millions of people need emergency treatment for TBI. Unfavorable consequences of TBI are about 20%. Determining the severity of TBI is the first guideline for treatment and prediction of the outcome of trauma *(Gorji et al., 2015).*

Egypt recorded 11,098 traffic accidents in 2017, marking a 24.6 % decrease compared to 14,710 accidents in 2016. Those accidents resulted in the death of 3,747 people and the injury of 13,998, according to the 2017 report released by the Central Agency for Public Mobilization and Statistics *(CAPMAS, 2018).*

Prediction of death and functional outcomes is essential for determining treatment strategies and allocation of resources for patients with traumatic brain injury *(Emami et al., 2017).* Using the GCS score for assessing the level of injury may not be sufficient; thus, considering the pupil reaction, patient age, and CT findings as the gold standard could give more precise prognostic information regarding outcomes in those patients than using either alone *(Nayebaghayee & Afsharian, 2016; Brennan et al., 2018).*

So, this study might help validate the Glasgow Coma Scale by considering three additional factors: Pupil reactivity, patient age, and CT findings.

3. Aim of the study

This study aimed to examine the validity of the Glasgow coma scale - Pupil Age charts in predicting outcomes for patients with traumatic brain injury.

3.1. Research question

Is Glasgow coma scale - Pupil Age charts valid in predicting outcomes in patients with traumatic brain injury?

3.2. Conceptual definition

Glasgow coma scale - Pupil Age chart is the Glasgow coma scale minus pupil reaction score and considers a patient's age as a prognostic evaluation of traumatic brain injury patients.

4. Subjects & Methods

4.1. Research Design

A descriptive exploratory design was utilized to achieve the aim of the study. Descriptive research is a type of quantitative research which an appropriate choice when the research aim is to identify characteristics, trends, and categories. While exploratory research is a methodological approach that investigates research questions that have not been studied in depth and are used when the issue is new or when the data collection process is challenging for some reason *(Scribbr, 2020).*

Criterion validity (with its two types of predictive validity and concurrent validity) was used to validate GCS-Pupil Age. Criterion validity is evidence that a survey instrument can predict existing outcomes. Criterion validity is split into two different types of outcomes: Predictive validity and concurrent validity. If the outcome of interest occurs sometime in the future, then predictive validity is the correct form of criterion validity evidence. If the outcome occurs simultaneously, then concurrent validity is correct. The outcome is the criterion, and the survey instrument is correlated to that outcome/criterion *(Heidel, 2022).*

4.2. Study setting

The study was conducted at El-Fayoum University Hospitals and EL-Nabawi El Mohandas General hospital in Fayoum governorate in the neurosurgical intensive care unit and neurosurgical inpatients ward. El-Fayoum University Hospitals: Neurosurgical intensive care unit is on the second floor and consists of a large room with six beds, a supplies store, and two bathrooms. Besides, the neurosurgical inpatients' ward on the fourth floor consists of two large partitions, one for male and the other for female patients, with twenty beds.

Furthermore, The EL-Nabawi Mohandas General Hospital's neurosurgical intensive care unit is on the first floor. It consists of a large room with six beds, manager offices, a supplies store, two bathrooms, and one nurse locker. In addition, the neurosurgical inpatient ward on the second floor consists of two large partitions, one for male patients and another for female patients, with a total of thirty beds

4.3. Subjects

A purposive sample of 100 adult patients who were diagnosed with TBI. Patients with TBI were recruited in this study according to certain inclusion criteria: Adult male and female patients > 18 years old with different levels of TBI (mild, moderate, and severe injury). Patients were excluded if they had a history of a pre-existing chronic disease (diabetic ketoacidosis coma, hepatic, & uremic coma) or had a previous brain injury requiring medical treatment and patient under sedation.

The sample size was calculated using the Steven equation *(2012)*, which allowed the confidence level of 95% and the precision rate at 0.05 since the total number of patients admitted was 150 in 2019.

$$n=\frac{N\times p(1-p)}{[[N-1\times(d^2\div z^2)]+p(1-p)]}$$

With,
P= 0.5
N= Total population
Z= Z value "1.96"
D= Standard Error
n= sample size

4.4. Tools of data collection

Three tools were used to collect the data as follows:

4.4.1. Structured Interview Questionnaire

The investigator developed it to collect patient personal and clinical data. It consists of two parts:
Part one: The patient's assessment record was designed to collect data about the study subjects' demographic characteristics such as age, gender, occupation, education, marital status, and admission date.
Part two intended to collect data about the clinical presentation among studied patients as the patient diagnosis and mechanism of trauma.

4.4.2. Glasgow Coma Scale - Pupil Age

It was adopted from *Brennan et al. (2018)*. The tool measures patient conscious level considering pupil reaction and patient age. The GCS evaluates three independent neurologic responses: Eye-opening, verbal, and motor. It includes assessment of eye-opening (five responses), verbal response (six responses) and motor response (seven responses), and pupil responses (three responses). The patient was assessed once for each item only on admission.

Scoring Glasgow Coma Scale - Pupil Age prognostic charts in five steps as follows:
- Calculation of GCS.
- Calculation of pupil reaction.
- Calculation of GCS-P reactivity score.
- Finding the probability of mortality and favorable outcome for each patient according to his/her age and GCS-P score.
- Finding the probability of mortality and favorable outcome for each patient according to his/her number of CT findings, age, and GCS-P score.

The prediction of mortality and favorable outcomes were calculated through the following steps:
- *Calculation of GCS*

Eye-opening contains five responses when the patient opens his/her eye spontaneously obtains four degrees; when open after a spoken or shouted request obtains three degrees; when open after fingertip stimulus obtain two degrees; when no opening at any time obtains one degree; and finally when eye closed by a local factor (such as the presence of eye injury) is counted as non-testable.

The verbal response contains six responses; when the patient is oriented to person, time, and place obtains five degrees; when the not oriented but communicating coherently obtains four degrees; when the patient talks intelligible single words obtain three degrees; when the patient expresses only moans/groans sound obtain two degrees when patient express no audible response with no interfering factors (such as insertion of endotracheal intubation, and patient on mechanical ventilation or lower jaw fractures) obtains one degree, and when factor (such as insertion of endotracheal intubation and patient on mechanical ventilation or lower jaw fractures interfering with communication, non-testable is considered.

The motor response is the third parameter. It contains seven responses when the patient obeys commands (obey two-part request) obtains six degrees; when the patient can bring hand above clavicle to stimulus on the head neck, rated as localizing, and obtains five degrees; when the patient can bend the arm at elbow rapidly but features not predominantly abnormal, it rated as normal flexion and obtained four degrees; when bends the arm at elbow clearly predominantly abnormal obtains three degrees; when a patient extends the arm at elbow obtains two degrees; when no movement in arms/legs, with no interfering factor, the patient obtains one degree, and when the patient is paralyzed or had another limiting factor non-testable is considered.

The total GCS score was recorded at this stage separately to be used in calculating concurrent validity.
- *Calculation of pupil reactivity score (PRS)*

Finally, the pupil reactivity score is measured by assessing the pupil response to light; it is assessed when both pupils react and obtain zero degree; when one pupil reacts, the patient obtains one degree, and when neither pupil is not reactive to light, the patient obtains two degrees.
- *Calculation of GCS-P score*

The Glasgow Coma Scale minus Pupil (GCS-P**)** is calculated by subtracting the Pupil Reactivity Score (PRS) from the Glasgow Coma Scale (GCS) total score:

GCS-P = GCS – PRS

- *Finding the probability of mortality and favorable outcome for each patient according to his/her age, and GCS-P score.*

The graphs are based on admission GCS, pupil reactivity, age, and CT scan findings. Age is analyzed in

5-year steps. After GCS-P is calculated, the investigator uses the chart to explore the intersection point between the patient's age and his/her score of the GCS-P, one time on the mortality chart and another time on the favorable outcome chart. Two produced numbers were recorded for each patient to predict his/her expected outcomes. The expected outcomes were in the form of the chance of mortality and the chance of a favorable outcome.

Example: A patient 50 years old with a GCS-P of 12 will have a 12% probability of mortality. The same patient will have an 82% chance of favorable outcomes according to the Age/GCS-P Score chart.

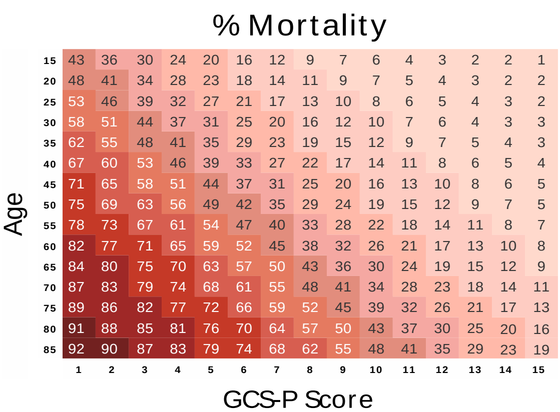


Figure (1): GCS-PA prediction charts for the probability of mortality based on the patient's admission GCS-P (derived as the GCS total score minus the number of nonreactive pupils).

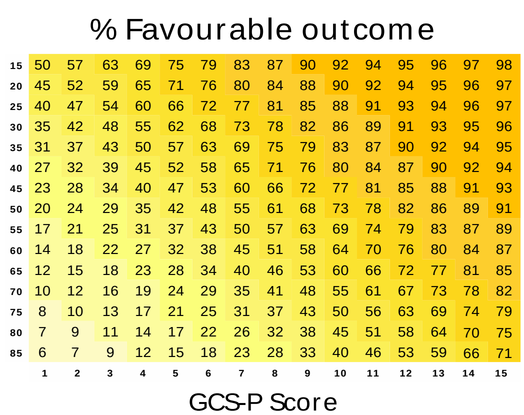


Figure (2): GCS-PA prediction favorable outcome charts based on the patient's admission GCS-P (derived as the GCS total score minus the number of nonreactive pupils).

- *Finding the probability of mortality and favorable outcome for each patient according to his/her number of CT findings, age, and GCS-P score.*

CT Scan findings are classified as the patient showed either no abnormality (Non), one abnormality (One), or two or more abnormalities (Two or more) on the Age/GCS-P score/number of abnormal CT findings chart, one time for a percentage of mortality and another time for favorable outcomes. The neurologist diagnosed the abnormalities.

Considering CT findings that were presented according to the type of injury as follows:

- Epidural Hematoma

It represents hematomas most located in the temporal or temporoparietal regions. This type of bleeding is located between the inner table of the skull and the dura. A computed tomography scan shows a variably sized oval or "lens-shaped" hyperdensity between the bone and the dura.

- Sub-Dural Hematoma

A computed tomography (CT) scan typically shows a hyperdense crescent of blood between the dura and the brain.

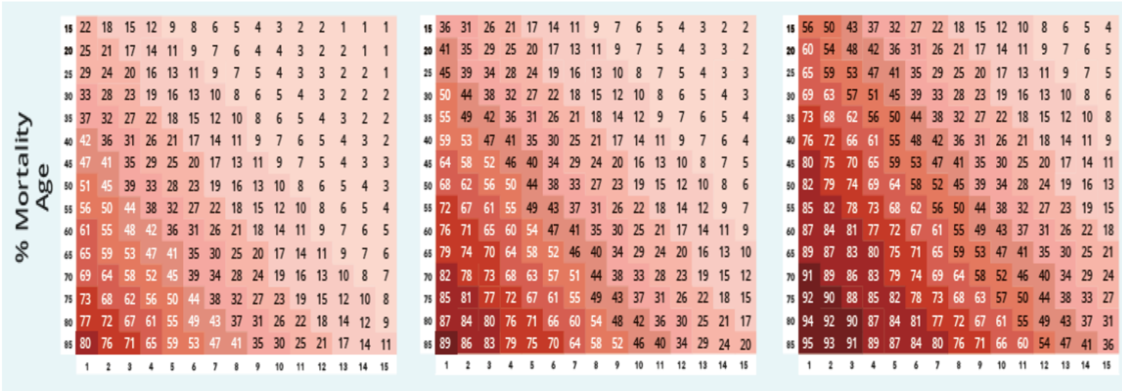
- Contusions/Intracerebral Hemorrhage

Contusions of the brain are often concomitant with subdural hematoma. Most contusions occur in the frontal and temporal lobes, although they can occur at almost any site, including the cerebellum and brainstem *(Ellenbogen et al., 2018).*

The scoring of CT findings was calculated based on three levels of none, one, two, or more CT findings. Criterion validity (with its two types of predictive and concurrent validity) was used to validate the GCS-Pupil Age chart.

Example: A patient 50 years old with a GCS-P of 12, with no (None) abnormal CT findings, will have a 6% probability of mortality. The same patient will have an 82% chance of favorable outcomes according to the Age/GCS-P/number of CT findings score chart.

Number of Abnormal CT Findings

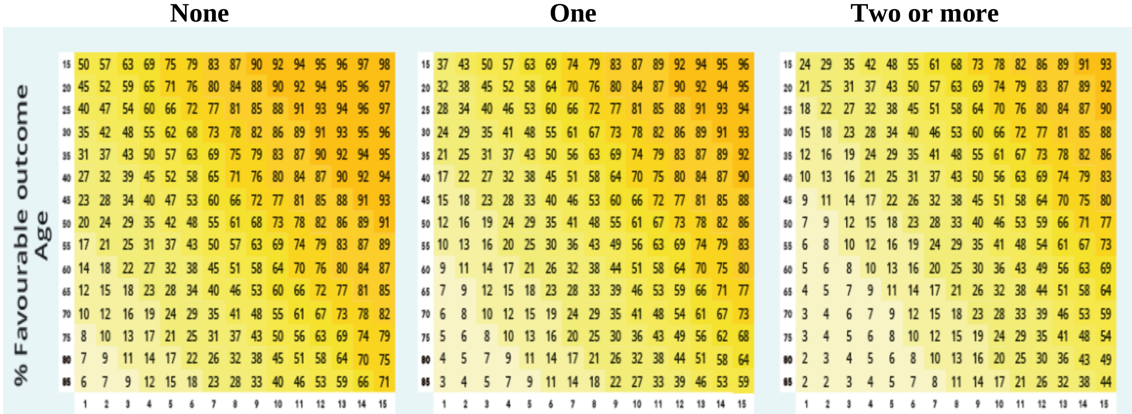


GCS-P Score *GCS-P Score* *GCS-P Score*

Figure (3): GCS-PA CT prediction charts for the probability of mortality based on the patient's admission GCS-P (derived as the GCS sum score minus the number of nonreactive pupils) and age with no CT abnormality, one CT abnormality, and two or more CT abnormalities.

Number of Abnormal CT Findings

None **One** **Two or more**



GCS-P Score **GCS-P Score** **GCS-P Score**

Figure (4): GCS-PA CT prediction charts for the probability of a favorable outcome based on the patient's admission GCS-P (derived as the GCS sum score minus the number of nonreactive pupils) and age with no CT abnormality and age with no CT abnormality, one CT abnormality, and two or more CT abnormalities.

4.4.3. Glasgow Outcome Scale

It was adopted by *Jennett & Bond (1975).* The most widely used assessment scale of patient outcomes after a head injury is the Glasgow Outcome Scale (GOS). The GOS is based on the ability of patients with traumatic brain injury patients to recover, to perform activities of daily living, and the degree of assistance required *(King et al., 2005).* The assessment was done once one month after patient admission. The tools included seven dimensions:

The first dimension is concerned with the assessment of consciousness and whether a vegetative state (it is defined as a patient unable to obey commands or say any simple words) is present or not. If the patient could communicate, the other dimension of Glasgow's outcome would be assessed.

The second dimension is concerned with the assessment of the patient need for assistance by another person and contains two sub-dimensions. It includes the assessment of the essence of the presence of another person at home to help the patient with daily living activities and if this assistance was essential at home before the injury.

The third and fourth dimensions are concerned with independence outside the home (Shopping and traveling). It contains another four sub-dimensions. It includes assessing the patient's ability to shop without assistance and if the patient could shop without assistance before the injury. Besides, assessing if the patient can travel locally without assistance and if the patient was able to travel without assistance before the injury.

The fifth dimension is concerned with work. It includes two sub-dimensions to assess if the patient can currently be able to work to their previous capacity and if the patient was either working or studying before the injury.

The sixth dimension is concerned with social and leisure activities. It includes three sub-dimensions. They are assessing if the patient can resume regular social and leisure activities outside the home, to what extent there is a restriction on his/her social and leisure activities, and if the patient is engaging in regular social and leisure activities outside the home before the injury.

The seven and final dimension is concerned with family and friendships. It includes three sub-dimensions of assessing the presence of psychological problems resulting in ongoing family or friendship disruption, the extent of disruption or strain, and whether there were problems with family or friendship before the injury.

Scoring system

The total score of the Glasgow outcome scale includes five categories. They are vegetative state, severe disability, moderate disability, good recovery, and death.

- Vegetative state if the patient cannot obey commands or say a simple word such as "No." and scored as two grades.
- Severe disability (SD) was considered when the patient answered all the main questions concerning independence and preinjury problems in these areas (Q2-Q4). If the patient was conscious but dependent with the patient either partially independent in activities of daily living but cannot return to previous activities totally or almost dependent for activities of daily living, and scored as three grades.
- Moderate disability (MD) was considered when the patient obtained answers to all the main questions concerning disability and the questions concerning preinjury problems (Q5-Q7). When the patient was independent but disabled with either the signs present but the patient can resume most former activities, or the patient is independent in activities of daily living but cannot resume previous activities and scored as four grades.
- Good recovery (GR) was considered if the patient was either fully recovered without symptoms or signs, capable of resuming normal activities, and did not fulfill the criteria for any of the lower outcome categories but had minor complaints. The good recovery scored five grades.
- Death scored as one grade.

4.5. Procedures

Ethical considerations: Written approval was obtained from the Scientific Research Ethical Committee of the Faculty of Nursing at Ain Shams University. The investigator clarified the objective and aim of the study to the subjects and their caregiver included in the study. The investigator obtained verbal consent from the study subjects or their guardians. All data were kept confidential and used only for their benefit and research purposes. Patients' privacy was assured. The study subjects and their caregiver were informed that; they were free to withdraw from the study at any time.

Official permission with a written letter clarifying the purpose and the study methodology was obtained from the dean of faculty of nursing at Ain Shams University to the directors of the hospital of Fayoum university and EL-Nabawi El Mohandas General hospital to conduct the study and requesting permission for data collection from the studied sample to facilitate the data collection process.

Pilot study: Before performing the actual study, a pilot study was carried out on ten (10%) of a total number of 100 patients under study who were included and chosen from the previously mentioned setting to evaluate clarity, the applicability of the tools, and the time required to fill them. There was no change in the data collection tools, so they were included in the main study sample.

Field of work: Approval was obtained from hospital directors. After that, the study tools were filled in and completed by the investigator. The study was carried out from May 2021 to October 2021. The investigator attended three days a week, including Saturday, Tuesday, and Thursday, in the afternoon shift because these are the days of emergency in the neurosurgical department that allowed for admitting a large number of patients, especially road traffic accidents, and during the afternoon shift, allowed the investigator to meet patient relative or caregiver. This schedule was continued to collect data during the whole study period.

The demographic and medical baseline data were collected then the investigator assessed the Glasgow coma scale Pupil Age (including eye response, verbal response, motor response, and pupil response) on the first day of admission of each patient to the hospital by the following order firstly check for factors interfering with communication or other injuries; secondly observe for eye-opening, the content of speech and movements of the right and left sides; thirdly stimulate patient either by sound (spoken or shouted request) or by applying physical pressure on the fingertip, or supraorbital notch, and finally record patient response for each component of Glasgow coma scale.

Then evaluate pupil reaction response, and report computed tomography findings for patients with traumatic brain injury. After determining the age, Glasgow coma scale, pupil response score using Glasgow coma scale - PA charts to evaluate percentage for each of mortality and favorable outcome, then evaluate the number of abnormalities of CT finding plus age, Glasgow coma scale score, pupil response score used charts which belong CT finding to determine mortality and favorable outcome according to CT finding.

Each patient had taken about 15 minutes/day. The investigator visited the study setting three days per week. Data collections were obtained from 2-3 patients per day. After one month of admission, the investigator met the same patient/relative or caregiver in the neurosurgical intensive care unit or inpatient ward or called them by phone to assess the Glasgow outcome scale using Glasgow Outcome Scale to assess seven dimensions, including consciousness, independence in the home, independence outside the home, work, social & leisure activities, and family & friendships. Then give a score according to patient status (Death, vegetative state, severe disability, moderate disability, and good recovery).

4.6. Data analysis

All data were collected, tabulated, and subjected to statistical Analysis. The Statistical Package for Social Science (SPSS) program version 25 for data handling and graphical presentation. Quantitative variables were presented as a minimum, maximum, mean, and standard deviation, while qualitative data were presented as count and percentage. A student t-test was used to compare quantitative data between two independent groups. Chi-square and Fisher Exact tests were used to compare qualitative data between different groups.

ROC curve analysis was done to measure predictive ability and determine the best cut-off value for quantitative data to predict the outcome. Sensitivity was identified in this study as the probability of giving a 'positive' result when the patient is indeed positive, and specificity is the probability of getting a negative result when the patient is indeed negative *(Sharma, 2008).* A *p*-value less than or equal to 0.05 was considered statistically significant. Highly significant was considered at $p \leq 0.001$.

5. Results

Table 1 describes the frequency and percentage distribution of patients' demographic characteristics. This table reveals that 64% of the studied patients were between 18-30 years, with an age range of 19-65 and a mean age of 31.53±12.30; 77% were males. Regarding occupation, 43.0% were doing nonskilled jobs, 43.0% of them had secondary education, and finally, 48.0% of them were singles.

Table 2 describes the frequency and percentage distribution of patients' medical data. This table shows that 31.0% of patients were diagnosed with intracerebral hemorrhage, 25.0% had a concussion, and 21.0% had an epidural hemorrhage. As regards the mechanism of trauma, 80.0% are traumatized because of road traffic accidents.

Table 3 describes the frequency and percentage distribution of Glasgow coma score minus pupil reaction of studied patients on admission. This table shows that 37.0% of patients opened their eyes in response to sound, 34% of the patient's verbal responses were non-testable, 33.0% of patients' best motor responses were obeyed commands, 76.0% were neither pupil unreactive to light, and 38.0% of patient had a GC score of less or equal to eight representing severe traumatic brain injury according to Glasgow coma scale with a mean score of 9.59±4.53.

Table 4 describes the frequency and percentage distribution of patients' CT findings. This table reveals that only 6.0% of the patients did not show any abnormal CT findings, 62.0% had one abnormal CT finding, and 32.0% showed two or more abnormalities.

Table 5 describes the frequency and percentage distribution of patient outcomes according to the Glasgow outcome scale after one month of patient admission. This table reveals that 29% of the studied traumatic brain injuries patient died, 28% had a good recovery, 25% got a moderate disability, 18% were severely disabled, and no one fell into a vegetative state. Based on the Glasgow outcome scale, 53% of the patients showed a favorable outcome, and 47% had an unfavorable outcome.

Table 6 describes the relationship between patients' demographic characteristics and outcomes based on the Glasgow Outcome Scale. This table reveals a statistically significant difference between patients' mean age and the outcomes, as the patients in the favorable outcome group have a younger mean age. This table also shows that 64% of highly educated patients had a favorable outcome. In comparison, 100% of study subjects who read and write, those who cannot read and write, and those with primary education showed unfavorable outcomes. Gender, occupation, and marital status did not show any statistically significant relationship with patients 'outcomes.

Table 7 describes the relationship between patients' medical data and their outcomes based on the Glasgow Outcome Scale. This table reveals a statistically significant relation between patient diagnoses and patients ‘outcomes, as 96% and 95.2% of the patients with concussion and epidural hematomas showed favorable outcomes, respectively, while 100% of patients with traumatic subarachnoid hemorrhage and skull base fracture exhibit unfavorable outcomes. The table also shows non-significant relation between the mechanism of trauma and patients’ outcomes.

Table 8 shows the relation between the number of patients' CT findings abnormalities and their outcomes based on the Glasgow Outcome Scale. This table shows a statistically significant relationship between the number of abnormal CT findings abnormalities and patients' outcomes, as 100% of patients who showed no CT abnormalities had a favorable outcome. In comparison, 96.9% of patients with two or more CT abnormalities exhibited unfavorable outcomes ($p<0.001$).

Table 9 shows the validation of GCS-Pupil Age CT charts in predicting the outcome of patients with traumatic brain injury. This table reveals that GCS-Pupil Age CT charts statistically significantly predict the outcomes in traumatic brain injury patients with a sensitivity of 91.5% and specificity of 98.1% ($p<0.001$).

Table 10 shows the validation of GCS in the prediction outcome of patients with traumatic brain injury. This table shows that GCS is statistically significantly predicting outcomes in patients with traumatic brain injury, with a sensitivity of 87.2% and specificity of 94.3% ($p<0.001$).

Table 11 represents the comparison of GCS-P Age CT charts and GCS in the prediction outcome of patients with traumatic brain injury. This table compares the GCS and GCS- P Age CT chart. Both scales were statistically significant in predicting patient outcomes with traumatic brain injury. GCS shows a sensitivity of 87.2% and specificity of 94.3%, while the GCS-P Age CT Chart shows a sensitivity of 91.5% and specificity of 98.1% ($p<0.001$).

Table (1): Frequency and percentage distribution of patient's demographic characteristics (n=100).

Demographic characteristics	N	%
Age (years)		
18-30	64	64.0
31-50	26	26.0
51-65	10	10.0
Range	19-65	
Mean±SD	31.53±12.30	
Gender		
Male	77	77.0
Female	23	23.0
Occupation		
Non-Skilled	43	43.0
Skilled	24	24.0
not working	33	33.0
Education		
Read and write	1	1.0
Cannot read and write	5	5.0
Primary	5	5.0
Preparatory	12	12.0
Secondary	43	43.0
University education	34	34.0
Marital status		
Single	48	48.0
Married	42	42.0
Divorced	6	6.0
Widow	4	4.0

Table (2): Frequency and percentage distribution of patients' medical data (n=100).

Medical variables	N	%
Patient diagnosis		
Concussion	25	25.0
Epidural hemorrhage	21	21.0
Subdural hemorrhage	10	10.0
Traumatic subarachnoid hemorrhage	6	6.0
Intracerebral hemorrhage	31	31.0
Skull base fracture	7	7.0
Mechanism of trauma		
Road traffic accident	80	80.0
Falls	17	17.0
Assaults	3	3.0

6. Discussion

Traumatic brain injuries are induced structural injuries and physiological disruptions of brain function as a result of an external force, resulting in a period of loss, or a decreased level of consciousness, loss of memory for events immediately before or after the injury, and neurological deficits (for example, weakness, loss of balance or change in vision) *(Blennow et al., 2016).* The most important prognostic features for predicting outcomes following traumatic brain injury included early GCS score, pupil response, patient age, and CT findings. Therefore, this study aimed to examine the validity of the Glasgow coma scale - pupil age charts in predicting outcomes for a patient with traumatic brain injury. This discussion was covered to fulfill the aim.

The patient with traumatic brain injury presented in this study with a mean age of 31.53±12.30, nearly two-thirds of the studied patient between 18-30 years old. These findings might be due to this age group mostly leaving the house either for work or education using motor vehicles or different transportation means, so they are always prone to accidents compared to the elderly, whose injuries always result from falls.

Biswas et al. (2017), in a study titled **"**Effect of sex and age on traumatic brain injury," reported that the age group between 25 and 58 years represented most of the sample, approximately more than half, while the age group more than 59 years represented less than half.

Additionally, *Tamás et al. (2019),* in their study entitled "The Young male syndrome—an analysis of sex, age, risk-taking and mortality in patients with severe traumatic brain injuries," reported that TBI happened more often among younger individuals, approximately more than half of all patients between 15 and 35 years old.

Table (3): Frequency and percentage distribution of Glasgow coma score minus pupil reaction of studied patients on admission (n=100).

GCS variables	N	%
Eye-opening		
Non-testable	1	1.0
None	12	12.0
To pressure	31	31.0
To sound	37	37.0
Spontaneous	19	19.0
Verbal response		
Non-testable	34	34.0
None	0	0.0
Sounds	4	4.0
Words	8	8.0
Confused	31	31.0
Oriented	23	23.0
Best motor response		
Non-testable	0	0.0
None	5	5.0
Extension	4	4.0
Abnormal flexion	14	14.0
Normal flexion	19	19.0
Localizing	25	25.0
Obeys commands	33	33.0
Pupils unreactive to light		
Neither pupil	76	76.0
One pupil	18	18.0
Both pupils	6	6.0
GCS total score		
Mild (13-15)	34	34.0
Moderate (9-12)	28	28.0
Severe (≤8)	38	38.0
Range	1-15	
Mean	9.59±4.53	

Table (4): Frequency and percentage distribution of patients' CT findings (n=100).

CT findings	N	%
Number of abnormalities		
None	6	6.0
One	62	62.0
Two or more	32	32.0

Table (5): Frequency and percentage distribution of patient outcome according to Glasgow outcome scale after one month of admission (n=100).

Patient outcomes	N	%
Glasgow outcome		
Good recovery	28	28.0
Moderate disability	25	25.0
Severe disability	18	18.0
Vegetative state	0	0.0
Death	29	29.0
Outcome		
Favorable outcome	53	53.0
Unfavorable outcome	47	47.0

Table (6): Relation between patients' demographic characteristics and outcomes based on the Glasgow outcome scale (n=100).

Variables	Outcome-based on the Glasgow outcome scale				X^2	*p*-value
	Favorable outcome		Unfavorable outcome			
	N	%	N	%		
Age (years)						
18-30	35	54.7	29	45.3		
31-50	14	53.8	12	46.2	0.76	0.68
51-65	4	40.0	6	60.0		
Mean±SD	29.21±11.13		34.15±13.13		t*=2.02	0.05
Gender						
Male	40	51.9	37	48.1	0.15	0.70
Female	13	56.5	10	43.5		
Occupation						
Skilled	19	44.2	24	55.8		
Non-skilled	12	50.0	12	50.0	3.90	0.14
Not working	22	66.7	11	33.3		
Education						
Read and write	0	0.0	1	100.0		
Cannot read and write	0	0.0	5	100.0		
Primary	0	0.0	5	100.0	14.17	0.01
Preparatory	7	58.3	5	41.7	FE**	
Secondary	24	55.8	19	44.2		
High education	22	64.7	12	35.3		
Marital status						
Single	30	62.5	18	37.5		
Married	18	42.9	24	57.1	5.07	0.15
Divorced	4	66.7	2	33.3	FE**	
Widow	1	25.0	3	75.0		

**Student t-test **Chi-square test (FE: Fisher Exact)*

Table (7): Relation between patients' medical data and their outcomes based on the Glasgow outcome scale (n=100).

Medical data	Outcome-based on the Glasgow outcome scale				X^2	*p*-value
	Favorable outcome		Unfavorable outcome			
	N	%	N	%		
Patient diagnosis						
Concussion	24	96.0	1	4.0		
Epidural hemorrhage	20	95.2	1	4.8		
Subdural hemorrhage	6	60.0	4	40.0	79.80	<0.001
Traumatic subarachnoid hemorrhage	0	0.0	6	100	FE*	
Intracerebral hemorrhage	3	9.7	28	90.3		
Skull base fracture	0	0.0	7	100		
Mechanism of trauma						
Road traffic accident	40	50.0	40	50.0	2.79	
Falls	10	58.8	7	41.2	FE*	0.30
Assaults	3	100.0	0	0.0		

**Chi-square test (FE: Fisher Exact)*

Table (8): Relation between the number of patients' CT findings and their outcomes based on the Glasgow outcome scale (n =100).

CT findings	Outcome-based on the Glasgow outcome scale				X^2	*p*-value
	Favorable outcome		Unfavorable outcome			
	N	%	N	%		
Number of abnormalities						
None	6	100.0	0	0.0	54.12	
One	46	74.2	16	25.8	FE*	<0.001
Two or more	1	3.1	31	96.9		

**Chi-square test (FE: Fisher Exact)*

Table (9): Validation of GCS-Pupil Age CT charts in prediction outcome of patients with traumatic brain injury.

Area Under the Curve							
Cut off	Sensitivity	Specificity	Area	Std. Error	Asymptotic Sig.	Asymptotic 95% Confidence Interval	
						Lower Bound	Upper Bound
≤ 10.50	91.5 %	98.1%	0.967	0.016	<0.001	0.935	0.998

Table (10): Validation of GCS in prediction outcome of patients with traumatic brain injury.

Area Under the Curve							
Cut off	Sensitivity	Specificity	Area	Std. Error	Asymptotic Sig.	Asymptotic 95% Confidence Interval	
						Lower Bound	Upper Bound
≤ 9.50	87.2%	94.3%	0.966	0.016	<0.001	0.935	0.998

Table (11): Comparison of GCS-P Age CT charts and GCS in prediction outcome of patients with traumatic brain injury.

Scale	Cut off	Sens.	Spec.	Area	Std. Error	Asymptotic Sig.	Asymptotic 95% Confidence Interval	
							Lower Bound	Upper Bound
GCS	≤ 9.50	87.2%	94.3%	0.966	0.016	<0.001	0.935	0.998
GCS – P	≤ 10.50	91.5 %	98.1%	0.967	0.016	<0.001	0.935	0.998

The data collected in this study related to gender show that more than three-quarters of the study subjects were males, and less than a quarter were females. This result may be due to male work in developing countries, characterized by engaging in injury-prone work or being a risk taker of dangerous activities. This result is congruent with *Eom et al. (2021)* in a study titled **"**Gender differences in adult traumatic brain injury according to the Glasgow coma," who reported that the proportion of men was more than two-thirds of the study sample. Nevertheless, there was no gender difference in the TBI ratio in elderly patients above 65 years, and after 75, women have a slightly higher incidence of mild TBI than men due to more falls.

Also, this finding is similar to *Capizzi et al. (2020)* in a study entitled "Traumatic brain injury an overview of epidemiology, pathophysiology, and medical management." The study documented that male cases greatly outnumbered female cases, accounting for more than two-thirds of all reported TBIs. Conversely, in sports-related concussions, female cases outnumber male cases due to cultural differences (women being more willing to report injury than men). However, among older individuals above 65 years, the frequency of TBI is about the same for men and women.

However, in this study, gender is not significant in predicting outcomes. This finding may be because the number of male patients is more than that of female patients, as males represented more than three-quarters of studied patients. Similar findings were reported by *Cancelliere et al. (2016)* in a study aimed to determine gender differences in the recovery and prognosis after TBI in adults. They revealed that gender is not a consistent or strong prognostic indicator for recovery after TBI.

Conversely, *Gupte et al. (2019)* reported in a study entitled "Sex differences in traumatic brain injury: What we know and what we should know" that sex differences in TBI outcomes are likely, but these effects are not universal. The largest fraction of studies report worse outcomes in women than men.

Munivenkatappa et al. (2016) revealed in a study entitled "Traumatic brain injury: Does gender influence outcomes?" that female patients were higher in mild head injury and mortality. The number of deaths was more among females than males, and severe injuries were more among females than male patients.

Regarding occupation, the current study result shows that more than one-third of the studied patients work in non-skilled jobs such as working on farming land or in the construction industry. These jobs expose workers to the danger of falling from a height, frequently using motor vehicles, or other risky transportation means. This result is incongruent with *Brolin et al. (2021)* in their study entitled "Work-related traumatic brain injury in the construction industry in Sweden and Germany," where they reported that brain injuries account for more than half of all work-related head injuries in the construction industry. The most frequent cause of work-related TBIs in the construction industry was falling, followed by loss of control and failure of material agents, ladders, and other building structures.

Regarding the TBI patients' medical data, the patient diagnosis in the current study result shows that a quarter of patients were diagnosed with a concussion. It is a common type of injury that matches a finding of one Egyptian study conducted by *Ragab et al. (2018)*, who reported that 82.4% of patients were diagnosed with post-concussion in 2010, and 34.86% in 2011. In contrast, *Costello et al. (2018)* reported in a study titled "Concussion incidence in amateur Australian rules footballers" that the incidence of concussions is only about ten people per thousand among Australian players in football.

Also, *Breck et al. (2019)* reported in a study titled "Characteristics and incidence of concussion among a US collegiate undergraduate Population" that concussion incidence was ninety-five per ten thousand among the general population and varsity athletes. The difference between these studies and the current study might refer to the focus of Costello and Breck's studies on footballers and college students. In contrast, the current study involved patients of different ages, occupations, educational backgrounds, and genders. Also, Ragab's study was conducted during the Egyptian revolution in 2011.

As for intracerebral hemorrhage, it represents nearly one-third of the cases studied in the current study. In addition, epidural hemorrhage constitutes nearly one-fourth of the studied TBI patients. Intracranial bleeding is a common and serious consequence of TBI. Similar findings were reported by *Waseem et al. (2020)* in a study titled "The evaluation of frequency of intracranial hemorrhage in patients of head trauma with GCS 10-15 on computed tomography scan," out of fifty patients, half of them had an intracerebral hemorrhage. Also, this finding was supported by *Fitzgerald et al. (2020),* who studied "Functional outcomes at 12 months for patients with traumatic brain injury, intracerebral hemorrhage and subarachnoid hemorrhage treated in an Australian neurocritical care unit." It revealed that one-third of patients had an intracerebral hemorrhage. While *Motah et al. (2021),* in a study titled "Traumatic intracranial hemorrhage in Cameroon: Clinical features, treatment options, and outcome," represented that few patients had an intracerebral hemorrhage.

The current study reveals that diagnosis among the studied TBI patients significantly predicts the outcome following TBI. From the investigator's point of view, it might be due to the association between injury severity and outcomes. The concussion had a more favorable outcome compared to the unfavorable outcome. In contrast, a hundred percent of the studied TBI patients with traumatic subarachnoid hemorrhage and skull base fracture had unfavorable outcomes compared to a favorable outcome, and so for intracerebral hemorrhage. This finding is similar to *Motah et al. (2021),* who reported that traumatic intracranial hemorrhage provided significant mortality, and road traffic accident is the leading cause affecting young adults.

Regarding the mechanism of trauma, road traffic accident (RTA) represents the major cause of TBI in the current study, as more than three-quarters of patients exposed to RTA, followed by falls, represent less than two-fifths of the studied patients. Finally, assaults represented only a few patients. Egypt recorded 11,098 road traffic accidents in 2017, marking a 24.6 percent decrease compared to 14,710 accidents in 2016. Those accidents resulted in the death of 3,747 people, injury of 13,998, and the damage of 17,201 vehicles, according to the 2017 report released by the Central Agency for Public Mobilization and Statistics *(CAPMAS, 2018, Kassem et al., 2019).* Another Egyptian study by *Refaat et al. (2019)* reported that 66.8% of the studied TBI patients were a result of road traffic accidents.

This finding was supported by *Rosyidi et al. (2019)*They reported in their study titled "Toward zero mortality in acute epidural hematoma" that two third of traumas were from road traffic crashes, and about one-third of cases were from sustained falls. In the same context, *Motah et al. (2021)* reported that road traffic accidents accounted for most cases, approximately more than half of cases, falls represented approximately less than one-third, and assaults represented few cases.

On the contrary, *Laeke et al. (2021),* in a study titled **"**Prospective study of surgery for traumatic brain injury in Addis Ababa, Ethiopia: Trauma causes, injury types, and clinical presentation," showed that assault was the most common injury mechanism account for more than two third of the studied TBI patients, followed by road traffic accidents that represented about half of cases and fall only a few cases. On the other hand, *Brolin et al. (2021)* showed that falls from a height were the most frequent event leading to severe work-related TBI, approximately two third of all work-related head injuries.

Glasgow coma scale represents a cornerstone in assessing patients with traumatic brain injury. Firstly, regarding eye-opening, this study reveals that more than one-third of eyes opened in response to sound. From the investigator's point of view, most patients respond to verbal stimulation with high-pitched bedside patients' heads more than open their eyes spontaneously or respond to the sounds around them. In the same context, *Park & Davis (2016)*, in their study on "Effectiveness of direct and non-direct auditory stimulation on coma arousal after traumatic brain injury," indicated a statistically significant difference in GCS scores after both direct and non-direct auditory stimulation as compared with the pre-stimulation baseline. Auditory stimuli increase arousal and responsiveness in coma patients.

Secondly, regarding verbal response, this study reveals that more than one-third of the patients were non-testable. This finding may be because most cases had orally endotracheal intubation on a mechanical ventilator. Similar findings were reported by *Brennan et al. (2018)* in their study entitled "A practical method for dealing with missing Glasgow coma scale verbal component scores," which found that verbal data were most commonly missing in patients with no eye-opening and with a motor score of four or less in patients with a severe head injury who characterized by no eye-opening and not obeying commands. However, the verbal score was rarely missing in the remaining assessments of patients with mild or moderate head injury.

Thirdly, regarding motor response, obeying commands represents approximately one-third of responses. From the investigator's point of view, it might be because obeying commands response was done after stimulating patients to move one of their limbs. In addition, twenty-five percent of patients had a concussion, and fifty-three percent had favorable outcomes. This finding means most of the patients had good motor scores. Conversely, *Chou et al. (2017),* in their study entitled "Predictive utility of the total Glasgow coma scale versus the motor component of the Glasgow coma scale for identification of patients with serious traumatic injuries," reported that total GCS was associated with slightly greater discrimination than the motor component alone.

Finally, related to pupil reactivity to light, this study reveals that neither pupil unreactive to light (this means both pupils react to light) represented more than three-fourths of studied patients. Similar findings were reported by *Majdan et al. (2015)* in their study entitled "Glasgow coma scale motor score and pupillary reaction to predict six-month mortality in patients with traumatic brain injury: Comparison of field and admission assessment." They showed that pupillary reactivity is more stable over time; GCS motor score and pupillary reactivity at hospital admission compared to other combinations of these parameters possess the best prognostic value to predict 6-month mortality in patients with moderate or severe TBI.

This finding was supported by *Brennan et al. (2018)* in a study entitled "Simplifying the use of prognostic information in traumatic brain injury. Part 1: The GCS-pupils score: An extended index of clinical severity traumatic brain injury," who reported overall mortality about less than one quarter when both pupils reacted, to more than one third when only one reacted, and to half when both of pupils not reacted. Similarly, unfavorable outcomes increased from one-third to more than half and to seventy-nine percent as pupil reactivity deteriorated.

Concerning GCS total score, this study reveals that severe TBI (GCS ≤8) represents more than one-third of studied patients. This finding may be related to most cases diagnosed with intracerebral hemorrhage. In the same context, *Becker et al. (2018),* in a study entitled "Analysis of incidence of traumatic brain injury in blunt trauma patients with Glasgow coma scale of 12 or less." The study showed that more than two third of patients have a GCS of 3-8.

Regarding the number of abnormal CT findings, this study reveals that one abnormality represented more than sixty percent of patients' CT findings, and two or more abnormalities represented nearly one-third of patients' CT findings. This result may be due to approximately half of the cases having a concussion and epidural hemorrhage where they showed as only one abnormal finding but traumatic subarachnoid hemorrhage, intracerebral hemorrhage, and skull base fracture when occurred not appeared alone, but always associated with another abnormality such as skull base fracture accompanied by intracerebral hemorrhage.

In the same context, *Faried et al. (2019),* in a study entitled "Correlation between the skull base fracture and the incidence of intracranial hemorrhage in patients with traumatic brain injury," reported that most patients with epidural hemorrhage have a single traumatic lesion on CT scan. In contrast, most patients with cerebral contusion have multiple traumatic lesions on CT scans. Also, the number of abnormal CT findings shows a statistically significant relationship between the number of abnormal CT findings and patients' outcomes. This finding may be due to the number of abnormalities of brain injury that appeared in CT, which determine patients' outcomes with increasing abnormalities tend to get worse.

This finding was supported by *Talari et al. (2019),* whose study showed that CT is a significant independent predictor of TBI outcome with acceptable sensitivity and specificity. Therefore, it is recommended for primary assessment of pediatric TBI. This result is consistent with *Nayebaghayee and Afsharian (2016)* in a study titled "Correlation between Glasgow Coma Scale and brain computed tomography-scan findings in head trauma patients" and reported that CT findings are the gold standard to stratify brain injury levels.

As regards patients' outcomes, this study reveals that death represented almost a third of patient outcomes. From the investigator's point of view, this is due to that a reasonable number of cases diagnosed with intracerebral hemorrhage (who represent near one-third of the studied patients), which is considered severe traumatic injury (the severely affected patients according to GCS with their GCS ≤8 represents more than one-third of the studied patient in the current study) leading to an unfavorable outcome. Similar findings were reported by *Motah et al. (2021),* where mortality remains high, particularly in older age and severe traumatic brain injury.

While *Spaite et al. (2017)* reported in a study entitled "Mortality and prehospital blood pressure in patients with major traumatic brain injury implications for the hypotension threshold" that thirteen percent of patients died, also, *Taylor et al. (2017)* aimed to describe the estimated incidence of TBI-related emergency department (ED) visits, hospitalizations, and deaths and reported that only two percent of the total deaths were TBI-related deaths.

Good recovery in this study accounted for less than a third of the studied patients. Also, favorable outcomes (including good recovery and moderate disability) represented more than unfavorable outcomes **(**including death, vegetative state, and severe disability). This finding might be because the concussion and epidural hemorrhage had mostly favorable outcomes. According to the Glasgow outcome scale, about fifty-three percent of the studied patients had a favorable outcome. This finding might be due to nearly half of the studied patients having contusion, epidural hemorrhage, and subdural hemorrhage. Besides, nearly two-thirds of the patients had single CT finding abnormalities, anticipating a good recovery.

In the same context, *Eaton et al. (2017)* reported in a study entitled "Epidemiology, management, and functional outcomes of traumatic brain injury in Sub-Saharan Africa" that more than two-thirds of patients had good recovery with no appreciable clinical neurologic deficits and 13 percent of them had a moderate disability with deficits that still allowed the patient to live independently, while only a few patients had a severe disability which requires assistance with activities of daily life. Conversely, *Fitzgerald et al. (2020)* reported favorable outcomes in more than one-third of patients at six months. Intracranial hemorrhage reported the highest rates of unfavorable outcomes, with two-thirds of patients at one year.

This study reveals that the Glasgow coma scale – pupil Age charts significantly predict patients' outcomes with a sensitivity of 91.5% and a specificity of 98.1%. This tool includes the original GCS with its three components of eye-opening, verbal response, and best motor response, in addition to the three additional features of pupil reactivity, age, and CT findings, which make the new scale more sensitive and specific. This finding is evidenced in the current study when compared to the original GCS sensitivity, which equals 87.2%, and specificity of 94.3%. This finding answers the research question that the GCS-P Age CT chart was highly statistically significantly valid in predicting the outcome with high sensitivity and specificity values.

This finding was supported by *Murray et al. (2018),* who reported that these charts permit a rapid assessment of prognosis for neurotrauma patients; GCS-PA CT charts include three factors of the original GCS score (eye-opening, best verbal, and best motor response), pupil reactivity, patient age, and CT appearance that have been extensively validated as the most important prognostic feature in head-injured patients.

On the other hand, *In-Suk Bae et al. (2020)* reported in a study entitled "Using components of the Glasgow coma scale and Rotterdam CT scores for mortality risk stratification in adult patients with traumatic brain injury," that the new TBI score, which composed of GCS and Rotterdam computed a tomography score is a useful tool for assessing TBI patients with intracranial hemorrhage in that it combines the GCS and RCTS components that increase the area under the curve for predicting in-hospital mortality and unfavorable outcomes. It also showed a linear relationship between in-hospital mortality and unfavorable outcomes without a paradoxical relationship shown in the GCS score. It allows a practical method to stratify the risk of outcomes after TBI.

In the same context, *Kreitzer et al. (2017)* reported that serial GCS measurements provided a more accurate prediction of mortality and long-term functional outcomes. Specifically for 6-month functional outcome prediction, the combination of serial measurements of GCS on arrival, seven days, and 14 days gave a sensitivity of 83.5% and specificity of 89.73%, with an area under the curve of 96.13%.

Yousefifard et al. (2020), in a study entitled "Comparison of Glasgow coma scale with physiologic scoring scales in the prediction of the in-hospital outcome of trauma patients," showed that GCS is still the best method for evaluating injury severity and trauma patients' outcome. Adding physiologic parameters such as blood pressure, heart rate, respiratory rate, arterial blood O_2 level, and body temperature to the level of consciousness does not increase the efficiency of GCS in predicting the outcome of patients; it might even decrease its efficiency in some cases.

Conversely, *Reith et al. (2017)*, in a study entitled "Factors influencing the reliability of the Glasgow Coma Scale," reported that education and training, the experience of the observer, treatment using sedation or intubation, and the type of stimulus applied to assess the GCS in an unresponsiveness patient influence on the reliability of the GCS.

Finally, this discussion answered the research question as the Glasgow Coma Scale - Pupil Age Charts and Computed tomography finding charts are valid and significantly predict outcomes compared to the original Glasgow Coma Scale.

7. Conclusion

The study findings concluded that Glasgow Coma Scale - Pupil Age Charts and Computed tomography finding charts are valid and significantly predict outcomes with sensitivity and specificity more than Glasgow Coma Scale.

8. Recommendations

Based on the findings of this research, the following recommendations had suggested:

- Construct an educational program for nurses about GCS and GCS- PA charts in the intensive care unit to assess traumatic brain injured patients.
- In the patient assessment record, document pupil response (size, equality, and reactivity) at admission.
- Construct an educational program for nurses guided by the brain trauma foundation guidelines for nursing management of traumatic brain-injured patients.
- Apply the GCS- PA charts in the emergency and neurosurgical intensive care units.
- Design clinical pathways for traumatic brain-injured patients from admission until discharge using the GCS, considering age, pupil reactivity response, and CT findings.
- Further studies about using GCS- PA charts in predicting outcomes for traumatic brain injured patients on a larger probability sample and a different recovery period.
- Perform discharge plans for traumatic brain-injured patients using the GCS- PA charts.

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