ORIGINAL RESEARCH

Role of MRI in Acute Spinal Trauma

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Abstract
The purpose of this prospective observational study was to enumerate the MRI findings in patients with acute spinal trauma andtocorrelate them with clinical and neurological profile of the patients at the time of admission and discharge and predict their neurological outcome. The study included 40 patients and was conducted in the Department of Radiodiagnosis, Dr. S. N. Medical College Jodhpur, Rajasthan, between the periods of June 2014 to May 2015. When patient came for MRI in our department detailed motor and sensory examination of the patient was done graded according to ASIA impairment scale. Neurological status at admission and neurological recovery at discharge was compared with various cord findings on MRI. Results of our study showed thatcord hemorrhage was associated with worst neurological status at admission and poor neurological recovery on discharge. Cord contusion showed better neurological recovery than cord hemorrhage. Cord edema and normal cord was associated with favourable neurological outcome. Higher values of lesion length present with high grade of neurological impairment and poor neurological recovery. We conclude that MRI is an excellent modality of imaging in the diagnosis of cord abnormalities in spinal trauma. The cord findings correlate well with the neurological status of the patient.Cord hemorrhage, cord contusionand longer lesion have poor prognostic value in spine injury patients.
Keywords: Magnetic Resonance Imaging (MRI), American Spinal Injury Association (ASIA), cord haemorrhage, cord contusion.

Introduction

Acute traumatic spinal cord injury (SCI) is one of the most devastating injuries to afflict the human body. Annual incidence of traumatic spinal cord injury is approximately 15 to 40 cases per million. It commonly results from motor vehicle accident, fall from height, community violence and workplace related injury [1]. The incidence in South Asia is around 21 per million.[2]

The injury has a high rate of prevalence in the younger population, occurring most frequently in persons between 16 and 40 years of age. It creates physical, emotional, and economic burdens on both the individual and society.[3]The priority in any case of suspected spinal injury is to assess the spine as quickly, accurately and comprehensively as possible for acute injuries or instability. However, a significant proportion of patients presenting to emergency department with suspected spinal injury are obtunded or incapable of undergoing a satisfactory neurological examination for one reason or another. In such patients, the primary investigation to rule out spinal injury is usually some form of crosssectional imaging.[4]

Plain radiography, computed tomography (CT), and magnetic resonance imaging (MRI) may all be used in the evaluation of the spinal column and are often complementary. Conventional radiography is the first line imaging investigation in most spinal trauma clearance protocols, and a large proportion of patients, particularly those who are neurologically intact with a normal Glasgow coma scale, very often do not require further imaging.[4]In the setting of acute spinal trauma, CT scan has been shown to be more time efficient and significantly more sensitive for fracture detection than plain films.[5][6][7]

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.

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Many advantages of MRI such as, higher contrast resolution, absence of bony artefacts, multiplanar capability, and choice of various pulse sequences make 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. Several types of traumatic spinal cord lesions can be found eg; intramedullary hemorrhage, spinal cord contusion, cord edema, extrinsic compression by a bone fragment or a traumatic disc herniation, and even complete transection of the cord.[8]

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 an 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 soft tissue abnormalities including spinal cord oedema and haemorrhage, ligamentous injury, disc herniations, and epidural fluid collections.

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. Neurological recovery is usually insignificant in patients with intramedullary hemorrhage or cord transection, whereas patients with cord edema may significantly recover from neurological dysfunction.[9] Plain radiographs, and even multidetector computed tomography, do not rule out injury to the spinal cord.[10]

Quantitative measurements for evaluating spinal trauma like mean canal compromise (MCC), mean spinal cord compression (MSCC), and lesion length of cord are also important in predicting the severity of damage and pre-dicting recovery.[11]

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 deficit according to ASIA impairment scale. The present study aims to analyze cord findings on MRI in acute spinal injury patients and correlate them with the clinical profile and neurological recovery and predict the outcome.

Materials and methods

This prospective study was conducted in a span of one year between the periods of June 2014 to May 2015. The study included 40patients of acute spinal trauma from inpatient department who came for MRI evaluation in our department (Department of Radiodiagnosis, Dr. S. N. Medical College Jodhpur, Rajasthan). All the patients were underwent MRI evaluation within a week of injury, in most of the cases within 72 hours of injury. The included patients were either with injury on radiograph or radiographically normal patients with neurologic deficit.Prior written informed consent was obtained from each patient after explaining the procedure, risks and benefits. Patient assessment was done by taking detailed history in a chronological order about age, sex, mode of injury. Thorough general physical examination and neurological examination of the patient was performed at the time of admission and at the time of discharge according to international guidelines and correlated with the MRI findings.

Type of Study

Hospital based prospective study.

Method of Data Collection

MR Imaging of spine was performed with 1.5 Tesla MR Scanner (PHILIPS Achieva 1.5T) 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 obtaining sagittal T2 and T1-weighted fast spin echo images, sagittal STIR, coronal STIR and axial T2 and T1-weighted fast spin echo images for proper evaluation of the cord. In some patients sagittal or axial T2 FFE images were taken for confirmation of cord hemorrhage.

Sagittal and coronal images were 3 to 5.0 mm thick with a 0.1 to 0.5 mm slice gap. The field of view (FOV) of the area of interest is adequate at 25 cm in cervical spine and at 30 cm in lumbosacral spine. In the dorso-lumbar spine, a large FOV was needed (50-75 cm) for accurate labelling of the involved levels. For axial images relatively small FOV was used (15-20cm).

Fat suppression was employed on the long TR sequences to improve visualization of oedema in theposterior ligamentous complexes (STIR - short tau inversion recovery). Technical parameters included minimum TR/TE 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.

Patients were placed in various groups based on American Spinal Injury Association (ASIA) impairment scale.[9,12] Change in ASIA impairment scale toward lower grade between admission and discharge was considered neurological recovery.

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

1. Cord hemorrhage with edema: seen as low signal intensity area surrounded by thin rim of high signal intensity edema on T2-weighted image (T2WI) and heterogeneous signal on T1-weighted image (T1WI) within 24 hours which changes to heterogeneous signal pattern on T2WIbetween 48 hours to 1 week (Figure 1A).

2. Cord contusion with edema: seen as area of intermediate to low intensity signal on T2WI surrounded by thick rim of high signal intensity edema on T2WI and normal signal intensity on T1WI (Figure 1B).
3. Cord edema only: seen as uniform high signal intensity on T2WI and normal intensity on T1WI (Figure 1C).[13]
4. Lesion length was measured in centimetres as the length of abnormal signal from cord in craniocaudal direction on T2WI (Figure 2). This included signals from cord edema, cord contusion, and cord hemorrhage.[11,14]

Clinical Assessment of Spinal Cord Injury

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 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 sensory or motor function is preserved in sacral segments S4-S5.
- B = Incomplete: Sensory, but not motor, function is preserved below the neurologic level and extends through sacral segments S4-S5.
- C = Incomplete: Motor function is preserved below the neurologic level, and most key muscles below the neurologic level have a muscle grade of less than 3.
- D = Incomplete: Motor function is preserved below the neurologic level, and most key muscles below the neurologic level have a muscle grade that is greater than or equal to 3.
- E = Normal: Sensory and motor functions are normal.

Data Analysis

Data was entered in Microsoft excel version 2010 and all the statistical analyses and computations were performedusing the software SPSS Version16.0 for Windows.

Inclusion Criteria

All the inpatient department patients of acute spinal injuryor suspected SCI with neurological deficits undergoing MR Imaging formed the study group.

Exclusion Criteria

1. Patients presenting after 1 week of injury.
2. Patients with non-traumatic cause for SCI.
3. Non-cooperative patients.
4. Medically unstable patients.
5. Patients with previous implanted metallic devices.
6. Patients with claustrophobia, pacemakers, and cochlear implants.
7. Patients presenting with previous neurological deficits.
8. Fractures in pathological bone.

Results

1. Epidemiology

Out of 40 patients, 32 (80%) were males and 8 (20%) were females. Male to female ratio was 4:1.Majority of patients were in age group of 20–40 years 23 (57.5%). Mean age of patient was 34.5 ± 13.1 years (mean ± SD).The cervical level was the most commonly involved segment in patients of trauma spine.The common cause of injury was road traffic accident (55%) followed by fall from height (35%).

Table 1:Distribution of patients according to Cause of Injury

Cause of Injury	Number of patients	Percentage (%)
Road traffic accident	22	55
Fall from height	14	35
Assault	1	2.5
Sports injury	2	5
Others (electric shock)	1	2.5
Total	40	100

2. Neurological status

SCI was grouped into five categories based on the ASIA impairment scale at the time of admission. Most common presentation was ASIA A impairment scale injury in 17 (42.5%) patients followed by ASIA C in 9 (22.5%), ASIA B in 7 (17.5%), ASIA D in 4 (10%) and ASIA E in 3 (7.5%) patients in decreasing order.

3. Trauma associated qualitative changes of spinal cord and correlation of these qualitative parameters with neurological status of the patient at the time of admission

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Table 2: Neurological status of patients with different qualitative parameters (cord findings) at the time of admission

Cord Findings	American Spine Injury Association impairment scale					Total no. of patients
	A	B	C	D	E	
Cord haemorrhage with edema	11(100)	0	0	0	0	11
Cord contusion with edema	3(60)	1(20)	1(20)	0	0	5
Cord edema only	3(18.7)	6(37.5)	5(31.3)	2(12.5)	0	16
Normal cord	0	0	3(37.5)	2(25)	3(37.5)	8
Total	17	7	9	4	3	40
Chi square value= 52.73, df= 12, P-Value < 0.001						

Values are presented as numbers (%).

MRI examination revealed the cord abnormalities in 32(80%) out of 40 patients. Most common lesion seen was cord edema in 16 (40%) patients followed by cord hemorrhage in 11 (27.5%) and cord contusion was seen in 5 (12.5%) patients. Normal cord was seen in 8 (20%) patients.

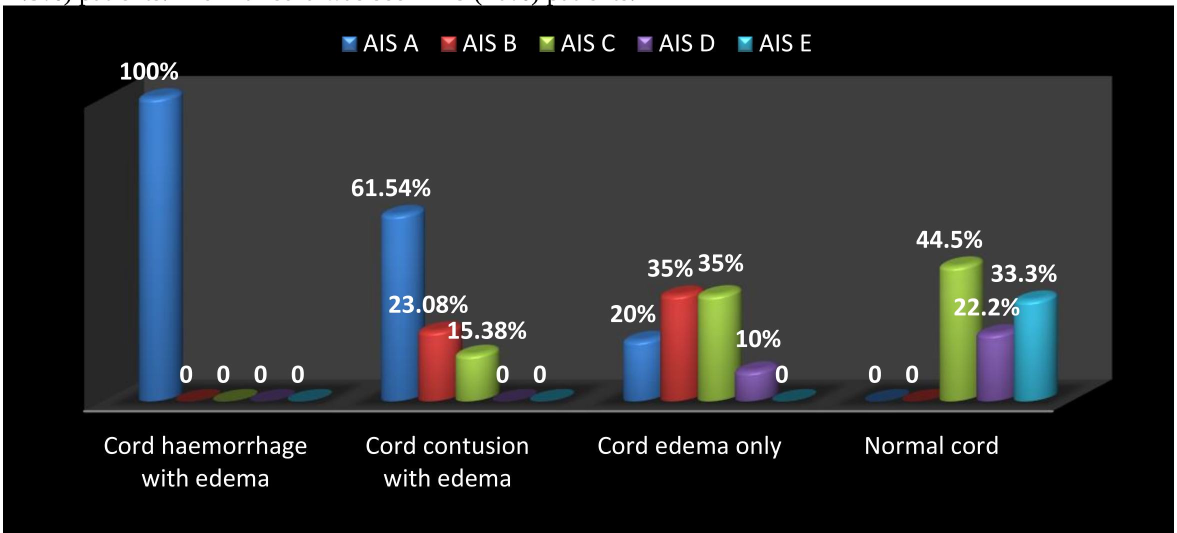

Figure :1 Neurological status of patients with different cord findings at admission

Detailed neurological examination of the patient was done when the patient came to our department first time for MRI scan and the cord changes were correlated with the neurological status of the patient. In all the patients with cord hemorrhage, initial neurological status was ASIA A. Three out of five (60%) patients having contusion pattern on MRI had ASIA A status where as three out of sixteen (18.75%) patients with only cord edema pattern had ASIA A status at the time of admission. This data was statistically significant on applying Pearson chi-square test (p<0.001).

4. Correlation of lesion length with neurological status at the time of admission

Parameter	American Spine Injury Association impairment scale					Total no. of patients
	A	B	C	D	E	
Lesion length (more than 3cm)	15	1	1	0	0	17
Lesion length (less than 3 cm)	2	6	8	4	3	23

Chi Squre value = 25.634, df=4, P-Value< 0,05 (0.000)

The lesion length was calculated in centimetres in patients presenting with different neurological grade at admission according to ASIA impairment scale. The lesion length was higher for patients presenting with complete SCI (ASIA A) than incomplete SCI (ASIA B, C, and D) and least for neurologically normal patients (ASIA E). The data was statistically significant on application of chi squre test.

5. Neurological recovery

Table 4: Neurological recovery of patients with initial neurological status

ASIA Impairment scale	Number of	Neurological recovery at the time of discharge

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at admission	patients	Present	Absent	NA
A	17	8 (47.05)	9 (52.95)	0
B	7	7 (100)	0	0
C	9	9 (100)	0	0
D	4	4 (100)	0	0
E	3	0	0	3 (100)
Total	40	28 (70.0)	9 (22.50)	3 (7.50)

Chi Square value = 13.992, P-Value< 0,05 (0.003)

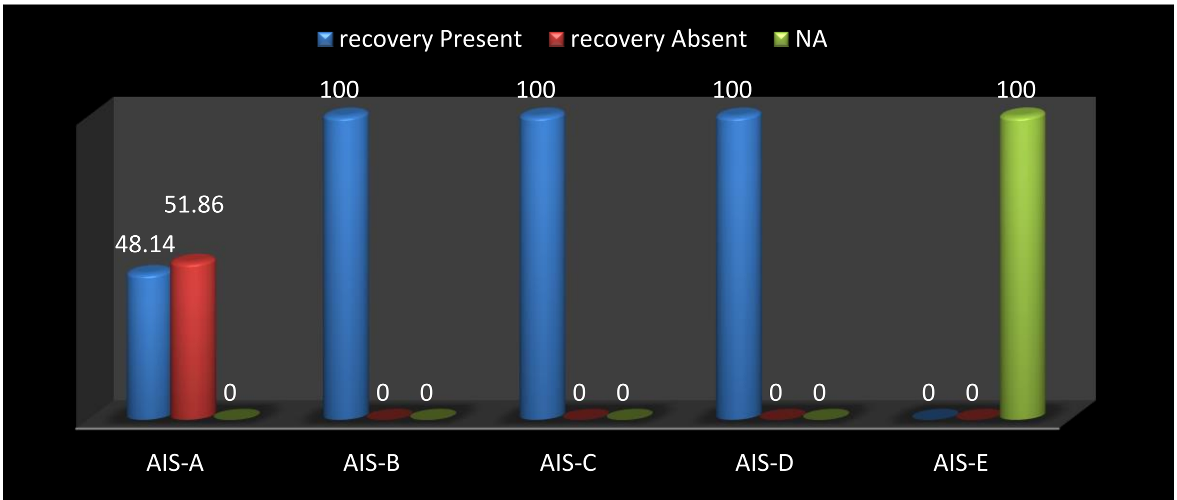


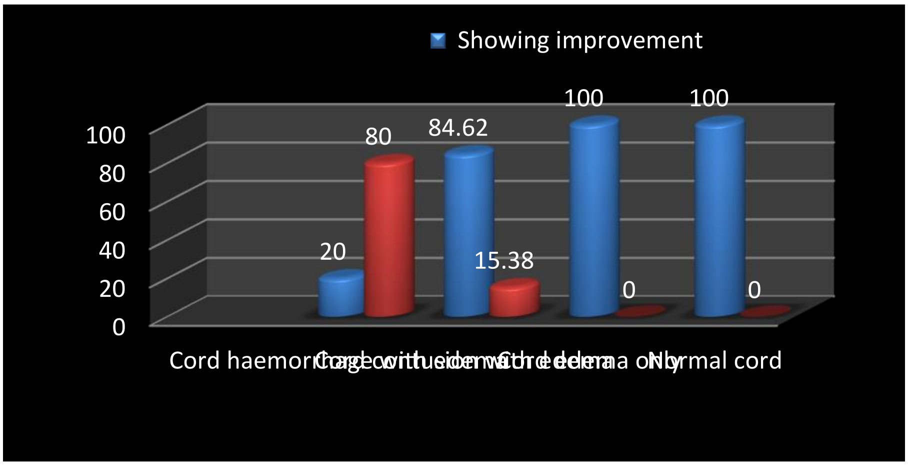
Figure : 2 Neurological recovery at discharge with initial neurological status

Initially at the time of admission out of 40 patients, total 37 patients present with some neurological impairment, of which total 28(75.67%) patients showed some neurological recovery at the time of discharge.

8(47.05%) out of 17patients with complete SCI (ASIA-A) showed some level of improvement in their neurological status over the period of hospital stay; whereas, all the patients with incomplete SCI (ASIA B, C, and D) showed some improvement.

Table 5: Neurological recovery in patients with different cord findings

Cord Finding	Number of patients	No. of patient with neurological impairment	Patient Showing improvement	Patient not Showing improvement
Cord haemorrhage with edema	11	11	2(18.2)	9(81.8)
Cord contusion with edema	5	5	5(100)	0
Cord edema only	16	16	16(100)	0
Normal cord	8	5	5(100)	0
Total	40	37	28(75.68)	9 (24.32)
Chi square value= 28.11, df= 3, P- Value < 0.05 (0.000)				



Only two (20%) patients with cord hemorrhage in initial MRI showed improvement in neurological status. Patients with cord contusion pattern and cord edema only pattern, all the patients (100%) showed improvement.

Table 6: Correlation of quantitative parameters with improvement in neurological status of the patient at discharge

Parameter	Total no. of patients	Patients with neurological impairment	No. (Mean lesion length) in patients showing neurological improvement	No. (Mean lesion length) in patients Not showing neurological improvement
Lesion length (more than 3 cm)	17	17	8 (4.41±1.10)	9 (8.33±2.08)
Lesion length (less than 3 cm)	23	20	20 (0.98±0.90)	0
Total	40	37	28 (2.06±1.77)	9 (8.33±2.08)

P- Value < 0.05 (0.000), df =1

Out of total 17 patients having lesion length more than 3 cm at admission, 8(47.05%) patients showed some degree of neurological improvement at discharge, while 9(52.95%) patients showed no improvement. All the patients presenting with lesion length less than 3 cm showed neurological improvement at discharge. Mean lesion length in patients showing no improvement in neurological status was 8.33±2.08 cmand the mean values of lesion length for the group showing improvement was 2.06±1.77 cm.

Discussion

The male to female ratio in our study was (32:8) 4:1. Roop Singh et al. [48] in their study had observed the male to female ratio of 3:1.

In our study the most common age group affected was 20-40 years (57.5%%). This was in concordance withAgarwal et al. [49]which showed that the spinal trauma was more common in men and in the age group 20–39 years.

The mean age of patients in the present study was 34.5 ± 13.10years.Singh et al. [48] had a mean age of 35.4 years in their study.

In present study, the commonest cause of injury was road traffic accident (55%) followed by fall from height (35%). The most common level of injury was cervical (63.16%). Similar results were obtained by Kalfas I et al [50] and Mahmood et al. [51] in their study.

Pattern described in present study was similar to patterns described by Mahmood et al. [51], and Bondurant et al. [52] However, the cord lesion described by Kulkarni et al. [9] comprised of type I: as T2WI showing large area of hypointensity surrounded by thin rim of hyperintensity and T1WI as inhomogeneous signals i.e. cord hemorrhage; type II: as area of hyperintensity on T2WI and normal intensity on T1WI i.e. cord edema; type III: as small area of central hypointensity surrounded by thick peripheral hyperintensity on T2WI i.e. cord contusion.

In the present study of 40 patients, cord abnormality was seen in 32 (80%)patients, out of which cord hemorrhage was present in 11 (27.5%) patients, cord contusion in5(12.5%) patients and cord edema in16 (40%) patients.No cord abnormalities were found in 8(20%) patients at admission. Thus the most common pattern of injury in this study was cord edema. Almost similar results were also shown by Mahmood et al.[51] and Kulkarni et al. [9] in their study.

In this present study, the most common neurological status at the time of admission was ASIA-A in 17 patients (42.5%). Almost similar results were reported by Andreoli et al. [43] and Ramon et al. [54]who reported 42% and 51% patients in ASIA-A group respectively in their studies.

In the present study, the mean value of lesion length (in centimetre) was 6.26 ± 2.90 in patients presenting with complete SCI (ASIA-A). The value was lesser in patients with incomplete SCI (ASIA-B, C and D) and minimal in neurologically normal patients.Miyanji et al. [11]also showed that patients with complete SCI (ASIA-A) had higher MCC (p=0.005), MSCC (p=0.002), and lesion length (p=0.005) values, as compared to incomplete SCI or neurologically normal status. Similarly Haar et al. [55] also found a positive correlation between the complete SCI on Frankel grade with the MCC (p=0.009), MSCC (p=0.008), and lesion length (p=0.001). Furlan et al. [56] also reported similar results in their study.

Present study showed that out of total 40 patients, 37 patients presented with some neurologic deficit at the time of admission, of which 28(75.68%) patients showed improvement over the period of hospital stay. These values were significant on applying Pearson's Chi Square Test (Chi square value= 32.69, p- value < 0.001).

We observed that out of 11 patients with cord hemorrhage, only 2 (20%) patients had shown improvement and 9 (80%) patients did not show any improvement.While all patients who presented with cord contusion, cord

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edema only pattern with neurological deficit at admission had shown improvement over the period of hospital stay.

Thus it may be suggested that initial cord hemorrhage pattern was associated with less chances of recovery i.e. poor neurological outcome, as compared to contusion or edema pattern. Similar results were also shown byMahmood et al. [51], Bondurant et al. [52], Parashari et al. [53], andRamon et al. [54] in their studies.

Similar study done by Andreoli C et al.[43] demonstrated that patients with initial haemorrhage had poor prognosis while those with oedema had better prognosis.Flanders et al. [34] showed that patients without spinal cord haemorrhage had significant improvement in self-care and mobility scores compared to patients with haemorrhages. Their study revealed that rostral limit of oedema positively correlated with admission and discharge self-care scores. Poor prognostic factors were haemorrhage, long length of cord oedema and high cervical location.

This present study revealed that the mean value of the length of the lesion was significantly more in the group of patients showing no improvement in neurological grade than the group of patients showing some level of neurological improvement during hospital stay (p-value <0.001). Thus it is suggested that higher values of lesion length were associated with poor neurologic outcome. Haar et al. [55] also concluded that the lesion length (p=0.011) and MSCC (p=0.063) are predictors of poor neurological recovery. Miyanji et al. [11], Roop Singh et al. [33], and Fehlings et al. [42] also studied the quantitative variables and their relationship with neurological status and found similar results.

Conclusion

The present study was conducted as a hospital based prospective study using a 1.5 Tesla MRI in the department of Radiodiagnosis, Dr. S. N. Medical College, Jodhpur, aiming to depict the role of MRI in patients with acute spinal trauma and to correlate MR findings with the clinical profile and neurological outcome of the patients.

In this study it was found that:

1. Patients with cord haemorrhage had initial high grade AIS (ASIA Impairment Scale) and less chance of recovery and vice versa.
2. Cord haemorrhage with edema pattern was turned out as an indicator of complete injury (ASIA-A) and the most important prognostic predictor of neurological outcome in patients with trauma spine. Patients with presence of cord haemorrhage had more severe grade of initial AIS than those without haemorrhage and significantly more chances of retaining complete injury at follow up.
3. There was a definitive correlation of mean value oflength of the lesion with neurological outcome.
4. Initial higher values of lesion length were associated with initial high grade AIS and poor neurological recovery.
5. Cord contusion, cord edema and normal cord was associated with favourable neurological outcome.

With this study,we concluded that various MRI findings in acute spinal cord injury correlate well with the neurological deficits on admission and discharge according to ASIA impairment scale.It differentiates between spinal cord edema, contusionand hemorrhage, each of which has different prognosticimplications for the patients.Cord hemorrhage andhigher lesion length values have poor prognostic value in spine injury patients.

Summary

MRI is an excellent modality of imaging in the diagnosis of cord abnormalities in spinal trauma. The cord findings correlate well with the neurological status of the patient. 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. Patients with cord haemorrhage not only present with complete neurological deficit but also show less improvement on follow up.Patients presenting with higher value of lesion length are associated with poor neurological recovery. Patients with small cord oedema have comparatively better prognosis. Other non-cord findings like fractures and soft tissue abnormalities and their effect on the cord can also be evaluated on MRI study. In spite of its cost, MRI has been readily accepted by both patients and referring clinicians. However longer acquisition time (which can cause delay in therapeutic measures), poor bony details compared to CT, restrictions on the use of resuscitative and monitoring equipment in haemodynamically unstable patients andlimited availability are certain drawbacks.