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Jaimin Modh,
Kushal Shah,
Varshesh Shah,
Kalpesh Shah,
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Renish Padshala,
Nazar Imam

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Clinical and radiological assessment of diffuse axonal injury in traumatic brain injury patients. A retrospective study

Jaimin Modh, Kushal Shah, Varshesh Shah, Kalpesh Shah, Krushi Soladhara, Dharmik Velani, Renish Padshala, Nazar Imam

SMT NHL Municipal Medical College, Ahmedabad, Gujarat, INDIA

ABSTRACT

Background: Diffuse Axonal Injury (DAI) is a severe form of traumatic brain injury (TBI), characterised by widespread damage to white matter tracts due to shearing forces. It is often associated with high morbidity and mortality, especially when diagnosis and management are delayed.

Objective: This study aims to evaluate the clinical, demographic, and radiological features of DAI patients and assess their treatment outcomes. Additionally, it investigates the correlation between MRI-based Adams Grading and prognosis using the Glasgow Outcome Scale (GOS).

Methods: A retrospective analysis was conducted on 30 patients diagnosed with DAI and admitted to the Department of Neurosurgery, SVP Hospital, Ahmedabad, from June 2022 to June 2024. Data collected included age, gender, mechanism of injury, initial Glasgow Coma Scale (GCS) score, MRI findings (Adams Grade), treatment modalities, and GOS scores at discharge or follow-up.

Results: DAI was most commonly observed in young adults aged 11–30 years, with road traffic accidents being the leading cause. MRI demonstrated superior diagnostic accuracy compared to CT. Adams Grading showed a strong correlation with clinical outcomes: higher grades (II and III) were associated with poorer GOS scores (1–3), while lower grades (I) had better outcomes (4–5). Early neurocritical care and timely imaging significantly influenced recovery.

Conclusion: DAI predominantly affects young individuals, primarily due to preventable trauma. MRI plays a crucial role in early diagnosis and prognostication. A multidisciplinary approach, including prompt neuro-intensive care and rehabilitation, is essential for improving outcomes in DAI patients.

Keywords
diffuse axonal injury,
traumatic brain injury,
MRI grading,
Glasgow coma scale,
Glasgow outcome scale

Corresponding author:
Nazar Imam

SMT NHL Municipal Medical College
Ahmedabad, Gujarat, India

mohd.nazar002@gmail.com

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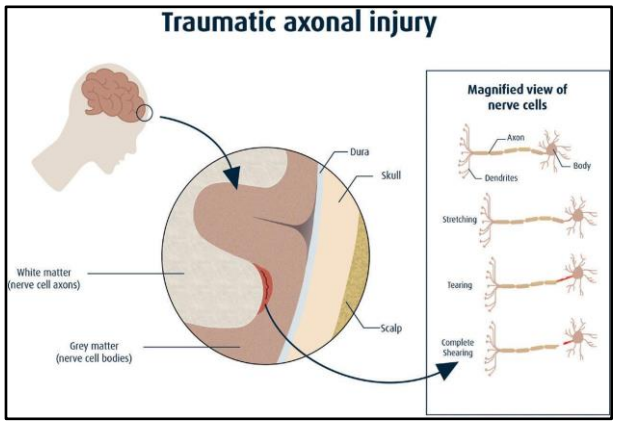
INTRODUCTION

TBI is divided into three groups; mild, moderate, and severe. This division is based on the Glasgow Coma Scale (GCS) in the (sub)acute phase after trauma[1]. Axonal injury is mostly seen in patients with moderate to severe TBI, but also occurs in patients with mild TBI[2,3,4]. Axonal injury is mostly seen after high-energy level trauma, such as road traffic accidents and falls from height[2]. In these types of trauma, acceleration and deceleration forces can cause shear injury of axons[5-

7]. In the brain, the cell body of the neuron lies in the more dense grey matter and the axon in the white matter with a lower density. Due to the difference in density between grey and white matter, acceleration deceleration forces result in a difference in speed between grey and white matter. This results in the stretching of the axons (figure 1)[6]. The shear injury can cause primary lesion to the axon (axonotomy) and secondary injury as a result of an overstretched axon. This secondary or delayed injury is a result of axonal stretch followed by a progressive cascade of pathologic cellular mechanisms disrupting the structural integrity of the axon and neuron [8].

Figure 1. Illustrates the mechanism of traumatic axonal injury due to acceleration-deceleration forces.



Schematic representation of acceleration-deceleration forces leading to shear injury at the grey-white matter interface. These forces cause stretching, tearing, or complete shearing of axons, resulting in primary and secondary axonal damage.

Axonal injury is referred to as diffuse axonal injury (DAI) or traumatic axonal injury (TAI). In radiologic imaging of TBI the definition of DAI is multiple axonal lesions in multiple brain regions, when lesions are confined to only one region it should be named TAI[9]. In clinical practice DAI and TAI are being used almost interchangeably. Most patients with axonal injury have sustained moderate or severe TBI, but after mild TBI axonal injury can also be present[4].

In patients with axonal injury a Computed Tomography (CT) scan of the brain can appear normal, but sometimes microbleeds can be visible indicating the presence of axonal injury. Magnetic Resonance Imaging (MRI) is more sensitive for axonal injury. It can be visible as microbleeds on a T2 star gradient echo (T2*GRE), a fast field echo (FFE), and/or susceptibility weighted image (SWI)[10-13].

The condition is often associated with prolonged unconsciousness and poor neurological outcomes. This study provides a comprehensive understanding of DAI to improve early diagnosis and patient care.

Aim and Objectives

This study aims to:

- Assess the demographic profile of DAI patients
- Evaluate clinical presentations and Glasgow Coma Scale (GCS) scores
- Correlate MRI-based Adams Grading with clinical outcomes
- Analyze treatment modalities and patient prognosis

Methodology

This study consists of analysis of 30 cases of Diffuse axonal injury admitted and treated in the Department of Neurosurgery, SVP Hospital, Ahmedabad from June 2022 to June 2024. Patient`s data were documented in case record form and were followed up till the end of the study. Written and informed consents were taken of all patients' relatives before participation in the study.

Inclusion Criteria

1. Patient`s relatives who are willing to participate in the study.
2. Patients of any age.
3. Patients who have Diffuse axonal injury

Exclusion Criteria

- Patient`s relatives who are not willing to participate in the study.
- Patients who do not have diffuse axonal injury.

Total 30 patients were included in the study of which 24 were male and 6 were female. Patients were categorized into mild, moderate, and severe DAI based on MRI grading. Outcomes were analyzed statistically.

Results

Key findings from the study include:

- Age Group Most Affected: 11-30 years (highest incidence, 50%), followed by 31-50 years (30%).

- Common Causes: Road traffic accidents (70%) were the leading cause, followed by falls (20%) and assault-related injuries (10%).

Table 1. Age distribution of patients with diffuse axonal injury (DAI)

Age Group	Number of Patients	Percentage (%)
≤10	2	6.67
11–30	15	50.00
31–50	6	20.00
51–70	5	16.67
≥71	2	6.67

Maximum incidence is in the young population due to higher incidence of motor vehicle accidents in young people [Table 1].

Table 2. Association between DAI Grade III and Admission GCS Scores

GCS Score on Admission	Number of Patients	Percentage (%)
<8	11	100

As shown in Table 2, all patients with DAI Grade III had a GCS score <8 on admission.

Table 3. Association between DAI Grades I/II and Admission GCS Scores

GCS Score on Admission	Number of Patients	Percentage (%)
≥8	11	57
<8	8	43

More than half of patients with DAI Grades I/II had GCS scores ≥8 at admission [Table 3].

Table 4. Distribution of Diffuse Axonal Injury (DAI) grades among study cohort

DAI Grade	Number of Patients	Percentage (%)
I	8	26.66
II	11	36.66
III	11	36.66

There was no significant predilection for any particular DAI grade among the cohort [Table 4].

Table 5. Correlation between dai grade and duration of ICU stay (survivors only)

Hospital ICU Stay	DAI Grade III	DAI Grade II	DAI Grade I
>10 days	2/2 (100%)	7/10 (70%)	2/8 (25%)
<10 days	0	3/10 (30%)	6/8 (75%)

Higher DAI grades correlated with longer ICU stays [Table 5].

Table 6. Final outcomes based on Glasgow Outcome Scale (GOS) in DAI patients

Final Outcome (GOS)	Number of Patients	Percentage (%)
GOS 1 (Death)	10	33.33
GOS 2 (Vegetative)	1	3.33
GOS 3 (Severe Disability)	3	10.00
GOS 4 (Moderate Disability)	9	30.00

Final Outcome (GOS)	Number of Patients	Percentage (%)
GOS 5 (Good Recovery)	7	23.33
Total Favorable Outcomes (GOS 4–5)	16	53.33%

Final outcome analysis showed that 53.33% of patients had favorable outcomes (GOS 4–5), while 33.33% died [Table 6].

Table 7. Discharge and mortality outcomes in DAI patients

Outcome Type	Number of Patients	Percentage (%)
Discharged	20	66.66
Died	10	33.33

Out of 30 patients, 20 were discharged, and 10 met with mortality [Table 7].

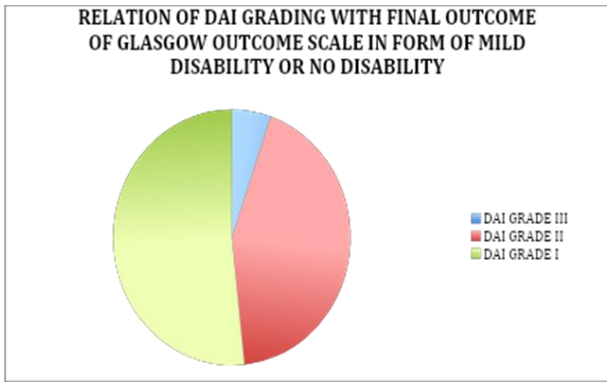


Figure 2. Relationship between MRI-Based Adams Grading and Glasgow Outcome Scale (GOS) at discharge

Bar chart showing the distribution of patient outcomes (GOS scores) stratified by DAI grade. Grade III injuries show a higher proportion of poor outcomes (GOS 1–3), while Grade I injuries are associated with better recovery (GOS 4–5).

Discussion

Maximum incidence of Traumatic brain injury and hence DAI is in the young population due to higher incidence of motor vehicle accidents in young people. In the age group of 11-40 there are 17 patients (57%) in our study. Males are frequently involved in Road traffic accidents. In our study, 24 patients (80%) are male. Previous studies have established that MRI is the gold standard for diagnosing DAI, with Adams Grading (Grade I-III) predicting severity. However, limited research has focused on patient outcomes based on MRI findings and Glasgow Outcome Scale (GOS) scores in an Indian setting. This study aims to bridge this gap by correlating MRI grades with clinical outcomes.

The study findings align with existing literature that young adults are the most affected by DAI due to high-speed vehicle accidents. Peeters W, et al. in their study 'Epidemiology of traumatic brain injury in Europe' and Maas AI, et al in their study 'Moderate and severe traumatic brain injury in adults' published in The Lancet Neurology. 2008;7(8) also had similar findings[15,16]. MRI grading was found to strongly correlate with neurological outcomes, emphasizing the importance of early imaging. Patients with Grade I DAI had better recovery, while Grade III cases showed high mortality and severe disability rates. Fiersching et al. reported mortality in his study in which relation was established between Mortality in DAI patients and MRI grading[14]. Farukh javeed, Lal Rehman, Ali afzal published an article in Surgical Neurology International about DAI which also showed similar findings[17].

The use of neurocritical care (mechanical ventilation, sedation, and supportive therapy) plays a key role in improving survival rates. However, long-term rehabilitation and physiotherapy remain essential for neurological recovery.

Conclusion

There is a critical role of MRI-based grading in predicting DAI outcomes. Early diagnosis and intensive neurocritical care significantly improve prognosis. Given the high incidence of DAI in young adults due to road traffic accidents, preventive measures such as helmet use, traffic regulation enforcement, and public awareness are necessary. Future research should focus on long-term functional recovery and rehabilitation strategies for DAI survivors.

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