"EVALUATION OF TRAUMATIC SPINE BY MAGNETIC RESONANCE IMAGING AND ITS CORRELATION WITH CLINICO-NEUROLOGICAL OUTCOME"

 $\mathbf{B}\mathbf{y}$

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Under the Guidance of

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MAY 2018





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Dr. BUKKE RAVINDRA NAIK





LIST OF ABBREVIATIONS



AF - Annulus Fibrosus

AIS - ASIA Impairment Scale

ALL – Anterior Longitudinal Ligament

ASIA – American Spinal Injury Association

BSS – Brown Sequard Syndrome

CNS – Central Nervous System

CSF – Cerebrospinal fluid

CT – Computed Tomography

DTI – Diffusion tensor imaging

FDA – Food and Drug Administration

FOV - Field of View

FSE – Fast Spin Echo

GRE - Gradient Echo

IVD - Intervertebral Disc

IVF - Intervertebral Foramen

ISPs – Interspinous Ligaments

LF – Ligamentum Flavum

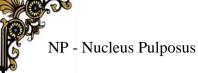
MIP – Maximum Intensity Projection

MRA – Magnetic Resonance Angiography

MRI – Magnetic Resonance Imaging

NLI – Neurological Level of Injury

NMR – Nuclear Magnetic Resonance



PLL – Posterior Longitudinal Ligament

RF – Radiofrequency

SCI - Spinal Cord Injury

SCIWORA – Spinal Cord Injury without Radiological Abnormality

SI – Signal Intensity

STIR – Short T1 Inversion Recovery







ABSTRACT

Background: Spinal trauma is associated with long-term disability. Early detection often leads to prompt and accurate diagnosis, expeditious management and avoidance of unnecessary procedures. Magnetic resonance imaging (MRI) helps to accurately depict presence and extent of spinal cord injury (SCI) in these patients.

Purpose: This study was aimed to look for various MRI findings which are predictive of initial neurological deficit in patients with spinal trauma and to correlate the findings with resultant neurological outcome.

Material and Methods: The present study was conducted over a period of eighteen months from January 2016 to June 2017 in 57 patients with spinal trauma referred for MRI spine. Neurological status of patients was assessed at the time of admission and discharge in accordance with the American Spine Injury Association (ASIA) impairment scale. Various MRI parameters were evaluated for correlation with severity of spinal injury.

Results: Patients with cord transection, cord hemorrhage and epidural hematoma had initial high grade ASIA impairment scale (AIS). Patients with cord transection and cord hemorrhage did not show any improvement in their neurological status during their hospital stay. Patients with only cord edema and epidural hematoma showed favorable neurological outcome. Cord contusion showed lesser neurological recovery, as compared with cord edema and normal cord.

Conclusion: MRI is an excellent available tool for depicting the changes within the injured spine. MRI findings in acute spinal cord injury correlate well with the initial neurological deficits on admission and at the time of discharge. MRI should be recommended in all patients with suspected spinal trauma both as diagnostic and prognostic indicator.

Keywords: Magnetic resonance imaging, spinal trauma, ASIA score, spinal cord injury, cord transection, cord contusion, cord edema, cord hemorrhage, cord hematoma, cord edema, neurological deficit, trauma.







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INTRODUCTION

Acute traumatic spinal cord injury (SCI) is a common cause resulting in debilitating injuries. SCI has high prevalence in younger population. Diagnostic imaging, particularly magnetic resonance imaging (MRI), plays a crucial role in evaluating and detecting spinal trauma. Subtle bone marrow, soft-tissue, and spinal cord abnormalities, which may not be apparent on other imaging modalities, can be readily detected on MRI. Early detection often leads to prompt and accurate diagnosis, expeditious management, and avoidance of unnecessary procedures¹.

Magnetic resonance imaging (MRI) has high contrast resolution, multiplanar capabilities and with various pulse sequences makes possible to diagnose spinal trauma more accurately. Adequate information about neural and extra neural injuries requiring surgical interventions, for example, significant disc herniations and epidural hematomas can be obtained. In cases of spinal cord edema, contusion, haemorrhage and ischemia, MRI findings may serve as prognostic indicators².

Most of the diagnostic information in spinal trauma is derived from the sagittal images. Axial images serve as a supplement. Sagittal T1-weighted images offer excellent anatomic overview. Disc herniations, epidural fluid collections, subluxation, vertebral body fractures, cord swelling, and cord compression are also visualized. Sagittal T2-weighted images depict most of the abnormalities including

spinal cord edema, ligamentous injury and disc herniations and epidural fluid collections. Axial and sagittal gradient echo (GRE) images aid in the identification of acute spinal cord hemorrhage.

The depiction of spinal cord injury (SCI) on MRI not only correlates well with the degree of neurologic deficit, but it also bears significant implications in regard to prognosis and potential for neurologic recovery³.

As MRI is an excellent diagnostic modality for evaluation of spinal trauma, it is possible to suggest that the MRI findings correlated directly with the degree of neurological deficit according to ASIA impairment scale. The purpose of this study is to evaluate this correlation.

AIMS AND OBJECTIVES

The aims and objectives of the study were:

- 1. To perform MRI and document morphological changes in spinal cord, vertebra and adjacent soft tissues in patients with trauma.
- 2. To correlate the level and severity of injury on MRI with resultant neurological outcome.

REVIEW OF LITERATURE

Historic background

The study of MRI launched in 1882 with a major breakthrough in Physics: namely, the discovery of the rotating magnetic field by Nikola Tesla. In his honor, the "Tesla" became the international unit of magnetic flux density, which calibrates the strength of the magnetic field used in all MRI systems.

In 1952 when Herman Carr produced a one-dimensional MRI image. Then in 1971 Raymond Damadian, an Armenian-American physician, scientist and professor at the Downstate Medical Centre State University of New York reported that tumours and normal tissue can be distinguished in vivo by nuclear magnetic resonance ("NMR")^{4.} In 1972 Damadian created a first MRI machine.

Lauterbur published the first nuclear magnetic resonance image and the first cross-sectional image of a living mouse in 1973. Damadian, along with Larry Minkoff and Michael Goldsmith, performed the first MRI body scan of a human being in 1977. Mansfield was successful and in 1978 presented the first cross-section images of both a finger and the abdomen⁵. In 1980, Paul Bottomley joined the GE Research Center in Schenectady, New York, and his team ordered the highest field-strength magnet then available a 1.5T system and built the first high-field and overcame problems of coil design, RF penetration and signal-to-noise ratio to build the first whole-body MRI/MRS scanner.

Paul Lauterbur of the University of Illinois at Urbana-Champaign and Sir Peter Mansfield of the University of Nottingham were awarded the 2003 Nobel Prize in Physiology or Medicine for their "discoveries concerning magnetic resonance imaging.

The final step towards advancing the clinical use of MRI was to build a magnet scanner, which was accomplished in 1977 and approved for clinical use by the FDA (Food and Drug Administration) in 1984. In addition, gadolinium, an MRI contrast agent, was patented and approved by the FDA four years later. Clinical MRI is a rather young field that has yielded extraordinary achievements, most of which occurred in the United States⁵.

ANATOMY OF SPINAL CORD AND SPINE

Anatomy of spinal cord

The spinal cord represents a caudal extension of the medulla oblongata. It terminates in the conus medullaris, typically located at D12 or L1 in adults. The cord widens first for the brachial plexus from C3 to D2, then for the lumbosacral plexus from D9 to D12. The filum terminale is slender fibrous strand extending from conus to the coccyx. The cauda equina is the spinal nerve roots extending caudal from the conus within the lumbar subarachnoid space (Figure 1)⁶.

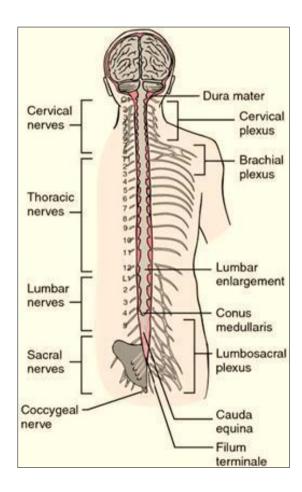


Figure 1. Normal anatomy of spinal cord.

The three layered meningeal covering of the CNS is contiguous with the spinal cord and all lie within the bony spinal canal. The innermost layer, the pia mater is adherent to the surface of the cord. The middle arachnoid membrane remains closely adherent to the outer layer, the dura mater. The space between the arachnoid and pia mater is called the subarachnoid space which contains CSF. The space is contiguous with the intracranial sub arachnoid space. Subdural space is a potential space between dura mater and arachnoid membrane⁶.

The gray matter of the spinal cord is located internally, in contradistinction to the gray matter of the brain and is surrounded by the white matter tracts. Both dorsal (sensory) and ventral (motor) roots arise along the entire length of the cord and unite to form a total of 31 paired spinal nerves¹. There are 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal nerve roots (Figure 2)⁷.

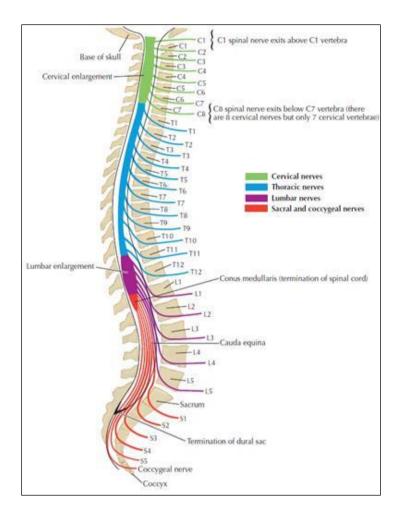


Figure 2. Cord segments with nerve roots.

Arterial supply to the cord originates from arterial vessels that enter the spinal canal through neural foramina at all the levels of the spinal cord which are termed radicular arteries. Radicular arteries arise from the vertebral arteries, costocervical trunk, intercostal and lumbar arteries. The distal branches of the radicular arteries which continue to supply the cord are called as radiculomedullary arteries (Figure 3)⁶. The above running radiculomedullary arteries anastomose with the below running ones to form anterior and posterior spinal arteries before supplying the spinal cord⁶.

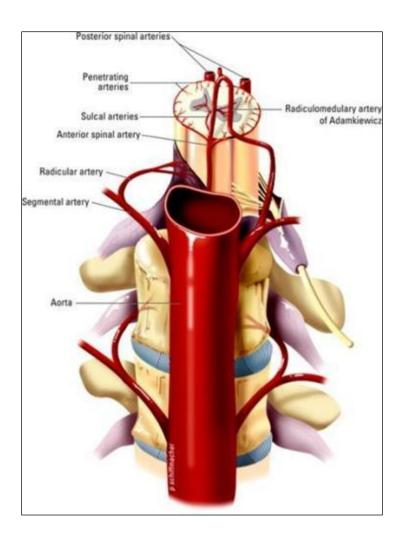


Figure 3. Blood supply of the spinal cord.

Anatomy of spine

The vertebral column forms the central axis of the skeleton and consists of 33 vertebrae. There are seven cervical, twelve thoracic and five lumbar vertebrae (the true, "moveable" vertebrae), and caudally there are five sacral and four coccygeal segments, all of which are fused as the sacrum and coccyx, respectively (Figure 4)⁸. The cervical and lumbar vertebrae form a curve that is convex anteriorly (lordosis), whereas the thoracic vertebrae have a curve that is convex posteriorly (kyphosis)⁷

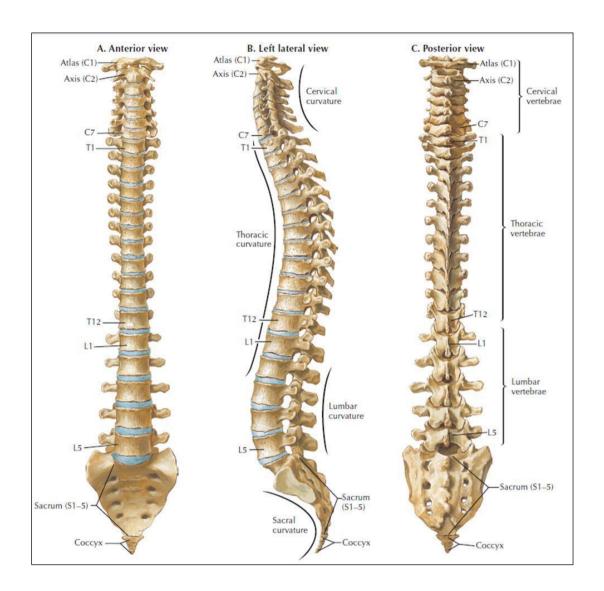


Figure 4. Illustration showing vertebral column with seven cervical vertebrae, 12 thoracic vertebrae, five lumbar vertebrae and 5 sacral vertebrae. Note the cervical, thoracic, lumbar and sacral curvature.

The Cervical vertebrae

The seven cervical vertebrae are characterized by transverse foramina in the transverse processes. The first six are for passage of the vertebral arteries; the seventh is vestigial. The articulations between superior and inferior articular processes of adjacent vertebrae (facet joints) are flat and relatively horizontal (Figure 5). The atlas is the widest cervical vertebra, and it lacks a body (centrum). It articulates superiorly with the occipital condyles in a hinge joint for flexion and extension (Figure 6). Together with the skull, it pivots on the dens (odontoid process) of the axis (C2). The dens is the body of C1 that fuses to the axis during development (Figure 7)⁷.

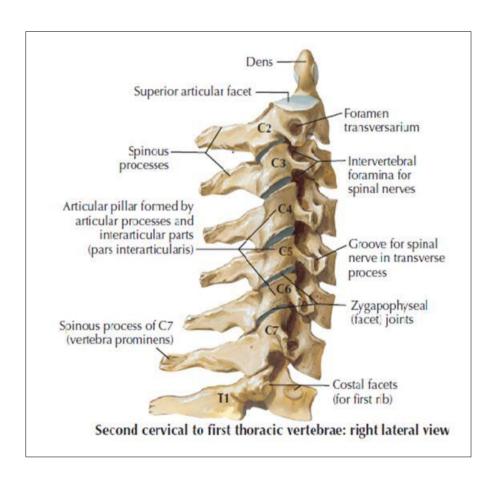


Figure 5. Right lateral view from second cervical to first thoracic vertebrae.

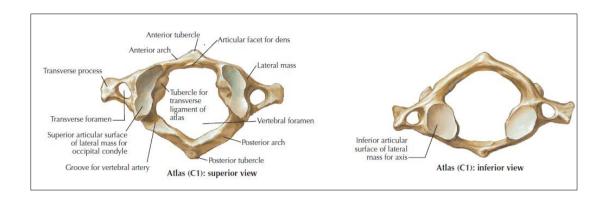


Figure 6. Superior (left side) and inferior view (right side) of atlas.

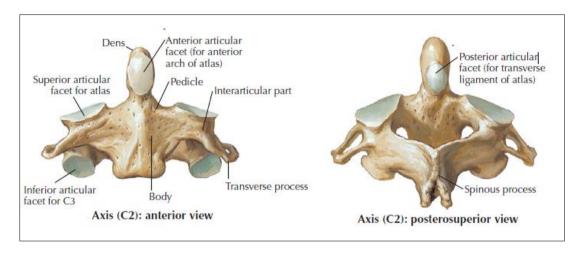


Figure 7. Anterior (left side) and posterosuperior view (right side) of axis.

The Thoracic Vertebrae

A typical vertebra consists of a body and vertebral arch enclosing a vertebral foramen that contains the spinal cord. The arch consists of pedicles and laminae, and extending from the arch are bony projections called transverse and spinous processes. The heads of ribs articulate with superior and inferior costal facets on adjacent bodies (two demifacets), and the tubercles of ribs articulate with the facets on the thick transverse processes. The thoracic spinous processes are long and slope

inferiorly. The laminae are broad and flat, and the articular facets between vertebrae are oriented in a coronal plane (Figure 8)⁷.

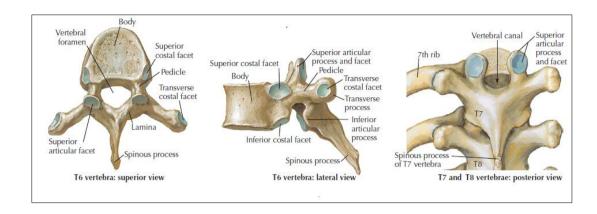


Figure 8. Superior (left side) and lateral view (middle) of T6 vertebra and posterior view of T7 and T8 vertebrae (right side).

The Lumbar Vertebral Column

There are five lumbar vertebrae, the third (L3) being the largest. Lumbar vertebrae have square-shaped anterior vertebral bodies covered by fenestrated cartilage attached to the adjacent disks. Projecting posteriorly are bilateral pedicles composed of thick cortical bone connecting to lamina forming the spinal canal⁸.

The articular facets face each other in the sagittal plane, and the transverse distance between the pedicles increases (the interpedicular distance) from L1 to L5. L5 is somewhat atypical with a wedge-shaped body, articulating inferiorly with the sacrum (Figure 9). Not infrequently, it may be fused, wholly or partly, with the body of the sacrum ("sacralization of L5"). Extending from the pedicles is a bony plate

called the pars articularis from which extend the superior and inferior articular facets⁸.

The posterior superior articular facet of an inferiorly located vertebra connects to the posterior inferior facet of the superior vertebra above creating a diarthrodial synovial lined joint, surrounded by a fibrous capsule posterolaterally with absence of the joint capsule anteriorly, where the ligamentum flavum and synovial membrane are present⁸.

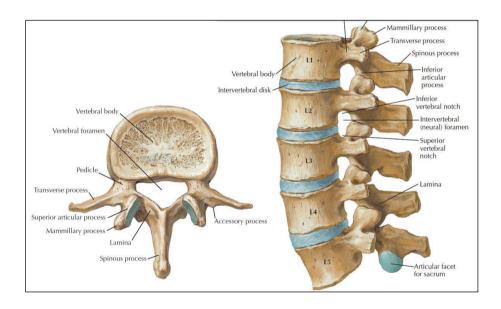


Figure 9. Axial and longitudinal view of lumbar vertebrae showing normal lumbar curvature and vertebral bodies.

The vertebral canal

The vertebral canal transmits the spinal cord and in the lumbar region, the cauda equina. It is formed by the posterior margins of the vertebral bodies and discs anteriorly, and the pedicles and laminae (the neural arch) posteriorly⁸.

The Intervertebral Canal (Neural Foramen)

The spinal nerves arise from the spinal cord and leave the spinal canal through the intervertebral canals, each of which is situated between adjacent pedicles (Figure 10). The nerves are accompanied by blood vessels and are supported by extradural fat within each canal⁸.

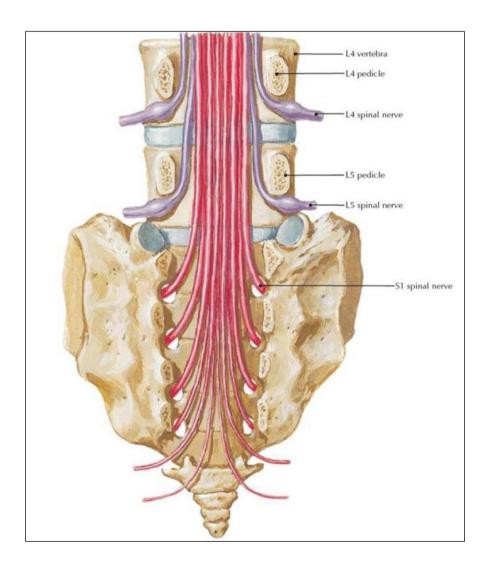


Figure 10. Relationship between the lower spinal nerves and their respective neural foramina (intervertebral foramina) in lumbosacral spine.

The Ligaments of Vertebral Column

A number of ligaments strengthen the vertebral column. The anterior longitudinal ligament runs supero-inferiorly between the anterior surfaces of the vertebral bodies from the occiput to the sacrum. The posterior longitudinal ligament is applied to the posterior surfaces and narrows as it passes downward (Figure 11). The ligamentum flavum joins adjacent laminae and the interspinous ligaments run between the spinous processes⁸.

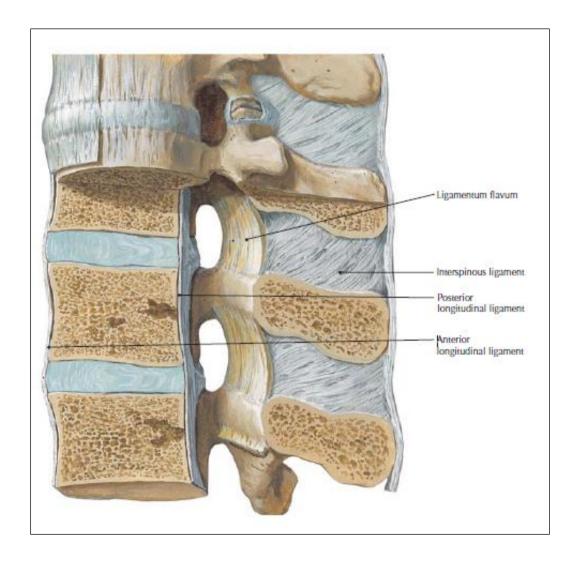


Figure 11. Longitudinal section showing ligaments of spine (lumbar region).

In the axial plane the ligamentum flavum appears V shaped and is thickest in the lumbar region. The vertebral column can be considered as a three-column structure. The anterior column is formed by the anterior longitudinal ligament, the anterior annulus fibrosus, and the anterior part of the vertebral body. The middle column comprises the posterior longitudinal ligament, the posterior annulus fibrosus, and the posterior part of the vertebral body. The posterior column consists of the neural arch and posterior ligamentous complex⁸.

Intervertebral Discs

The intervertebral discs (IVD) lie between the superior and inferior cartilaginous endplates of the adjacent vertebrae, being formed of an outer annulus fibrosus (AF) and an inner nucleus pulposus (NP) (Figure 12). The IVD functions to provide motion between individual vertebrae and also allows the effective transfer of load⁸.

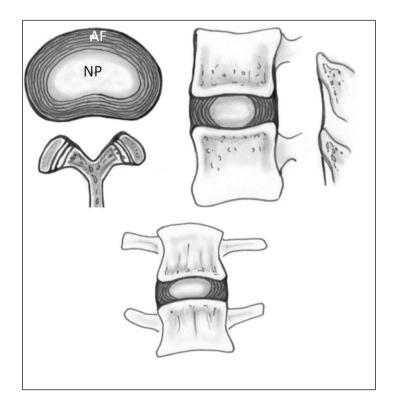


Figure 12. Normal lumbar disc. (Top Left) Axial, (Top Right) sagittal, and (Bottom) coronal images demonstrate that the normal disc, composed of central NP and peripheral AF, is wholly within the boundaries of the disc space, as defined, craniad and caudad by the vertebral body end plates and peripherally by the planes of the outer edges of the vertebral apophyses, exclusive of osteophytes (NP, nucleus pulposus; AF, annulus fibrosus).

MRI ANATOMY OF SPINE

MRI is the primary imaging method for the vertebral column. MRI is ideally suited to the demonstration of soft tissue anatomy of the spinal cord, including the vertebral medullary cavity, the intervertebral discs, the spinal ligaments and the paravertebral musculature⁹.

A typical MRI series will consist of T1W and T2W sagittal and axial images. Further coronal images and intravenous gadolinium contrast administration may be undertaken depending on the clinical picture. The tissue discrimination of MRI is superior to CT. MRI is the only method to show an intrinsic abnormality of the spinal cord substance. On T1W images the CSF is dark and, in general, this sequence shows the anatomy. On T2W images the CSF appears white and thus there is a myelographic effect. T2W sequences, in general, demonstrate pathology⁸.

The Vertebral Body

The vertebral body contains marrow, MRI signal intensity (SI) of which is dependent upon the proportion of red (haemopoietic) and yellow (fatty) marrow, this varying with the age. In adults, the high proportion of yellow marrow results in the marrow appearing hyperintense to the IVD, particularly in the lumbar region. Islands of red marrow or marrow fibrosis appear as areas of reduced T1W and T2W SI.

Focal areas of fatty marrow may be seen, particularly around the basivertebral veins. In the elderly, the marrow SI may be very heterogeneous⁹.

Intervertebral Discs

The annulus fibrosus (AF) is formed by 15-25 laminae of fibrous connective tissue, which due to its fibrous nature appears hypointense on all MR pulse sequences, particularly T2W images. The AF is attached circumferentially to the periphery of the vertebral body via Sharpey's fibres. The anterior annulus is thicker than the posterior annulus, resulting in the NP lying relatively posteriorly within the IVD. The NP consists of a gel-like substance with approximately 90% of its content being water, rendering it hyperintense on T2W images and of intermediate SI on T1W images. The intranuclear cleft appears as a horizontal band of low SI on sagittal T2W images, which is a normal finding after the age of 30 years⁹.

The Spinal Canal

The spinal canal is divided into the central canal, the lateral recess, and the intervertebral foramen (IVF). The boundaries of the central canal are vertebral body, IVD and PLL anteriorly; posterior epidural fat pad, LF and base of the spinous process posteriorly. Central canal contains the thecal (dural) sac and CSF, the intradural nerve roots and, in the cervical and thoracic region, the spinal cord⁹.

The boundaries of the lateral recess are vertebral body and IVD anteriorly; thecal sac medially; pedicle, facet joint and IVF laterally; and LF and lamina

posteriorly. The lateral recess contains epidural fat, the traversing nerve root, and epidural vessels. The boundaries of the IVF are vertebral body and IVD anteriorly; LF, pars interarticularis and facet joint posteriorly; pedicles of the adjacent vertebrae superiorly and inferiorly. IVF contains epidural fat, the exiting nerve root, radicular epidural vessels and sinuvertebral nerves⁹.

The Paraspinal Musculature

The thoracolumbar muscles are divided into anterior and posterior:

Anteriorly - psoas major and occasionally psoas minor.

Posteriorly - Multifidus, erector spinae, quadratus lumborum, and intertransversarius⁹.

Cross-sectional MR Anatomy of Spinal Cord

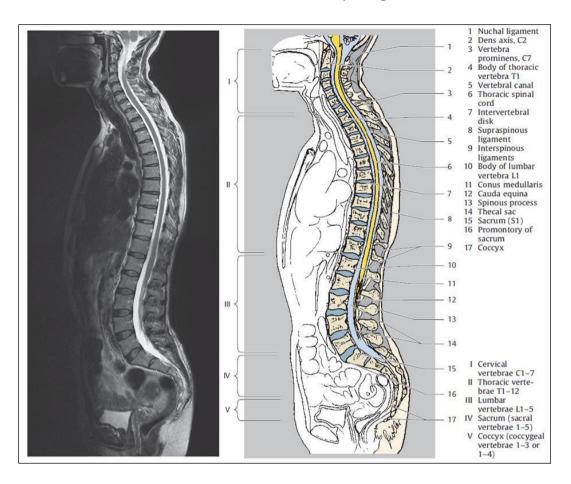


Figure 13. Sagittal T2 WI MRI showing whole spine 10

SPINAL TRAUMA

With the recent urbanization the incidence of accidents and hence that of spinal trauma has seen a significant increase. Most common age group is 16 to 35 years. Male to female ratio is 4:1. Automobile accidents are the most common cause in person less than 65 years. Falls are the most common cause in person more than 65 years. The other causes include assault, gunshot wounds, industrial accidents, motor vehicle accidents and sports injuries (particularly diving into shallow water)¹¹.

Mechanism of Injury

These mechanisms have been described in the literature 12,13

- 1. Distraction-hyperextension of spine. Eg- hangings.
- 2. Compression caused by axial loadings. Eg falls.
- 3. Torsional-high energy. Eg motor vehicle collisions.
- 4. Penetrating-stab or gunshot wounds.

Manifestations of spinal trauma¹³

- 1. Spinal cord injury
- 2. Bony injury
- 3. Soft tissue injury
- 4. Disk injury
- 5. Vertebral artery injury
- 6. Extramedullary haemorrhage

Spinal cord injury

Around 70% of patients have spinal cord involvement in spinal trauma¹⁴. The cause may be direct spinal cord injury or may be secondarily due to other injuries mentioned above.

Sites of cord injury

Commonly occurs between flexible and inflexible segments. Mid-thoracic injuries are less common because of the rotational stabilization provided by rib cage and intercostal musculature. So injuries are much common above and below the thoracic vertebra^{12,14}.

Pathophysiology of spinal cord injury

Direct injury, such as cuts, can occur to the spinal cord. Fragments of bone (from broken vertebrae) or fragments of metal (such as from a traffic accident or gunshot) can cut or damage the spinal cord. Direct damage can also occur if the spinal cord is pulled, pressed sideways, or compressed. This may occur if the head, neck, or back are twisted abnormally during an accident or intense chiropractic manipulation. The build-up of blood or fluid can press on the spinal cord and damage it. Spinal vascular disruption may result in diminished arterial supply or venous drainage. Cellular edema will lead to increased pressure within the spinal canal, with compromise to blood flow 12,14.

Secondary injury may occur due to hypotension, hypoxia, and anemia or during intubation.

Presenting Complaints

The presentation and severity of the complaint depend on the degree of injury.

There are two degrees of spinal cord injury.

- Complete transection, in which there is total paralysis and loss of motor and sensory functions.
- 2. Incomplete, where there is incomplete paralysis with varied loss of motor and sensory function depending on the level of injury.

Complete Transection

Table 1. Symptoms Based on the Level of Transection¹⁴.

T DEZIOT			
LEVEL	SYMPTOMS		
	Quadriplegia, respiratory insufficiency, Horner's		
High Cervical	syndrome, hypotension, abnormal thermoregulation, ileus,		
	, , , , ,		
	abdominal distension, bladder and bowel incontinence.		
	accommendation, clauder and cover meaninement		
	No diaphragmatic involvement, Otherwise same		
Low cervical	110 diapinaginade involvement, Otherwise same		
	symptoms.		
High Thoracic	Para paresis, autonomic involvement.		
O			
	Description of the day and beautiness times at the section of		
Low thoracic	Para paresis, bladder, and bowel incontinence.		
	Para paresis, bladder, and bowel incontinence. Autonomic		
Lumbar	1		
Zumour	system spared.		
	system spared.		

Incomplete cord patterns

- 1. Central cord syndrome
- 2. Anterior cord syndrome
- 3. Posterior cord syndrome
- 4. Brown-Sequard syndrome
- 5. Cauda equina syndrome

Central cord syndrome

It typically occurs following trauma to the mid cervical and lower cervical spinal cord. It involves the grey matter and central portion of the cord more than the peripheral. It usually happens in older individuals sustaining hyperextension injuries to the cervical spine. Acute central cervical spinal cord injury with maximum motor and sensory impairment involving the upper limbs is a specific entity. Because of the anatomical arrangement of the motor tracts to the upper limbs being more medial followed by thoracic, lumbar and sacral components this syndrome manifests with greater weakness of the upper than the lower limbs. The majority of patients will have bowel and bladder control. The prognosis is good with 75% recovery 15,16.

Anterior cord syndrome

There is compression of the anterior cord. Patient has motor paralysis at lesion and below. There is loss of pain and temperature sensation below site. Touch, position, vibration and motion remain intact ^{17,18}.

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Posterior cord syndrome

Associated with cervical hyperextension injuries. Dorsal area of cord is damaged resulting in loss of proprioception. Pain, temperature sensation and motor function remain intact ^{17,19}.

Brown-Sequard syndrome

There is partial transection of cord. BSS may be caused by a spinal cord tumor, penetrating injuries to spinal cord. There is paralysis and loss of vibration sense on same side of the body. There is loss of pain and temperature (hemi anesthesia) on the opposite side ^{20,21,22}.

Cauda-equina syndrome

There is damage to the cauda equina. There is paraplegia, bowel and bladder dysfunction, sexual dysfunction and sciatic leg pain.

Assessment of spinal cord injury

- 1. Clinical assessment
- 2. Radiological assessment

Clinical assessment²³

The most accurate way to assess a patient who has sustained a SCI is by performing a standardized physical examination as endorsed by the International Standards for Neurological and Functional Classification of Spinal Cord Injury Patients, also commonly called the American Spinal Injury Association (ASIA) guidelines.

The neurologic examination of the patient with SCI had two main components, sensory and motor, with certain required and optional elements. The required elements allows the determination of the sensory, motor, and neurologic levels; generation of sensory and motor index scores; determination of the completeness of the injury; and classification of the impairment.

Sensory examination

There are 28 key dermatomes, each are separately tested for pinprick/dull (with a safety pin) and light touch (with a cotton-tip applicator) on both sides of the body. A three-point scale (0 to 2) is used, with the face as the normal control point. Absent sensation yielded a score of 0. A score of 1 (impaired) for pinprick testing is given when the patient can distinguish between the sharp and dull edge of the pin, but the pin is not felt as sharp as on the face. The score of 2 (normal or intact) is

given only if the pin is felt as sharp, in the tested dermatome, as when tested on the face.

For light touch, a cotton-tip applicator is used, with 2 (intact) being the same touch sensation as on the face and 1 (impaired) if less than on the face. The cotton-tip swab is stroked across the skin moving over a distance not to exceed 1 cm. When testing the digits for dermatomes C6 through C8, the dorsal surface of the proximal phalanx is tested. When testing the chest and abdomen, sensory testing is performed at the midclavicular line.

S4-5 dermatome is also tested for both pinprick and light touch because this represents the most caudal aspect of the sacral spinal cord. To test for deep anal sensation, a rectal digital examination is performed. The patients are asked to report any sensory awareness, touch, or pressure, with firm pressure of the examiner's digit on the rectal walls. Deep anal sensation is recorded as either present or absent.

The sensory level is the most caudal dermatome to have intact (2/2) sensation for both pinprick and light touch on both sides of the body. Sensory index scoring is calculated by adding the scores for each dermatome, for a total score possible of 112 (56 on each side) for pinprick and for light touch.

Motor examination

The required elements of the ASIA motor examination consist of testing 10 key muscles: 5 in the upper limb and 5 in the lower limb on each side of the body. The muscles are examined in a rostral to caudal sequence, starting with the elbow flexors (C5 tested muscle) and finishing with the ankle plantar flexors (S1 muscles). Testing of all key muscles is performed during initial and follow-up examinations with patient in supine position. The observations are graded and recorded on the standard form, on a six-point scale from 0 to 5. Voluntary anal contraction is tested as part of motor examination and graded as either present or absent by sensing contraction of external anal sphincter around examiner's finger.

The ASIA has defined the motor levels as "lowest key muscle function that has a grade of at least 3 (on supine testing), providing the key muscle functions represented by segments above that level are judged to be intact (graded as a 5)." In regions, which do not have a myotome for testing, the sensory level is presumed to represent the motor level, if motor function above the aforementioned level is normal.

The total score possible is 100, 25 for each extremity. The neurologic level of injury (NLI) is the most caudal level at which both motor and sensory modalities intact on both sides of the body.

The grading is done by using ASIA impairment scale which as follows:

A - Complete: No motor or sensory function is preserved in the sacral segments S4-

S5.

B - Incomplete: Sensory but not motor function preserved below the neurologic level

and includes the sacral segments S4-S5.

C - Motor function is preserved below the neurologic level, and more than half of the

key muscles below the neurologic level have a muscle grade less than 3.

D - Incomplete: Motor function is preserved below the neurologic level, and at least

half of key muscles below the neurologic level have a muscle grade of 3 or more.

E - Normal: Motor and sensory function are normal.

Radiological assessment

The clinical assessment is followed by imaging. The mainstay of imaging in spinal trauma has four modalities:

- 1. Plain Radiograph
- 2. CT
- 3. MRI
- 4. Angiography

Plain Radiograph

Plain radiograph has always been the initial modality of imaging for spinal trauma. Findings on plain radiograph include abnormal alignment and curvature of the spine, fractures of the vertebrae, spondylolisthesis and soft tissue abnormalities. Because it lacks the multiplanar capability it has a limited role in spinal cord injury assessment²⁴.

\mathbf{CT}

It is still the choice of imaging modality in spinal trauma. In addition to the radiographic findings CT will show the spinal canal involvement especially in case of retro pulsed fractured segment. Detailed assessment of the fractures is possible by CT. The radiation exposure and inability to image the spinal cord remain the drawbacks of CT in comparison with the MRI^{25,26}.

Plain Radiograph vs. CT

Plain films have been shown to be inferior to CT with respect to fracture detection in a number of studies¹. A meta-analysis by Holmes and Akkinepalli²⁷ showed that pooled sensitivities for plain radiography was 52% and for CT was 98% for identifying patients with cervical spine injury.

ROLE OF MRI

MRI is the modality of choice for evaluation of ligamentous and other soft tissue structures, disc, spinal cord and occult osseous injuries^{28,29}. MRI has had a greater impact on our understanding of SCI than any other diagnostic modality developed in the last decade. The clarity with which MRI is able to depict the internal architecture of the spinal cord is unmatched by any other imaging modality³⁰. Moreover, the depiction of parenchymal SCI on MRI not only correlates well with the degree of neurologic deficit, but it also bears significant implications for prognosis and the potential for neurologic recovery^{3,31}.

Advantages of MRI

- 1. Lack of ionizing radiation.
- 2. Non-invasiveness.
- 3. Multiplanar imaging capabilities.
- 4. Excellent soft tissue contrast.

Contraindications of MRI

- 1. Cardiac pacemaker
- 2. Cochlear implants
- 3. Tissue expanders
- 4. Ocular prosthesis

- 5. Dental implants
- 6. Neurostimulators
- 7. Bone growth stimulators
- 8. Implantable cardiac defibrillators
- 9. Implantable drug infusion pumps
- 10. Claustrophobia

Sequences

The study is performed with patient in supine position with quiet breathing obtaining following sequences²⁹.

- Sagittal T2 and T1-weighted fast spin echo images, STIR and fat suppression images.
- Coronal STIR
- Axial T2, T1-weighted fast spin echo images and GRE images for proper evaluation of cord haemorrhage.

MRI Findings in Spinal cord injury

- 1. Cord haemorrhage
- 2. Cord edema
- 3. Cord swelling
- 4. Cord transection
- 5. SCIWORA Spinal cord injury without radiographic abnormality.

Cord haemorrhage³²

Posttraumatic spinal cord haemorrhage (i.e., hemorrhagic contusion) is defined as the presence of a discrete focus of haemorrhage within the substance of the spinal cord after an injury. The most common location is within the central gray matter of the spinal cord, centred at the point of mechanical impact. In the acute phase after injury, deoxyhemoglobin is generated. Thus, the hemorrhagic component of the SCI is depicted as a discrete area of hypo intensity on the T2-weighted and GRE images.

Cord oedema³³

It is seen as a focus of abnormal high signal intensity on T2-weighted images. This signal abnormality presumably reflects a focal accumulation of intracellular and interstitial fluid in response to injury. Oedema is usually well defined on the midsagittal long-TR image. Axial T2-weighted images offer

supplemental information on the involvement of structures in cross section. Oedema involves a variable length of spinal cord above and below the level of injury, with discrete boundaries adjacent to uninvolved parenchyma.

Spinal cord oedema is invariably associated with some degree of spinal cord swelling; however, it can occur without MRI evidence of intramedullary haemorrhage. The length of spinal cord affected by oedema is directly proportional to the degree of initial neurologic deficit.

Posttraumatic spinal cord haemorrhage always coexists with spinal cord oedema; however, the converse is not always true, that is, oedema alone can be produced after an injury.

Cord swelling³⁴

Spinal cord swelling is the most non descriptive imaging finding associated with SCI. It is defined as a focal increase in calibre of the spinal cord centred at the level of an injury. By itself, swelling does not specifically describe any signal changes in the spinal cord. Spinal cord swelling is best demonstrated on the T1-weighted sagittal images. The parenchyma may be normal to slightly hypo intense.

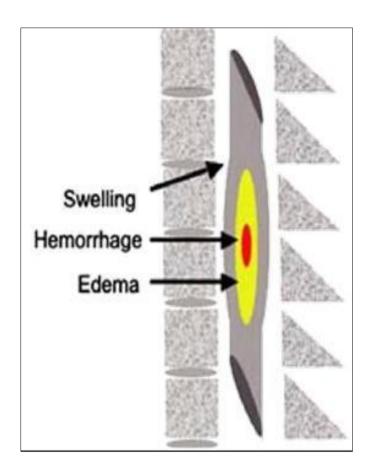


Figure 14. Diagrammatic representation of the cord findings in spinal trauma.

Cord Transection³⁵

Spinal cord transection is more common in children. In adults, there is generally severe accompanying bone trauma. MR reveals that the injured spinal cord may appear nearly transected. MR allows identification of the level of the proximal spinal cord stump, which helps to establish the level of permanent clinical disability. Haemorrhage involving the entire transverse diameter of the spinal cord behaves clinically as a complete transection.

Spinal cord injury without radiological abnormalities (SCIWORA)³⁶

Patients have some neurological deficits but no radiological abnormality. There is also no associated bony or ligamentous injuries. It is commonly seen in children. SCIWORA can also occur in adults³⁷.

Prognostic value of MRI

Many studies have shown that MRI findings of the spinal cord correlate well with the clinical profile and neurological outcome of the patients^{2,3,38,39,40}.

Generally patients with haemorrhage and multi-level edema of the spinal cord had a very poor prognosis. Patients with single level edema of the spinal cord showed good improvement of the deficits. Kulkarni et al classified the spinal cord injury as follows with a prognostic factor for each¹⁴ (Table 2).

Table 2. Cord Findings and Prognosis in Spinal Trauma¹⁴.

INJURY TYPE	T1 SIGNAL	T2 SIGNAL	PROGNOSIS
Type -1 haemorrhage	Isointense	Low	Poor
Type -2 Oedema	Hypo to Isointense	High	Good
Type -3 Mixed	Hypo to Isointense	Mottled	Poor

Andreoli et al⁴¹ showed the correlation between the spinal cord injury on MRI and the prognosis. The neurological examination scale used was ASIA impairment scale. The study showed the most severe neurological outcomes are associated with hemorrhagic pattern, where no or very less improvement was seen in ASIA grade.

MRI evaluation of non-spinal cord structures

Non spinal structures that need to be evaluated include the bony elements, soft tissue i.e. the ligaments, discs, dural spaces and the vasculature. The evaluation of above is important in the view of secondary cause of spinal cord injury.

Bones

The evaluation of the fracture site is better performed with CT⁴². If a question as to the aetiology underlying an acute spinal fracture (particularly thoracic and lumbar) arises, MRI is essential. Findings which tend to indicate a non-pathologic (non-tumour) underlying aetiology are: a fracture line within the collapsed vertebral body absence of soft tissue mass, retro pulsed bone fragments into the spinal canal, presence of fluid inside the collapsed vertebra, and normal signal intensity. Diffusion MRI is also helpful, as osteoporotic compression fractures are of low signal intensity and pathologic compression fractures are bright. MRI may also discover unsuspected fractures, particularly involving the sacrum. These patients present with lower extremity pain and a normal lumbar spine MRI examination. MRI may also show unsuspected fractures of vertebral end-plates, particularly in patients with injuries induced by hyperextension. Evaluation of the facet joints is easily done using the parasagittal images. These images allow one to make the diagnosis of perched facets and dislocated facets. Small facet joint fractures may be missed on MR images and require CT evaluation^{43,44}.

Ligaments

MRI is the only imaging modality that directly visualizes changes to the ligaments as a result of trauma. The ligamentous structures that are readily identified on routine sagittal MRI of the spine includes the anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), ligamentum flava (LF), and interspinous ligaments (ISPs) (Figure 15). They are relatively avascular structures composed primarily of strong fibro elastic tissue with very short T2 relaxation properties. Therefore, ligaments appear relatively hypo intense to other structures on all MRI pulse sequences. When overstretched or ruptured, a gap in the ligament may be identified, and the surrounding tissues may increase in signal intensity on T2-weighted or GRE images because of an increase in free water content from extracellular fluid and/or adjacent haemorrhage. Because of the similarity in imaging characteristics, distinction between a ligament fragment and cortical bone fragment may prove difficult on MRI 45,46,47,48.

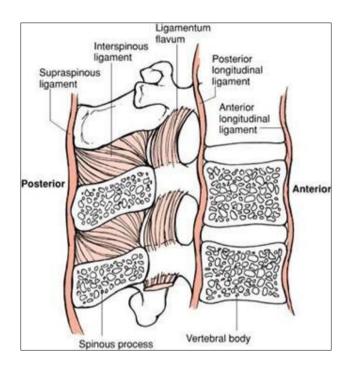


Figure 15. Diagrammatic representation of ligaments of spine

Discs

MRI allows identification of disc abnormalities in acute spinal trauma. In Hangman's fractures and Chance-type fractures, the disc is disrupted and may be herniated. True posttraumatic disc herniations are uncommon. However, in the presence of severe trauma, disc herniations are seen in 42% of cervical injuries. Also, patients with bilateral facet dislocations have an increased incidence of disc herniations. In the setting of severe hyperextension injuries, disc herniations are found in nearly 50% of cases. Patients with the following neurologic sequel are also at an increased risk for disc herniations: complete or incomplete deficits, Brown-Sequard syndrome, and central cord syndrome. Most post-traumatic disc herniations occur in the cervical region (C5-6=40%, C6-7=23%, and C4-5=19%)⁴⁹. The neurological deficits correspond well with the level of the disc herniation⁵⁰. Most acute post trauma disc herniations are bright on T2-weighted images and may be

associated with epidural hematoma. Acute intravertebral disc herniations (Schmorl's nodes) may result in pain and show contrast enhancement but need no treatment. The incidence of post-traumatic disc herniations in the thoracic and lumbar regions is not yet determined⁵¹.

Subdural and epidural spaces

Only 15% of all epidural hematomas occur as a consequence of trauma. Most occur in the presence of severe trauma but some are secondary to minor trauma (particularly in patients with a coagulopathy) or may be associated with acute disc herniations. Epidural hematoma may also follow lumbar puncture or spinal surgery.

While most spontaneous epidural hematomas are venous in nature, those following trauma are thought to be arterial in origin. Unlike the spontaneous ones, post-trauma epidural hematomas are ventral in location. Most are found in the thoracic, lumbar, and sacral regions and are uncommon in the cervical spine. Epidural hematomas have a biconvex shape, while subdural hematomas conform to the shape of the spinal canal. Subdural hematomas are less common in the spine. Most epidural and subdural hematomas are slightly bright on T1- and T2-weighted images but dark on T2* images. The presence of epidural hematoma carries a poor prognosis 52,53.

Vertebral arteries

Patients with cervical spinal injuries and ascending neurological deficits may be candidates for evaluation of the vertebral arteries. It is quoted that 40% of patients

with severe cervical spine fractures have either symptomatic or asymptomatic injuries to the vertebral arteries⁵⁴. The presence of a vascular injury may indicate the need for anticoagulation. Because these patients may have other injuries which prevent anticoagulation, such as epidural hematomas, they are better imaged with MR. The vertebral arteries may be occluded, dissected, or show pseudo aneurysm formation. Occluded and dissected vertebral arteries are well depicted by MRI and MRA, but suspected pseudo aneurysms need confirmation with catheter angiography. Evaluation of possible dissection needs careful review of the source images, as the arteries may only appear diffusely narrowed on the MIP MR images. Since the intramural clot tends to be acutely bright, it may be difficult to separate it from the normal fat in the foramen transversarium without fat suppression techniques. Occlusion of a vertebral artery in presence of a contra lateral normal one has little clinical significance. However, dissection of one vertebral artery (even if the contra lateral one is normal) may predispose the patient to emboli and chronic recurrent neurological events. Patients with a complete neurological deficit have a higher incidence of vertebral artery injury than those with incomplete injuries⁵⁵.

CLINICAL STUDIES

A study was done by Singh R et al. to correlate the clinical profile and neurological outcome with findings of imaging modalities in acute spinal cord injury (SCI) patients. In this study imaging features of 25 patients of acute SCI were analyzed prospectively and correlated with clinical and neurological outcome. This study concluded that imaging modalities in spinal cord injuries have a major role in diagnosis, directing management and predicting prognosis. Imaging findings of cord hemorrhage, compression, edema and cord swelling are associated with poor initial neurological status and recovery. Various findings noted on MRI have a significant role in predicting severity of neurological status and outcome¹.

Miyanji et al. conducted a study to correlate the MR imaging findings with neurologic outcome on 100 patients. The ASIA impairment scale was used to classify patients according to injury severity. Patients with complete SCIs had higher frequencies of hemorrhage, edema, cord swelling correlated with ASIA scores. This study concluded that spinal cord hemorrhage, and cord swelling are associated with a poor prognosis for neurologic recovery⁵⁶.

A retrospective study was done by Mahmood et al. to correlate the spinal cord changes as depicted by magnetic resonance imaging (MRI) with the neurological deficit and motor recovery of patients with acute cervical spinal cord injury (SCI). A total of 57 patients with acute cervical spine trauma were included in this study. The pattern and extent of spinal cord changes on MRI were compared

with the American Spinal Injury Association (ASIA) grade. The differences in the recovery rates among patients with cord edema, contusion and hemorrhage were tested statistically. It was concluded that Cord edema is associated with a better neurological outcome when compared with cord contusion or hemorrhage⁵⁷.

A retrospective observational study done by Haar et al. on 88 patients of Acute traumatic cervical spinal cord injuries and correlating MRI findings with neurological outcome demonstrated that MR imaging to be a useful tool in prognosticating a patient's potential for neurological recovery and it is indicated that length of lesion and intramedullary haemorrhage are associated with a poor prognosis for neurological recovery⁵⁸.

A study done by Qiu Z et al.to evaluate the clinical predictors of neurological outcome within 72 h after traumatic cervical spinal cord injury on 57 patients. AIS was used as the outcome measure. Relationships between evaluated factors and outcomes were investigated by univariate and multivariate methods. It was concluded that cord transection in MRI is a good predictor for complete spinal cord injury⁵⁹.

A study done by Magu S et al. on 57 patients to compare MRI findings with clinical profile and neurological status of patients. Neurological status of patients was assessed according to ASIA Impairment scale. Neurological status at admission

and neurological recovery at discharge was compared with various MRI findings. The authors concluded that cord edema and normal cord associated with favorable neurological outcome. Cord hemorrhage is associated with complete SCI and poor neurological recovery².

A study done by Parashari UC et al. on 62 patients to evaluate the Diagnostic and prognostic role of MRI in spinal trauma, its comparison and correlation with clinical profile and neurological outcome, according to ASIA impairment scale (AIS). The magnetic resonance images were analyzed and correlated with findings on neurological examination according to AIS at the time of MRI examination and subsequently at sub-acute interval to assess neurological outcome. With this study the authors concluded that various MRI findings in acute spinal cord injury correlated well with the initial clinical findings and on follow-up according to ASIA impairment scale. MRI is useful for initial diagnosis of acute spinal cord injury and its prognostication for predicting neurological recovery³.

A study done by Andreoli C. et al. on 38 patients demonstrated that patients with initial hemorrhage had poor prognosis while those with edema had better prognosis. MRI is particularly important in the initial evaluation of unconscious patients who cannot undergo a motor and sensory neurological evaluation, and to define the prognosis, which will influence the correct therapeutic choice⁴¹.

A study done by Saifuddin A. et al. concluded that MRI is particularly useful in unconscious patients who cannot undergo motor and sensory neurological evaluation²⁸.

A study done by Demaerel P. et al. concluded that MR is also indicated for the evaluation of patients with late complications and sequelae following spinal trauma⁶⁰.

A study done by Gupta R et.al on 50 patients to look for various MRI findings which are predictive of initial neurological deficit in patients with spinal trauma. ASIA Score was used for assessing neurological status at the time of admission and at the time of discharge. It was concluded that MRI is excellent imaging modality for detecting and assessing severity of spinal trauma. Presences of cord oedema, cord haemorrhage were best correlated with neurological deficit at presentation. While poor baseline ASIA score and cord haemorrhage confers a poor outcome. On the other hand, absence of cord haemorrhage usually indicates better potential for neurological recovery⁶¹.

A study conducted by Thomas A et al. to assess the prognostic value of MRI findings in acute spinal trauma by assessing the neurological outcome and correlating it with the different MRI patterns of injury. Sixty patients with acute spinal trauma were included in the study and concluded that MRI is useful not only

for initial diagnosis of acute spinal cord injury, but also for its prognostication and predicting neurological recovery 62 .

MATERIALS AND METHODS

Source of data

Study was conducted over a period of eighteen months from January 2016 to

June 2017 on 57 patients with spinal trauma referred for MRI of spine to the

Department of Radio-Diagnosis at R. L. Jalappa Hospital and Research Center

attached to SDUMC, Kolar.

Prior Informed consent was taken.

Study design: Prospective observational study

Sample size: A sample size of 30 was selected using n masters' software.

Sample size was estimated by using the proportion of cord edema without

hemorrhage detected in Spinal trauma by MRI was 41.5% from the study by Umesh

C Parashari et al. using the formula

Sample size =
$$\frac{Z_{1-\alpha/2}^{2} p(1-p)}{d^{2}}$$

Here

 $Z_{1-\alpha/2} = 1.96$ at 5 % error alpha. As in majority of studies P values are considered

significant below 0.05 hence 1.96 is used in formula.

p = Expected proportion in population based on previous studies or pilot studies.

d = Absolute error or precision – Has to be decided by researcher.

P = 41.5 or 0.415

50

q = 58.5 or 0.585

d = 20% or 0.02

Considering 10% Nonresponse a sample size of $23 + 2.3 \approx 26$ subjects were planned to be included in the study. However, the study included 57 patients with traumatic spine injury.

Method of collection of data:

MR Imaging of spine was performed with 1.5 Tesla MR Scanner (Magnetom Avanto, Siemens) (Figure 16) both in the axial and sagittal planes using a combination of pulse sequences (Figure 16). The study was performed with patient in supine position, obtaining sagittal and axial T1and T2-weighted fast spin echo images, coronal STIR images and gradient echo (GRE) images, for proper evaluation of vertebra, disc, spinal cord and soft tissue.

Sagittal images were 5.0 mm thick with a 0.5 mm slice gap. The field of view (FOV) of the area of interest is adequate at 24 cm in cervical spine and at 32 cm in lumbosacral spine. In the dorso-lumbar spine, a large FOV was needed (34/36 cm) for accurate labelling of the involved levels.

T2-weighted information was obtained using a single FSE acquisition using a split echo train, resulting in an intermediate T2WI sequences. For the short TE image, an echo train of three with two excitations was used, whereas for the long TE

image an echo train of 15-30 with single excitation was used. For each sequence, 256-448 steps were followed in both the frequency and phase axes. Fat suppression was employed on the long TR sequences to improve visualization of oedema in the posterior ligamentous complexes (STIR - short tau inversion recovery). Axial images were obtained using FSE or gradient-echo (GRE) pulse sequences. Technical parameters included 16° flip angle, minimum TR/TE, 224 × 320 matrix and two excitations in T1WI and one excitation in T2WIs. The TE used was less than 15 ms in T1WI and up to 100 ms in T2WIs in order to minimize unwanted susceptibility effects that might exaggerate bony stenosis.



Figure 16. Siemens Magnetom Avanto 1.5 T MR scanner.

The following findings were identified after assessing the MR images and considered for the study

- 1. Cord transection
- 2. Cord haemorrhage.
- 3. Cord edema.
- 4. Epidural hemorrhage
- 5. Normal cord

Clinical assessment of spinal cord injury

Patient assessment was done by performing a standardized physical examination of the patient at the time of admission and at the time of discharge according to International Standards for Neurological and Functional Classification of Spinal Cord Injury Patients, also commonly called the American Spinal Injury Association (ASIA) guidelines was performed. A detailed motor and sensory examination of the patient was done and graded according to American Spinal Injury Association Scale which is as follows:

A-Complete: No motor or sensory function is preserved in the sacral segments S4-S5.

B-Incomplete: Sensory but not motor function preserved below the neurologic level and includes the sacral segments S4-S5.

C-Motor function is preserved below the neurologic level, and more than half of the key muscles below the neurologic level have a muscle grade less than 3.

D-Incomplete: Motor function is preserved below the neurologic level, and at least half of key muscles below the neurologic level have a muscle grade of 3 or more.

E-Normal: Motor and sensory function are normal.

Change in ASIA impairment scale toward lower grade between admission and

discharge was considered neurological recovery.

Data analysis:

The strength of association between extent of spinal cord injury and outcome

were described using Odds ratio. Chi square test of significance (p<0.005) was used

to assess the association between MR findings and clinical outcome.

Inclusion criteria: All the patients of acute spinal trauma undergoing MR Imaging

formed the study group.

Exclusion criteria:

Patients with associated head injury.

Patients in whom MRI is contraindicated. (Non-cooperation, in situ metallic

implants, cochlear implants, pacemakers, previous spine surgeries and

claustrophobia) were excluded from the study.

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RESULTS

Demographics

In this study 57 patients of spinal trauma were observed.

Gender wise distribution:

Out of 57 patients 49 (86%) were males and 8 (14%) were females (Figure 17; Table 3).

Table 3. Gender Wise Distribution.

Gender	No. of patients	%
Males (n = 49)	49	86.0
Females (n = 8)	8	14.0
Total	57	100.0

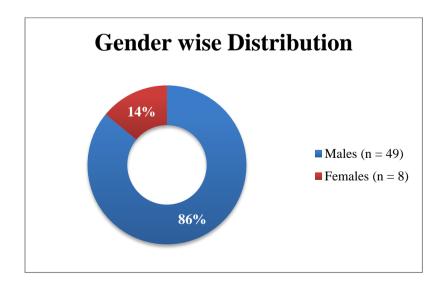


Figure 17. Gender-wise distribution.

Age group distribution

Most common age group in our study was 21-40 years (45.6%), followed by 41-60 years (33.3%). Patients with age group of 20 years and below were 12.3% and 8.8% of patients were in the age group of 61 years and above (Figure 18; Table 4).

Table 4. Age Group Distribution.

Age group	Number of patients	%
0-20 years	7	12.3
21-40 years	26	45.6
41-60 years	19	33.3
>61 years	5	8.8
Total	57	100

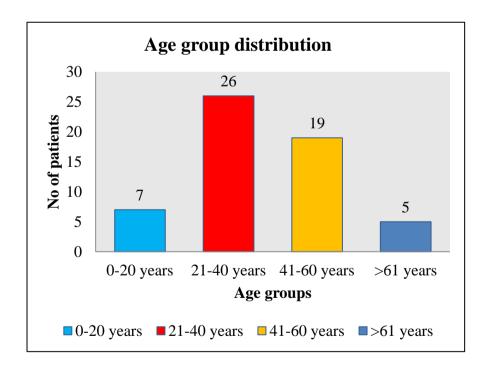


Figure 18. Age group distribution.

Cause of injury:

The commonest cause of injury was fall from height.

In 32 patients (56.14%) the cause of injury was fall from height followed by RTA which was observed in 21 patients (36.84%). 4 patients (7.02%) had h/o fall of weight (Figure 19; Table 5).

Table 5. Cause of Injury.

Cause	Number	%
RTA (n = 21)	21	36.84
Fall from height (n = 32)	32	56.14
Fall of weight (n = 4)	4	7.02
Total	57	100

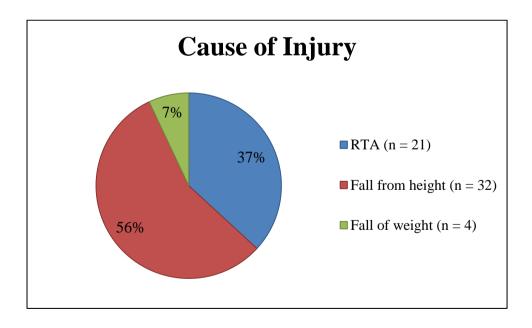


Figure 19. Cause of injury.

Level of injury:

Most common level of injury was cervical level.

Out of 57 patients, in 25 patients (43.86%) had injury at cervical level the followed by dorsal and lumbar levels in 12 patients each (21.05%) and lastly 8 patients (14.04%) had injury at dorso-lumbar level (Figure 20; Table 6).

Table 6. Level of Injury.

Level of injury	No of patients	%
Cervical	25	43.86
Dorsal	12	21.05
Dorsolumbar	8	14.04
Lumbar	12	21.05
Total	57	100.00

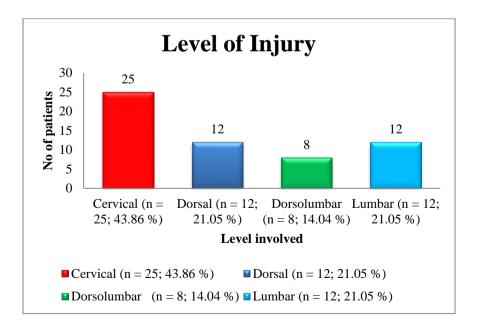


Figure 20. Level of injury.

MRI findings in spinal trauma cases

Out of 57 patients, 44 patients (77.19%) had cord abnormalities and 13 patients (22.80%) had no cord changes (normal cord).

The various MRI findings were cord edema (n = 23), cord contusion/edema (n = 10), spinal canal stenosis due to retropulsion (n = 7), cord transection with contusion/edema (n = 4), cord hemorrhage, epidural edema (n = 3 each) and normal findings in 13 patients (Figure 21). It was observed that patients with normal cord were associated with significantly better neurological status at admission (P<.001). Out of 57 patients 12 patients (21.05 %) had cord compression.

Table 7. MRI Findings.

MRI Findings	Number of	%
	patients	
Cord transection with contusion/edema	4	7.0
Cord Hemorrhage	3	5.3
Cord contusion / edema	10	17.5
Cord edema	23	40.4
Spinal canal stenosis due to retro pulsed fracture fragment	7	12.3
Normal Cord	13	22.8
Epidural hematoma	3	5.3
Total	63	

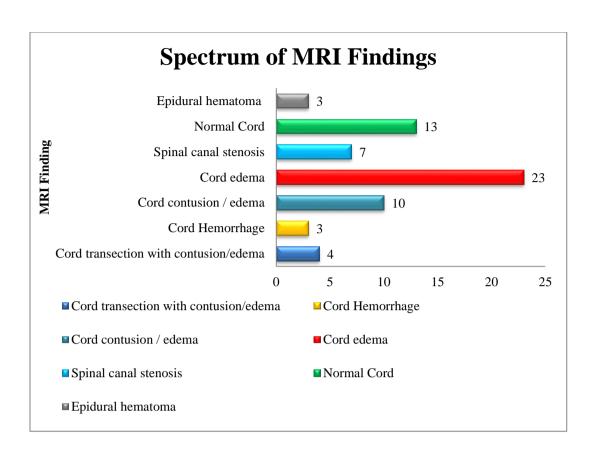


Figure 21. Spectrum of MRI findings.

Categorization of patients based on ASIA impairment scale (AIS):

In this study spinal trauma patients were grouped into 5 categories based on ASIA impairments scale (AIS) at the time of admission.

Most common presentation was ASIA A in 22 patients (39%) followed by ASIA C in 13 patients (23%), ASIA D in 12 patients (21%), ASIA E in 8 patients (14%) and ASIA B in 2 patients (3.5%) (Figure 22; Table 8).

Table 8. Categorisation of patients based on AIS.

ASIA category	No of patients	%
A (n = 22)	22	38.6
B (n = 2)	2	3.5
C (n = 13)	13	22.8
D (n = 12)	12	21.1
$\mathbf{E}\;(\mathbf{n}=8)$	8	14.0
Total	57	100.0

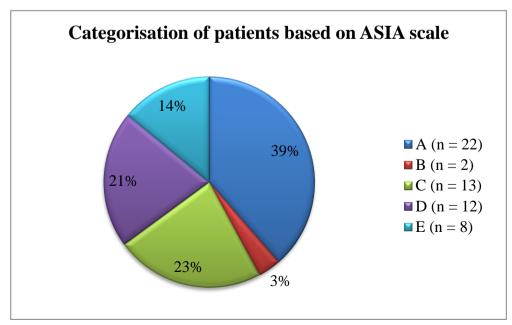


Figure 22. Categorisation of patients based on ASIA scale

MRI findings and neurological status at the time of admission:

In all patients with cord transection (n = 4), cord hemorrhage and epidural hematoma (n = 3 each) the initial neurological status was ASIA A. There were 23 patients with cord edema among whom 10 patients had initial neurological status of ASIA A, seven had ASIA C, four had ASIA D and remaining two had ASIA B.

Cord contusion /edema noted in 10 patients, among them the initial neurological status of ASIA A in 8 patients and rest of two had ASIA C. Spinal canal stenosis was noted in 7 patients, among them 3 patients had the initial neurological status of ASIA C, 3 patients had ASIA D and 1 patient had ASIA E (Figure 23; Table 9)

Table 9. MRI findings and Neurological status at the time of admission.

MRI Findings	ASIA impairment scale Tot			Total		
	A	В	С	D	Е	
Cord transection with contusion/edema	4	0	0	0	0	4
Cord Hemorrhage	3	0	0	0	0	3
Cord contusion / edema	8	0	2	0	0	10
Cord edema	10	2	7	4	0	23
Spinal canal stenosis	0	0	3	3	1	7
Normal Cord	0	0	1	5	7	13
Epidural hematoma	3	0	0	0	0	3
Total	28	2	13	12	8	63 [*]
*Few patients had multiple findings						

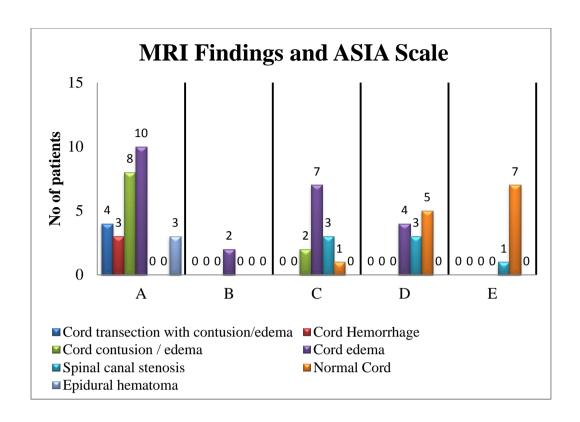


Figure 23. MRI findings and ASIA impairement scale.

Treatment provided

Out of 57 patients 30 patients (53 %) were managed by surgically and 27 patients (47 %) were managed conservatively (Figure 24; Table 10).

Table 10. Treatment Provided.

Treatment given	No of patients	%
Conservative (n = 27)	27	47.37
Surgical (n = 30)	30	52.63
Total	57	100

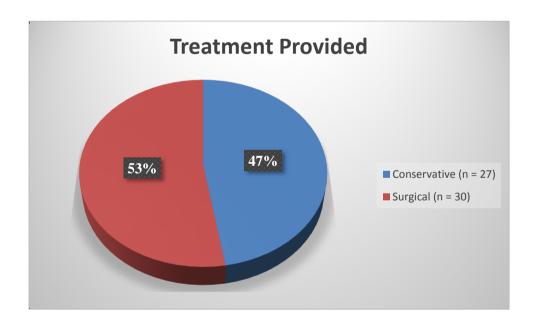


Figure 24. Treatment provided.

Neurological recovery in patients with different MRI findings

Four patients with cord transection and 3 patients with cord hemorrhage did not show any improvement in their neurological status over the period of their hospital stay. Out of 10 patients with cord contusion/edema pattern, improvement in neurological status was seen in 5 patients (50%) and 5 patients (50%) showed no improvement. Out of 23 patients with only cord edema 13 patients (56.52%) showed improvement and 10 patients (43.47%) showed no improvement. Out of 3 patients with epidural hematoma 2 patients (66.66%) showed improvement, whereas 1 patient did not improve. Out of 13 patients with normal cord 6 patients had neurological deficit, all of them improved. In our study 7 patients had spinal canal stenosis out of which 6 patients had neurological deficit, of them 4 patients showed improvement and 2 patients did not improve (Table 11).

When MRI findings were compared with neurological outcome, it was observed that there was no neurological improvement in patients with cord transection with contusion/edema and cord hemorrhage. Furthermore, these patients had significantly worse outcome when compared with other MRI findings (P<.05). There was no significant difference in outcome among patients with cord contusion/edema compared with spinal canal stenosis (P = .34) and cord contusion/edema with cord edema only (P = .37 respectively). There was statistically no significant difference in terms of neurological improvement among patients with cord contusion/edema and epidural hemorrhage (P = .34). Similarly, when patients with cord edema were compared with patients with epidural hemorrhage there was

no significant difference in terms of neurological improvement (P = .39). There was no significant difference in neurological outcome among patients with spinal canal stenosis when compared with patients with cord contusion/edema (P = .28), cord edema (P = .34), and epidural hematoma (P = .49). All the patients with normal cord showed neurological improvement at the end of study.

Table 11. Neurological Recovery in Patients with Different MRI Findings.

MRI Findings	No of patients	Neurological status on admission		Neurological improvement at discharge		Hospital stay (in days) (mean ± SD)	
M	\mathbf{Z}	No deficit	Deficit present	Improved		Hospite (m	
Cord transection with contusion/edema	4	0	4	0	4	21 ± 6.38	
Cord Hemorrhage	3	0	3	0	3	20 ± 7.64	
Cord contusion / edema	10	0	10	5	5	22 ± 9.1	
Cord edema	23	0	23	13	10	18 ± 5.24	
Spinal canal stenosis*	7	1	6	4	3	16 ± 2.27	
Normal Cord	13	7	6	6	7	14 ± 2.76	
Epidural hematoma	3	0	3	2	1	24 ± 2.62	
Total	Total 8 55 30 33 -			-			
*Spinal canal stenosis due to retropulsed fracture fragments							

Neurological outcome at the time of discharge.

Change in ASIA Status at Discharge (Initial ASIA scale A)

Out of 22 patients with complete spinal cord injury (ASIA A) 9 patients (41%) showed improvement in their neurological status over the period of hospital stay (Figure 25).

Table 12. Change in ASIA status at discharge (initial ASIA scale A)

ASIA SCALE A $(n = 22)$				
Change in ASIA scale	No of patients	%		
Not improved	13	59.1		
A to B	0	0		
A to C	7	31.8		
A to D	2	9.1		
Total	22	100		

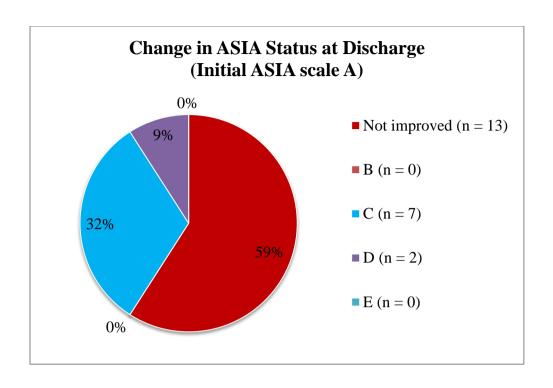


Figure 25. Change in ASIA status at discharge (initial ASIA scale A)

Change in ASIA Status at Discharge (Initial ASIA scale B)

Two patients were in ASIA B, among them 1 patient (50%) improved to ASIA C and 1 patient did not improve (Table 13).

Table 13. Change in ASIA status at discharge (initial ASIA scale B)

ASIA SCALE B $(n = 2)$				
Change in ASIA scale	No of patients	%		
Worsened to A	0	0		
Not improved	1	50		
B to C	1	50		
Total	2	100		

Change in ASIA Status at Discharge (Initial ASIA scale C)

Out of 13 patients with ASIA C, 8 patients (61.5 %) showed improvement and 5 patients (38.5%) did not improve (Figure 26).

Table 14. Change in ASIA status at discharge (initial ASIA scale C)

ASIA SCALE C (n = 13)				
Change in ASIA scale	No of patients	%		
Worsened to A	0	0		
Worsened to B	0	0		
Not improved	5	38.5		
C to D	7	53.8		
C to E	1	7.7		
Total	13	100		

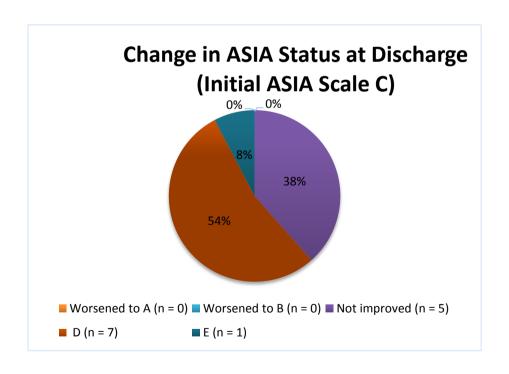


Figure 26. Change in ASIA status at discharge (initial ASIA scale C)

Change in ASIA Status at Discharge (Initial ASIA scale D)

Out of 12 patients with initial ASIA D, 10 patients (83 %) showed improvement, 2 patients (17%) did not improve (Figure 27).

Table 15. Change in ASIA status at discharge (initial ASIA scale D)

ASIA SCALE D (n = 12)		
Change in ASIA scale	No of patients	%
Worsened to A	0	0
Worsened to B	0	0
Worsened to C	0	0.0
Not improved	2	16.7
D to E	10	83.3
Total	12	100

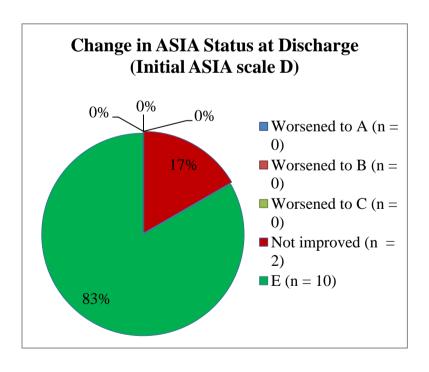


Figure 27. Change in ASIA status at discharge (initial ASIA scale D)

Neurological outcome in patients of spinal trauma

In this study, out of 57 patients, 27 patients (49 %) showed improvement in neurological status, 21 patients (37%) showed no improvement and 8 patients (14%) had no neurological deficit at the time of admission (Figure 28).

Table 16. Neurological outcome.

Neurological outcome	No of	%
	patients	
Improvement	28	49.12
No improvement	21	36.84
No neurological deficit at the time of	8	14.04
admission		
Total	57	100

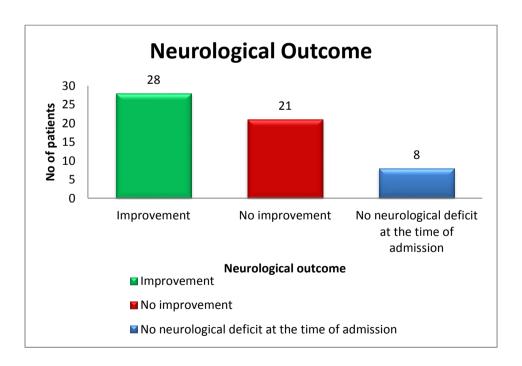


Figure 28. Neurological outcome.

IMAGES

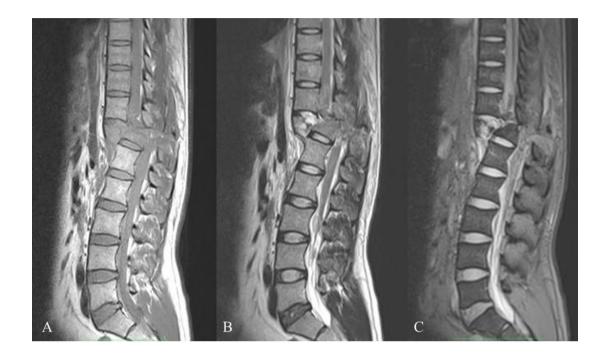


Figure 29. Sagittal T1 weighted (A), T2 weighted (B), and gradient echo (C) images showing comminuted fracture of D12 vertebral body with posterior translation. There is complete transection of distal thoracic cord at this level with blooming on gradient echo sequence, representing cord hemorrhage.

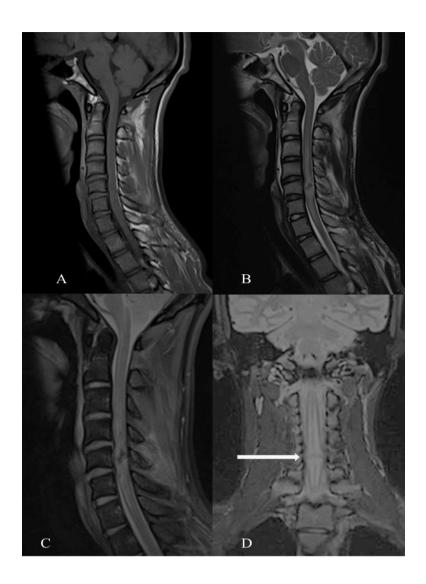


Figure 30. Sagittal T1 weighted (A), T2 weighted (B) and gradient echo (C) and Coronal Short tau inversion recovery (STIR) (D) images of cervical spine. There is linear hypointense signal with blooming on gradient echo sequence involving entire thickness of cord at C5 mid vertebral body level, likely partial transection (C). Note the central focal T2 hypointense cord signal at this level likely hemorrhagic contusion. There is diffuse surrounding T2 hyperintense signal from C3 vertebral body level to C6-7 disc level likely cord edema (B). STIR image (D) showing transverse hypointense signal involving entire thickness of cord at C5 mid vertebral body level likely partial transection.

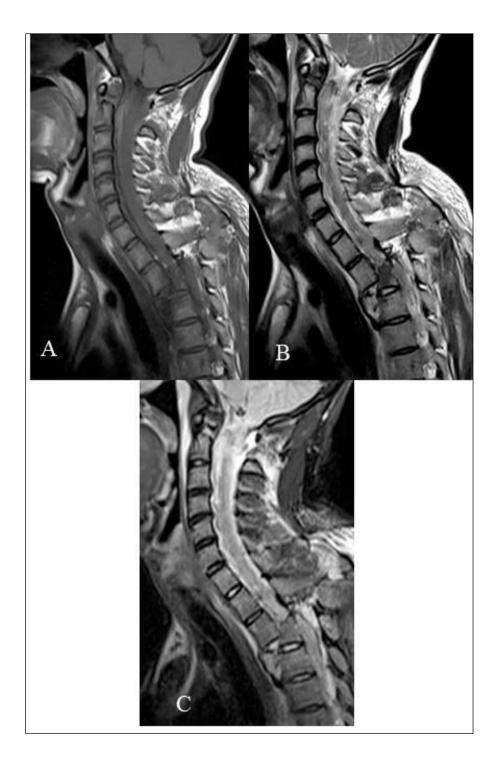


Figure 31. Sagittal T1 weighted (A), T2 weighted (B) and short tau inversion recovery (STIR) (C) images showing fracture and posterior dislocation of D3 vertebra. There is loss of continuity of spinal cord fibres at this level suggestive of transection. Note the increased T2 signal intensity from D1-D3 suggestive of edema.



Figure 32. Sagittal T1 weighted (A) and T2 weighted (B) images showing burst fracture with minimal retropulsion of D12 vertebral body with diffuse marrow edema. T2 hyperintense cord signal at D11 – 12 level likely cord edema.



Figure 33. Sagittal T1 weighted (A) T2 weighted (B) images showing anterior wedge compression fracture with mild retropulsion of L1 vertebral body causing spinal canal narrowing with diffuse marrow edema and contusion versus edema at conus.

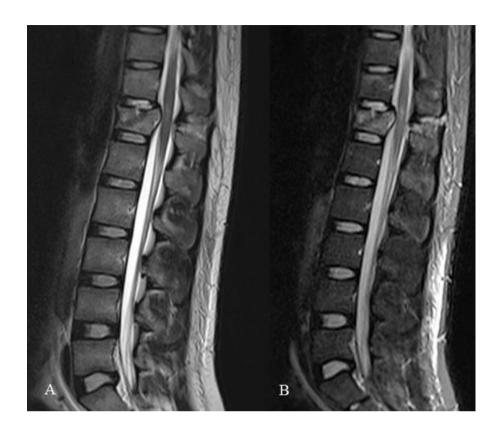


Figure 34. Sagittal T2 weighted (A) and short tau inversion recovery (STIR) (B) images showing anterior wedge compression fracture of D12 vertebra with mild retropulsed fracture fragment. T2 hyperintensity seen in the cord likely cord contusion versus edema at D11-D12 level.

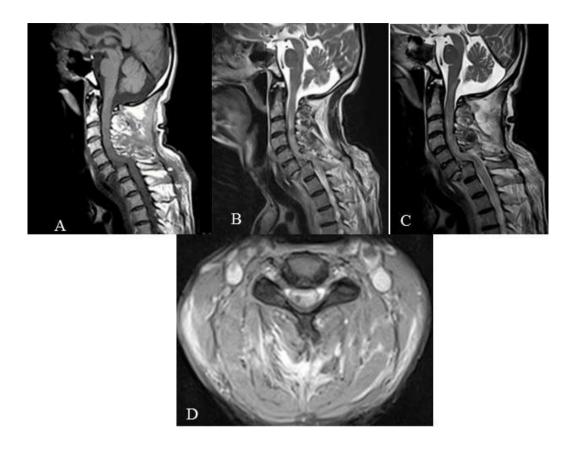


Figure 35. Sagittal T1 weighted (A), T2 weighted (B, C), and axial gradient echo (D) images showing fracture with retropulsion of C7 vertebra with resultant compression and kinking of cervical cord at this level. Cervical cord contusion which is hypointense on T2 and blooming on GRE at C3-C4 and C6-C7 levels suggestive of hemorrhage. Cord edema is seen from C2 – C3 to C7- D1.

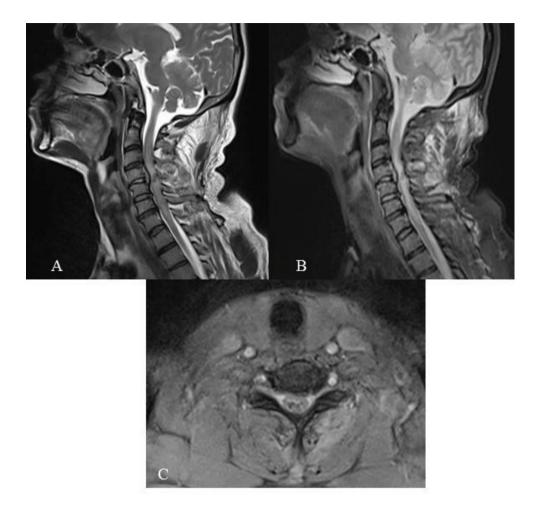


Figure 36. Sagittal T2 weighted, short tau inversion recovery (STIR) (B) and axial gradient echo (C) images showing intrinsic hyperintense signal changes of the cord extending from C3 to C7 vertebral levels suggestive of cord edema with small focal cord hemorrhage at C4-5 disc level which demonstrates blooming on GRE.

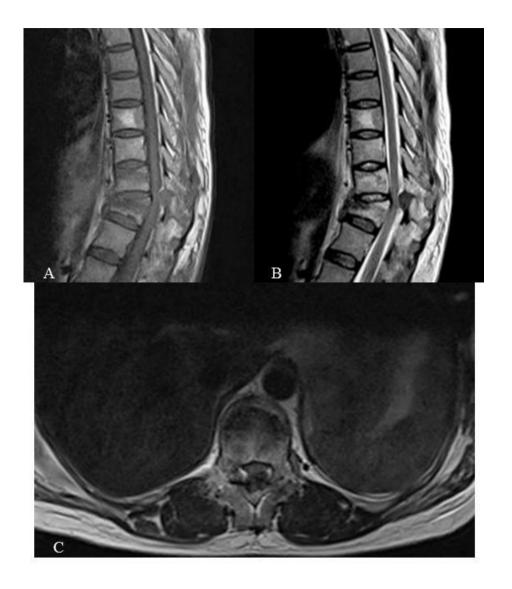


Figure 37. Sagittal T1 weighted (A), T2 weighted (B) and axial T2 weighted (C) images showing anterior wedge compression fracture of D12 vertebral body with mild retropulsion causing cord compression and edema at D11-D12 level. There is T1 isointense and T2 hypointense posterior epidural hematoma at D11-D12 disc level.

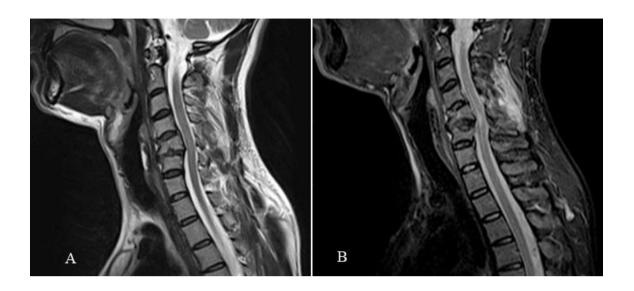


Figure 38. Sagittal T2 weighted (A) and short tau inversion recovery (STIR) (B) images showing comminuted fracture involving body of C5 vertebra with mild retropulsion causing mild cord edema at C5-C6 level. Also noted contusion in the muscular plane.

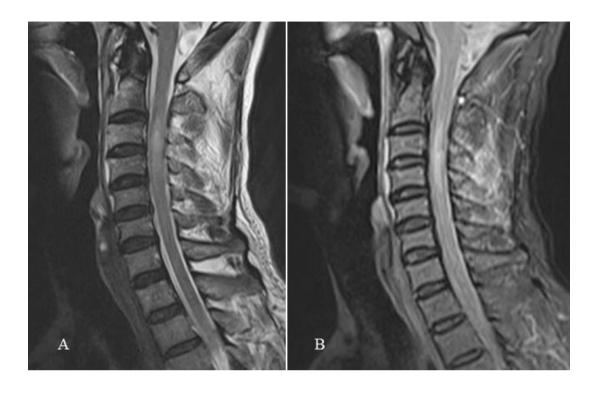


Figure 39. Sagittal T2 weighted (A) and short tau inversion recovery (STIR) (B) images showing hyperintense signal intensities within the spinal cord extending from C2-3 to C4-5 disc levels, likely edema.



Figure 40. Sagittal T2 weighted (A) and short tau inversion recovery (STIR) (B) images showing hyperintense signals extending from C3 mid vertebral body level to C6-7 intervertebral disc level, suggestive of edema.

DISCUSSION

In our prospective study, 57 patients underwent MR imaging for evaluation of spinal trauma. Out of 57 patients, 49 (86 %) were males with a male:female ratio of 6.1:1. A similar result was found in a study conducted by Gupta R et.al⁶¹ in their study which was conducted on 50 patients and reported that male to female ratio of 6:1.

Most common age group in our study was 21-40 years (45.6 %) with a mean age of 39.9 years (range 18 to 75 years). In a study conducted by Agarwal et al⁶³ 20-39 years of age group had the commonest predilection. Singh et al⁶⁴ observed the mean age of 35.4 years in their study and the study done by Katzberg et al⁶⁵ had a similar mean age of 37.8 years.

In our study, most common cause of injury was fall from height (56%), followed by RTA (37%). A study conducted by Chiu et al also reported that the most common modes of injuries were fall from height, followed by RTA, in concordance with our study⁶⁶.

In our study, 25 patients (43.86%) had injury at cervical level the followed by dorsal and lumbar levels in 12 patients each (21.05%). Similar results were found

by Gupta R et.al⁶¹ in their study. Cervical spine is probably the commonest site for injury due to its excessive mobility and lack of supporting structures.

In our study 44 patients (77%) had abnormal cord findings. A study done by Parashari et al³ on 62 patients showed a similar percentage of cord abnormalities in more than 75% patients (n = 47). A study done by Kulkarni et al¹⁴ revealed cord abnormalities in 70% of their study subjects.

In our study, cord edema was the most common cord signal abnormality detected, which is in agreement with the studies done by Parashari et al^3 and Andreoli et al^{41} .

Cord transection was detected in 4 patients (7%), Cord edema in 23 patients (40.4%), cord hemorrhage was detected in 3 patients (5.3%) cord contusion / edema noted in 10 patients (17.5%), epidural hematoma in 3 patients (5.3%), spinal canal stenosis in 7 patients (12.3 %). Out of 57 patients cord compression was noted in 12 patients (21.05%).

The categorization of patients into different groups based on ASIA impairments scale (AIS) showed that most common neurological status was ASIA A in 22 patients (39%), followed by ASIA C in 13 patients (23%), ASIA D in 12 patients (21%), ASIA E in 8 patients (14%) and the least common being ASIA B in

2 patients (3.5%). Various studies done by Parashari et al³, Andreoli et al⁴¹ and Maghu et al² all pointed out to ASIA A being the most commonest neurological status in patients with spinal trauma in agreement with our study.

Correlation of MRI findings with neurological outcome revealed that out of 57 patients, 28 patients (49%) showed improvement in their neurological status, 21 patients (37%) showed no improvement and 8 patients had no neurological deficit at the time of admission.

Four patients with cord transection and 3 patients with cord hemorrhage did not show any improvement in their neurological status over the period of their hospital stay.

Various studies have reported that cord hemorrhage was associated with poor neurological outcome as compared to cord contusion and edema^{57,60,67,68,69}. Shepard M J et al⁷⁰. showed that presence of cord hemorrhage is associated with worse prognosis. Gupta R et al⁶¹ reported that cord haemorrhage in their study was associated with complete SCI with no recovery on follow up. Qiu Z et al³⁵ reported that all the cases with cord transection showed complete SCIs when discharged. Cord transection should be the best predictors for complete SCI.

These findings suggest that patients with cord transection and cord hemorrhage have less chances of recovery.

Out of 10 patients with cord contusion/edema pattern, improvement in neurological status was seen in 5 patients (50%) and 5 patients (50%) showed no improvement.

Out of 23 patients with cord edema only, 13 patients (56.5%) showed improvement and 10% (43.4%) showed no improvement. These findings are similar to other studies done by Gupta R et al⁶¹, Ramon et al⁶⁷ and Kulkarni et al¹⁴ Cord oedema indicates incomplete type of spinal cord injury as the damage at cellular level is reversible to some extent. Many of these patients initially show evidence of neurological deficit, however there is good chance of neurological recovery and usually has favorable outcome.

Out of 3 patients with epidural hematoma, 2 patients (66.66%) showed improvement, whereas 1 patient (33.3%) did not improve. Out of 13 patients with normal cord 6 patients had neurological deficit, all of them improved.

Out of 12 patients with ASIA D in our study, 10 patients (83 %) showed improvement, while the rest 2 patients (17%) did not improve. In patients with ASIC C (n = 13), 8 patients (61.5 %) showed improvement and 5 patients (38.5%) did not

show any improvement. There were two patients in ASIA B, of which one improved to ASIA C and one did not show any improvement. In 22 patients with ASIA A, 9 patients (41%) showed improvement in their neurological status, while the others did not (59%).

These findings are suggestive of chances of improvement being less likely with initial high grade ASIA A whereas the maximum chances of recovery was associated with low grade ASIA C and D.

Out of 62 patients, 30.65 % showed improvement and 43.5 % showed no improvement in a study done by Parashari et al³. 23 % of ASIA A grade improved in the study in contrast to 41 % in our study.

In a study done by Harrop et al⁷¹, only 7 % of ASIA A showed improvement and 94.3% of ASIA D showed improvement. A study done by Rao et al⁷² reported that none of the patients with ASIA A had improved whereas all patients in ASIA D had improved. They also observed that 84 % of patients with cord edema showed improvement and Maghu et al² reported that 86 % of patients with cord edema had shown improvement in their neurological status.

Andreoli C et al⁴¹ reported that patients with cord hemorrhage had poor prognosis while those with cord edema had better prognosis. Flanders et al³³ showed

that patients without spinal cord hemorrhage had significant improvement in their neurological status.

Selden et al⁵³ reported that severe cord compression by extra axial hematoma is associated with poor neurological function and also showed that MRI after spinal cord injury provides accurate prognostic information regarding neurological function.

A study done by Miyanji et al⁵⁶ on 100 patients concluded that final outcome of neurological recovery has no significant correlation with presence or absence of canal stenosis.

A study done by Saifuddin A et al²⁸ concluded that MRI is particularly useful in unconscious patients who cannot undergo motor and sensory neurological evaluation.

We did not perform diffusion tensor imaging (DTI) in our study, which was the limitation. DTI helps delineate the preserved white matter tracts at the level of injury as well as the extent of injury to distant normal-appearing white matter.

CONCLUSION

In our study it was concluded that MRI plays a major role in diagnosis of spinal cord injuries, directing management and predicting prognosis of neurological recovery.

MRI is an excellent tool for depicting the changes in the injured spine and cord. Various MRI findings in acute spinal cord injury correlate well with the initial neurological deficits on admission and at the time of discharge according to ASIA impairment scale.

Cord edema and normal cord were associated with favourable neurological outcome. Cord contusion shows poor neurological recovery, as compared to cord edema and normal cord. Cord transection and cord haemorrhage is associated with complete spinal cord injury and with poor neurological recovery.

SUMMARY

Spinal trauma is relatively more common in young active individuals. Although its mortality is low, it is an important cause of long term disability. MRI is the established gold standard for imaging of acute spinal trauma. It can accurately depict intrinsic changes in the spinal cord i.e. cord haemorrhage and cord oedema as well as extrinsic compression of cord by herniated disc, epidural hematoma or bony fragments.

MRI is not only a diagnostic tool in spinal trauma but also a prognostic predictor. It is possible to predict the neurological outcome of the patients with different cord abnormalities. Various MRI findings in acute spinal cord injury correlate well with the initial neurological deficits on admission and at the time of discharge according to ASIA impairment scale. Cord edema and normal cord was associated with favorable neurological outcome. Cord contusion showed lesser neurological recovery, as compared to cord edema. Cord hemorrhage and cord transection was associated with worst neurological status at admission and poor neurological recovery. Other non-cord findings like fractures and soft tissue abnormalities and their effect on the cord can also be evaluated on MRI study. This assertion notes the importance of MRI performed in the acute period after trauma is to predict future neurological recovery.

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PROFORMA

EVALUATION OF TRAUMATIC SPINE BY MAGNETIC RESONANCE IMAGING AND ITS CORRELATION WITH CLINICO-NEUROLOGICAL OUTCOME

NAME:
AGE:
SEX :
HOSP. NO.:
DOA:
DOD:
PRESENTING HISTORY
PAST HISTORY
ON EXAMINATION
PULSE
BP
SYSTEMIC EXAMINATION:
CNS
NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY ON ADMISSION
MOTOR SCORE
SENSORY SCORE
ASIA IMPAIRMENT SCALE
MRI FINDINGS
NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY ON DISCHARGE
MOTOR SCORE
SENSORY SCORE
ASIA IMPAIRMENT SCALE
CVS
RS
PER ABDOMEN

INFORMED CONSENT

STUDY TITLE: EVALUATION OF TRAUMATIC SPINE BY MAGNETIC RESONANCE IMAGING AND ITS CORRELATION WITH CLINICONEUROLOGICAL OUTCOME

Chief researcher/ PG guide's name: Dr. ANIL KUMAR SAKALECHA

Principal investigator: Dr. BUKKE RAVINDRA NAIK

Chief Researcher/ Guide signature

Name o	the subject :	
Age	:	
Sex	:	
a. I patients brain/an implants stents/sh complic b. I part of it c. I	with metallic implants, cardiac eurysmal clip, metal in eyes, metal for a surple of the control	untary and may refuse to participate or
•	•	e participation at any time without
d. I	e to my present or future care at this in agree not to restrict the use of any dates such a use is only for scientific purpo	ta or results that arise from this study
has exp undergo	ained to me the purpose of research and the possible risks and discomform. I hereby agree to give valid cons	(chief researcher/ name of PG guide) n and the study procedure that I will rts that i may experience, in my own ent to participate as a subject in this
	ntient's signature gnature of the witness:	Date:
	nave explained to rch, the possible risk and benefits to t	

Date:

PATIENT INFORMATION SHEET

TITLE: EVALUATION OF TRAUMATIC SPINE BY MAGNETIC RESONANCE IMAGING AND ITS CORRELATION WITH CLINICO-NEUROLOGICAL OUTCOME

I, Dr. Bukke Ravindra Naik, post graduate in the department of Radio - Diagnosis, Sri Devaraj Urs Medical College, Kolar. We are carrying out a study on Spinal trauma. The study has been reviewed by the local ethical review board and has been started only after their formal approval. You require MRI to evaluate the spinal trauma which is also our study project.

Participation in this study doesn't involve any cost for you. This study is not only beneficial to you but also to the community at large. All the information collected from you will be strictly confidential and will not be disclosed to any outsider unless compelled by law. This information collected will be used only for research. I request you to kindly give consent for the clinical examination.

There is no compulsion to participate in this study. You will be no way affected if you don't wish to participate in this study. You are required to sign only if you voluntarily agree to participate in this study. Further, you are at a liberty to withdraw from the study at any time, if you wish to do so. Be assured that your withdrawal will not affect your treatment by the concerned physician in any way. It is up to you to decide whether to participate. This document will be stored in the safe locker in the department of Radio - Diagnosis in the college and a copy is given to you for information.

For any further clarification you are free to contact the principal investigator,

Dr. Bukke Ravindra Naik; Mobile No: 9591760877

Dr. Anil Kumar Sakalecha; Mobile No: 9844092448

ಮಾಹಿತಿಯುಕ್ತ ಸಮ್ಮತಿಯ ನಮೂನೆ

ನಾನು ರುಜುಮಾಡಿರುವ, ಈ ಅಧ್ಯಯನದಲ್ಲಿ ಭಾಗವಹಿಸಲು ಈ ಸಮ್ಮತಿಯ ರೂಪ ಅಂಶಗಳಂತೆ ನನ್ನ ವೈಯಕ್ತಿಕ ಮಾಹಿತಿಯ ಸಂಗ್ರಹಣೆ ಮತ್ತು ಬಹಿರಂಗಪಡಿಸುವಿಕೆಯ ಅಧಿಕೃತಗೊಳಿಸಲು ಒಪ್ಪುತ್ತೇನೆ.

ನಾನು ವಿಧಾನ ಮತ್ತು ಸಂಗ್ರಹಿಸಿ ಅಧ್ಯಯನ ಮಾಡುವ ಸಂದರ್ಭದಲ್ಲಿ ಬಹಿರಂಗಪಡಿಸಲಾಗುತ್ತದೆ ಮಾಹಿತಿಯನ್ನು ಗೌಪ್ಯ ಪ್ರಕೃತಿಯ ಅಪಾಯಗಳು ಮತ್ತು ಲಾಭಗಳ ಈ ಅಧ್ಯಯನದ ಉದ್ದೇಶ ಅರ್ಥ. ಸಂಗ್ರಹಿಸಿದ ಮಾಹಿತಿಯನ್ನು ಮಾತ್ರ ಸಂಶೋಧನೆಗೆ ಬಳಸಲಾಗುತ್ತದೆ.

ನಾನು ಈ ಅಧ್ಯಯನದಲ್ಲಿ ವಿವಿಧ ಅಂಶಗಳನ್ನು ಕುರಿತು ಪ್ರಶ್ನೆಗಳನ್ನು ಕೇಳಲು ಅವಕಾಶ ಹೊಂದಿದ್ದರು ಮತ್ತು ನನ್ನ ಪ್ರಶ್ನೆಗಳಿಗೆ ನನ್ನ ತೃಪ್ತಿ ಉತ್ತರಗಳನ್ನು ನೀಡಲಾಗಿದೆ.

ನಾನು ಯಾವುದೇ ಸಮಯದಲ್ಲಿ ಈ ಅಧ್ಯಯನದಿಂದ ಹಿಂಪಡೆಯಬಹುದು ಉಚಿತ ಉಳಿದು ಈ ನನ್ನ ಭವಿಷ್ಯದ ಕಾಳಜಿ ಬದಲಾಗುವುದಿಲ್ಲ ಎಂದು ಅರ್ಥ.

ಈ ಅಧ್ಯಯನದಲ್ಲಿ ಭಾಗವಹಿಸುವಿಕೆ ನನಗೆ ಯಾವುದೇ ಹೆಚ್ಚುವರಿ ವೆಚ್ಚವಿಲ್ಲದೆ ಒಳಗೊಳ್ಳುವುದಿಲ್ಲ.

ವಿಷಯದ ಹೆಸರು ಮತ್ತು ಅರ್ಜಿದಾರರ ಸಹಿ ದಿನಾಂಕ:

ಹೆಸರು ಮತ್ತು ಸಾಕ್ಷಿ ಸಹಿ: ದಿನಾಂಕ

ಹೆಸರು ಮತ್ತು ವ್ಯಕ್ತಿ ಪಡೆಯುವ ಒಪ್ಪಿಗೆ ಸಹಿ: ದಿನಾಂಕ

KEY TO MASTER CHART

AIS – ASIA impairment scale
C – Cervical
CO– Conservative
D - Dorsal
DL – Dorso-lumbar
F – Female
FH – Fall from height
FW – Fall of weight
L - Lumbar
M - Male
N - No
S – Surgery
Y – Yes

SI.No	Name	Age	Sex	Trial ID	Cause	Level of injury	Cord transection with contusion/edema	Cord Hemorrhage	Cord contusion / edema	Cord edema	Spinal canal stenosis	Normal Cord	Epidural hematoma	Treatment	No. of days of hospital stay	AIS at admission	AIS at discharge
1	Murali	20	M	50210	RTA	С	Y	N	N	N	N	N	N	CO	16	A	A
2	Sadam	24	M	31520	RTA	D	Y	N	N	N	N	N	N	S	17	A	A
3	Asha	24	F	4209.8	FH	C	Y	N	N	N	N	N	N	CO	30	A	A
4	Umesh	29	M	27114	FH	D	Y	N	N	N	N	N	N	CO	21	A	A
5	Nanjundappa	57	M	15115	FH	C	N	Y	N	Y	N	N	N	CO	22	A	A
6	Munireddy	42	M	72234	RTA	С	N	N	Y	N	N	N	N	CO	29	A	D
7	Karthik	24	M	38453	FH	L	N	N	Y	N	N	N	N	S	14	A	C
8	Mohan	24	M	87384	RTA	С	N	N	Y	N	N	N	N	CO	16	C	С
9	Bheemanna	50	M	54693	FH	D	N	N	Y	N	N	N	N	CO	13	С	D
10	Rajanna	38	M	49719	FH	С	N	N	N	Y	N	N	N	S	14	D	D
11	Shivanna	65	M	73838	FW	С	N	N	N	Y	N	N	N	CO	16	C	D
12	Mahalakshmi	50	F	35521	FH	С	N	N	N	Y	N	N	N	CO	15	D	Е
13	Sudharshan	20	M	96464	FH	С	N	N	N	Y	N	N	N	S	16	C	C
14	Reddappa	75	M	57639	RTA	С	N	N	N	Y	N	N	N	CO	14	В	C
15	Rani	20	F	96397	FH	DL	N	N	N	Y	N	N	Y	S	36	A	A
16	Amarvthamma	40	F	25962	FH	D	N	N	N	Y	N	N	Y	S	18	A	С
17	Anitha	32	F	54244	RTA	DL	N	N	N	Y	N	N	Y	S	20	A	С
18	Govindappa	55	M	13885	FH	С	N	N	N	Y	N	N	N	CO	18	С	С
19	Anjappa	54	M	82189	FH	С	N	N	N	Y	N	N	N	CO	17	В	В
20	Shafiulla	24	M	78670	FW	DL	N	N	N	Y	N	N	N	S	18	A	A

AIS – ASIA impairment scale, C – Cervical, CO– Conservative, D – Dorsal, DL – Dorso-lumbar, F – Female, FH – Fall from height, FW – Fall of weight, L – Lumbar, M – Male, N – No, RTA – Road traffic accident, S – Surgery, Y – Yes,

SI.No	Name	Age	Sex	Trial ID	Cause	Level of injury	Cord transection with contusion/edema	Cord Hemorrhage	Cord contusion / edema	Cord edema	Spinal canal stenosis	Normal Cord	Epidural hematoma	Treatment	No. of days of hospital stay	AIS at admission	AIS at discharge
21	Venkateshappa	48	M	59991	FH	С	N	N	N	Y	N	N	N	CO	14	С	D
22	Nanjundappa	65	M	48501	FH	D	N	N	N	Y	N	N	N	CO	15	C	С
23	Srinivas	20	M	90799	FH	L	N	N	N	N	Y	N	N	S	16	C	C
24	Anwar pasha	50	M	58567	FH	D-L	N	N	N	N	Y	N	N	CO	16	D	E
25	Chinnappa	34	M	30189	FH	L	N	N	N	N	Y	N	N	S	19	C	D
26	Raheesh	26	M	36450	FW	L	N	N	N	N	Y	N	N	CO	12	D	D
27	Adinarayana	20	M	33801	FH	L	N	N	N	N	Y	N	N	S	15	Е	Е
28	Krishna reddy	28	M	11658	FH	L	N	N	N	N	Y	N	N	CO	17	C	D
29	Murali	40	M	64508	FH	L	N	N	N	N	Y	N	N	S	18	D	Е
30	Naryna swamy	55	M	92706	FW	С	N	N	N	N	N	Y	N	CO	12	D	Е
31	Anish akthar	52	M	25741	RTA	L	N	N	N	N	N	Y	N	S	12	Е	Е
32	Girish	18	M	65117	FH	DL	N	N	N	N	N	Y	N	S	14	D	Е
33	Venkateshappa	60	M	67460	FH	L	N	N	N	N	N	Y	N	S	13	Е	Е
34	Paletappa	65	M	72718	FH	D	N	N	N	N	N	Y	N	S	12	D	Е
35	Srinath	40	M	12869	RTA	L	N	N	N	N	N	Y	N	S	20	Е	Е
36	Anand	35	M	63830	RTA	D	N	N	N	N	N	Y	N	CO	20	Е	Е
37	Naryan swamy	40	M	43694	RTA	DL	N	N	N	N	N	Y	N	S	13	D	Е
38	Thimmakka	72	F	83142	FH	L	N	N	N	N	N	Y	N	CO	17	Е	Е
39	Rajashekar	35	M	17406	FH	L	N	N	N	N	N	Y	N	S	16	D	Е
40	Naryan swamy	45	M	66293	RTA	C	N	N	N	N	N	Y	N	CO	15	Е	Е

 $AIS-ASIA\ impairment\ scale,\ C-Cervical,\ CO-Conservative,\ D-Dorsal,\ DL-Dorso-lumbar,\ F-Female,\ FH-Fall\ from\ height,\ FW-Fall\ of\ weight,\ L-Lumbar,\ M-Male,\ N-No,\ RTA-Road\ traffic\ accident,\ S-Surgery,\ Y-Yes,$

SI.No	Name	Age	Sex	Trial ID	Cause	Level of injury	Cord transection with contusion/edema	Cord Hemorrhage	Cord contusion / edema	Cord edema	Spinal canal stenosis	Normal Cord	Epidural hematoma	Treatment	No. of days of hospital stay	AIS at admission	AIS at discharge
41	Venkatamma	50	F	84863	RTA	С	N	N	N	Y	N	N	N	S	25	A	С
42	Parvathamma	55	F	12905	FH	DL	N	N	N	Y	N	N	N	S	14	D	Е
43	Sonna Pillappa	35	M	95066	RTA	С	N	Y	N	Y	N	N	N	CO	12	A	A
44	Sonnappa	45	M	98441	RTA	С	N	Y	N	Y	N	N	N	CO	27	A	A
45	Naryna Swamy	55	M	96785	RTA	D	N	N	N	Y	N	N	N	S	19	A	C
46	Manjunath	35	M	78597	FH	D	N	N	N	Y	N	N	N	S	19	D	Е
47	Nagaraj	40	M	76159	RTA	C	N	N	N	N	N	Y	N	CO	15	C	D
48	Shiva Kumar	23	M	71679	RTA	D	N	N	Y	N	N	N	N	S	21	A	A
49	Firoz Pasha	18	M	91044	RTA	C	N	N	Y	N	N	N	N	CO	43	A	A
50	Anandappa	40	M	94089	FH	C	N	N	N	Y	N	N	N	S	20	C	D
51	Prudhvi	35	M	68171	RTA	D	N	N	N	Y	N	N	N	S	20	A	D
52	Ravi Kumar	45	M	70699	FH	С	N	N	Y	N	N	N	N	CO	19	A	С
53	Naveen Kumar	35	M	73227	RTA	С	N	N	N	N	N	Y	N	CO	14	Е	Е
54	Manjunath	21	M	63872	FH	DL	N	N	N	Y	N	N	N	S	18	С	Е
55	Ambarish	26	M	59266	RTA	D	N	N	Y	N	N	N	N	S	28	A	A
56	Venktaramappa	52	M	40590	FH	С	N	N	Y	N	N	N	N	S	16	A	A
57	Krishnappa	50	M	38238	FH	С	N	N	Y	N	N	N	N	S	24	A	С

AIS – ASIA impairment scale, C – Cervical, CO– Conservative, D – Dorsal, DL – Dorso-lumbar, F – Female, FH – Fall from height, FW – Fall of weight, L – Lumbar, M – Male, N – No, RTA – Road traffic accident, S – Surgery, Y – Yes,