

Original Article

# Diagnostic and prognostic role of MRI in spinal trauma, its comparison and correlation with clinical profile and neurological outcome, according to ASIA impairment scale

Umesh C. Parashari, Sachin Khanduri, Samarjit Bhadury, Neera Kohli<sup>1</sup>, Anit Parihar<sup>1</sup>, Ragini Singh<sup>1</sup>, R. N. Srivastava<sup>2</sup>, Deepika Upadhyay<sup>3</sup>

Departments of Radio Diagnosis, Era's Lucknow Medical College, <sup>1</sup>Radio Diagnosis, <sup>2</sup>Orthopaedics, C.S.M. Medical University, <sup>3</sup>Pathology, S.G. Post Graduate Institute of Medical Sciences, Lucknow, India.

Corresponding author: Dr. Umesh Chandra Parashari, Department of Radiodiagnosis, Era's Lucknow Medical College, Lucknow, India. E-mail: [drumesh.rd@gmail.com](mailto:drumesh.rd@gmail.com)

Journal of Craniovertebral Junction and Spine 2011, 2:4

## Abstract

**Aims and objectives:** To evaluate the role of magnetic resonance imaging (MRI) as a non-invasive diagnostic tool in patients with acute and chronic spinal trauma and to compare and correlate the MRI findings with those of patients' clinical profile and neurological outcome according to ASIA impairment scale to assess prognostic and clinical value of MRI. **Materials and Methods:** Sixty two patients of spinal trauma formed the study group in a prospective fashion. The patients undergoing MR imaging and magnetic resonance images were analyzed and correlated with findings on neurological examination according to American Spinal Injury Association (ASIA) impairment scale (AIS) at the time of MRI examination and subsequently at sub-acute interval to assess neurological outcome. **Statistical Analysis:** Sample profile was described in terms of 95% confidence limit and proportion. To describe strength of association between extent of spinal cord injury and outcome, odd's ratio, bivariate and multi variant analysis, was used. Pearson's chi square ( $\chi^2$ ) statistics was applied to test the association between two categorical variables. Data were analyzed using statistical software package, STATA 9.2 and the difference was considered to be significant if 'P' value was <0.05. **Observation and Results:** The cord edema without hemorrhage was the most common MR finding (41.5%). The others were sizable focus of hemorrhage within the cord (33%), epidural hematoma (5.0%), and normal cord (26%). Majority of MR findings correlated well with clinical profile of the patient according to ASIA impairment scale. This study demonstrated that patients with presence of sizable focus of haemorrhage had larger cord edema and more severe grade of initial ASIA impairment scale (AIS) with poor recovery at follow up ( $P=0.032$ ). Improvement in upper extremity was more than lower extremity. Severe cord compression was also associated with poor neurological outcome; however it was not statistically significant ( $P=0.149$ ). **Conclusions:** With this study the authors

Access this article online	
Quick Response Code:	Website: <a href="http://www.jcvjs.com">www.jcvjs.com</a>
	DOI: 10.4103/0974-8237.85309

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 recovery.

**Key words:** ASIA impairment scale, MRI, spinal trauma, acute spinal cord injury, prognostication

## INTRODUCTION

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 procedures.

Many advantages of MRI such as, higher contrast resolution, absence of bony artifacts, multiplanar capability, and choice of various pulse sequences make possible to diagnose spinal trauma more accurately. More 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, hemorrhage and ischemia, MRI findings may serve as prognostic indicators.

Most of the diagnostic information in spinal trauma is derived from the sagittal images. Axial images serve as a supplement.<sup>[1]</sup> Sagittal T1-weighted images offer an excellent anatomic overview. Disc herniations, epidural fluid collections, spondylolisthesis, vertebral body fractures, cord swelling, and cord compression are also visualized.<sup>[2]</sup> Sagittal T2-weighted images depict most of the soft tissue abnormalities including spinal cord edema and hemorrhage, ligamentous injury, disc herniations, and epidural fluid collections.<sup>[3]</sup> Axial and sagittal GE images aid in the identification of acute spinal cord hemorrhage, disc herniations, and fractures.

The depiction of parenchymal 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 recovery.<sup>[4-13]</sup>

Several investigators have attempted to identify the initial MRI patterns of injury that predict chronic changes in the spinal cord parenchyma that ultimately lead to post-traumatic progressive myelopathy (PTPM).<sup>[13-15]</sup> Of the five imaging patterns described by Yamashita, lesions that were low in signal intensity on T1-weighted images and hyper intense on T2-weighted images predicted the worst prognosis.<sup>[15]</sup>

Considering the advantages of MRI as an excellent diagnostic modality for evaluation of spinal trauma, it was possible to suggest that the MRI findings correlated directly with the degree of weakness according to ASIA impairment scale. The purpose of this study was to evaluate this correlation.

## MATERIALS AND METHODS

This prospective study was conducted in a span of one year. All patients with traumatic spinal injuries reporting were included in the study. Detailed history with respect to age, sex, mode of trauma, date of trauma and examination was carried out. Sixty two patients of spinal trauma formed the study group in a prospective fashion. All patients underwent MRI examination. Exclusion criteria were patient with at least one absolute contraindication, non-cooperative patient, patients with metallic implants, claustrophobia, pacemakers, and cochlear implants *in situ*.

The spinal trauma patient required special consideration before MR imaging. All potential risks for imaging the medically unstable patient were carefully weighed against the need for the diagnostic information provided by MRI. MRI-compatible monitors were used. Patients with cervical spine injuries were usually stabilized with a fiberglass cervical collar. Sedation was used when necessary to complete an examination. Choice of surface coil was determined by the location(s) of injury, access to the area of interest, and the types of coils available.

### MRI techniques in spinal trauma

We performed the MR imaging of injured spine on Signa Excite 1.5T (GE) MR scanner both in the axial and sagittal planes using a combination of pulse sequences. The study was performed with patient in supine position with quiet breathing and with abdominal band compression obtaining sagittal T2 and T1-weighted fast spin echo images, STIR and fat suppression images, coronal STIR and axial T2, T1-weighted fast spin echo images and GRE images for proper evaluation of cord hemorrhage. A maximum of nine images were needed to interrogate the spine including the lateral elements. 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 labeling of the involved levels.

T2-weighted information was obtained using a single FSE acquisition using a split echo train, resulting in an intermediate T2WIs sequences. For the short TE<sub>eff</sub> image, an echo train of three with two excitations was used, whereas for the long TE<sub>eff</sub> image an echo train of 15–30 with single excitation was used. For each sequence, 256–448 steps were followed in both the frequency (xres) and phase (yres) axes. Fat suppression was employed on the long TR sequences to improve visualization of edema in the posterior ligamentous complexes (STIR - short tau inversion recovery).

Usually, 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. To maximize detection of acute intramedullary hemorrhage, at least one GE sequence was performed when FSE sequences were used to obtain T2-weighted images.

As a supplement to the cervical examination, a survey of the extra cranial vasculature was done to detect post-traumatic occlusion or dissection of the carotid and vertebral arteries. This was achieved with 2D and 3D time-of-flight (TOF) magnetic resonance angiography (MRA). No use of contrast agents was done.

### Clinical assessment of spinal cord injury

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 allowed 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. The rectal examination, which tested for voluntary anal contraction and deep anal sensation, was part of the required components of the examination.

### Sensory examination

There are 28 key dermatomes, each were 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) was used, with the face as the normal control point. Absent sensation yielded a score of 0. A score of 1 (impaired) for pinprick testing was given when the patient could distinguish between the sharp and dull edge of the pin, but the pin was not felt as sharp as on the face. The score of 2 (normal or intact) was given only if the pin was felt as sharp, in the tested dermatome, as when tested on the face.

For light touch, a cotton-tip applicator was 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 was 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 was tested. When testing the chest and abdomen, sensory testing was performed at the midclavicular line.

S4-5 dermatome was also tested for both pinprick and light touch because this represented the most caudal aspect of the

sacral spinal cord. To test for deep anal sensation, a rectal digital examination was performed. The patients were asked to report any sensory awareness, touch, or pressure, with firm pressure of the examiner's digit on the rectal walls. Deep anal sensation was recorded as either present or absent.

The sensory level was 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 was 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. If accurate sensory testing in any dermatome could not be performed, NT (not tested) was recorded, or an alternate location within the dermatome was tested with notation that an alternate site was used.

### Motor examination

The required elements of the ASIA motor examination consisted of testing 10 key muscles: 5 in the upper limb and 5 in the lower limb on each side of the body. The muscles were 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 during the initial and the follow-up examinations was performed with the patient in the supine position and graded and recorded on the standard form, on a six-point scale from 0 to 5. Voluntary anal contraction was tested as part of the motor examination by sensing contraction of the external anal sphincter around the examiner's finger and graded as either present or absent.

The motor level was the lowest normal motor segment, which might differ by side of the body. It was defined as the lowest key muscle that has a grade of at least 3, providing the key muscles represented by segments above that level are graded as 5. When the patients were not fully testable for any reason, we recorded NT instead of a numeric score. Motor index scoring was calculated by adding the muscle scores of each key muscle group. The total score possible was 100, 25 for each extremity. The neurologic level of injury (NLI) was the most caudal level at which both motor and sensory modalities was intact on both sides of the body.

The Frankel classification was replaced in 1992 by the ASIA Impairment Scale. This scale was revised in 1996 and again in the year 2000. The name of the Frankel classification was officially changed, in 1992, to the ASIA Impairment Scale, and optional tests (position sense, vibration, and additional muscles to localize better the level of the lesion) were added.

## ASIA IMPAIRMENT SCALE

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.

A patient with cervical SCI can have sensory and motor function in the trunk or even the legs, but unless sacral sparing is present, the injury must be classified as complete (ASIA A), with a large ZPP. The ZPP, in 1992, was defined as all segments below the NLI with preservation of sensory function and used only in incomplete (ASIA A) injuries. We utilized the American Spinal Injury Association 2000 Standards for clinical evaluation.

Below is a summary of the steps which we used in classifying patients with SCI:

- IST sensory examination was done in 28 dermatomes bilaterally for pinprick and light touch, including the S4–S5 dermatome, and tested for anal sensation on rectal examination.
- Then we determined sensory level (right and left) and total sensory score.
- After that we performed examination in the 10-key muscle groups, including voluntary anal contraction on rectal examination and determined the motor level (right and left), motor index score and NLI.
- After that we classified the injury as complete or incomplete and categorized ASIA Impairment Scale (A through E) with ZPP if was ASIA A.
- Magnetic resonance images were analyzed and correlated with findings on neurological examination according to ASIA Impairment Scale (AIS) at the time of MRI examination and subsequently at sub-acute interval to assess neurological outcome.

### Statistical methods

Sample profile was described in terms of 95% confidence limit and proportion. To describe strength of association between extent of spinal cord injury and outcome, odds ratio, bivariate and multi variant analysis, whichever is applicable, was used. Pearson's chi square ( $\chi^2$ ) statistics was applied to test the association between two categorical variables. Data were analyzed using statistical software package, STATA 9.2 and the difference was considered to be significant if 'P' value was <0.05.

## OBSERVATION, RESULTS AND DISCUSSION

We performed this prospective study in 62 patients of spinal trauma referred for an MRI examination.

The results of our study have shown that MRI is an excellent

diagnostic modality for the evaluation of patients of spinal trauma. It accurately defines the extent of bony and soft tissue damage in the zone of trauma. With the help of MRI we were able to correlate objective imaging findings in spinal trauma and clinical neurological examination findings according to ASIA Impairment Scale.

### Abnormal cord findings in MRI in spinal trauma

MRI examination revealed that cord abnormalities [Table 1] were present in 47 out of 62 patients i.e. 75.80% of patients. In 15/62 i.e. 26.32% of patients (95% CL; 15.54–39.66 %), no abnormality was noted in cord. In a similar study, Kulkarni *et al.* revealed the presence of cord abnormalities in 70% of patients and skeletal abnormalities in 78% of patients.<sup>[6]</sup> Sizable focus of hemorrhage (>1 cm) involving cord was present in 20/62 patients i.e. 32% of patients with 95% confidence limit of 20.94–45.34% [Figure 1]. In 67.74%, significant hemorrhage was not seen (95% CL of 54.66–79.06%). Cord edema/non-hemorrhagic contusion involving less than 3 cm cord was present in 14/62 patients i.e. 24.56% with 95% confidence limit of 14.13–37.76% [Figure 2]. Cord edema/contusion involving more than 3 cm of cord was present in 28/62 patients i.e. 49.12% with 95% confidence limit of 35.63–62.71% [Figure 3]. So cord edema/contusion involving more than 3 cm of cord was the most common cord finding in our study. In 5/62 i.e. 8.06% chronic myelopathic changes were noted in the cord.

### Comparison of MRI findings with clinical profile of patients

In our study we found out that initial paralysis was graded as AIS A in 26 patients (41.93%), B in 1 (1.61%), C in 6 (9.67%), D in 17 (27.42%) and E in 12 (19.35%) patients [Table 2]. In patients with presence of sizable focus of hemorrhage, among the

**Table 2: Comparison of ASIA impairment scale (AIS) at the time of admission and discharge in patients of spinal trauma**

AIS	Number of patients at admission	Number of patients at discharge
A	26	22
B	1	1
C	6	4
D	17	22
E	12	12
Not applicable	0	1
Total	62	62

**Table 1: Abnormal cord findings**

Cord abnormality	Number of patients (n=62)
Sizable focus of hemorrhage in cord (>1 cm)	20/62 (32.26% with 95% CL, 20.94-45.34)
Cord edema / non-hemorrhagic contusion (<3 cm)	14/62 (24.56 % with 95% CL, 14.13-37.76)
Cord edema / contusion (>3 cm)	28/62 (49.12% with 95% CL, 35.63–62.71)
No finding in cord	15/57 (26.32 % with 95% CL, 15.54–39.66)
Myelopathic changes	5/62 (8.06%)



**Figure 1:** The patient presented with h/o fall from height 1 day prior to date of MRI. T2 sagittal (a) and T2\*-GRE (b) MR images reveal fracture dislocation at C6-7 level with grade 4 spondylolisthesis of C6 over C7 with fracture of C6 and D3 and contusion of cord involving about 6.1 cm long segment with sizable focus of hemorrhage with severe cord compression. On clinical exam AIS at admission was A, on discharge no improvement was noted. Thus involvement of long segment of cord, presence of sizable focus of hemorrhage with severe cord compression were bad prognostic indicator for high-grade AIS at admission and no recovery of patient at discharge



**Figure 2:** History of fall of weight over the patient 7 days prior to MRI examination. Sagittal T2W MR image shows anterior wedge collapse of L1 vertebral body with cord edema in the region of conus in about 1.4 cm span. Clinical examination showed initial AIS D, patient was followed till discharge. No improvement was noted as initial AIS was good. Involvement of small segment of cord, absence of cord hemorrhage and severe cord compression were good prognostic indicator for the patient



**Figure 3:** Alleged history of fall from height 4 days prior MRI. Sagittal T2W MR imaging reveals partial wedge collapse of C5 vertebra with grade 2 spondylolisthesis at C5-6 level with cord contusion in 5.8 cm span extending from C4 to C8 vertebral level. On clinical exam at admission the AIS was C, patient was followed till discharge. The AIS at discharge was D s/o improvement. Absence of hemorrhage was good prognostic indicator for the recovery of the patient. The long segment of cord involved was responsible for high-grade AIS at admission

19 patients graded initially as AIS A, only one patient showed improvement to AIS C [Table 3]. Ninety percent patients with initial AIS A showed no improvement. It may suggest that the patients with initial high-grade AIS did not show significant improvement. In patients with cord edema/non-hemorrhagic contusion involving <3cm of cord, initial paralysis was graded as

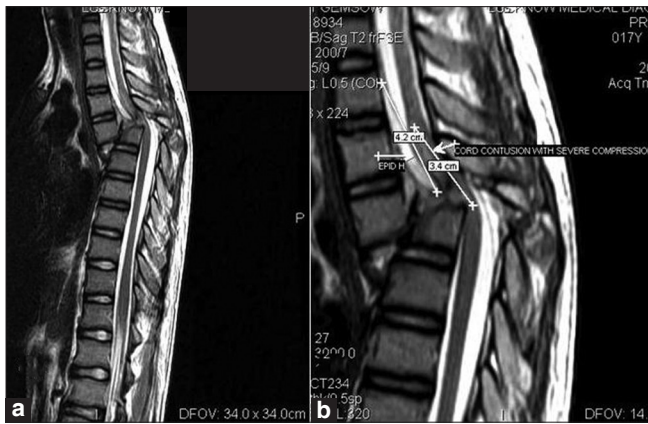
**Table 3: Comparison of AIS at admission and discharge in patients with presence of sizable focus of hemorrhage in cord (>1 cm) (n=20)**

AIS	Number of patients at admission	Number of patients at discharge
A	19	18
B	1	1
C	0	1
D	0	0
E	0	0
Total patients	20	20

AIS A in only 2 of 14 patients – 14.3% of patients, AIS D in 11 patients – 78.57 %. Out of two patients with initial AIS A, one patient has shown improvement to AIS C [Table 4]. The data in Table 5 shows that in patients with initial cord edema involving >3 cm of cord, 21 patients i.e. 75% were graded as AIS A and on follow-up only two patients showed improvement to AIS D. Of the 15 patients who had shown no finding in cord, 12 showed no clinical deficit, 2 patients were graded as AIS D and one patient was graded as AIS C [Table 6].

**Correlation of MRI findings with clinical profile of patients and neurological outcome**

In our study 19 of 62 patients (30.65%, 95% CL of 19.56–43.65) showed improvement and 27 patients (43.55%, 95% CL of 30.99–56.74) showed no improvement, one patient had left against medical advice (LAMA), 2 patients i.e. (3.23%, 95% CL of 0.39–11.17) had died. In 13 patients initially no



**Figure 4:** Patient presented with history of fall from height 1 day prior to date of MRI. Sagittal T2W MR imaging shown fracture dislocation at D4–5 level with grade 4 spondylolisthesis of D4 over D5 with fracture of D5, contusion of cord in about 3.4 cm span , a small focus of hemorrhage in cord (8 mm), a small epidural hematoma and severe cord compression. On clinical exam AIS at admission was A. Patient was followed till discharge, no improvement was noted. Presence of long length of cord involved severe cord compression and were responsible for high-grade AIS at admission and discharge.

weakness was present [Table 7a]. The outcome was graded according to ASIA impairment scale. Out of 26 patients with initial AIS A only 6 i.e. 23.07% showed improvement while out of 17 patients with initial AIS D, 8 i.e. 47.05% patients showed improvement. In patients with initial AIS C, 4/6 i.e. 66.66% had shown improvement, it suggests that chances of improvement are less in patients with initial high-grade AIS [Table 7b]. Extremity-wise improvement was also evaluated, which revealed improvement in upper extremities significantly more than the lower extremity [Table 8]. While considering cord hemorrhage as a risk factor only 3/30 patients (15.0%, 95% CL of 3.2–37.9) showed improvement and 17 patients (85%, 95% CL of 62.1–96.8) showed no improvement. In none of the patients, improvement of lower extremity was noted [Table 9]. Of the 42 patients without sizeable cord hemorrhage 16 (95% CL mentioned in the table) patients had shown variable grade of improvement and 13 patients (30.9%, 95% CL of 17.6–47.1) showed significant improvement in the upper extremities than the lower extremities. In only 1 patient (2.4%, 95% CL of 0–12.6), improvement of upper extremity was noted with no improvement of lower extremity [Table 10]. Data in the table shows that in patients with presence of sizeable focus of cord hemorrhage, 1 patient i.e. 5% (95% CL 0-25) showed improvement in sensory scores [Table 11a]. While considering edema as a risk factor sensory improvement was noted in 6/14 patients with cord edema involving <3 cm of cord. In patients with cord edema involving >3 cm of cord, four patients showed improvement [Table 11b]. Odds ratio is 5.75 (95% CL 0.95-36) and the Fisher’s exact P value is 0.0427 (P<0.05), which is significant. It indicates that in patients with cord edema involving >3 cm of cord, chances of sensory improvement was 5.75 times lesser than in patients with cord edema involving <3 cm of cord. Multivariate analysis was done to see the effect of

**Table 4: Comparison of AIS at admission and discharge in patients with cord edema/ non hemorrhagic contusion (<3 cm) (n=14)**

AIS	Number of patients at admission	Number of patients at discharge
A	2	1
B	0	0
C	1	2
D	11	11
E	0	0
Total	14	14

**Table 5: Comparison of AIS at admission and discharge in patients with presence of edema / contusion involving > 3 cm of cord**

AIS	Number of patients at admission	Number of patients at discharge
A	21	19
B	1	1
C	4	2
D	2	6
E	0	0
Total	28	28

**Table 6: Comparison of AIS at admission and discharge in patients with absence in finding any cord**

AIS	Number of patients at admission	Number of patients at discharge
A	0	0
B	0	0
C	1	0
D	2	2
E	12	12
Not applicable	0	1
Total	15	15

various risk factors studied on the outcome of trauma patients. It shows that over and above all the risk factors only sizeable focus of bleed (>1 cm) was significantly associated with poor prognosis (OR 6.73; 95% CL 1.2, 38.6; p=0.032) [Table 12].

In a similar study, Boldin *et al* showed the effect of hemorrhage and length of hematoma on neurological impairment.<sup>[16]</sup> They showed that patients with hemorrhage were more likely to have completed SCI at the time of follow-up (odds ratio = 2.33, 95% confidence interval, 1.42-3.82). Similar to our study they also showed that presence of small hemorrhage was not associated with complete SCI and showed good prognosis. Similar results were also shown by Andreoli C.<sup>[17]</sup> They demonstrated that patients with initial hemorrhage had poor prognosis while those with edema had better prognosis. Flanders *et al.* showed

**Table 7a: Neurological outcome in patients of spinal trauma (n = 62)**

Improvement	Non-improvement	No improvement - LAMA	Mortality	Not applicable	Total patients
19 (30.65%, 95% CL, 19.56–43.65)	27 (43.55% , 95% CL, 30.99–56.74)	1 (1.61%, 95% CL, 0.04–8.66)	2 (3.23%, 95% CL, 0.39–11.17)	13 (20.97% , 95% CL, 11.66–33.18)	62

CL: Confidence limit

**Table 7b: Outcome in patients of spinal trauma according to ASIA impairment scale at admission (n=62)**

AIS	Improvement	Non-improvement	Mortality	Not applicable	Total number of cases
A	6	19	1		26
B	1				1
C	4	2			6
D	8	8	1		17
E	-			12	12
	19	29	2	12	62

CL: Confidence limit

**Table 8: Extremity-wise improvement in motor scores (at discharge / follow-up)**

Extremity-wise improvement	No. of cases	% (95%, CL)
Improvement in upper extremity more than lower	9	25.8 (15.5, 38.4)
Upper extremity normal, improvement in lower extremity	7	
Improvement in both extremities	2	3.2 (0.3, 11.2)
Improvement in lower extremity, no improvement in upper extremity	1	1.6 (0, 8.6)
No improvement	30	48.4 (35.5, 61.4)
No weakness	12	19.3 (10.4, 31.4)
No follow-up	1	1.6 (0, 8.6)
Total	62	

CL: Confidence limit

**Table 9: Extremity-wise improvement in motor scores in patients with presence of sizable focus of hemorrhage in cord (at discharge / follow-up)**

Extremity wise improvement	No. of cases	% (95%, CL)
Improvement in upper extremity more than lower	1	15.0 (3.2, .37.9)
Upper extremity normal, improvement in lower extremity	2	
Improvement in both extremities	0	
Improvement in lower extremity, no Improvement in upper extremity	0	
No improvement	17	85 (62.1, 96.8)
No weakness	0	
No follow-up	0	
Total	20	

CL: Confidence limit

that patients without spinal cord hemorrhage had significant improvement in self-care and mobility scores compared to patients with hemorrhages.<sup>[18]</sup> Their study revealed that rostral limit of edema positively correlated with admission and discharge self-care scores. Poor prognostic factors were hemorrhage, long length of cord edema and high cervical location. Selden NR also showed similar results – presence of long length of intra-axial hematoma and cord edema, each associated with poor neurological outcome.<sup>[19]</sup>

In their contrary, randomized clinical trials by Shepard MJ showed that MRI provides diagnostic information on degree

of damage to bone and soft tissues but does not add much to diagnosis of neurological function,<sup>[20]</sup> although they showed that presence of hemorrhage is associated with worse prognosis but did not provide any prognostic information. AE Flanders *et al.* also showed similar result as our study.<sup>[21]</sup> Patients with hemorrhage had lower motor scores with poor recovery ( $P < 0.001$ ). They showed that upper extremity improves better than lower extremity. They performed multiple regression analysis and stated that MR information on hemorrhage and edema increases the ability to predict clinical outcome by 16.33% over that with initial clinical score alone.

**Table 10: Extremity-wise improvement in motor scores in patients without presence of sizable focus of hemorrhage in cord (at discharge / follow-up)**

Extremity-wise improvement	No. of cases	% (95%, CL)
Improvement in upper extremity more than lower	8	30.9 (17.6, 47.1)
Upper extremity normal, improvement in lower extremity	5	
Improvement in both extremities	2	4.8 (0.5, 16.2)
Improvement in lower extremity, no improvement in upper extremity	1	2.4 (0, 12.6)
No improvement	13	30.9 (17.6, 47.1)
No weakness	12	28.6 (15.7, 44.6)
No follow-up	1	2.4 (0, 12.6)
Total	42	

CL: Confidence limit

**Table 11a: Improvement in sensory scores in patients with various cord findings (at follow-up / discharge)**

Cord findings	Improvement	No improvement	Not applicable (No follow-up)
Patients with presence of sizable focus of hemorrhage in cord (n=20)	1 (5%; 95% CL 0, 25)	19 (95%; 95% CL 75, 100)	-
Cord edema / non-hemorrhagic contusion involving <3 cm of cord (n=14)	6 (42.8%; 95% CL 18, 71)	6 (42.8%; 95% CL 18, 71)	2 (14.3%, 95% CL 2, 43)
Cord edema / contusion involving >3 cm of cord (n=28)	4 (14.3%; 95% CL 4, 33)	23 (82.1, 95% CL 63, 94)	1 (3.6; 95% CL 0, 18)
Patients with presence of significant cord compression (n=14)	6 (42.8%; 95% CL 18, 71)	6 (42.8%; 95% CL 18, 71)	2 (14.3%, 95% CL 2, 43)

CL: Confidence limit

**Table 11b: Sensory outcome in patients with cord edema involving >3 cm and <3 cm of cord.**

Cord findings	No sensory improvement	Sensory improvement
Cord edema / contusion involving >3 cm of cord (n=28*)	23	4
Cord edema / non-hemorrhagic contusion involving <3 cm of cord (n=14*)	6	6

\*Patients in which follow-up is not being done are excluded from analysis

**Table 12: various cord findings and their effect on outcome (Multi variate analysis)**

Outcome 0 improved, 1 Not improved	Odds ratio (95% Confidence Limit)	P value
Cord compression 0 Absent   Present	4.32 (0.59, 31.50)	0.149
Sizeable focus of bleed 0 <1 cm, 1 >1 cm	6.73 (1.17, 38.63)	0.032
Cord edema 0 Absent   Present	0.25 (0.33, 1.87)	0.178

Severe cord compression was present in 21 of 62 patients – 34% with 95% confidence limit of 22.33–47.01% [Figure 4, Table 13]. In patients with severe cord compression at the time of admission, AIS was graded as A in 18 out of 21 patients (85.74%). At the time of discharge, in 17 out of 21 (80.95%) patients AIS was graded as A [Table 14a]. In patients with severe cord compression, improvement was noted in 21.05% patients. In 56.67% patients with severe cord compression no improvement was noted [Table 14b]. Bivariate and multivariate analysis was carried out to correlate severe

cord compression with neurological findings at admission and discharge. Bivariate analysis showed that SCC was significantly associated with poor neurological function at admission and discharge; however, multivariate analysis showed that although the chances of poor neurological function are more in patients with SCC, it is however not statistically significant ( $P=0.149$ ). Similarly, Selden NR showed that presence of severe cord compression by vertebral or extra-axial hematoma are associated with poor neurological function at presentation and follow-up.<sup>[19]</sup> Takahashi M had also shown the correlation of degree of cord compression with prediction of recovery of neurological functions.<sup>[22]</sup>

Epidural hematoma was present in 3 patients (4.84%) [Figure 4] [Table 15]. Selden NR showed that severe cord compression by extra-axial hematoma is associated with poor neurological function at presentation and on follow-up.<sup>[19]</sup> However, in our study on multiple regression analysis, we did not find extra-axial hematoma (epidural hematoma) as a significant cause of poor neurological function at presentation and on follow-up (odds ratio 0.50,  $P=0.22$ ).

Philippe Demaerel<sup>[16]</sup> showed the crudity of MRI in determining



**Table 13: Presence of severe cord compression and its effect on outcome**

Severe cord compression	Number of cases
Present	21 (33.87%, 95% CL 22.33–47.01)
Absent	41 (66.13%, 95% CL 52.99–77.67)

CL: Confidence limit

**Table 15: Presence of epidural hematoma and its effect on outcome**

Patients with presence of epidural hematoma	
Epidural hematoma	Number of cases
Present	3 (4.84%, 95% CL 1.01, 13.50)
Absent	59 (95.16%, 95% CL 86.50, 98.99)

CL: Confidence limit

the management of spinal trauma.<sup>[16]</sup> They showed that MR is also indicated for the evaluation of patients with late complications and sequelae following spinal trauma. Andreoli C. showed the strong correlation between MRI appearance of traumatic spinal cord injuries in acute phase and long-term recovery of motor and sensory functions.<sup>[17]</sup> MRI is particularly useful in unconscious patients who cannot undergo motor and sensory neurological evaluation.

Saifuddin A also established that MRI is a vital imaging technique.<sup>[23]</sup> Selden NR showed that emergency MRI after spinal cord injury provides accurate prognostic information regarding neurological function and aids in diagnosis and treatment of cases of persistent cord compression after vertebral alignment.<sup>[19]</sup> Slucky AV *et al.* showed that MRI of acute spinal injury provides excellent visualization of neurological and soft tissue structures in non-invasive format.<sup>[24]</sup> Slucky AV *et al.* also showed the correlation of MRI findings with experimental and clinical SCI with a relative predictive value to SCI pattern on MR images indicative of long-term neurological outcome.

## CONCLUSIONS

Patients with large cord edema had initial high grade AIS and less chance of recovery with vice versa.

Sizable focus of hemorrhage (>1 cm) within the cord was most important prognostic factor. Patients with presence of sizable focus of hemorrhage had larger cord edema and more severe grade of initial AIS than those without hemorrhage with significantly more chances of retaining complete injury at follow up. Patient with small amount of hemorrhage (<1 cm) showed relatively better outcome. Patients with hemorrhage had significantly lower upper extremity motor scores at the time of injury and at follow-up. There was little recovery of lower extremity function even in patients without hemorrhage. There was a definitive correlation of length of cord edema with sensory outcome. Recovery rates of sensory scores were significantly lower in patients with hemorrhage when compared with those without hemorrhage in the spinal cord. Improvement in upper extremity was more than the lower extremity.

**Table 14a: Severity of injury according to ASIA impairment scale in patients with presence of severe cord compression**

Ais	Admission	Discharge
A	18	17
B	0	0
C	2	1
D	1	3
E	0	0
Total	21	21

In patients with severe cord compression at the time of admission, AIS was graded as A in 18 out of 21 patients (85.74%). At the time of discharge in 17 out of 21 (80.95%) patients, AIS was graded as A.

**Table 14b: Outcome in patients with severe cord compression**

Severe cord compression	Improvement	No improvement
Present	4 (21.05%)	17 (56.67%)
Absent	15 (8.95%)	13 43 (33%)
Total	19	30

Severe cord compression was associated with poor neurological function at admission and discharge; however, it was not statistically significant.

Extra-axial hematoma (epidural hematoma) was not a significant cause of poor neurological function at presentation and on follow-up.

With this study we concluded that various MRI findings in acute spinal cord injury correlate 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

## REFERENCES

1. McArdle CB, Crofford MJ, Mirfakhraee M, Amparo EG, Calhoun JS. Surface coil MRI of spinal trauma: Preliminary experience. *Am J Neuroradiol* 1986;7:885-93.
2. Kalfas I, Wilberger J, Goldberg A, Probstko ER. Magnetic resonance imaging in acute spinal cord trauma. *Neurosurgery* 1988;23:295-9.
3. Goldberg AL, Daffner RH, Schapiro RL. Imaging of acute spinal trauma: An evolving multi-modality approach. *Clin Imag* 1990;14:11-6.
4. Wittenberg RH, Boetel U, Beyer HK. Magnetic resonance imaging and computed tomography of acute spinal cord trauma. *Clin Orthop* 1990;260:176-85.
5. Flanders AE, Schaefer DM, Doan HT, Mishkin MM, Gonzalez CF, Northrup BE. Acute cervical spine trauma: Correlation of MRI imaging findings with degree of neurologic deficit. *Radiology* 1990;177:25-33.
6. Kulkarni MV, McArdle CB, Kopanicky D, Miner M, Cotler HB, Lee KF, et al. Acute spinal cord injury: MRI imaging at 1.5T. *Radiology* 1987;164:837-43.
7. Schouman-Claeys E, Frijia G, Cuenod CA, Begon D, Paraire F, Martin V. MRI imaging of acute spinal cord injury: Results of an experimental study in dogs. *Am J Neuroradiol* 1990;11:959-65.
8. Schaefer DM, Flanders A, Northrup BE, Doan HT, Osterholm JL. Magnetic resonance imaging of acute cervical spine trauma: Correlation with severity of neurologic injury. *Spine* 1989;14:1090-5.
9. Silberstein M, Tress BM, Hennessy O. Prediction of neurologic outcome in acute spinal cord injury: The role of CT and MRI. *Am J Neuroradiol*

- 1992;13:1597-608.
10. Marciello M, Flanders AE, Herbison GJ, Schaefer DM, Friedman DP, Lane JI. Magnetic resonance imaging related to neurologic outcome in cervical spinal cord injury. *Arch Phys Med Rehabil* 1993;74:940-6.
  11. Flanders AE, Schaefer DM, Friedman DP, Lane JI, Herbison GR. Predictive value of MRI imaging in the determination neurologic recovery in acute cervical spinal cord injury. *Radiology* 1991;181:172.
  12. Schaefer DM, Flanders AE, Osterholm JL, Northrup BE. Prognostic significance of magnetic resonance imaging in the acute phase of cervical spine injury. *J Neurosurg* 1992;76:218-23.
  13. Silberstein M, Tress BM, Hennessy O. Delayed neurologic deterioration in the patient with spinal trauma: Role of MRI imaging. *Am J Neuroradiol* 1992;13:1373-81.
  14. Yamashita Y, Takahashi M, Matsuno Y, Kojima R, Sakamoto Y, Oguni T, et al. Acute spinal cord injury: Magnetic resonance imaging correlated with myelopathy. *Br J Radiol* 1991;64:201-9.
  15. Silberstein M, Hennessy O. Implications of focal spinal cord lesions following trauma: Evaluation with magnetic resonance imaging. *Paraplegia* 1993;31:160-7.
  16. Demaerel P. Magnetic resonance imaging of spinal cord trauma: A pictorial essay. *Neuroradiology*. 2006;48:223-32.
  17. Andreoli C, Colaiacomo MC, Rojas Beccaglia M, Di Biasi C, Casciani E, Gualdi G. MRI in the acute phase of spinal cord traumatic lesions: Relationship between MRI findings and neurological outcome. *Radiol Med* 2005;110:636-45.
  18. Flanders AE, Spettell CM, Friedman DP, Marino RJ, Herbison GJ. The relationship between the functional abilities of patients with cervical spinal cord injury and the severity of damage revealed by MR imaging. *AJNR Am J Neuroradiol* 1999;20:926-34.
  19. Selden NR, Quint DJ, Patel N, d'Arcy HS, Papadopoulos SM. Emergency magnetic resonance imaging of cervical spinal cord injuries: Clinical correlation and prognosis. *Neurosurgery* 1999;44:785-92.
  20. Shepard MJ, Bracken MB. Magnetic resonance imaging and neurological recovery in acute spinal cord injury: Observations from the National Acute Spinal Cord Injury Study 3. *Spinal Cord* 1999;37:833-7.
  21. Flanders AE, Spettell CM, Tartaglino LM, Friedman DP, Herbison GJ. Forecasting motor recovery after cervical spinal cord injury: Value of MR imaging. *Radiology* 1996;201:649-55.
  22. Takahashi M, Izunaga H, Sato R, Shinzato J, Korogi Y, Yamashita Y, et al. Correlation of sequential MR imaging of injured spinal cord with prognosis. *Radiat Med* 1993;11:127-38.
  23. Saifuddin A. MRI of acute spinal trauma. *Skeletal Radiol* 2001;30:237-46.
  24. Slucky AV, Potter HG. Use of magnetic resonance imaging in spinal trauma: Indications, techniques, and utility. *J Am Acad Orthop Surg* 1998;6:134-45.

**How to cite this article:** Parashari UC, Khanduri S, Bhadury S, Kohli N, Parihar A, Singh R, et al. Diagnostic and prognostic role of MRI in spinal trauma, its comparison and correlation with clinical profile and neurological outcome, according to ASIA impairment scale. *J Craniovert Jun Spine* 2011;2:17-26.

**Source of Support:** Nil, **Conflict of Interest:** None declared.