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Original Research Article

Diagnostic and prognostic role of magnetic resonance imaging in spinal trauma, and correlation with clinical profile

Sangeeta Saxena, Dharmraj Meena, Harsh Khokar, Aditya Ganeriwala*

Department of Radio-diagnosis, Government Medical College, Kota, Rajasthan, India

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***Correspondence:**
Dr. Aditya Ganeriwala,
E-mail: ganeriwalaaditya@gmail.com

ABSTRACT

Background: Trauma is a common and devastating insult to the spine and spinal cord with important long-term sequelae for the individual. Diagnostic imaging, particularly Magnetic Resonance Imaging (MRI), plays a crucial role in evaluating and detecting spinal trauma. 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. The objective of this study is to enumerate the cord findings in MRI in patients with spinal trauma and to correlate the findings with clinical profile and neurological outcome of the patients.
Methods: A total of 50 cases of spinal trauma over a period of 1 year were included in the study. MRI of spine performed in patients with spinal trauma to see the cord findings. Detailed motor and sensory examination of the patient on admission and discharge was done and graded according to American Spinal Injury Association Scale (ASIA). Chi square test of significance ($p<0.005$) was used to assess the association between MR findings and clinical outcome.
Results: In the study we observed that patients with cord haemorrhage and large cord oedema had initial high grade AIS and less chance of recovery with vice versa. Patients with presence of focus of haemorrhage had more severe grade of initial ASIA than those without haemorrhage with significantly more chances of retaining complete injury at follow up. Patients with edema less than 3cm improved on follow up examination.
Conclusions: MRI is an excellent modality of imaging in the diagnosis of cord abnormalities in spinal trauma. The cord findings correlate with the neurological deficit of the patient on admission and discharge.

Keywords: American spinal injury association scale, Magnetic resonance imaging, Spinal trauma

INTRODUCTION

Trauma is a common and devastating insult to the spine and spinal cord with important long-term sequelae for the individual. It is seen more commonly in young adults. Neurological deficits may be transient, incomplete or complete. Spinal cord injury (SCI) is a traumatic event that results in disturbances to normal sensory, motor, or autonomic function and ultimately impacts a patient's physical, psychological, and social well-being.[1] In 2011, Cripps et al reported the global prevalence of SCI to be between 236 and 1,009 per million.[2] Traffic accidents were typically the most common cause of SCI, followed by falls in the elderly population.

Diagnostic imaging, particularly Magnetic Resonance Imaging (MRI), plays a crucial role in evaluating and detecting spinal trauma. The appearance of the damaged spinal cord after injury correlates with initial neurologic deficit, as determined by the American spinal injury association grade, as well as with recovery. 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 accurate diagnosis, prompt management and avoidance of unnecessary procedures. The management of SCIs requires significant health care resources and can place a substantial financial burden on patients, their families, and the community.[3]

Current management of SCI, however, has become more directed toward correction of the spinal cord and associated soft tissue damage and MRI has become increasingly important in the diagnostic evaluation of spinal injuries. 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, hemorrhages and ischemia, MRI findings may serve as prognostic indicators.[4]

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 surgical management and the potential for neurologic recovery.[5]

There is a spectrum of changes of the acutely injured cord on MRI from concussion, which is invisible on imaging, via cord oedema, haemorrhagic contusion and cord haematoma to complete transection.

Cord concussion: The most favourable outcome is seen in acute SCI patients, where the cord itself appears normal on standard T1W and T2W MRI sequences.[6,7]

Cord oedema: Cord oedema is detected as high T2 signal and normal/low T1 signal within the cord. It can also be associated with swelling of the cord. It has been shown that the length of oedema within the cord correlates both with the neurological presentation and outcome of the patient.[8] Cord oedema is not static and changes significantly within the first two weeks following injury.[9] 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.

Haemorrhagic contusion: Cord contusion was defined by Kulkarni[10] as a central intramedullary focus of low signal in the cord surrounded by a thick rim of hyperintensity on T2W or T2*W GRE imaging. In the acute phase after injury, deoxyhaemoglobin is generated which results in low signal intensity.

Gradient echo sequences should be used, as spin echo sequences may understate the degree of cord haematoma. The extent of haemorrhage within the cord has been correlated with outcome, with a small focus of haemorrhage of less than 4mm more likely to be associated with radiological and clinical improvement on follow-up imaging, compared with a larger cord haematoma.[11] There is good evidence from many studies that the presence of haemorrhage within the cord is associated with a poor neurological status on presentation, with patients more likely to have a complete SCI and worse baseline American spinal injury association motor scores.[12]

Cord transection: Cord transection is the most severe cord injury characterised by a complete disruption of the cord and high-signal CSF is seen between severed cord ends on the T2W images. It is a rare injury seen in extreme distraction and in penetrating injury. In penetrating injuries, it is possible that the cord may be significantly damaged with not much bone injury evident. In these cases, the cord injury is either due to a direct tear or secondary to blast injury from high-velocity mechanisms such as gun shots. Haemorrhage involving the entire transverse diameter of the spinal cord behaves clinically as a complete transaction.[13]

Cord swelling: 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.[14] The parenchyma may be normal to slightly hypo intense.

METHODS

The subjects of this study were Cases of acute spinal trauma who underwent MRI of spine in the Department of Radio diagnosis in the hospitals attached to Govt. Medical College, Kota. A total of 50 cases of spinal trauma over a period of 1 year were included. It was a prospective analytical study design. 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. 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, physical examination was taken. Patients of spinal trauma undergoing MRI scan of spine after 2 weeks of injury non-traumatic cause for cord injury were excluded. MRI was done on 1.5T Philips ACHIEVA machine both in the axial and sagittal planes using a combination of pulse sequences. Evaluation of the injured spine was performed both in the axial and sagittal planes using a combination of T1, T2, Gradient echo sequence. T2W images are very good in detecting the cord oedema, and T2*W GRE images are used to detect the haemorrhage in and around the cord.[15] Recently, diffusion tensor imaging (DTI) has been used to detect trauma related changes in the spinal cord which are not seen on conventional MRI technique.[16,17] Ideally MRI

should be performed within 72 hours of injury as the T2 hyperintensity produced by oedema improves.[18] The following findings were identified after assessing the MR images and considered for the study

- Cord haemorrhage,
- Cord oedema more than 3 centimetres in length,
- Cord oedema less than 3 centimetres in length,
- Normal cord.

Detailed examination of the patient was carried out during the initial presentation and discharge. The MRI findings was analysed 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. The neurologic examination of the patient with SCI has two main components, Sensory and motor, with certain required and optional elements. The required elements allow the determination of the sensory, motor, and neurologic levels and are determination of the motor and sensory scores, completeness of the injury and classification of the impairment.

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 will be classified as complete.

RESULTS

In this study 50 cases with spinal trauma were observed. Of these 35 (70.0 %) were males and 15 (30.0%) were females. Most of the patients of spinal trauma in the age group of 21-40 years (48%) followed by 41-60 years (34%). Patient below 20 years constituted 8% and above 60 years constituted only 10%. 32.0% had isolated cervical cord involvement, 24% had isolated thoracic cord involvement, and 24% had isolated lumbar cord involvement, 8% had involvement of both cervical and dorsal cords; and 12% had involvement of both thoracic and lumbar cords (Table 1). The cause of spinal cord injury was fall (46%), followed by road traffic accident (38%), assault (10%), and sports injury (6%) (Table 2).

Table 1: Part of cord involved.

Part of cord involved	Number of patients
Cervical cord	8
Thoracic cord	6
Lumbar cord	6
Cervico-dorsal	2
Thoraco-lumbar	3

Table 2: Cause of cord injury.

Cause of injury	Number of patients (in %)
Fall	23 (46%)
Road traffic accident	19 (38%)
assault	5 (10%)
Sports injury	3 (6%)

MRI examination revealed the cord abnormalities in 25 out of 50 patients, i.e. in 50% of patients. Rest 50% of patients had no cord findings in MRI.

Focus of cord haemorrhage was present in 7 out of 50 patients i.e. 14% of patients with 95% confidence limit of 12.24-40.58%. In 86%, significant haemorrhage was not seen (95% CL of 54.66-89.06%). Cord oedema/non-haemorrhagic contusion involving less than 3 cm cord was present in 11 out of 50 patients i.e. 22.0% with 95% confidence limit of 14.13-37.76%. Cord oedema/contusion involving more than 3 cm of cord was present in 14 out of 50 patients i.e. 28.0 % with 95% confidence limit of 25.63-52.7%. So, cord oedema/contusion involving more than 3 cm of cord was the most common cord finding in the study (Table 3).

Table 3: Cord findings in MRI in spinal trauma.

Cord findings	No. of patients
Haemorrhage	7
Cord oedema (>3cm)	14
Cord oedema (< 3cm)	11
No abnormality	25

In patients with focus of cord haemorrhage (Figure 1) all the 7 patients were graded initially as AIS A and out of them only 2 patients (28.5%) improved, with one patient improving to AIS B and AIS C scale respectively. 71.5% of them showed no improvement.

In 14 patients with focus of cord oedema for more than 3 cm (Figure 2), 11 patients (78.5%) were initially graded as AIS A, 1 patient (7.1%) was initially graded as AIS B, 1patients (7.1%) were graded as AIS C and 1 patient (7.1%) was initially graded as AIS D. 3 of 11 patients (27.28%) with AIS A improved to AIS B, AIS C and AIS D, one in each category. The patient with AIS B

improved to AIS D. Patients with AIS C and AIS D showed no improvement.

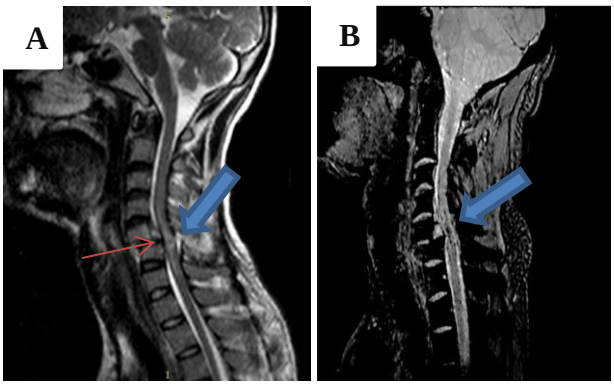

Figure 1: 25-year-old male with history of bike accident presented with quadriparesis. T2 sagittal. A) Grade 3 spondylolisthesis of C5 over C6 (arrow) with cord hyper intensity from C5 to C7 level (thick arrow), suggestive of cord oedema. Sagittal FFE. B) loss of signal within the cord at the level of oedema, suggestive of cord haemorrhage. There is tear of Anterior longitudinal ligament and ligamentum flavum at C5-C6 level.

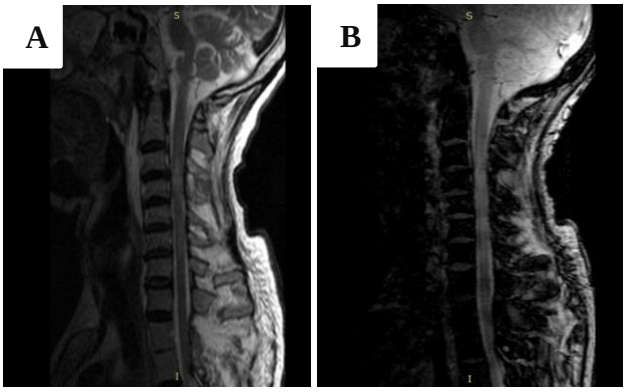

Figure 2: A 26-year-old male with history of road traffic accident presented with inability to move all four limbs. T2 sagittal A) Hyper intensity in the cord from C3 to C7 level (thick arrow), suggestive of oedema in the cord. Sagittal FFE B) No intramedullary signal loss which rules out cord haemorrhage. Linear displaced fracture seen involving spinous process of C6 & C7 vertebra noted.

In 11 patients with focus of cord oedema for less than 3cm, 1 patient (9.1%) was initially graded as AIS A, 1 patient (9.1%) was initially graded as AIS C and 9 patients (81.8%) were initially graded as AIS D. The patient with AIS A did not show improvement. The patient with AIS C showed improvement to AIS D. 2 out of 9 patients (22.22%) with AIS D showed improvement to AIS E.

In 25 patients with no cord findings, 20 patients had no clinical deficit and hence graded as AIS E (80.0%). 1 (4%) patient was initially graded as AIS B. 2 patients (8%) were initially graded AIS C and 2 patients (8%) were initially graded as AIS D. The patient with AIS B improved to AIS D. The patients with AIS C showed improvement to AIS D. the two patients with AIS D also showed improvement to AIS E.

Multivariate analysis was done to see the effect of various risk factors studied on the outcome of trauma patients. It shows that over and above all the risk factors only focus of haemorrhage was significantly associated with poor prognosis (OR 6.73; 95% confidence limit 1.17-38.63; p=0.032). Cord oedema more than 3cm was associated with a poor prognosis but was not significant (OR 0.41 95% confidence limit (0.59-31.5); p=0.178).

In our study, we found out that initial paralysis was grade ASIA impairment scale (AIS) A in 12 patients (24.0%), B in 2 patients (4%), C in 4 patients (8.0%), D in 12 patients (24.0%) and E in 20 patients (40.0%) (Figure 3).

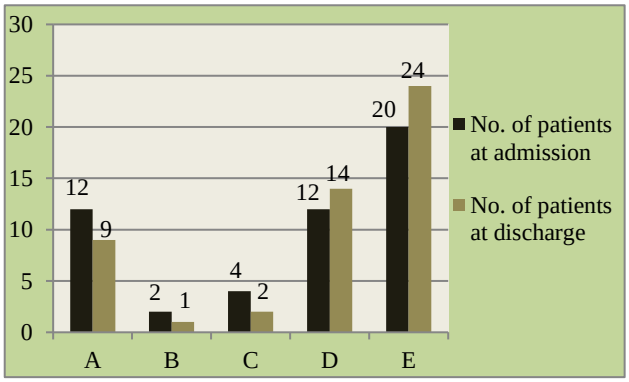

Figure 3: ASIA impairment scale (AIS) at the time of admission and discharge in patients of spinal trauma.

Of 12 patients with initial AIS A only 3, i.e. 25% showed improvement while out of 12 patients with initial AIS D, 4 i.e. 33.3% showed improvement. In patients with AIS B 2 i.e. 100% showed improvement and in patients with AIS C 3 i.e. 75 % showed improvement (Figure 4).

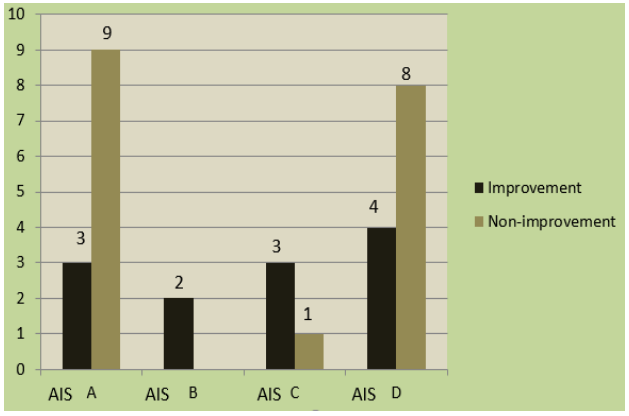

Figure 4: Outcome in patients of spinal trauma according to ASIA impairment scale.

DISCUSSION

In patients with focus of cord haemorrhage all the 7 patients were graded initially as AIS A and out of them only 2 patient (28.5%) improved. It may suggest that the patients with cord haemorrhage come with complete paralysis and also initial high-grade AIS did not show significant improvement.

In 14 patients with focus of cord oedema for more than 3 cm, 11 patients (78.5%) were initially graded as AIS A and out of which only 3 of 11 patients improved. It may be suggested that the patients with cord haemorrhage and patients with cord oedema more than 3 cms come with almost complete paralysis and also initial high-grade AIS and did not show significant improvement.

In a similar study, Boldin et al showed the effect of haemorrhage and length of hematoma on neurological impairment. They showed that patients with haemorrhage were more likely to have completed SCI at the time of follow-up and that presence of large haemorrhage was associated with complete SCI and showed poor prognosis.[11] Similar results were also shown by Andreoli C and Flanders et al.[14,19]

In 11 patients with focus of cord oedema for less than 3cm, 9 patients (81.8%) were initially graded as AIS D. It may be concluded that patients with cord oedema less than 3cm came with a lower AIS grade.

In 25 patients with no cord findings, 20 patients had no clinical deficit and hence graded as AIS E (80.0%). This suggests that there was some amount of neurological deficits even with the cord being normal. This may be attributed to presence of non-cord abnormalities like cord compression, fractured segments, epidural hematoma, soft tissue hematoma which indirectly effect the cord like in SCIWORA.

Our study clearly shows the significance of cord findings on the prognostication of patient and that MRI should be carried out in every case of traumatic spinal cord injury to prognosticate the patient.

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