THE TAMILNADU DR.M.G.R.MEDICAL UNIVERSITY

DIFFUSION WEIGHTED MR IMAGING IN DIFFUSE

AXONAL INJURY

Dissertation submitted in partial fulfillment by the requirements for the degree of

M.Ch. Branch –II
NEUROSURGERY

Examination in AUGUST 2013

INSTITUTE OF NEUROLOGY

MADRAS MEDICAL COLLEGE

CHENNAI – 3.

CERTIFICATE

This is to certify that this dissertation entitled **"DIFFUSION WEIGHTED MR IMAGING IN DIFFUSE AXONAL INJURY"** is the bonafide original work of **Dr.C.N.Ilankumaran** in partial fulfillment of the requirements for Branch II, M.Ch Neurosurgery, examination of THE TAMILNADU DR.M.G.R MEDICAL UNIVERSITY to be held in August 2013.The period of post graduate study and training was from August 2010 – August 2013.

DEAN
Madras Medical College,
Rajiv Gandhi Government
General Hospital-RGGGH
Chennai -600003.

PROF.K.DEIVEEGAN,MS,M.Ch
Professor and HOD,
Institute of Neurology,
Madras Medical College,
Rajiv Gandhi Government
General Hospital-RGGGH
Chennai – 600003.

DECLARATION

I solemnly declare that this dissertation **"Diffusion Weighted MR Imaging in Diffuse Axonal Injury"** was prepared by me in the Institute of Neurology, Madras Medical College and Rajiv Gandhi Government General Hospital-RGGGH Chennai under the able guidance and supervision of Professor of Neurosurgery, Madras Medical College and Rajiv Gandhi Government General Hospital-RGGGH Chennai between 2012 to 2013.

This dissertation is submitted to The Tamilnadu Dr.M.G.R. Medical University, Chennai in partial and fulfillment of the university requirements for the award of degree of M.Ch. Neurosurgery.

Place: Chennai

Date :

Dr.C.N.Ilankumaran
Postgraduate Student,
M.Ch Neurosurgery,
Institute of Neurology,
Madras Medical College,
Chennai – 600003.

ACKNOWLEDGEMENT

I owe my thanks to **THE DEAN**, Madras Medical College, Chennai, for permitting me to utilize the facilities and conducting this study and the members of Ethical Committee for their role.

I am extremely grateful to **Prof. K.DEIVEEGAN, M.S., M.Ch.,** Professor of Neurosurgery and Head of the Department, Institute of Neurology, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai, for his constant encouragement and guidance throughout the study and periodic reviews.

I sincerely thank all the Professors of our department P**rof.K.MAHESHWAR, Prof.S.D.SUBBIAH, Prof.RANGANATHAN JOTHI, Prof.G.S.JAGAN NARAYANA, Prof.S.SYAMALA** and our former Professors **Prof.R.ARUNKUMAR, Prof.V.G.RAMESH, Prof.C.SEKAR, Prof.V.SUNDAR, Prof.S.SUNDARAM,Prof.J.V.MAHENDRAN** for helping me with their time and advice during this study.

I am indebted to all my assistant professors for their support, guidance and help without which it would have been difficult to carry out this study.

I wish to thank the Professors, Assistant Professors, Post Graduates, Interns, Paramedics, Office Staff, Technicians and Workers of the department of Pathology and Radiology for their cooperation which enormously helped me in this study.

CONTENTS

ABBREVIATIONS USED

CT – Computed Tomography

DAI – Diffuse Axonal Injury

DWI – Diffusion Weighted Imaging

GCS – Glasgow Coma Scale

GOS – Glasgow Outcome Scale

LOC – Loss of Consciousness

MRI – Magnetic Resonance Imaging

INTRODUCTION

INTRODUCTION

Head Injury is one of the leading causes of disability and death in Middle Ages in Head Injury and in our country[1], about fifty thousand people loose their lives and another 80000 are disabled because of Traumatic Brain Injury

Head injury involves young people in their productive part of their life. Loss of life and rehabilitation of severely disabled victims costs a lot of money and incurs a significant economic burden to the family and country. One of the WHO report mentioned 3.5 million deaths all over the world in a year, due to injury, among them 700,000 were due to road accidents. The same report mentioned that 1.5 million people required medical care. Nakajima et al, reported 5000 billion US dollars being the medical bills and rehabilitation cost. This is a tremendous financial loss due to accidents.

India being a developing country increasing accidents not only results in loss of young life, but also damage to the family and financial burden Currently number of deaths due to the road accidents in India are over 60,000 and large number of deaths do occur due to various other injuries. Ramamurthy quoted Rs 350 cores financial loss per year, due to accidents. The figure is higher at present.

In India, the incidence of head injury is steadily increasing with urbanization and increasing number of vehicular population among the road traffic accidents 70% patients have head injury. Among road accidents 70 % deaths are due to head injury .Majority of deaths occur during the first 72 hours. Hence traumatic brain injury predominates in Road Accidents and in deaths due to road accidents

Recently number of fatal accidents has increased in India. Total number of vehicles in India are only 1% of world's total vehicles, however, total number of accidents in India as reported in 1991 were 6% of total accidents, thus making it highest incidence of accidents rate in the world. Currently annual road accidents in India are over 600,000 every year. Every minute there is an accident and every eighth minute there is a death. In 1987 New York Times reported that fatality rate in India for 10,000 vehicles is 55, which was that time reported to be highest in world.

Outcome prediction after catastrophic injury like Traumatic Brain Injury is of significant research interest[2,3] as well as to plan the short and long term patient management. Diffuse Axonal Injury is important pathological substrate of Traumatic Brain Injury. Better accuracy in prediction of outcome of Diffuse Axonal injury, is therefore

and important adjunct in planning the prognosis and estimation of treatment efforts and cost and time that may be needed.

Conventional imaging techniques like X Ray, CT Brain have failed to diagnose and characterize the DAI. So advanced MR imaging sequence is used to evaluate the DAI. This study is aimed at evaluation of usefulness of Diffusion weighted MRI in DAI. This is the first such study in India.

AIM OF THE STUDY

AIMS AND OBJECTIVES OF THE STUDY

- To study the usefulness of Diffusion Weighted MR Imaging (DWI) in assessing the prognosis of patients with Diffuse Axonal Injury (DAI)
- An attempt to understand the significance of various images and signs in DWI MRI of DAI Patients from neurosurgical perspectives.
- To enable the neurologists and neurosurgeons to understand and correlate the varied clinical manifestations and findings of images and to predict the outcome based on MR sequences.
- To study about various modes of injuries that are associated with DAI
- To study about the variations in MRI findings depending on the duration between Time of Injury and Time of MRI.
- To correlate the duration of LOC , site of lesion , GCS , GOS in DAI with DW sequence of MRI.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In traumatic brain injury, there are different pathologies such as EDH, SDH, ICH, Contusion and Diffuse Axonal Injury. Considering diffuse axonal injury, it is based on the forces that act during the impact.

The force of impact directed to the head the resultant physical and physiological effects on the brain stem constitutes the basis of head injury. The three factors which determine the severity of head injury are

1) The nature, severity and direction of force

2) The response of head to that force

3) The total momentum of injury produced by trauma and the succeeding train of events

Static and dynamic head injuries: The initial impact may be due to static and dynamic forces

Static loading: The head may be hit while it is stationary and unable to move because of a rigid support. There is no force of acceleration and deceleration of brain.

Dynamic loading: In impulse loading the stationary head is initiated into motion because of the movement of the whole body , there is varying response from the head and neck often with a rotatory movement of head

on neck. The common type of injury is due to impact loading like moving object hitting the head or by a moving head being stopped.

The forces that act on the head are classified as Acceleration and Deceleration in dynamic loading:

Three types of acceleration may occur

a) Translatory acceleration: With the center of gravity about the pineal and moving in straight line.

b) Rotational acceleration: The centre of gravity is static and brain tissue moves around it.

c) Angular acceleration: A combination of first two types, and the most common phenomenon which is responsible for most of the injuries and the severity depends on the amount of acceleration its rate and duration.

Acceleration injuries may involve three zones the surface zone where acceleration is dampened, an intermediate zone where brain tissue is affected and a third zone where Diffuse Axonal Injury (DAI) occurs.

Diffuse Axonal Injury:

The initial clinical definition of DAI was post traumatic loss of consciousness lasting longer than 6 hours. DAI was presumed in cases where no mass lesion is present to explain the comatose state of the patient. At present Dai may be detected with high sensitivity using MRI.

In the advanced era of neuroimaging, at present, Magnetic Resonance Imaging helps to visualize the traumatized brain clearly and helps to gain knowledge in diffuse axonal injury as it is more sensitive

Pathobiology of DAI:

The current concept of DAI is the secondary axotomy which involves the initial generation of diffuse shear and tensile forces within the brain as a result of angular acceleration caused by traumatic insult. These shear and tensile forces result in focal pertubation but not overt disruption of axonal membranes. Membrane disruption then initiates multiple pathological processes that result in cessation of axonal transport, degradation of cytoskeleton and ultimate axonal disconnection in the hours and days after injury, while it is certainly possible that immediate disconnection can occur with extraordinary shear forces.

The initial step in the process of DAI is the disconnection which involves the axonal membrane as a result of axolemmal pertubation, the

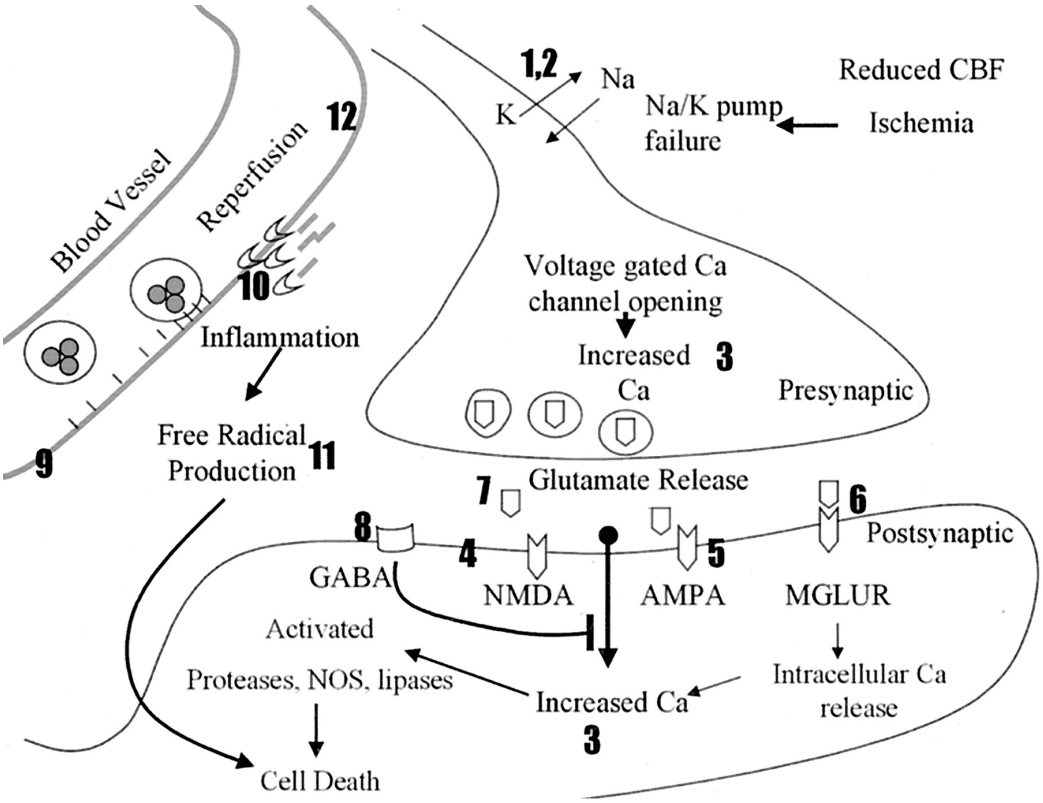
electromechanical homeostasis generated by various axonal transport system is disrupted because of uncontrolled passage of multiple ionic species down their respective concentration gradients. The most important of the ions in the generation of axonal injury is calcium.[4] Calcium influx occurs as a result of axolemmal pertubation resulting in rapid rise of cytosolic calcium levels. Increased cytosolic calcium levels can initiate Calpain a group of calcium dependent proteases that are activated by elevated levels of intracellular calcium. The proteases have numerous intracellular targets and can result in degradation of both the neuronal and axonal cytoskeleton.

Mitochondria are also essential for the maintenance of intracellular calcium levels and oxidative phosphorylation, the overwhelming mitochondrial uptake of calcium results in mitochondrial swelling and loss of electrochemical potentials across the membrane. This results in loss of oxidative phosphorylation and cessation of adenosine triphosphate production. Capsases a family of cysteine proteases activated by various intra and extracellular signals are essential for the process of apoptotic cell death.

Ischemic cascade:

A significant fall in cerebral blood flow produces a cascade of events which if unchecked can lead to increased production and accumulation of toxic compounds and apoptosis.

Role of Neurotransmitters:



Recent research has shown that one of the aminoacid excitatory neurotransmitters. Glutamate in excess is a powerful neurotoxin playing an important role in ischemic brain damage. Genetic susceptibility conferred by presence of ApoEA gene may also plays a part depending on the severity of injury, effects ranges from mild coma to death. The macroscopic appearances appear entirely normal but in some patient's

pathological sections show several small hemorrhages, particularly in corpus callosum or in the superior cerebellar peduncle. Microscopic evidence of neuronal damage depends on the duration and the severity of the injury, after a few days retraction balls and microglial clusters are seen in the white matter .If the patient survives 5 weeks or more after injury appropriate staining can demonstrate Wallerian degeneration of the long tracts and the white matter of the cerebral hemispheres .Even a minor injury causing a transient loss of consciousness produces some neuronal damage. Since neuronal regeneration is limited the effects of repeated minor injuries is cumulative.

Clinical Assessment of DAI can be done with GCS scoring

Glasgow Coma Scale

Eye Opening	Points
Eyes open spontaneously	4
Eyes open to verbal command	3
Eyes open only with painful stimuli	2
No eye opening	1
Verbal Response	
Oriented and converses	5
Disorented and converses	4
Inappropriate words	3
Incomprehensible sounds	2
No verbal response	1
Motor Response	
Obeys verbal commands	6
Response to painful stimuli (UE)	
Localizes pain	5
Withdraws from pain	4
Flexor posturing	3
Extensor posturing	2
No motor response	1

Total score = eye opening + verbal + motor
GCS<5: 80% die or remain vegitative
GCS>11: 90% complete recovery
From Teasdale G, Jennett B: Acta Neurochirurg 34:45, 1976.

The clinical scoring of diffuse axonal injury is as follows

- Mild : Coma 6-24 hours followed by mild to moderate memory impairment and mild to moderate disabilities
- Moderate : Coma > 24 hours followed by confusion and long lasting amnesia, mild to severe memory , behavioral and cognitive deficits
- Severe: Coma lasting months with flexor and extensor posturing, cognitive memory speech, sensorimotor and personality deficits, dysautonomia may occur .

Adams et al stages of DAI is according to the anatomical location of the lesions

- **Stage I** involves the parasagittal regions of the frontal lobes, periventricular temporal lobe, and less likely the parietal and occipital lobes, internal capsule and external capsule and cerebellum
- **Stage II:** Involvement of corpus callosum in addition to the white matter areas in Stage I, This is obscured in approximately 20 % of patients. Most commonly, the posterior body and splenium are involved, now ever the process is believed to advance anteriorly with increasing severity of disease
- **Stage III :** Involves the areas associated with Stage II with the addition of brain stem involvement, a predilection for superior cerebral peduncles, medial lemniscus, and corticospinal tract is found

CT Classification of head injury

- Diffuse Injury I : No visible intracranial pathology
- Diffuse Injury II : Cisterns present with midline shift 0-5 mm and or lesion densities present, no high or mixed density lesion > 25 cc and may include bone fragments and foreign bodies
- Diffuse Injury III (Swelling) : Cisterns compressed or absent with midline shift 0-5 mm; no high or mixed density lesion > 25 cc

↳ Diffuse Injury IV : Midline Shift > 5 mm ; no high or mixed density lesion > 25 cc

Magnetic Resonance Imaging:

Nuclear magnetic resonance signals have been used to study physics and chemistry since 1940, In 1970s it became possible to localize the signal and generate images. For clinical applications the term “nuclear” was dropped, the term “Magnetic Resonance” and “Magnetic Resonance Imaging” are preferred.

The technique produces very high quality images of brain parenchyma and individual structures, small infarcts can also be well visualized. In addition different sequences can be turned to identify very subtle brain pathologies.

Advantages:

- Images are more detailed than CT
- Small infarcts are better visualized
- Posterior fossa is better visualized.
- Best technique to study spinal cord.
- Sensitive for acute ischemia within minutes to hours of ischemia. (DWI).

- Can also provide information on brain biochemistry (MR Spectroscopy), brain function (Functional MRI, fMRI), and long tracts (Diffusion tensor imaging).

Limitations:

- Relatively expensive and Not widely available.
- Longer scanning time than CT, although ECHO planar imaging allows very rapid acquisition although with lower resolution.
- Contraindications like Pacemakers, metal implants.
- Some patients may have claustrophobia, open magnets can overcome that.

Recent advances:

- Higher strength of magnetic fields (3.0 Tesla) provides higher resolution and better signal to noise.
- More sequences to examine different underlying pathologies.
- Open MRI for claustrophobic patients.
- Intraoperative MRI scanner.

Physics of MRI:

Subatomic particles have the quantum mechanical property of spin. Certain nuclei such as 1H (protons), 2H, 3He, 23Na or 31P, have a non–zero spin and therefore a magnetic moment. In the case of the so-called spin-1⁄2 nuclei, such as 1H, there are two spin states, sometimes referred to as "up" and "down". Nuclei such as 12C have no unpaired neutrons or protons, and no net spin; however, the isotope13C does.

When these spins are placed in a strong external magnetic field they rotate around an axis along the direction of the field. Protons align in two energy states (the "Zeeman effect"): one low-energy and one high-energy, which are separated by a very small splitting energy.

When the protons are excited by a pulse of energy deliberately emitted from the scanner it results in

1) They spin in a high energy state and continue to do so until they give off that energy and return to their resting energy state.

2) The energy pulse makes them all spin together in phase. However they cannot maintain this and quickly spread out .They will be still in the high energy state and no longer in phase.

T1 Imaging:

The time it takes for the nuclei spins to return to the resting energy from the high energy state is the T1 relaxation time .It depends on the actual structure of brain. Images based on this are called T1 weighted images.T1 pictures provide good anatomical definition of the structures of brain and often used to estimate brain volume.

T2 Imaging:

The time it takes for the spins to diphase is the T2 relaxation time. It is usually short. Spins in solids diphase fast and spins in liquids are slower. These images are called T2 weighted images. Therefore altered water content in tissues (e.g. Brain Edema) is seen well. These images useful for pathological lesions. The scanner can be turned to the spin frequency of different nuclei. The main nucleus is 1H (i.e. A proton) the commonest chemical containing this is the water. Therefore MR images often show the distribution of water molecules in different tissues of the body.

Diffusion Weighted Imaging (DWI)

Water molecules of the tissues are in the continuous state of Brownian motion, when the protons in the selected slice are excited by the scanner radiofrequency pulse some of them will diffuse out of the slice. Restriction of diffusion results in a more coherent fashion and

giving off a strange signal where as free diffusion results in them becoming out of phase and a weaker signal. This phenomenon is usual in MRI.

If diffusion of water molecules is impaired more stay in the slice and signal acquired is altered. This is called restricted diffusion and shown as dark as the ADC is low whereas increased diffusion shown as bright as ADC is high. Prior to the introduction of CT, the diagnosis of DAI could be made only via microscopic examination at the time of autopsy. Following the development of CT Technology, it was recognized that DAI was associated with scattered petechial hemorrhages in the Centrum semi ovale, corpus callosum, basal ganglia and brain stem[5]

The most sensitive modality to date for the detection of DAI has been MRI, which has only became more effective as newer sequences have been developed to identify specific characteristics of DAI.

The initial experience with MRI found that while it is equally effective in detecting hemorrhagic areas of injury when compared to CT scanning, it is much more effective that CT in detecting areas of non hemorrhagic injury and brain stem injury[6], [7]

The identification of T2 hyperintensity in the splenium of corpus callosum and the dorsolateral brain stem in severe DAI represents the best example of this improved detection of non-haemorrhagic injury. With the development of T2 weighted gradient echo sequencing, microhaemorrhages not evident with CT scanning were resolved.[8] Even newer imaging modalities based on fractional anisotropy, which detects limits on the movement of intracerebral water, have further increased the sensitivity of MRI with respect to the detection of DAI.

Anisotropy based techniques rely on the detection of either restricted diffusion of water [increased anisotropy, Diffusion Weighted Imaging (DWI)], or decreased restriction on water movement [decreased anisotropy, Diffusion Tensor Imaging (DTI)]. DWI has been demonstrated to identify lesions associated with DAI that are not detected by any other MRI Sequences[9], [10]. DTI has been found to be especially sensitive to disruptions in the normal orderly arrangement of parallel axonal fibres in the white matter pathways[11],[12], [13]

Other techniques such as magnetization transfer imaging may also prove useful in the future detection of axonal injury[14]

MATERIALS AND METHODS

MATERIALS AND METHODS

The study was done in 48 patients who had been treated for Diffuse Axonal Injuries at Dept .of Neurosurgery, Madras Institute of Neurology, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai between August 2010 and February 2013.

This was a prospective study and included only when the relatives had given informed consent for taking part in the study

Inclusion Criteria

- All patients having recent closed head injury with GCS Score 12 and below with normal CT Scan Brain i.e. -severe and moderate head injury patients irrespective of mode of injury are included

Exclusion Criteria: The following patients were excluded

- An inability to stay for one hour for MR imaging,
- Contraindications for MR imaging
- Poly trauma
- The time delay between trauma and admission exceeding 48 hours.
- Patients who had definite lesion in CT Scan Brain
- Patients who underwent surgery
- Images with significant Motion artifacts.

Method

- Detailed history has been ascertained from the relatives of the patients who had sustained Head Injury and developed Diffuse Axonal Injury. In case where relatives were not available, the history was taken from the bystanders / EMRI Emergency Medical Technicians who brought the patients
- The following data are collected as per the enclosed proforma
    - Cause of Injury
    - Mode of Injury
        - Fall
        - RTA
        - Assault
    - History of LOC
        - Duration of LOC
    - History of Fits
    - History of Vomiting
    - History of ENT Bleed
    - Past history of traumatic injury
    - Time injury between the injury and first aid and later admission in hospital were asked and recorded

- Clinical examination was done and this included Evaluation of GCS, Pupils, Doll's Eye Movements, Examination for deficits
- Patients with CT Image consistent with DAI underwent DWI MRI BRAIN and findings were noted
    - All images were assessed by an attending neuroradiologist and neurosurgeons, in which the former was blinded to the clinical status of the patients.
    - The Lesions were evaluated for:
        - Location in the following sites,
            - Corpus callosum: Genu, Body, Splenium
            - Deep brain matter: Frontal, temporal lobes, Basal ganglia, and Thalamus,
            - Brain Stem
        - Appearance of the lesions
            - Circumscribed foci of signal, hyper intensity in DWI.
    - Evaluated for the appearance of diffuse axonal injury lesions, especially in the corpus callosum, deep white matter (Frontal, Temporal, Basal ganglia, Thalamus), and brain stem

- Outcome was assessed in each patient at discharge and after six months using the Glasgow Outcome Scale (GOS):
    - GOS 1 signifies Death,
    - GOS 2 signifies PVS or Persistent vegetative state,
    - GOS 3 signifies Severe disability,
    - GOS 4 signifies moderate disability,
    - GOS 5 signifies Good recovery.
  - Patients with a GOS score of 4 or 5 : favorable outcome
  - Patients with a GOS score of 1, 2 and 3: unfavorable outcome.

- Copy of Proforma is enclosed in annexure.
- Analysis of the data was done with SPSS and Epidemiological Information package (EPI 2003) developed by World Health Organization. Frequencies, percentages, mean, SD, and “p” values were calculated using this package.
- Collected data was tabulated in Master Chart.

RESULTS

RESULTS

The overall results of this study are as shown below

(I). various modes of injuries that are associated with DAI

Of the 48 patients enrolled in this study, the mode of injury was as follows

Mode of Injury		
Mode	Number	Percentage
Assault	1	2.08%
Accidental Fall	3	6.25%
RTA	44	91.67%
Total	48	100.00%

Table.No : 1

Mode of Injuries

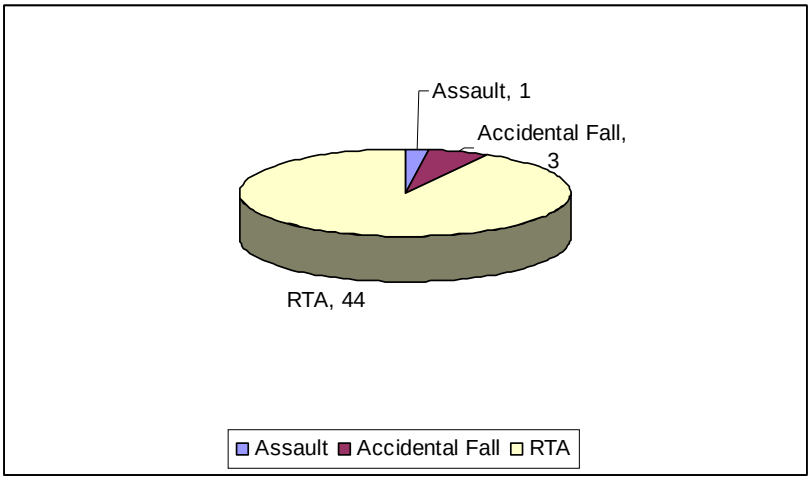


Chart : 1

↳ In this study 44 patients had RTA, followed by 3 patients with Accidental Fall and one patient has history of Assault

(II). To Study about GCS on admission in patients with DAI

We had patients on GCS scales of 3 to 12 in GCS on Admission. The mean score is 6.87 with a standard deviation of 2. 34 as shown in Table 2

Table.No : 2

GCS	Number of Patients	Percent
3	4	8.33%
4	5	10.42%
5	5	10.42%
6	7	14.58%
7	8	16.67%
8	8	16.67%
9	4	8.33%
10	3	6.25%
11	3	6.25%
12	1	2.08%

Patient Distribution based on GCS Scoring

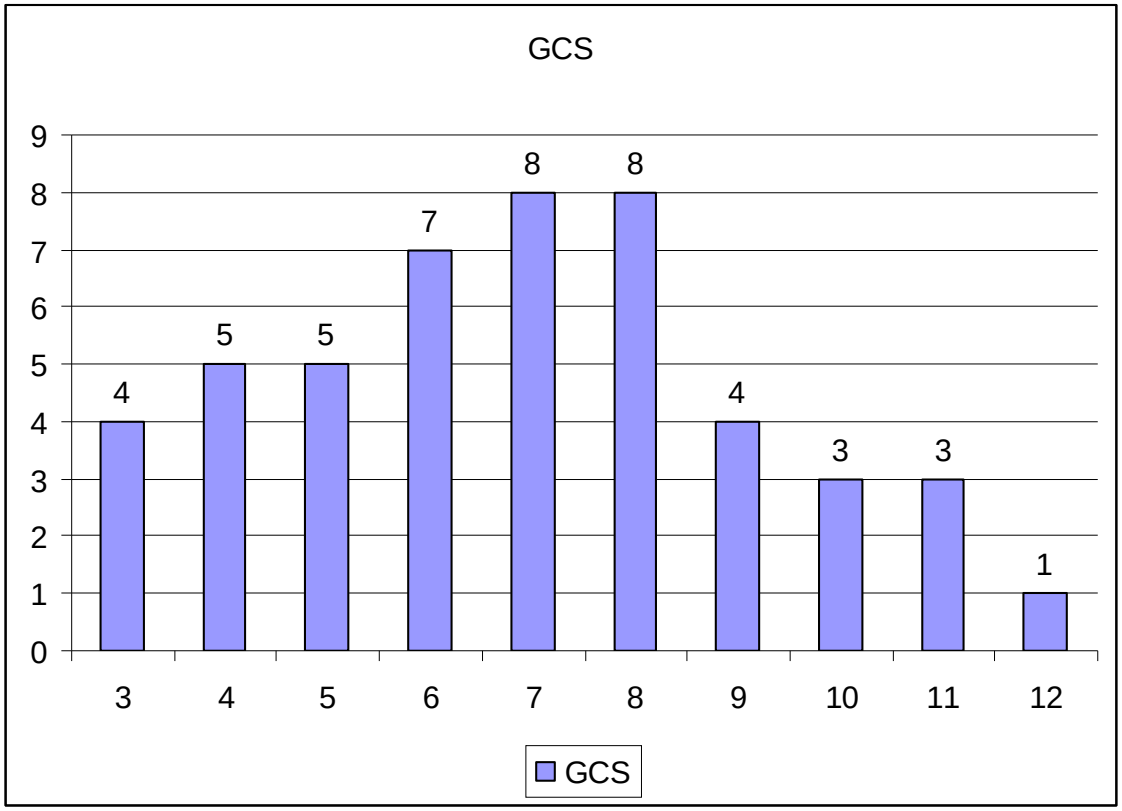


Chart: 2

- X Axis : GCS
- Y Axis : Number of Patients
- The study group showed predominance of GCS Score 7 and 8 and more than two third patients were less than 8 in GCS
- 60 % of study population had severe head injury as per GCS Scale

(III) **To study about the variations in MRI findings depending on the duration between Time of Injury versus Day of Imaging**

MRI_DAYS	Number of Patients	Percent
2	4	8.33%
3	1	2.08%
4	3	6.25%
5	7	14.58%
6	1	2.08%
7	13	27.08%
8	10	20.83%
9	4	8.33%
10	5	10.42%
Total	48	100.00%

Table.No : 3

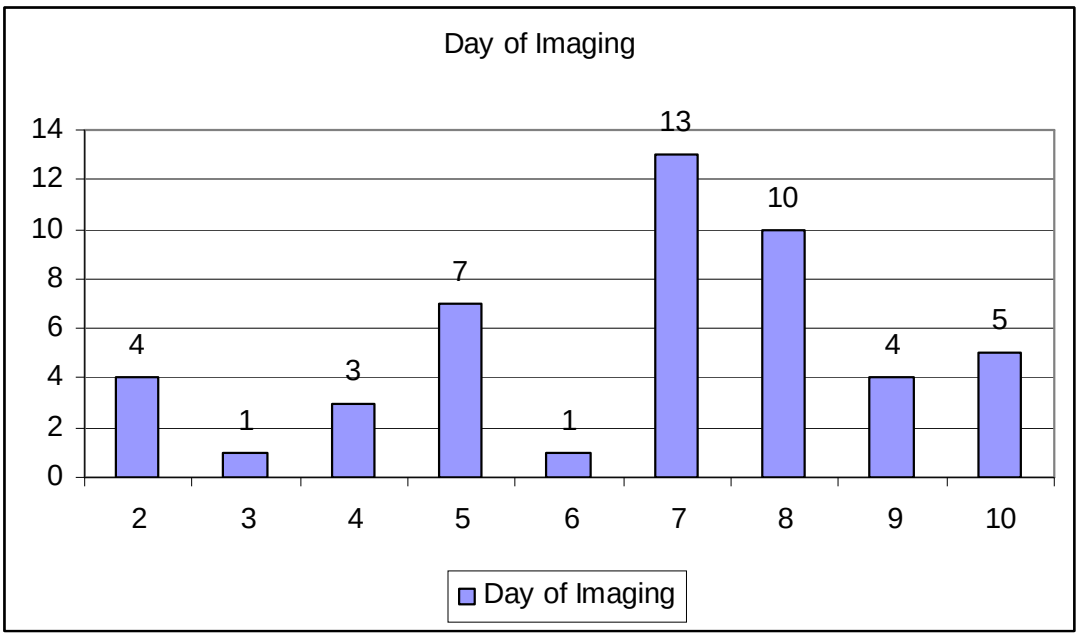


Chart : 3

Categorizing the 48 patients as per the interval between injury and the day of MRI study, most of the patients underwent MRI on 5th to 8th day

(IV). To study the duration of LOC in patients with DAI

Duration of LOC in days.	Number of Patients	Percent
2	2	4.17%
3	3	6.25%
4	1	2.08%
5	3	6.25%
7	3	6.25%
8	3	6.25%
9	1	2.08%
10	7	14.58%
11	2	4.17%
12	5	10.42%
14	2	4.17%
15	3	6.25%
16	2	4.17%

17	2	4.17%
20	3	6.25%
21	1	2.08%
25	1	2.08%
35	2	4.17%
45	1	2.08%
60	1	2.08%
Total	48	100.00%

Table : 4

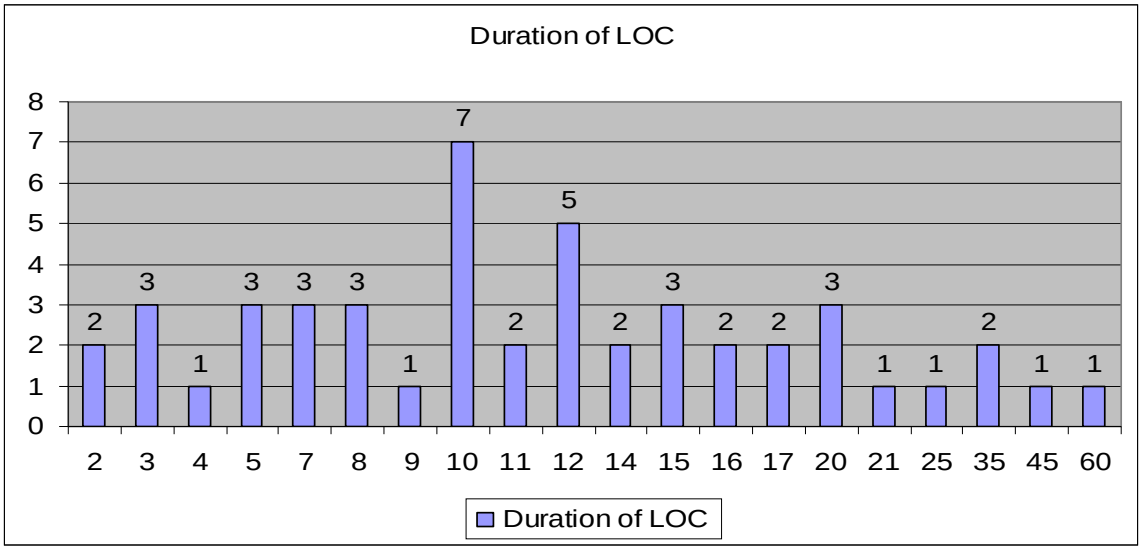


Chart : 4

X Axis – Duration of LOC in days. Y axis – No of patients

Of 48 patients, the duration of LOC was noted. The bar diagram denotes the number of patients against the duration of LOC days

(V). To study the various sites of lesion

DWI of the study population picked up lesions in 44 patients while 4 patients had normal study in this DWI sequence

Distribution of Lesions – Brain stem

Brain Stem Lesions	Frequency	Percent
Brain Stem Lesions not Seen in DWI	41	85.42%
Brain Stem Lesion Seen in DWI	7	14.58%
Total	48	100.00%

Table:5

Distribution of Lesions – Brain stem

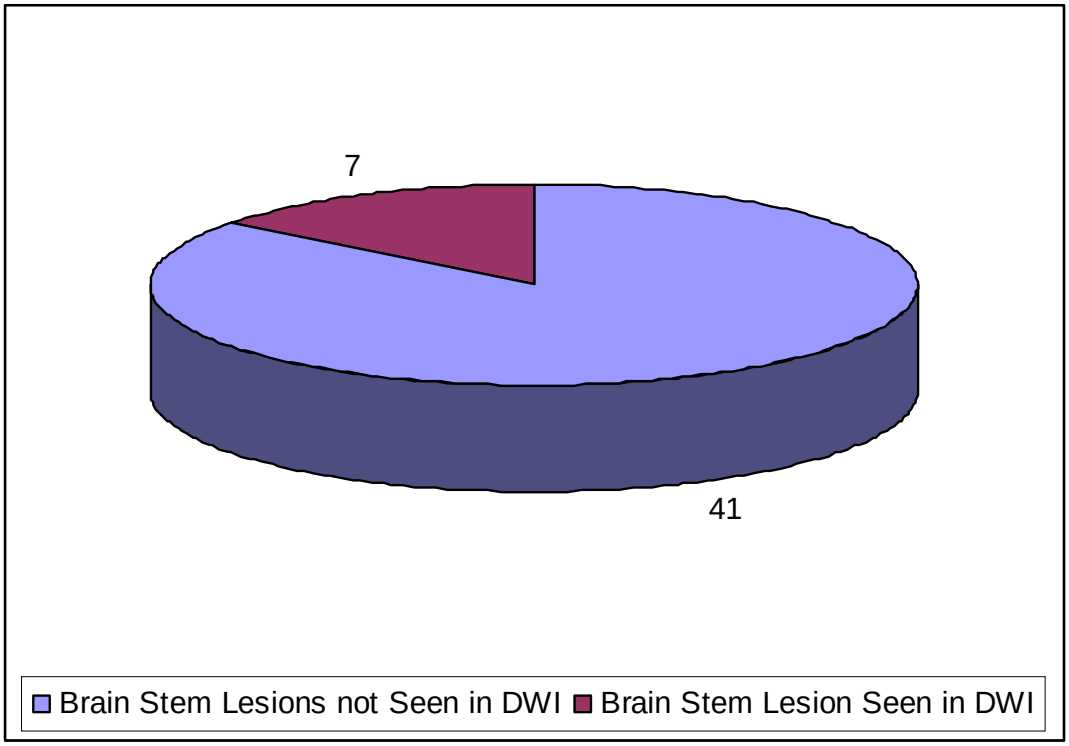
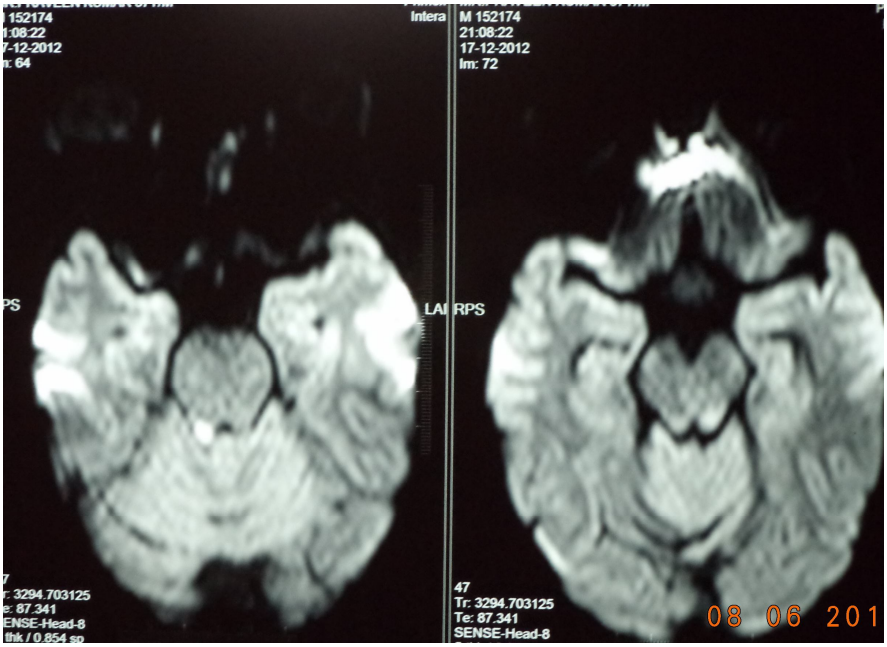
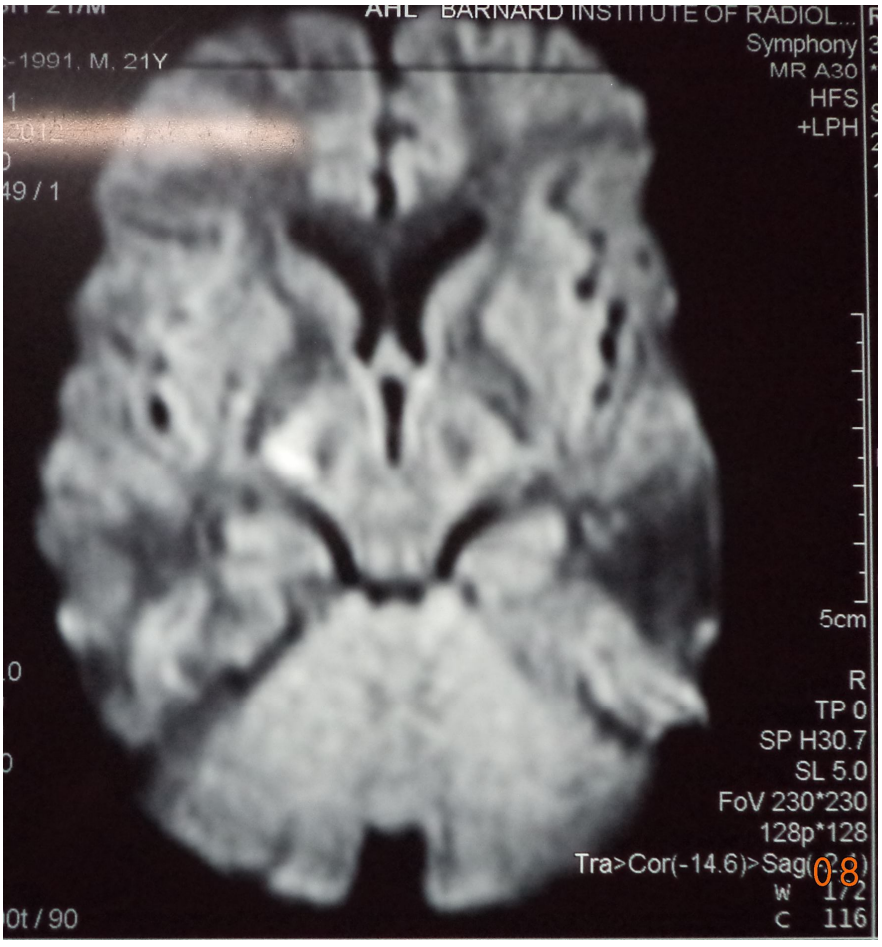


Chart:5

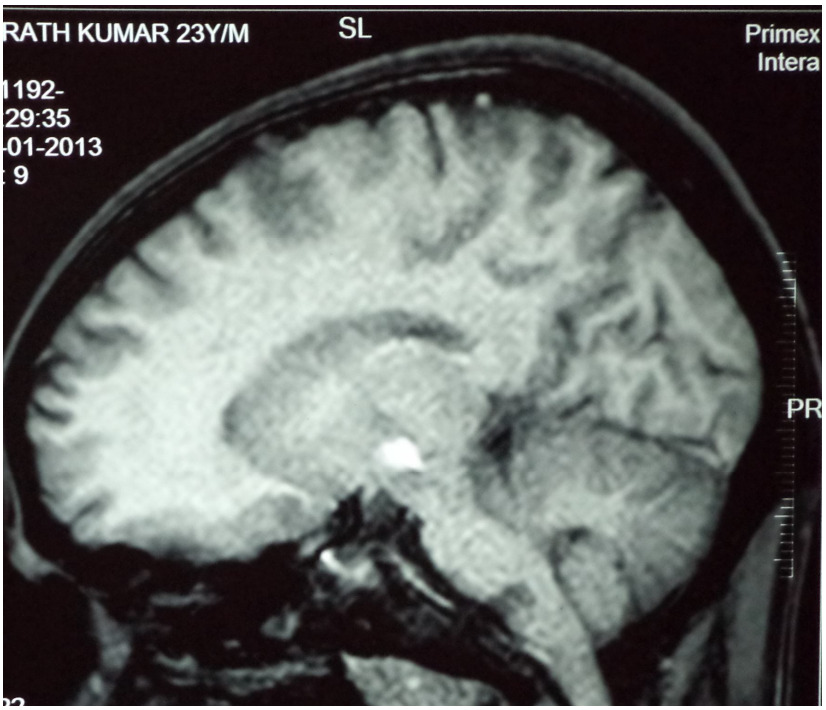
Analysing the various lesions in MRI Findings, it is observed that 7 of them showed brain stem lesions in DWI Sequence

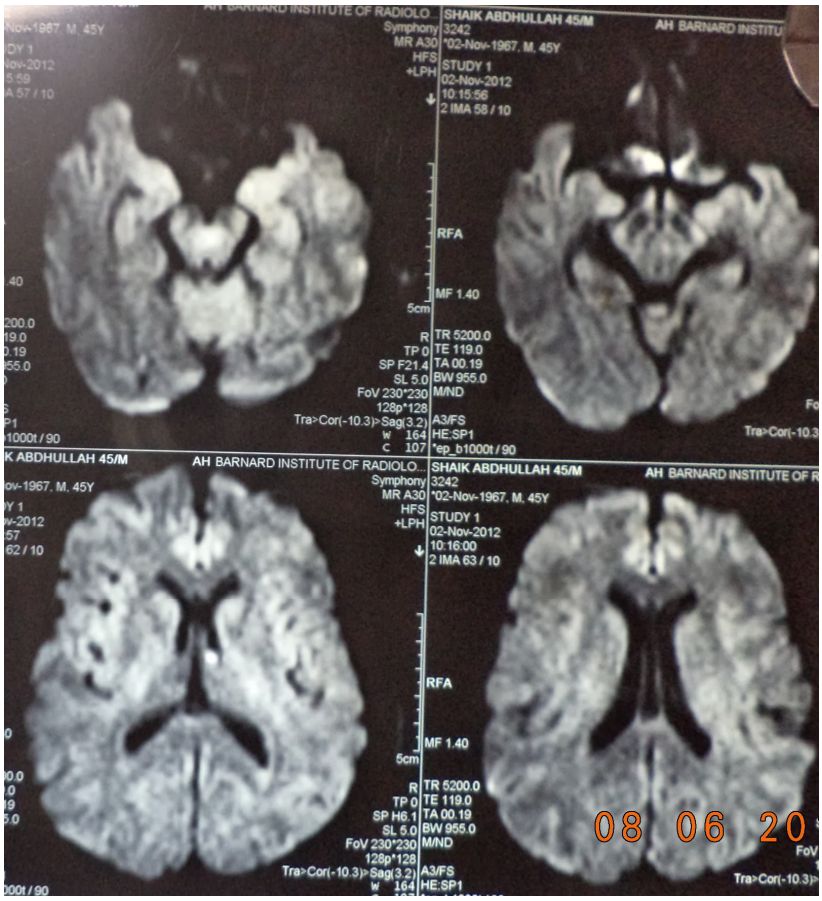
DWI Images showing Lesions in brain stem





DWI Images showing Lesions in brain stem





Distribution of lesions – Corpus callosum

CORPUS CALLOSUM	Frequency	Percent
Corpus Callosum Lesions not seen in DWI	37	77.08%
Corpus Callosum Lesions seen in DWI	11	22.92%
Total	48	100.00%

Table : 6

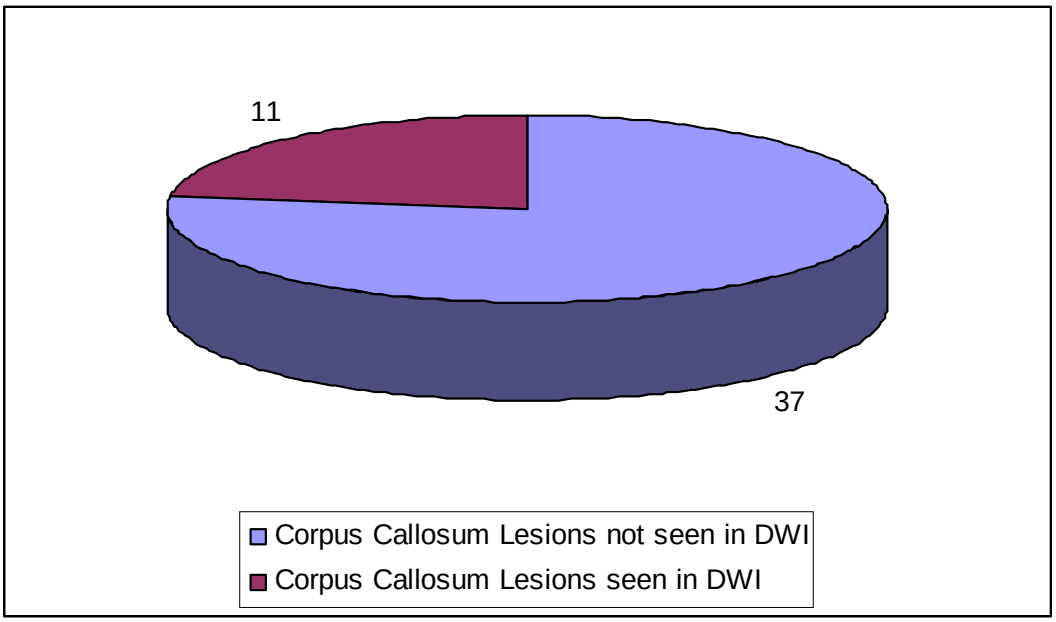
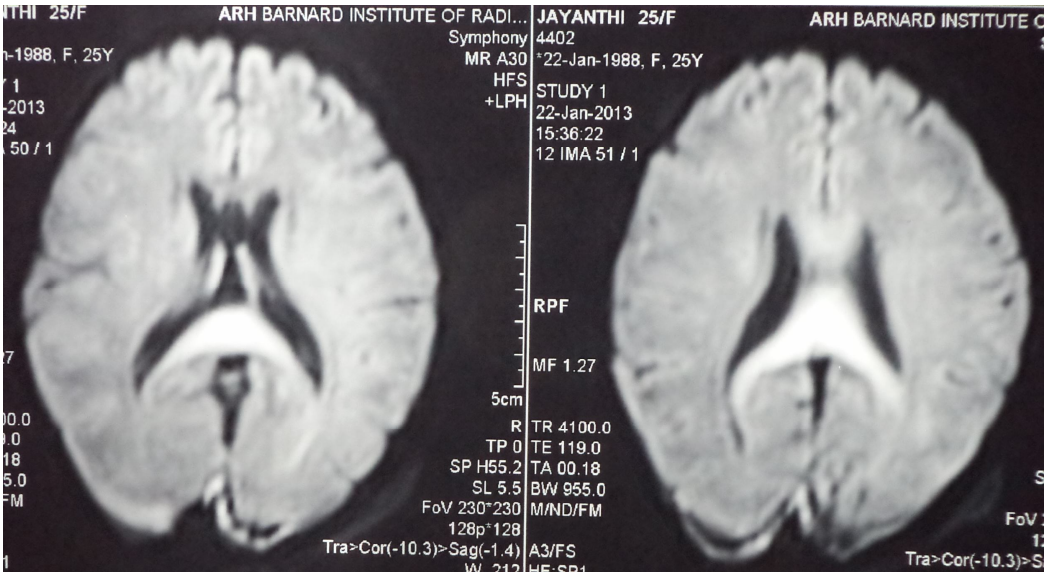


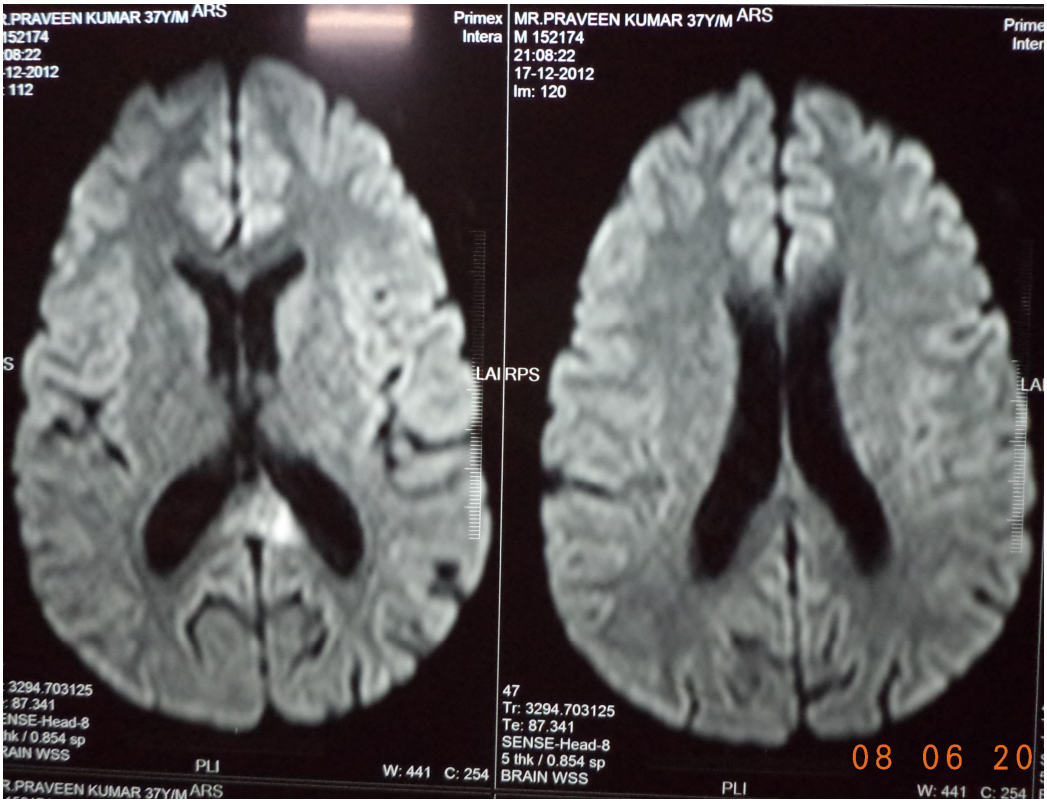
Chart:6

- The study group of patients showed corpus callosum lesions in 11 patients
- The percentage of corpus callosum lesions were 23 %

DWI Images showing Lesions in Corpus Callosum



DWI shows lesions in corpus callosum



Distribution of lesions – Other sites

OTHER SITES	Frequency	Percent
Lesions in sites other than Corpus Callosum and Brainstem - frontal, temporal, parietal, occipital, internal capsule and cerebellum	30	62.50%
Lesions in sites - Corpus Callosum and Brainstem	18	37.50%
Total	48	100.00%

Table : 7

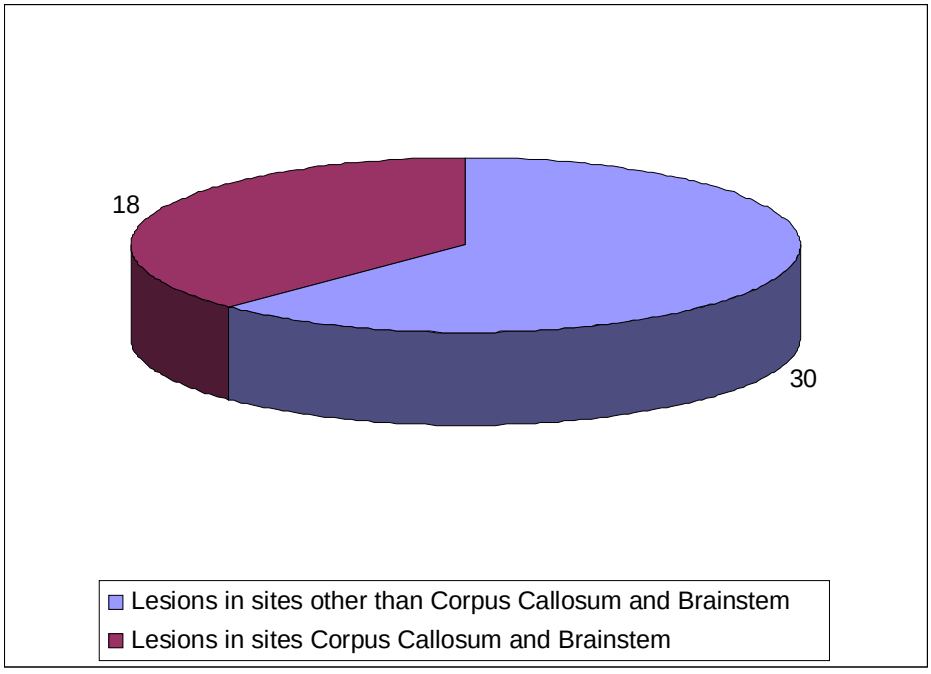
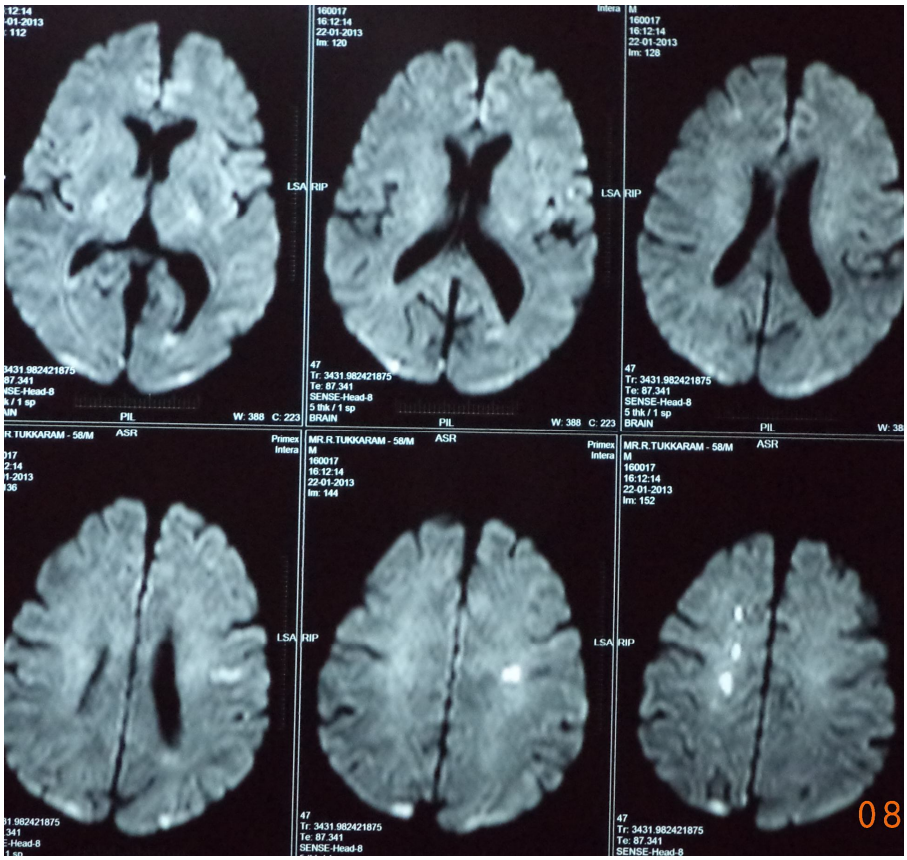
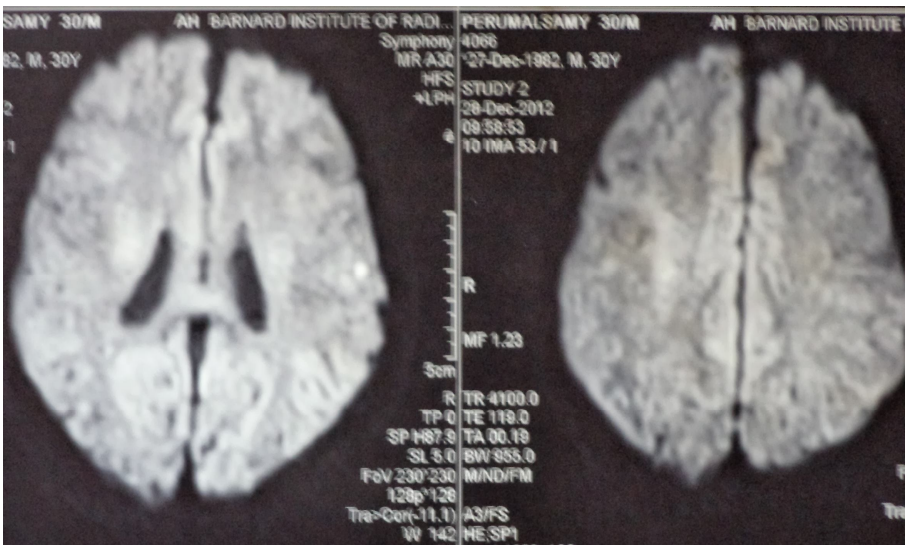


Chart : 7

DWI showing lesions in sites other than corpus callosum and brain stem





Distribution of lesions – Multiple sites

LESIONS IN MULTIPLE SITES	Frequency	Percent
No Lesion or Lesion in Single Site	40	83.33%
Lesion in Multiple Sites	8	16.67%
Total	48	100.00%

Table:8

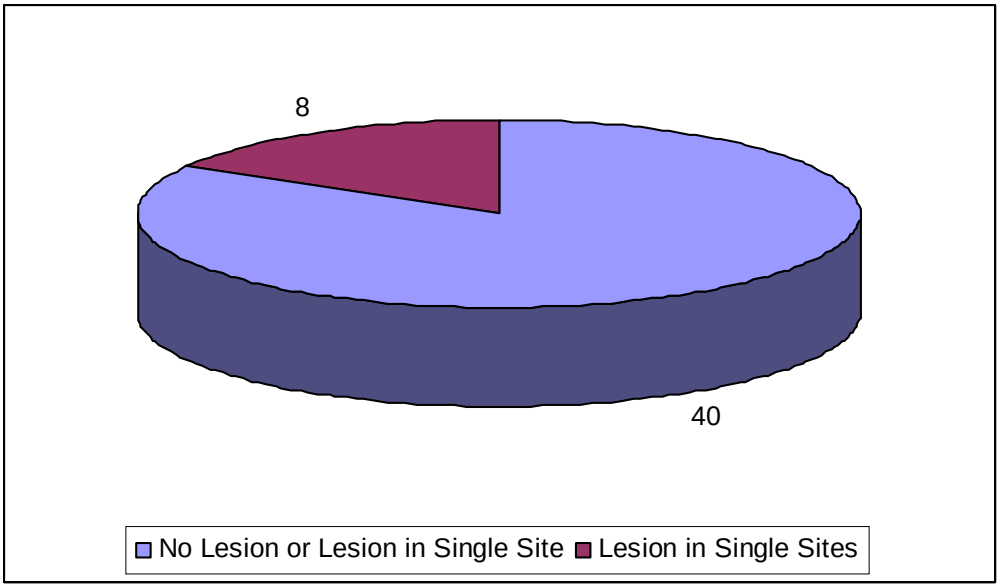
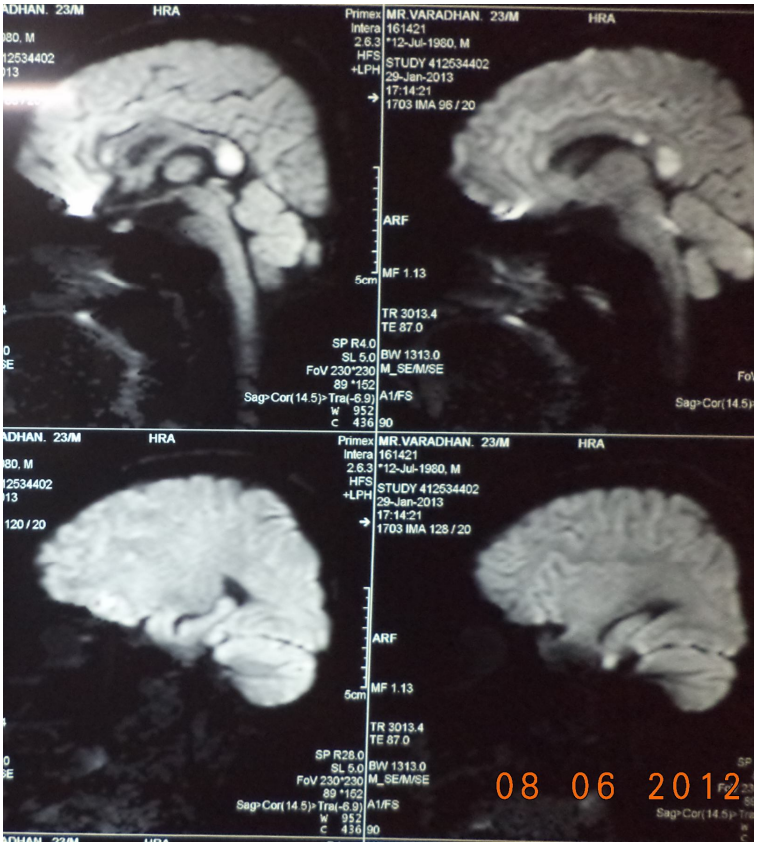
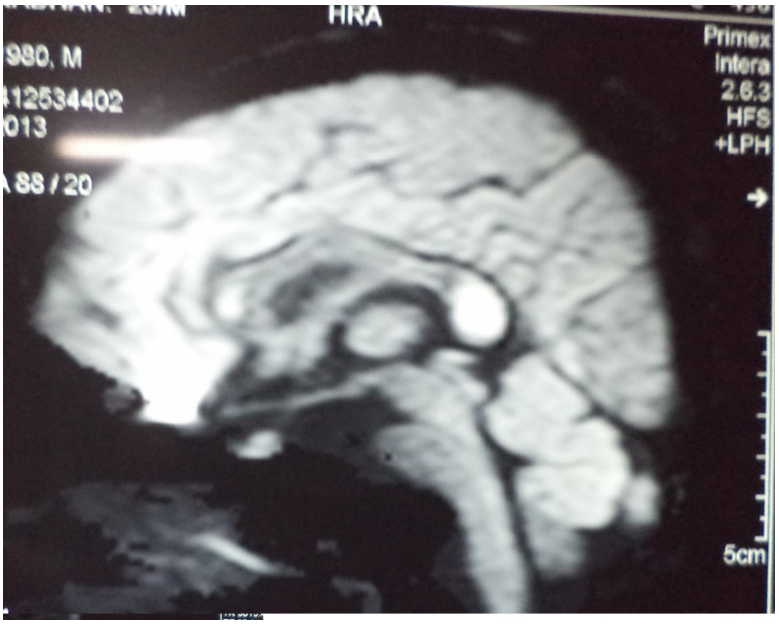


Chart:8

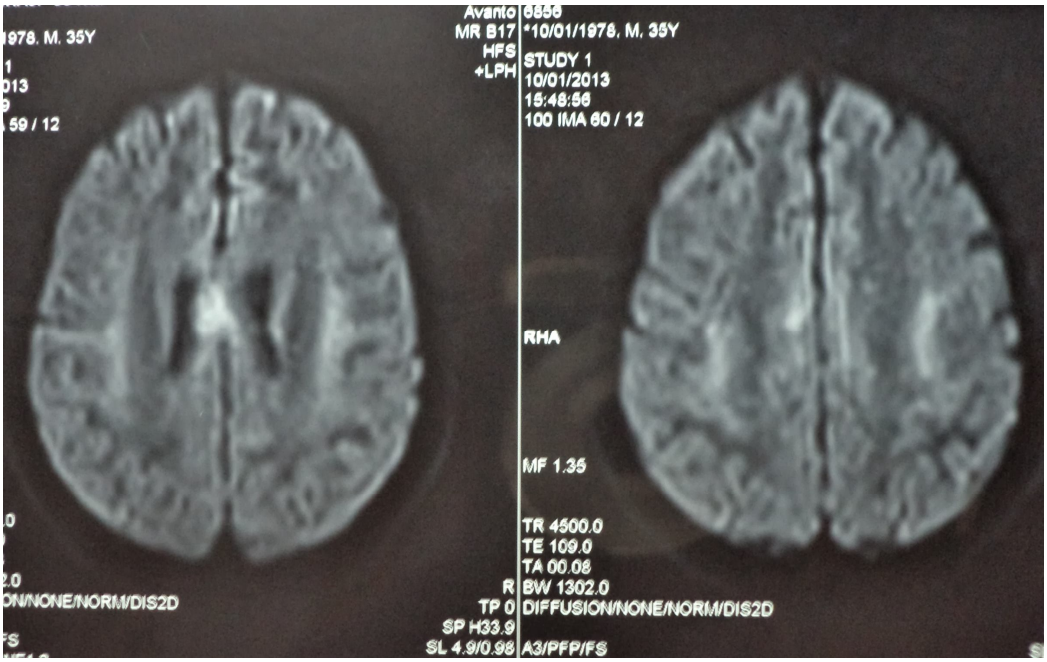
In 8 out of 48 patients, with DAI, DW MRI showed Lesions at Multiple Sites. This accounts to 17 %.

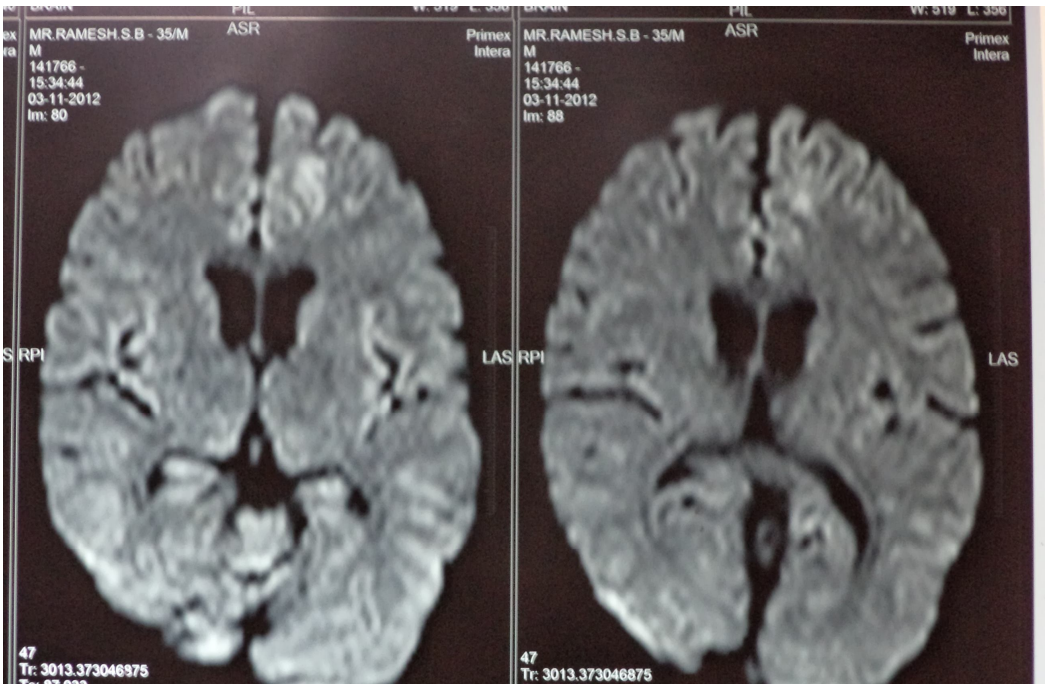
DWI Images showing lesions in multiple sites





DWI Images showing lesions in multiple sites





(VI). To study the relationship between GCS on Admission and Lesions in DWI in cases of DAI

Relationship between the Site of lesion and GCS – Table:9

	Lesions					
GCS	Lesions in Brain Stem	Lesions in Corpus Callosum	Lesions in Multiple Sites	Lesions in Other Sites	No Lesions	Total
3	1	1	1	1	0	4
4	1	2	1	1	0	5
5	0	1	2	1	1	5
6	2	1	1	3	0	7
7	1	4	0	3	0	8
8	0	1	2	5	0	8
9	0	0	1	1	2	4
10	1	0	0	2	0	3
11	0	1	0	1	1	3
12	1	0	0	0	0	1
TOTAL	7	11	8	18	4	48

GCS vs Site of Lesions

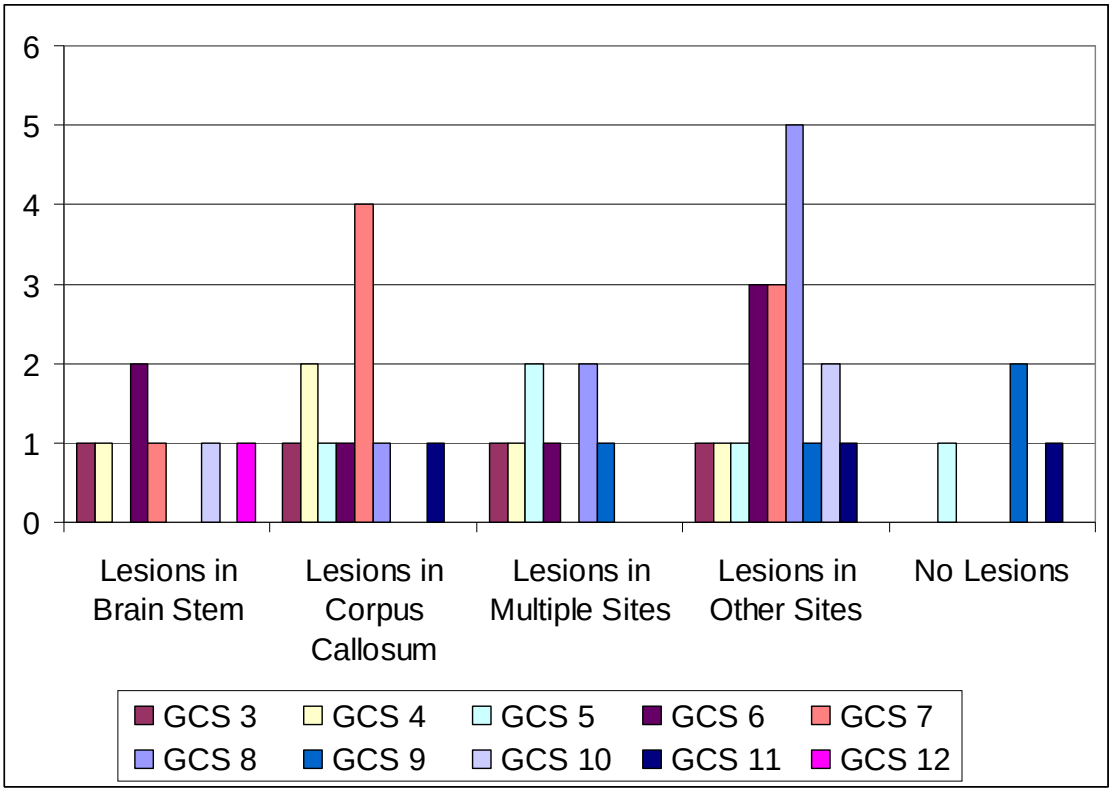


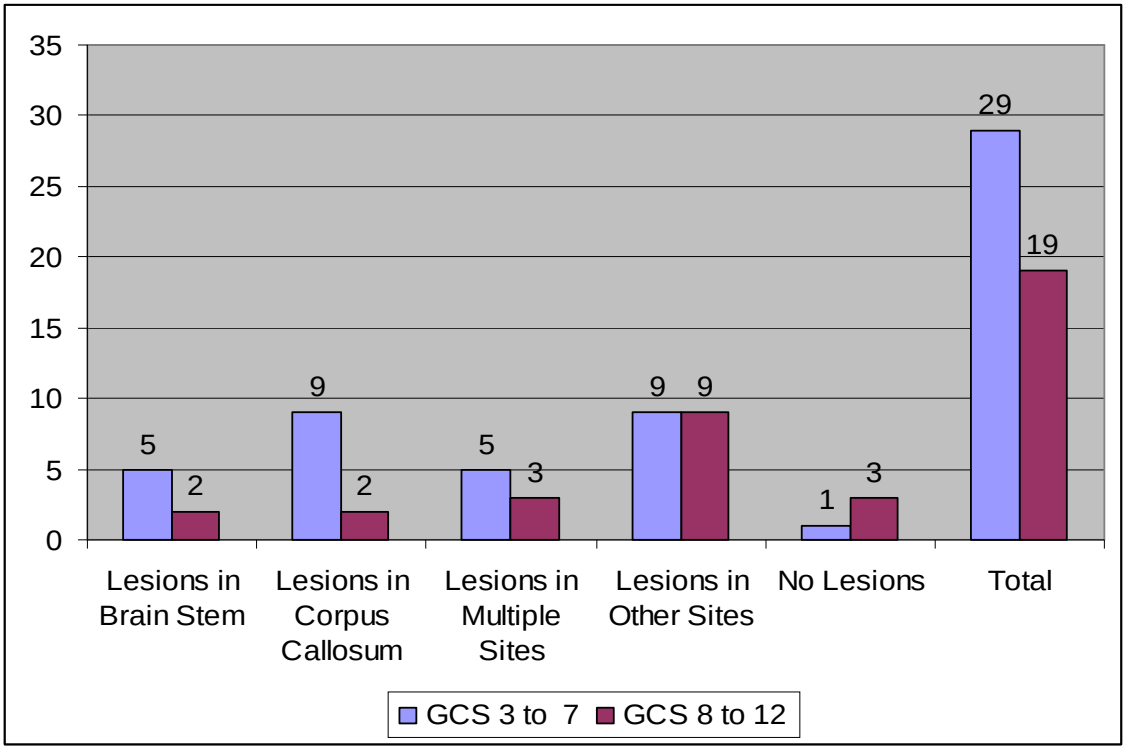
Chart : 9

This bar diagram represents the site of lesion and correlation with GCS. The X Axis denotes the various locations of the lesion and GCS, and Y axis denotes the number of patients for a particular GCS in a particular location.

Analysis of GCS vs Site of lesions

	Lesions					
GCS	Lesions in Brain Stem	Lesions in Corpus Callosum	Lesions in Multiple Sites	Lesions in Other Sites	No Lesions	Total
GCS 3 to 7	5	9	5	9	1	29
GCS 8 to 12	2	2	3	9	3	19
TOTAL	7	11	8	18	4	48

Table: 10



The study population was divided into two groups GCS 3-7 and GCS 8-12 and analyzed. GCS 8-12 showed more lesions at other sites. GCS 3-7 showed more lesions at brain stem and corpus callosum.

VII). The study the relationship between duration of LOC and site of Lesions in DWI in cases of DAI

Relationship between the Duration of LOC (days) and Site of Lesions

LOC_DAYS	Lesions in Brain Stem	Lesions in Corpus Callosum	Lesions in Multiple Sites	Lesions in Other Sites	No Lesions	Total
LOC 2 Days	0	0	1	0	1	2
LOC 3 Days	0	1	1	1	0	3
LOC 4 Days	0	0	1	0	0	1
LOC 5 Days	1	0	0	1	1	3
LOC 7 Days	1	0	0	1	1	3
LOC 8 Days	0	1	1	1	0	3
LOC 9 Days	0	0	0	1	0	1
LOC 10 Days	1	0	1	4	1	7

LOC 11 Days	0	1	0	1	0	2
LOC 12 Days	1	0	1	3	0	5
LOC 14 Days	0	1	0	1	0	2
LOC 15 Days	0	0	1	2	0	3
LOC 16 Days	0	0	1	1	0	2
LOC 17 Days	0	2	0	0	0	2
LOC 20 Days	2	1	0	0	0	3
LOC 21 Days	1	0	0	0	0	1
LOC 25 Days	0	0	0	1	0	1
LOC 35 Days	0	2	0	0	0	2
LOC 45 Days	0	1	0	0	0	1
LOC 60 Days	0	1	0	0	0	1
TOTAL	7	11	8	18	4	48

Table :11

Relationship between days of LOC and site of lesions

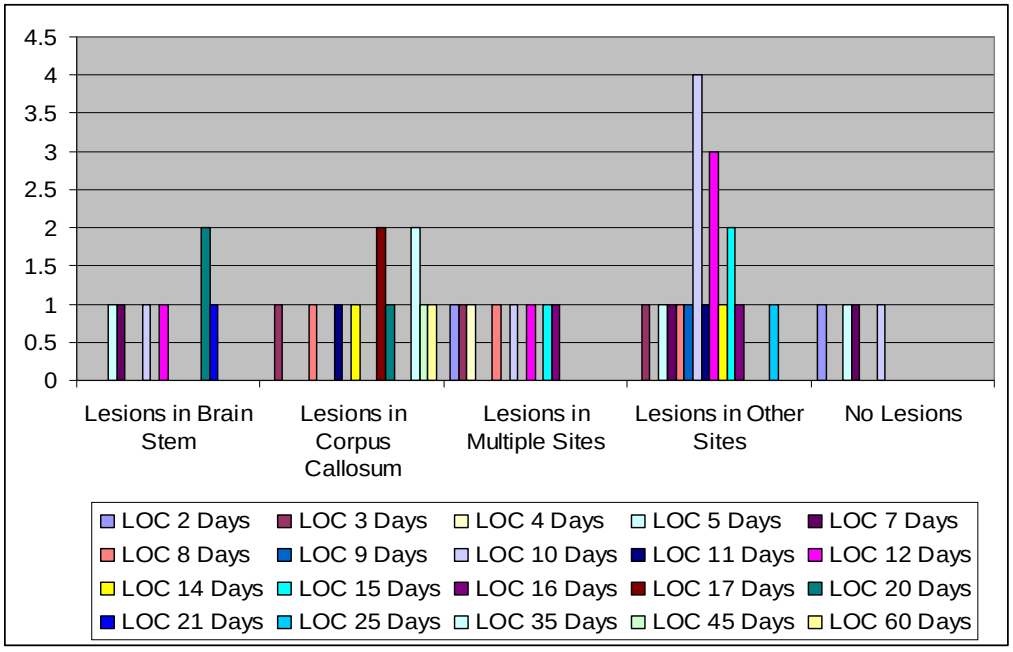


Chart: 11

The patients LOC days ranged from Day 1 to Day 60.Hence median of 11 days was taken and analyzed. Median 11 days

Analysis of LOC days vs Lesions (11 days as median)

	Lesions					
LOC DAYS	**Lesions in Brain Stem**	**Lesions in Corpus Callosum**	**Lesions in Multiple Sites**	**Lesions in Other Sites**	**No Lesions**	**Total**
LOC 0 to 11 Days	3	3	5	10	4	25
LOC 11 to 60 days	4	8	3	8	0	23
TOTAL	7	11	8	18	4	48

Table :12

This table correlates the duration of LOC with the site of lesion, based on median 11 days of LOC, 2 groups were denoted.

Analysis of LOC days vs Lesions

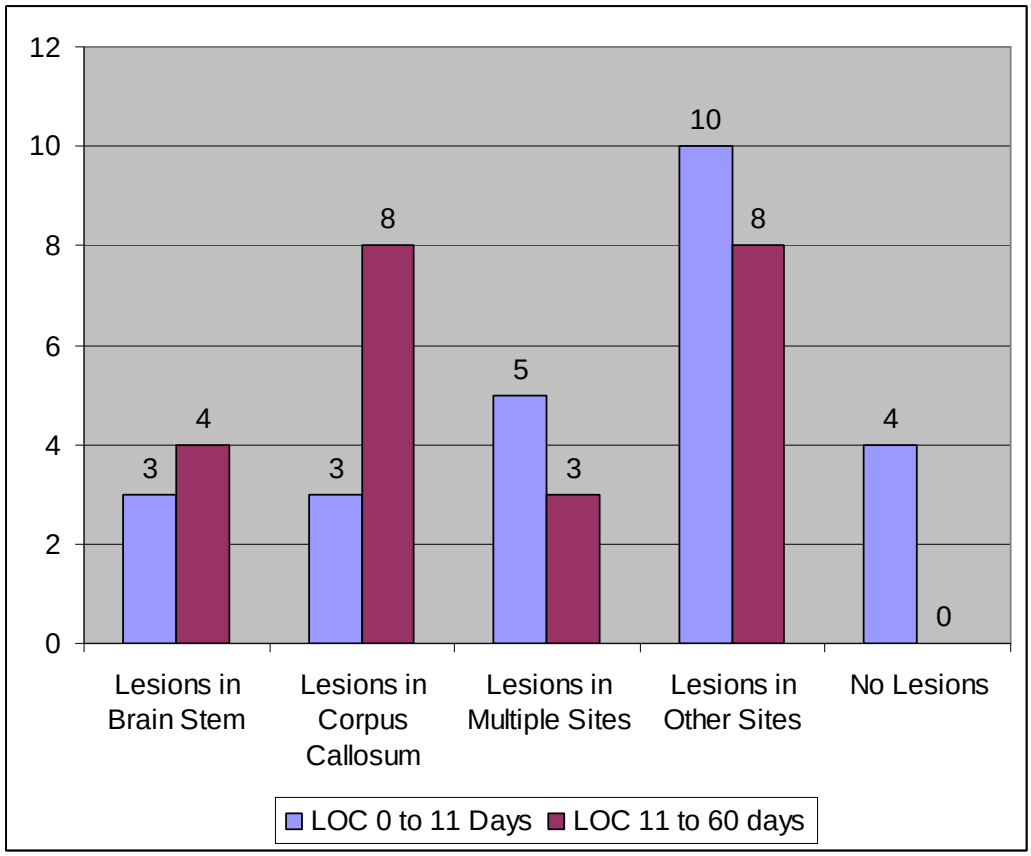


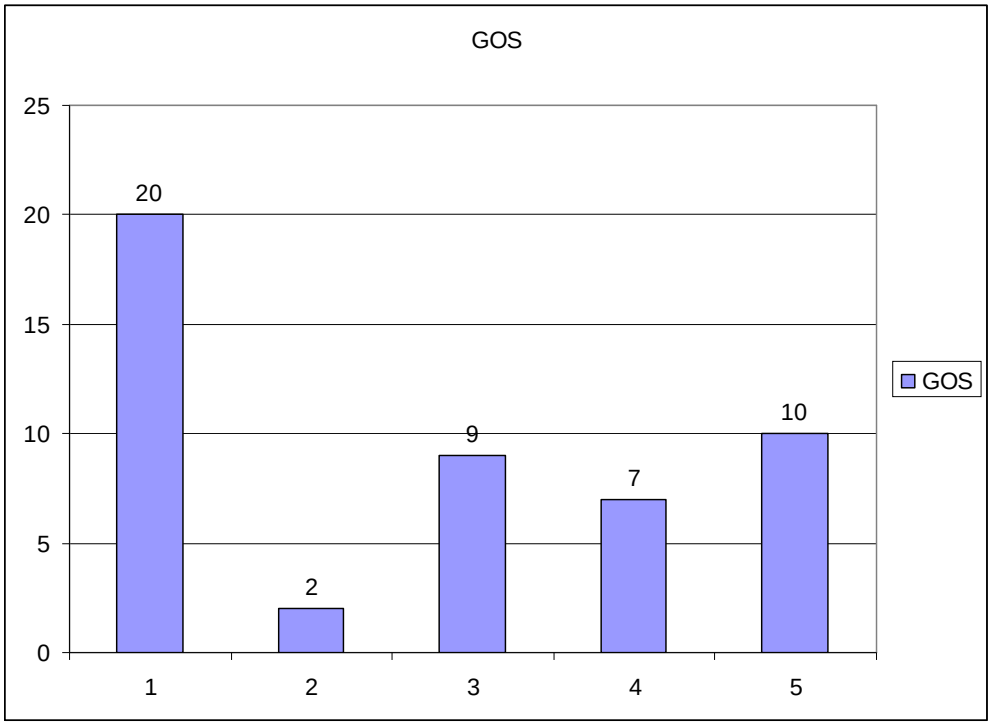
Table : 12

This bar diagram denotes the relationship between site of lesion and LOC days. The X Axis shows the site of lesion and LOC days and the Y axis shows the number of patients. The patients with lesions in corpus callosum had a longer duration of loss of consciousness.

(VIII). To Study about GOS in patients with DAI

Analysis of GOS Score Table No: 13

GOS	Number of Patients	Percent
1	20	41.67%
2	2	4.17%
3	9	18.75%
4	7	14.58%
5	10	20.83%
Total	48	100.00%



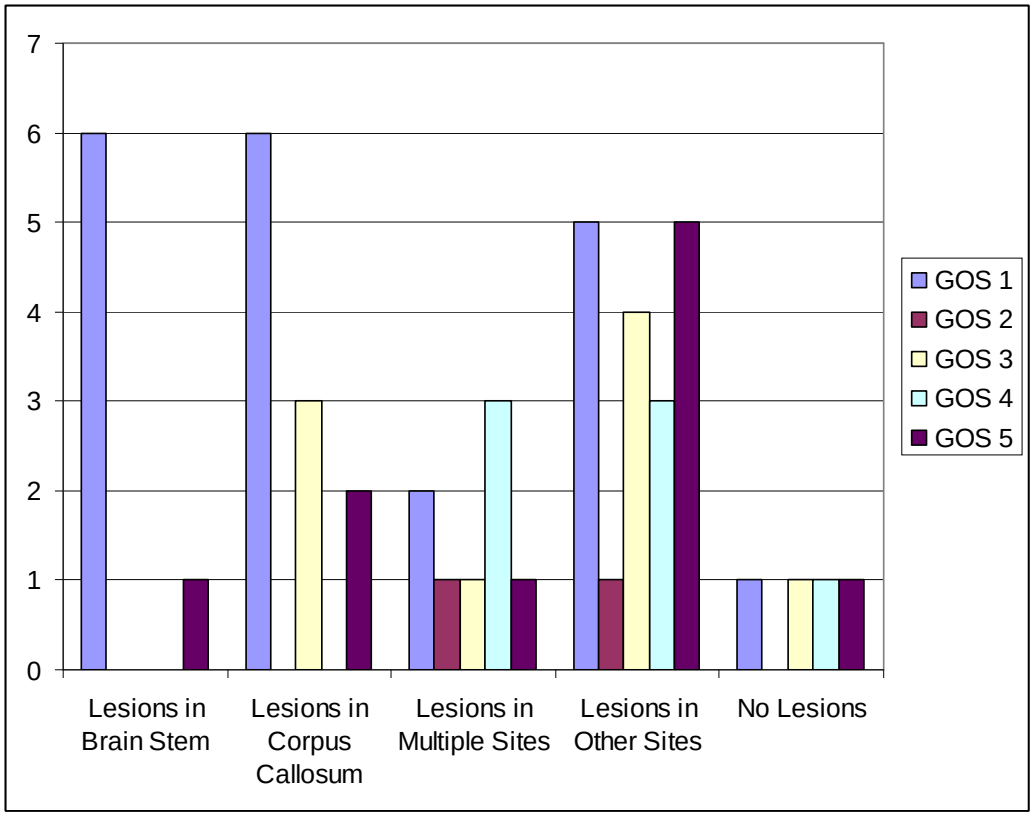
- 20 patients died, GOS being 1
- 2 patients had a GOS Score of 2 while nine patients scored 3 in GOS scoring
- 17 patients were in GOS 4 and 5
- In GOS 4 and 5, patients were independent for his routine living. This constituted nearly 34 %.

(IX). To study the relationship between GOS and site(s) of lesions in DAI

Relationship between the Site of Lesion and GOS Table No: 14

GOS	Lesions in Brain Stem	Lesions in Corpus Callosum	Lesions in Multiple Sites	Lesions in Other Sites	No Lesions	Total
GOS 1	6	6	2	5	1	20
GOS 2	0	0	1	1	0	2
GOS 3	0	3	1	4	1	9
GOS 4	0	0	3	3	1	7
GOS 5	1	2	1	5	1	10
TOTAL	7	11	8	18	4	48

Relationship between the Site of Lesion and GOS Chart No: 14



This bar diagram denotes the correlation between the site of lesion and the GOS. The X Axis denotes the various locations of lesion and GOS. The Y Axis denotes the number of patients in particular GOS in that location.

(X). Analysis of GOS and site of lesions:

GOS	Lesions in Brain Stem	Lesions in Corpus Callosum	Lesions in Multiple Sites	Lesions in Other Sites	No Lesions	Total
GOS 1 Grade I	6	6	2	5	1	20
GOS 2, 3 Grade II	0	3	2	5	1	11
GOS 4,5 Grade III	1	2	4	8	2	17
TOTAL	7	11	8	18	4	48

Table No:15

Analysis of GOS was made and inferred as Grade I patients expired. Grade II patients required assistance for daily routine activities. Grade II had a relatively good recovery.

Analysis of GOS and site of lesions

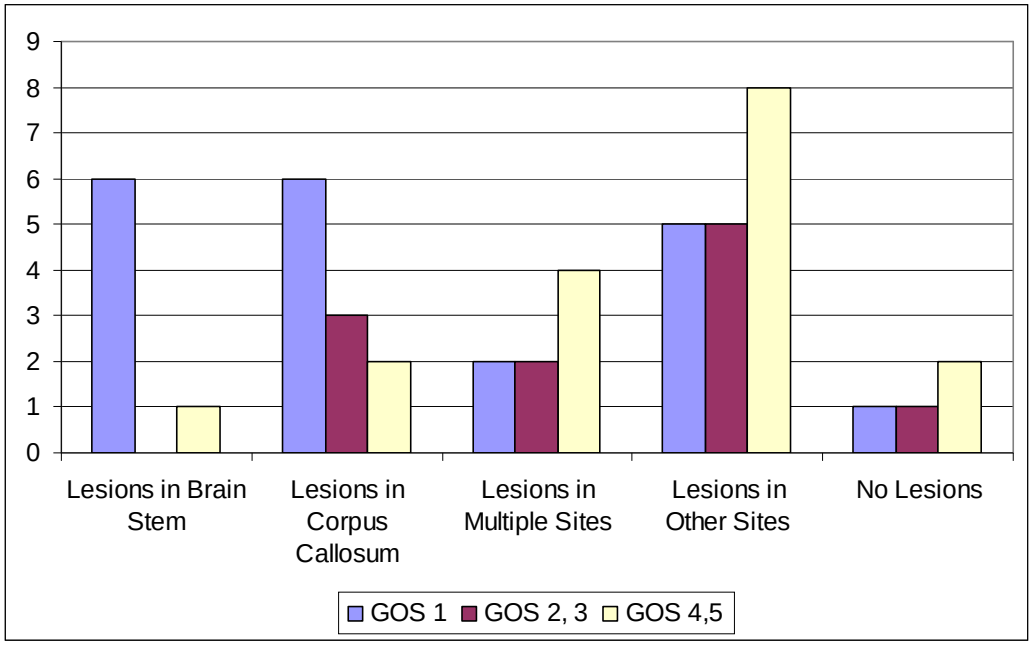


Chart No: 15

(XI) Comparison of GCS with GOS

	GOS					
GCS	**GOS 1**	**GOS 2**	**GOS 3**	**GOS 4**	**GOS 5**	**Total**
GCS 3	3	1	0	0	0	4
GCS 4	4	1	0	0	0	5
GCS 5	4	0	1	0	0	5
GCS 6	3	0	1	2	1	7
GCS 7	3	0	3	0	2	8
GCS 8	2	0	3	2	1	8
GCS 9	0	0	0	1	3	4
GCS 10	1	0	0	2	0	3
GCS 11	0	0	1	0	2	3
GCS 12	0	0	0	0	1	1
TOTAL	20	2	9	7	10	48

Table no: 16

Analysis of GCS with GOS

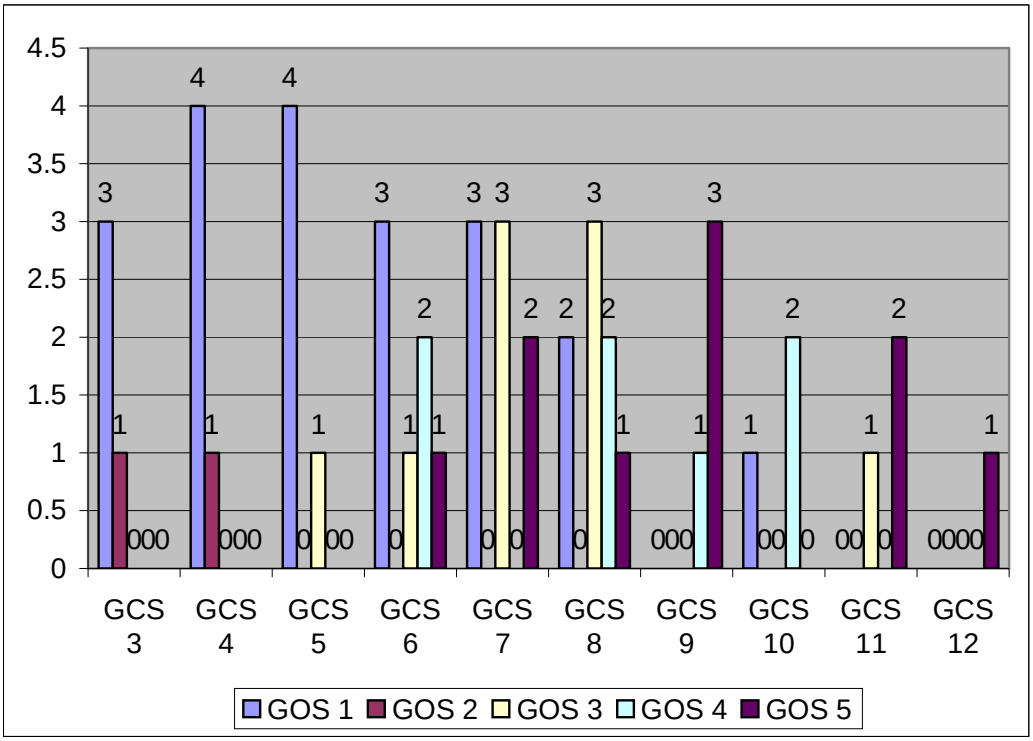


Chart No: 16

This bar diagram shows the correlation of GCS and GOS

The X Axis denotes GCS and GOS

The Y Axis denotes the number of patients

(XI). To study the sensitivity of DWI in finding DAI

Sensitivity of DWI

No Lesions	Lesions in Brain Stem	Lesions in Corpus Callosum	Lesions in Multiple Sites	Lesions in Other Sites	Total
4	7	11	8	18	48

Table No:17

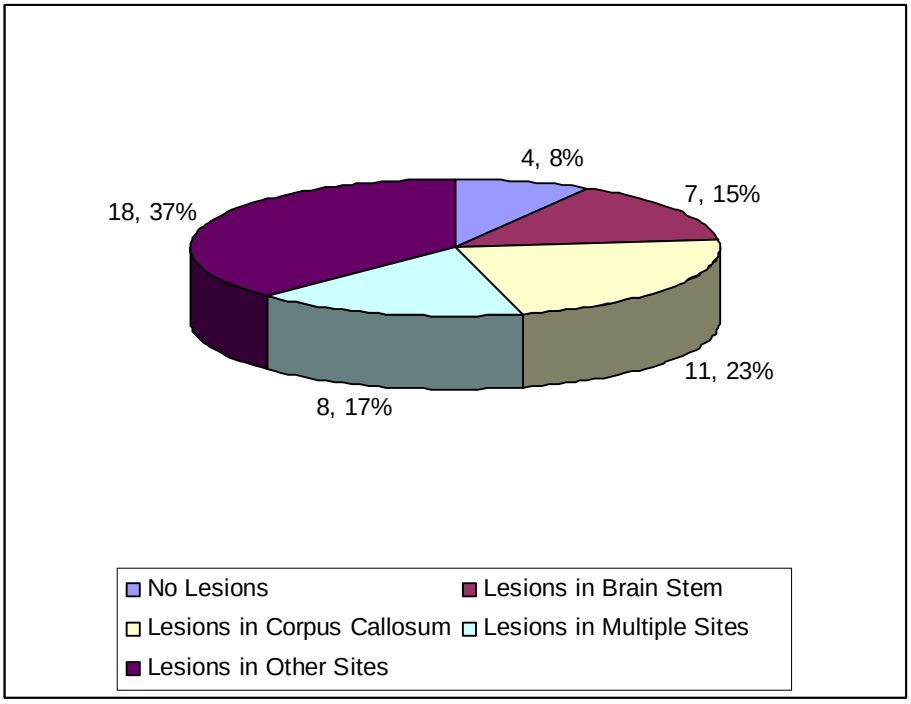


Chart No:17

Sensitivity of DWI

Lesions not picked up by DWI	Lesions picked up by DWI	Total
4	44	48

Table No: 18

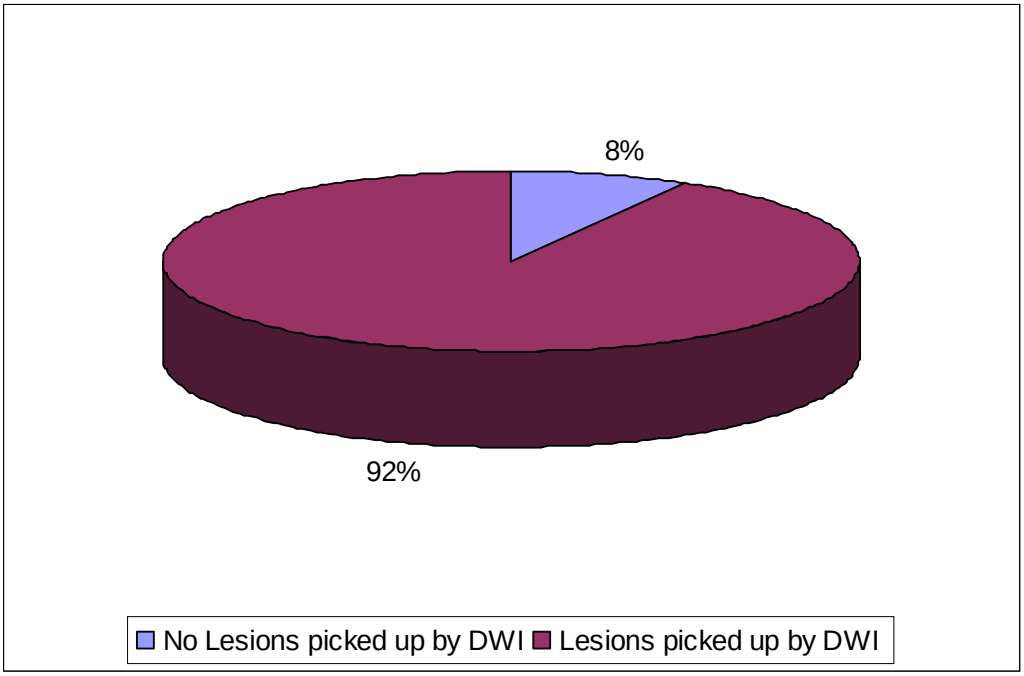


Chart No: 18

Out of the total 48 patients in our study 44 patients showed lesions in DWI while 4 persons did not show any lesions.

DISCUSSION

DISCUSSION

In this study of 48 patients, various data have been observed and analyzed. This study shows as per other published sources, diffuse axonal injury mostly occurs secondary to high velocity events such as motor vehicle accidents, 92 % of patients who had sustained diffuse axonal injuries had history of road traffic accident followed by fall, and then by assault.

The GCS of 45 patients were analyzed which showed 60% of patients had GCS less than 7 and 40% of patients were with GCS more than 7.The highest percentage of Glasgow coma scale incidence was in GCS 7 and GCS 8. It corresponds to 17 % respectively. Of 48 patients of diffuse axonal injury, DWI picked up lesions in 44 patients, hence the sensitivity of the DWI in DAI amounts to 92 %The patients were scanned for DW MRI on different days following injuries. This was due to hemodynamic instability of the patients.

In our sample, the location of lesions in DWI was observed and categorized as lesions in corpus callosum, lesions in brain stem, lesions in other locations involving frontal, parietal, temporal, occipital, internal capsule and cerebellum, lesions in more than one locations

The incidence in others involving frontal, parietal, temporal, occipital, internal capsule and cerebellum was 37.5 % followed by corpus callosum injuries which accounted for 22.9 % followed by lesions in more than one location which accounted to 16.7 % and finally lesions involving brain stem which was 14.6 %

The study of relationship between GCS on admission and lesions in DWI showed patients with lesions in brain stem and corpus callosum had predominantly low GCS. The Duration of LOC of the patients with DAI were noted and of the 48 patients in this study, 28 survived and of those who had survived, 52 % regained consciousness within 11 days and 48 percent of patients regained consciousness after 11 days. The group has median of 11 days and standard deviation of 10.99 days

The patients with lesions in corpus callosum had a longer duration of LOC than other groups. Most of the patients had LOC of 8 to 10 days. This was shown in the analysis. In this study of 48 patients, 20 patients died. Of those who had survived, Good Outcome, i.e. GOS 4 or 5 was seen in 35.4 % and GOS 2to 3 was seen in 23 percent.

CONCLUSION

CONCLUSION

Diffuse Axonal Injuries occur with motor vehicle accidents due to acceleration deceleration and rotational forces acting on the brain during impact. Patient with moderate and severe injuries according to GCS Scoring system had poor Glasgow Outcome scale. Brain Stem Lesions has poor outcome either death or persistent vegetative state probably due to shearing of tracts. Corpus Callosum lesions took a longer time to recover from LOC and are associated with lower Glasgow outcome scores In future, when supplemented with Diffusion tensor imaging and tractography, neuronal injuries can be analysed well

- Road Traffic Accidents are more often associated with Diffuse Axonal Injuries than Assaults and Accidental Falls
- Day of Imaging had no correlation with the findings or Outcome
- Lesions in Brain Stem and Corpus Callosum were associated with poor GCS on Admission
- Lesions in Brain Stem and Corpus Callosum were associated with Longer period of Loss of Consciousness
- Lesions in Brain Stem and Corpus Callosum were associated with poor Outcome as per GOS

. DWI is an eye opener for DAI analyzing the DAI.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. [1] Kraus JF, McArthur DL, Silverman TA, Jayaraman M. Epidemiology of brain injury. In: Narayan RK, Wilberger JE, Povlishock JT, eds. Neurotrauma. New York: McGrawHill ; 1996 : 13 -30
2. [2] Kurth SM, Bigler ED, Blatter DD. Neuropsychological outcome and quantitative image analysis of acute haemorrhage in traumatic brain injury: preliminary findings. Brain Inj 1994;8:489-500
3. [3] Bigler, ED. 2000. The Lesion(s) in Traumatic Brain Injury: Implications for Clinical Neuropsychology
4. [4] Wolf JA, Stys PK, Lusardi et al. Traumatic Axonal Injury induces calcium influx modulated by tetrodoxin sensitive sodium channels. JNeurosci 2001; 21(6):1923-30
5. [5] Parizel PM, Ozsarlak, Van Goethem JW et al. Imaging findings in Diffuse Axonal Injury after closed head trauma Eur Radiol 1998; 8(6):960-965
6. [6] Gentry LR, Godersky JC, Thompson B. MR Imaging of head trauma : review of distribution and radiopathology features of traumatic lesions. AJR Am J Roentgenol 1988; 150(3):663-672

7. [7] Gentry LR, Godersky JC, Thompson B. MR Prospective comparative study of intermediate field MR and CT in the evaluation of closed head trauma AJR Am J Roentgenol 1988; 150(3):673-682
8. [8] Mittal RL, Grossman RI, Hiehle JF, at al. Prevalence of MR evidence of diffuse axonal injury in patients with mild head injury and normal head CT Findings AJNR Am J Neuroradiol 1994; 15(8):1583-1589
9. [9] Ezaki Y, Tsutsumi K, Morikava M et al. Role of diffusion wighted magnetic resonance imaging in diffuse axonal injury. Acta Radio 2006; 47(7):733-740,
10. [10] Huisman TA, Sorensen AG, Hergan K, et al. Diffusion wighted imaging for the evaluation of Diffuse Axonal Injury in closed head injury J Computer Assist Tomogr 2003; 27(1):5-11
11. [11] Arfanakis K, Haughton VM, Carew JD et al. Diffusion Tensor MR Imaging in diffuse axonal injury AJNR Am J Neuroradiol 2002; 23(5):794-802
12. [12] Inglese M, Makani S, Johnson G et al, Diffuse Axonal Injury in mild traumatic brain injury: a diffusion tensor imaging study J Neurosurg 2005; 103(2):298-303

13.[13] Le TH, Mukherjee P, Henry RG et al. Diffusion tensor imaging with three dimensional fiber tractography of traumatic axonal shearing injury; an imaging correlate for the posterior callosal “disconnection” syndrome; case report. Neurosurgery 2005; 56(1): 189

14.[14] Sinson G, Bagley LJ, Cecil KM et al. Magnetization Transfer Imaging and proton MR Spectroscopy in the evaluation of axonal injury : correlation with clinical outcome after traumatic brain injury AJNR Am J Neuroradiol 2001; 22(1):143-151

APPENDIX

APPENDIX I - Ethical Committee Approval

INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE, CHENNAI -3

Telephone No : 044 25305301
Fax : 044 25363970

CERTIFICATE OF APPROVAL

To
Dr.C.N.Ilankumaran,
PG in Neurology
Madras Medical College,Chennai -3

Dear Dr.C.N. Ilankumaran,

The Institutional Ethics committee of Madras Medical College, reviewed and discussed your application for approval of the proposal entitled " Diffusion weighted MR imaging in diffuse axonal injury" No.29112012.

The following members of Ethics Committee were present in the meeting held on 01.11.2012 conducted at Madras Medical College, Chennai -3.

1. Prof. R. Nandhini MD — Member Secretary
   Director, Instt. of Pharmacology ,MMC, Ch-3
2. Prof. Reghu MD — Member
   Director , Inst. Of Internal Medicine, MMC, Ch-3
3. Prof. Shyamraj MD — Member
   Director i/c , Instt. of Biochemistry , MMC, Ch-3
4. Prof. P. Karkuzhali. MD — Member
   Prof., Instt. of Pathology, MMC, Ch-3
5. Prof. G.Muralidharan MS — Member
   Prof of Surgery, MMC, Ch-3
6. Thiru. S. Govindsamy, BA, BL — Lawyer

We approve the proposal to be conducted in its presented form.

Sd/ Chairman & Other Members

The Institutional Ethics Committee expects to be informed about the progress of the study, and SAE occurring in the course of the study, any changes in the protocol and patients information / informed consent and asks to be provided a copy of the final report.

RN 19/11/12

Member Secretary, Ethics Committee

APPENDIX II - Copy of Informed Consent ஆராய்ச்சி ஒப்புதல் கடிதம்

ஆராய்ச்சி ஒப்புதல் கடிதம்

ஆராய்ச்சி தலைப்பு : "**Diffusion weighted MR imaging in diffuse axonal injury**". பற்றிய ஆய்வு

பெயர் : வயது/பால் : தேதி :

ஆராய்ச்சி சேர்க்கை எண் :

- ராஜீவ் காந்தி அரசு மருத்துவக்கல்லூரி மற்றும் அரசு பொது மருத்துவமனையின் நரம்பியல் அறுவை சிகிச்சைத் துறையில் "**Diffusion weighted MR imaging in diffuse axonal injury**".பற்றிய ஆய்வு நடைபெறுகிறது என்பதை அறிந்து கொண்டேன்
- சிடி ஸ்கேன், மற்றும் எம்.ஆர்.ஐ ஸ்கேன் ஆகியவற்றின் அடிப்படையில் இந்த ஆய்வு நடைபெறுகிறது என்பதையும் மேலும் அறுவை சிகிச்சையின் போது நேரடியாக பார்க்கப்படுவதை வைத்தும் ஆய்வு நடைபெறுகிறது என்பதையும் அறிந்து கொண்டேன்
- இவ்வாய்வில் கலந்து கொள்பவர்களின் சொந்த தகவல்கள் ரகசியமாக பாதுக்காகபடும் என்பதையும் இந்த ஆய்வின் முடிவுகளை பிரசுரிக்குபோது அல்லது வெளியிடும்போதோ தங்களின் எனது தகவல்கள் ஏதும் வெளியிடபடாது என்பதையும் அறிந்து கொண்டேன்
- இந்த ஆராய்ச்சியிலிருந்து எந்த நேரமும் பின் வாங்கலாம் என்றும், அதனால் எந்த பாதிப்பும் எற்படாது என்பதையும் அறிந்து கொண்டேன்
- இந்த ஆய்வில் பங்குபெற அல்லது விலகிக்கொள்ள எனக்கு முழு சுதந்திரம் உண்டு என்பதையும், இந்த ஆய்வில் இருந்து நான் விலகிகொண்டாலும் எனக்கு கிடைக்கவேண்டிய சிகிச்சை தொடர்ந்து கிடைக்கும் என்பதையும் அறிந்து கொண்டேன்
- இந்த ஆராய்ச்சியின் விவரங்களும், அதன் நோக்கங்களும் எனக்கு தெளிவாக விளக்கப்பட்டது. எனக்கு விளக்கப்பட்ட விவரங்களை புரிந்து கொண்டு, இந்த ஆய்வில் கலந்து கொள்ள சம்மதிக்கிறேன்
- இந்த ஆராய்ச்சியில் பிறரின் நிர்பந்தமின்றி என் சொந்த விருப்பத்தின் பேரில் தான் பங்கு பெறுகிறேன்

கையொப்பம்

APPENDIX III - Copy of Patient Information Sheet

INFORMATION SHEET

We are conducting **Diffusion weighted MR imaging in diffuse axonal injury**" among patients attending Rajiv Gandhi Government General Hospital, Chennai and for that your specimen may be valuable to us.

The purpose of this study is to analyse **Diffusion weighted MR imaging in diffuse axonal injury**

- We are selecting certain cases and if your clinical condition is found eligible, we may be using your blood sample to perform extra tests and special studies which in any way do not affect your final report or management.
- The privacy of the patients in the research will be maintained throughout the study. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.
- Taking part in this study is voluntary. You are free to decide whether to participate in this study or to withdraw at any time; your decision will not result in any loss of benefits to which you are otherwise entitled.
- The results of the special study may be intimated to you at the end of the study period or during the study if anything is found abnormal which may aid in the management or treatment.

Signature of investigator Signature of participant

Date:

APPENDIX IV - ஆராய்ச்சித் தகவல் தாள்

ஆராய்ச்சி தகவல் தாள்

- தங்களின் சிடி ஸ்கேன் / எம்.ஆர்.ஐ ஸ்கேன் படம் அல்லது படத்தின் நகல் அல்லது படத்தின் நிழல்படம் இங்கு பெறப்பட்டுள்ளது
- ராஜீவ் காந்தி அரசு மருத்துவக்கல்லூரி மற்றும் அரசு பொது மருத்துவமனையின் நரம்பியல் அறுவை சிகிச்சைத் துறையில் **"Diffusion weighted MR imaging in diffuse axonal injury"** பற்றிய ஆய்வு நடைபெறுகிறது
- சிடி ஸ்கேன், மற்றும் எம்.ஆர்.ஐ ஸ்கேன் ஆகியவற்றின் அடிப்படையில் இந்த ஆய்வு நடைபெறுகிறது
- இவ்வாய்வில் கலந்து கொள்பவர்களின் சொந்த தகவல்கள் ரகசியமாக பாதுக்காகபடும்
- இந்த ஆய்வின் முடிவுகளை பிரசுரிக்குபோது அல்லது வெளியிடும்போதோ தங்களின் சொந்த தகவல்கள் ஏதும் வெளியிடபடாது
- இந்த ஆய்வில் பங்குபெற அல்லது விலகிக்கொள்ள உங்களுக்கு முழு சுதந்திரம் உண்டு
- இந்த ஆய்வில் இருந்து நீங்கள் விலகிகொண்டாலும் உங்களுக்கு கிடைக்கவேண்டிய சிகிச்சை தொடர்ந்து கிடைக்கும்

ஆராய்ச்சியாளர் கையொப்பம்பங்கேற்பாளர் கையொப்பம்

நாள்

APPENDIX V – COPY OF INFORMED CONSENT

INFORMED CONSENT FORM

Title of the study "**Diffusion weighted MR imaging in diffuse axonal injury**".

Name of the Participant: Dr.Ilankumaran.C.N,

Name of the Principal (Co-Investigator): Prof.V.SundarMCh

Name of the Institution: Institute of Neurology, MadrasMedicalCollege and RajivGandhiGovernment GeneralHospital, Chennai

Name and address of the sponsor / agency (ies) (if any): None.

Documentation of the informed consent

I _____ have read the information in this form (or it has been read to me). I was free to ask any questions and they have been answered. I am over 18 years of age and, exercising my free power of choice, hereby give my consent to be included as a participant in "*Diffusion weighted MR imaging in diffuse axonal injury*"

1. I have read and understood this consent form and the information provided to me.

2. I have had the consent document explained to me.

3. I have been explained about the nature of the study.

4. I have been explained about my rights and responsibilities by the investigator.

5. I have been informed the investigator of all the treatments I am taking or have taken in the past _____ months including any native (alternative) treatment.

6. I have been advised about the risks associated with my participation in this study.*

7. I agree to cooperate with the investigator and I will inform him/her immediately if I suffer unusual symptoms. *

8. I have not participated in any research study within the past _____month(s). *

9. I have not donated blood within the past _____ months—Add if the study involves extensive blood sampling. *

10. I am aware of the fact that I can opt out of the study at any time without having to give any reason and this will not affect my future treatment in this hospital. *

11. I am also aware that the investigator may terminate my participation in the study at any time, for any reason, without my consent. *

12. I hereby give permission to the investigators to release the information obtained from me as result of participation in this study to the sponsors, regulatory authorities, Govt. agencies, and IEC. I

understand that they are publicly presented.

13. I have understand that my identity will be kept confidential if my data are publicly presented

14. I have had my questions answered to my satisfaction.

15. I have decided to be in the research study.

I am aware that if I have any question during this study, I should contact the investigator. By signing

this consent form I attest that the information given in this document has been clearly explained to me and understood by me, I will be given a copy of this consent document.

For adult participants:

Name and signature / thumb impression of the participant (or legal representative if participant incompetent)

Name _____ Signature_____
Date_____

Name and Signature of impartial witness (required for illiterate patients):

Name _____ Signature_____
Date_____

Address and contact number of the impartial witness:

Name and Signature of the investigator or his representative obtaining consent:

Name _____ Signature_____
Date_____

For Children being enrolled in research:

Whether child's assent was asked: Yes / No (Tick one)

[If the answer to be above question is yes, write the following phrase:

You agree with the manner in which assent was asked for from your child and given by yourchild. You agree to have your child take part in this study].

[If answer to be above question No, give reason (s)
:_____.

Although your child did not or could not give his or her assent, you agree to your child's

participation in this study.

Name and Signature of / thumb impression of the participant's parent(s) (or legal representative)

Name _____ Signature_____
Date_____

Name _____ Signature_____
Date_____

Name and Signature of impartial witness (required for parents of participant child illiterate):

Name _____ Signature_____
Date_____

APPENDIX - COPY OF PROFORMA USED

INSTITUTE OF NEUROLOGY
GOVERNMENT GENERAL HOSPITAL, CHENNAI

PROFORMA

DIFFUSION WEIGHTED MR IMAGING IN DIFFUSE AXONAL INJURY

NAME:	AGE/SEX :	IP No :	MIN :
ADDRESS:	DOA:	DOD:	DOS :

Complaints:

Clinical Examination:

Mode of Injury:

Conscious Level (GCS):

Pupil Status:

EOM:	Full or Restricted
DEM:	Present (or) Absent
External Injuries:	Present (or) Absent
Associated Injuries:	Present (or) Absent

Fundus Examination:

Papilledema	Present (or) Absent
Any other Neurological Signs:	Present (or) Absent

APPENDIX V –MASTER CHART

Patient Number	GCS	Mode of Injury	Imaging on __ day post trauma	Lesion in Corpus Callosum	Lesion in Brain Stem	Lesion in Sites other than Corpus Callosum and Brain Stem	Lesion in Multiple Sites	Lesions	Days of LOC	GOS
1	3.00	RTA	2	YES	NO	NO	NO	Lesions in Corpus Callosum	3	1
2	4.00	FALL	3	NO	YES	NO	NO	Lesions in Brain Stem	5	1
3	7.00	RTA	5	NO	YES	NO	NO	Lesions in Brain Stem	7	1
4	8.00	RTA	5	NO	NO	YES	NO	Lesions in Other Sites	7	1
5	4.00	RTA	5	YES	NO	NO	NO	Lesions in Corpus Callosum	8	1
6	3.00	RTA	7	NO	NO	YES	NO	Lesions in Other Sites	10	1
7	10.00	RTA	7	NO	YES	NO	NO	Lesions in Brain Stem	10	1
8	5.00	RTA	8	NO	NO	NO	YES	Lesions in Multiple Sites	10	1
9	5.00	RTA	7	YES	NO	NO	NO	Lesions in Corpus Callosum	11	1
10	7.00	RTA	9	NO	NO	YES	NO	Lesions in Other	11	1

Patient Number	GCS	Mode of Injury	Imaging on __ day post trauma	Lesion in Corpus Callosum	Lesion in Brain Stem	Lesion in Sites other than Corpus Callosum and Brain Stem	Lesion in Multiple Sites	Lesions	Days of LOC	GOS
11	5.00	RTA	4	NO	NO	YES	NO	Sites Lesions in Other Sites	12	1
12	8.00	RTA	5	NO	NO	YES	NO	Lesions in Other Sites	12	1
13	3.00	RTA	8	NO	YES	NO	NO	Lesions in Brain Stem	12	1
14	6.00	RTA	5	YES	NO	NO	NO	Lesions in Corpus Callosum	14	1
15	4.00	RTA	7	YES	NO	NO	NO	Lesions in Corpus Callosum	17	1
16	7.00	FALL	7	YES	NO	NO	NO	Lesions in Corpus Callosum	17	1
17	6.00	RTA	10	NO	YES	NO	NO	Lesions in Brain Stem	20	1
18	6.00	RTA	10	NO	YES	NO	NO	Lesions in Brain Stem	21	1
19	4.00	FALL	2	NO	NO	YES	NO	Lesions in Other Sites	5	2
20	3.00	RTA	7	NO	NO	NO	YES	Lesions in Multiple Sites	12	2
21	7.00	RTA	2	NO	NO	YES	NO	Lesions in Other	3	3

Patient Number	GCS	Mode of Injury	Imaging on __ day post trauma	Lesion in Corpus Callosum	Lesion in Brain Stem	Lesion in Sites other than Corpus Callosum and Brain Stem	Lesion in Multiple Sites	Lesions	Days of LOC	GOS
22	8.00	ASS	8	NO	NO	YES	NO	Sites Lesions in Other Sites	10	3
23	5.00	RTA	7	NO	NO	NO	YES	Lesions in Multiple Sites	15	3
24	8.00	RTA	9	NO	NO	YES	NO	Lesions in Other Sites	15	3
25	7.00	RTA	7	YES	NO	NO	NO	Lesions in Corpus Callosum	20	3
26	6.00	RTA	10	NO	NO	YES	NO	Lesions in Other Sites	25	3
27	8.00	RTA	9	YES	NO	NO	NO	Lesions in Corpus Callosum	45	3
28	7.00	RTA	8	YES	NO	NO	NO	Lesions in Corpus Callosum	60	3
29	10.00	RTA	5	NO	NO	YES	NO	Lesions in Other Sites	8	4
30	10.00	RTA	7	NO	NO	YES	NO	Lesions in Other Sites	9	4
31	6.00	RTA	8	NO	NO	YES	NO	Lesions in Other Sites	14	4
32	6.00	RTA	8	NO	NO	NO	YES	Lesions in	16	4

Patient Number	GCS	Mode of Injury	Imaging on __ day post trauma	Lesion in Corpus Callosum	Lesion in Brain Stem	Lesion in Sites other than Corpus Callosum and Brain Stem	Lesion in Multiple Sites	Lesions	Days of LOC	GOS
33	7.00	RTA	4	NO	NO	YES	NO	Multiple Sites Lesions in Other Sites	10	5
34	11.00	RTA	7	NO	NO	YES	NO	Lesions in Other Sites	10	5
35	6.00	RTA	6	NO	NO	YES	NO	Lesions in Other Sites	12	5
36	8.00	RTA	5	NO	NO	YES	NO	Lesions in Other Sites	15	5
37	9.00	RTA	8	NO	NO	YES	NO	Lesions in Other Sites	16	5
38	12.00	RTA	7	NO	YES	NO	NO	Lesions in Brain Stem	20	5
39	7.00	RTA	7	YES	NO	NO	NO	Lesions in Corpus Callosum	35	5
40	11.00	RTA	7	YES	NO	NO	NO	Lesions in Corpus Callosum	35	5
41	9.00	RTA	10	NO	NO	NO	NO	No Lesions	7	5
42	5.00	RTA	4	NO	NO	NO	NO	No Lesions	10	1
43	9.00	RTA	8	NO	NO	NO	NO	No Lesions	2	4
44	11.00	RTA	9	NO	NO	NO	NO	No Lesions	5	3
45	8.00	RTA	10	NO	NO	NO	YES	Lesions in	8	4

Patient Number	GCS	Mode of Injury	Imaging on __ day post trauma	Lesion in Corpus Callosum	Lesion in Brain Stem	Lesion in Sites other than Corpus Callosum and Brain Stem	Lesion in Multiple Sites	Lesions	Days of LOC	GOS
46	9.00	RTA	8	NO	NO	NO	YES	Multiple Sites Lesions in Multiple Sites	4	5
47	8.00	RTA	8	NO	NO	NO	YES	Multiple Sites Lesions in Multiple Sites	3	4
48	4.00	RTA	2	NO	NO	NO	YES	Multiple Sites Lesions in Multiple Sites	2	1

Turnitin Originality Report

DIFFUSION WEIGHTED MR IMAGING IN DIFFUSE AXONAL INJURY by Ilankumaran Natrajaperumal 18101506 M.Ch. Neuro Surgery

From Medical (TNMGRMU APRIL 2013 EXAMINATIONS)

Similarity Index	Similarity by Source	
13%	Internet Sources:	11%
	Publications:	10%
	Student Papers:	5%

Processed on 24-Mar-2013 01:22 IST
ID: 312388877
Word Count: 8614

sources:

1 1% match (Internet from 08-Jan-2013)
http://www.makehumans.com/htmx/magnetic_resonance_imaging.php

2 1% match (Internet from 11-Apr-2007)
http://www.emedicine.com/radio/topic216.htm

3 1% match (Internet from 29-Nov-2006)
http://www.jficm.anzca.edu.au/pdfdocs/Journal/Journal2001/J2001%20(a)%20March/Head%20injury2.pdf

4 1% match (publications)
Robert Stevens. "Brain Imaging in Intensive Care Medicine", Seminars in Neurology, 11/2008

5 1% match (publications)
Sumit N. Niogi. "Diffusion Tensor Imaging of Mild Traumatic Brain Injury :", Journal of Head Trauma Rehabilitation, 07/2010

6 1% match (Internet from 22-Aug-2010)
http://wwwpub.utdallas.edu/~herve/abdi_DTI4TBI_AoN-2008.pdf

7 1% match (student papers from 24-Jan-2012)
Submitted to iGroup on 2012-01-24

8 1% match (Internet from 24-Oct-2012)
http://wiki.cns.org/wiki/index.php/Diagnosis_and_Management_of_Head_Trauma

9 < 1% match (Internet from 05-Dec-2012)
http://www.ispub.com/journal/the-internet-journal-of-gastroenterology/volume-11-number-1/intussuscepting-rectal-lipoma-a-case-report-and-review-of-literature.html