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Correlation between MRI Findings and Neurological Deficits in Spinal Trauma: An Evaluation Based on the ASIA Impairment Scale

Parth Patel ^{1*}, Sumit Kumar Ghosh ², Hetal Patel ³, Subhash C Sylvania ⁴

¹ Post Graduate Student (Radiodiagnosis), Saraswathi Institute of Medical Sciences Hapur, Uttar Pradesh, India

² Assistant Professor (Radiodiagnosis), Saraswathi Institute of Medical Sciences Hapur, Uttar Pradesh, India

³ Assistant Professor (Preventive and Social Medicine) Kiran Medical College, Surat, Gujarat, India

⁴ Professor and HOD, Department of Radiodiagnosis, Saraswathi Institute of Medical Sciences Hapur, Uttar Pradesh, India

* Corresponding Author: **Parth Patel**

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Abstract

Introduction: Spinal trauma is a major clinical challenge, often leading to significant morbidity and mortality. MRI has become essential in diagnosing spinal injuries due to its superior ability to visualize spinal cord pathologies and surrounding tissues. This study aims to evaluate the correlation between MRI findings and neurological deficits using the ASIA Impairment Scale in patients with spinal trauma.

Method: A hospital-based prospective study was conducted on 50 patients with spinal trauma who underwent MRI within four weeks of injury. Exclusion criteria included patients with contraindications to MRI. All patients underwent full-spine MRI, and clinical assessment was made using the ASIA Impairment Scale. MRI findings, including cord hemorrhage, edema, and epidural hematoma, were analyzed. Statistical analysis was performed using IBM SPSS version 25.0.

Result: The study cohort included 36 males and 14 females, with the majority aged 21-40 years. The most common MRI findings were cord edema (>3 cm, 34%) and cord hemorrhage (18%). The ASIA Impairment Scale revealed significant improvements in neurological outcomes, with 40% of patients improving to ASIA D and 42% to ASIA E. Cord hemorrhage was significantly associated with poor neurological recovery ($p=0.002$), while cord edema showed a positive correlation with recovery. Epidural hematoma did not significantly correlate with neurological or sensory improvement.

Conclusion: MRI findings, particularly cord hemorrhage and edema, were significantly correlated with neurological and sensory outcomes in spinal trauma patients. The ASIA Impairment Scale was effective in tracking recovery, highlighting MRI's role in predicting patient prognosis.

Keywords: Spinal trauma; MRI findings; ASIA Impairment Scale; Cord hemorrhage; Neurological outcomes; Sensory improvement

Introduction

Spinal trauma represents a significant clinical challenge, often resulting in severe morbidity and mortality. Accurate evaluation and management are essential to prevent long-term complications and optimize patient outcomes ^[1]. Magnetic Resonance Imaging (MRI) has become a critical diagnostic tool for assessing spinal trauma, offering superior visualization of the spinal cord, vertebral column, and surrounding soft tissues ^[2].

MRI is highly effective in detecting subtle abnormalities, such as bone marrow changes, soft tissue injuries, and spinal cord pathologies, which may be missed by other imaging modalities. Its advantages-high contrast resolution, absence of bony artifacts, multiplanar imaging, and various pulse sequences-enable precise diagnoses and timely interventions in spinal trauma cases ^[3].

MRI provides valuable insights into neural and extraneural injuries requiring surgical intervention, including disc herniations and epidural hematomas. It also helps identify prognostic indicators like spinal cord edema, contusions, hemorrhages, and ischemia. [4] Sagittal T1-weighted images are effective for evaluating anatomical abnormalities, while T2-weighted images excel in identifying soft tissue pathologies. Additionally, gradient echo images aid in detecting acute spinal cord hemorrhage and fractures [3, 5]. The depiction of spinal cord injuries (SCI) on MRI aligns with neurological deficits and provides prognostic insights into recovery potential. [3] This study aims to evaluate the correlation between MRI findings and neurological deficits based on the ASIA impairment scale, contributing to a deeper understanding of MRI's role in spinal trauma diagnosis and management.

Method

This hospital-based prospective study was conducted on 50 patients with spinal trauma referred to the Department of Radiodiagnosis at Saraswathi Institute of Medical Sciences, Hapur, from June 2022 to June 2024. Patients undergoing MRI within 4 weeks of spinal trauma were included, while those with contraindications to MRI (e.g., metallic implants, cochlear implants, pacemakers) and claustrophobic patients were excluded. After obtaining ethical clearance and informed consent, all patients underwent MRI of the whole spine using a GE HDXT 1.5 Tesla scanner. Scanning was performed in the axial and sagittal planes, utilizing pulse sequences such as sagittal T1 and T2-weighted fast spin echo images, STIR, coronal STIR, and axial T2, GRE, and T1-weighted fast spin echo images. Adjustments were made to the scanning technique based on the patient profile. Clinical assessment was conducted using the ASIA Impairment Scale, with findings categorized into five grades: A (complete), B

(sensory incomplete), C (motor incomplete with muscle grade <3), D (motor incomplete with muscle grade ≥3), and E (normal). MRI findings, including cord hemorrhage, edema, disc herniations, and epidural hemorrhage, were analyzed. The data were recorded in MS Excel and statistically analyzed using IBM SPSS version 25.0. The strength of associations between MRI findings and clinical outcomes was described using odds ratios, and a Chi-square test (p<0.05) was used to assess the significance of associations.

Result

A total of 50 individuals were included in the study, with 36 males and 14 females. The largest group was aged 21-40, comprising 54.0% of the total, with more males (50.0%) than females (64.3%). The 41-60 age group made up 36.0% of the participants, with 36.1% males and 35.7% females. The younger age group (<=20) had only 2 males (4.0%), while the oldest group (>=61) had 3 males (6.0%). Overall, males were more prevalent across all age groups. The most common finding recorded was cord edema greater than 3 cm, which was observed in 34.0% of the participants. This was followed by cord edema less than 3 cm (32.0%), and cord hemorrhage, which was found in 18.0% of participants. Epidural hematoma was the least frequent, occurring in 6.0% of the participants. These findings highlight the varying severity of cord-related issues observed in the study group. The most prevalent non-cord structural abnormality was bony vertebrae issues, affecting 56% of the participants. Disc rupture was the second most common finding, present in 30% of the participants. Ligament abnormalities were observed in 16% of the participants, while epidural hematoma was the least frequent non-cord abnormality, occurring in 6% of the cases. These findings highlight the variety of structural issues present in the participants beyond the cord itself.

Table 1: Changes in ASIA Impairment Scale Classification and Associated Spinal Pathologies from Admission to Discharge

Category	A	B	C	D	E	Total
Overall Admission n (%)	11 (22.0%)	4 (8.0%)	8 (16.0%)	11 (22.0%)	16 (32.0%)	50 (100.0%)
Overall Discharge n (%)	6 (12.0%)	1 (2.0%)	2 (4.0%)	20 (40.0%)	21 (42.0%)	50 (100.0%)
Cord Hemorrhage Admission n (%)	6 (66.7%)	0 (0.0%)	0 (0.0%)	3 (33.3%)	0 (0.0%)	9 (100.0%)
Cord Hemorrhage Discharge n (%)	5 (55.5%)	1 (11.1%)	3 (33.3%)	0 (0.0%)	0 (0.0%)	9 (100.0%)
Cord Edema (<3 cm) Admission n (%)	6 (37.5%)	1 (6.3%)	2 (12.5%)	7 (43.8%)	0 (0.0%)	16 (100.0%)
Cord Edema (<3 cm) Discharge n (%)	4 (25.0%)	0 (0.0%)	0 (0.0%)	8 (50.0%)	4 (25.0%)	16 (100.0%)
Cord Edema (>3 cm) Admission n (%)	5 (29.4%)	3 (17.6%)	6 (35.3%)	3 (17.6%)	0 (0.0%)	17 (100.0%)
Cord Edema (>3 cm) Discharge n (%)	3 (17.6%)	1 (5.9%)	2 (11.8%)	10 (58.8%)	1 (5.9%)	17 (100.0%)
Epidural Hematoma Admission n (%)	3 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (100.0%)
Epidural Hematoma Discharge n (%)	2 (66.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (33.3%)	3 (100.0%)

Table 1 highlights the changes in ASIA Impairment Scale classification and associated spinal pathologies from admission to discharge in the study participants. At admission, the largest proportion of patients were classified as ASIA E (42%), followed by ASIA A (22%), ASIA D (22%), ASIA C (16%), and ASIA B (8%). By discharge, a significant shift occurred, with 40% of patients improving to ASIA D and 42% achieving ASIA E classification. Conversely, the percentage of patients in ASIA A and B decreased to 12% and 2%, respectively, while ASIA C dropped to 4%. Regarding spinal pathologies, cord hemorrhage was most common in ASIA A at admission

(66.7%) but showed improvement by discharge, with more cases in ASIA C and B. Cord edema (<3 cm) was most prevalent in ASIA A (37.5%) and ASIA D (43.8%) at admission, with recovery seen in ASIA D (50%) and ASIA E (25%) by discharge. Cord edema (>3 cm) was initially predominant in ASIA C (35.3%) but showed notable improvement in ASIA D (58.8%) by discharge. All epidural hematoma cases were initially in ASIA A, and two-thirds showed improvement, with one patient recovering to ASIA E. Overall, the table demonstrates significant improvement in both spinal pathologies and ASIA impairment scores, indicating positive recovery trends in the study cohort.

Table 2: Neurological and sensory improvement outcomes in relation to the presence of spinal cord findings

Findings	Neurological Outcome				
	Improvement n (%)	No-Improvement n (%)	Not Applicable n (%)	Total n	P-value
Cord Hemorrhage	2 (22.2%)	7 (77.8%)	0	9	0.002*
Cord Edema (<3 cm)	9 (56.3%)	7 (43.8%)	0	16	0.004*
Cord Edema (>3 cm)	10 (58.8%)	7 (41.2%)	0	17	0.002*
Epidural Hematoma	1 (33.3%)	2 (66.7%)	0	3	0.29

As depicted in Table-2, For cord hemorrhage, only 22.2% of patients demonstrated neurological improvement, while a significant 77.8% showed no improvement. The statistical analysis showed a p-value of 0.002, indicating a significant relationship between cord hemorrhage and poor neurological recovery. In contrast, cord edema (<3 cm) was associated with a higher improvement rate, with 56.3% of patients showing neurological improvement compared to 43.8% who did not. The p-value of 0.004 confirms a significant positive association between mild cord edema and neurological recovery. Similarly, patients with cord edema (>3 cm) also showed substantial neurological improvement, with 58.8%

experiencing positive outcomes, while 41.2% had no improvement. The p-value of 0.002 further supports the significance of larger cord edema in promoting neurological recovery. On the other hand, epidural hematoma had a lower improvement rate, with only 33.3% of patients showing neurological progress and 66.7% showing no change. The p-value of 0.29 suggests that epidural hematoma was not significantly linked to neurological improvement. Overall, cord hemorrhage and cord edema (<3 cm and >3 cm) were significantly associated with better neurological outcomes, while epidural hematoma showed no such correlation.

Table 3: Sensory outcomes in relation to the presence of spinal cord findings

Findings	Sensory Outcome				
	Improvement n (%)	No-Improvement n (%)	Not Applicable n (%)	Total n	P-value
Cord Hemorrhage	2 (22.2%)	4 (44.4%)	3 (33.3%)	9	0.001*
Cord Edema (<3 cm)	3 (18.8%)	3 (18.8%)	10 (62.5%)	16	0.18
Present	3 (9.1%)	3 (9.1%)	27 (81.8%)	33	
Cord Edema (>3 cm)	2 (11.8%)	3 (17.6%)	12 (70.6%)	17	0.62
Epidural Hematoma	2 (66.7%)	1 (33.3%)	0	3	0.001*

As shown in Table-3, For cord hemorrhage, 22.2% of patients showed sensory improvement, while 44.4% had no improvement, and 33.3% were not applicable for sensory assessment. The p-value of 0.001 indicates a significant association between the presence of cord hemorrhage and sensory outcomes, suggesting a considerable impact on sensory recovery. In contrast, cord edema (<3 cm) showed no significant effect on sensory outcomes, with 18.8% of patients showing improvement and 18.8% showing no improvement. The remaining 62.5% of cases were categorized as not applicable, and the p-value of 0.18 indicates that this finding was not significantly linked to sensory recovery. For cord edema (>3 cm), 11.8% of patients experienced sensory improvement, while 17.6% had no improvement, and 70.6% were not applicable for sensory assessment. The p-value of 0.62 further supports the lack of a significant relationship between this spinal finding and sensory outcomes. Epidural hematoma, however, showed a notable trend, with 66.7% of patients showing sensory improvement, while 33.3% had no improvement. The p-value of 0.001 highlights a significant association between epidural hematoma and positive sensory recovery. Overall, while cord hemorrhage and epidural hematoma were significantly associated with sensory improvement, cord edema (<3 cm and >3 cm) showed no significant impact.

Table 4: Outcome among study participants

Outcome	Neurological Outcome	Sensory function
Improvement	19 (38.0%)	5 (10.0%)
No-improvement	15 (30.0%)	6 (12.0%)
Not applicable	16 (32.0%)	39 (78.0%)

The outcomes among the study participants were categorized

into neurological and sensory function improvements. For neurological outcome, 38.0% of participants showed improvement, while 30.0% had no improvement. A notable 32.0% of the participants were categorized as "not applicable" for neurological assessment. On the other hand, sensory function showed a much lower rate of improvement, with only 10.0% of participants experiencing sensory improvement. A slightly higher percentage, 12.0%, showed no improvement, while a large majority, 78.0%, were categorized as "not applicable" for sensory evaluation. This suggests that while neurological improvements were more common among the participants, sensory function recovery was less frequent.

Discussion

In our study, we observed a varied age distribution among participants. The 20 years or younger group consisted of 2 males (5.6%) and no females, representing 4.0% of the total participants. In the 21-40 age range, 18 males (50.0%) and 9 females (64.3%) comprised 54.0% of the study population. The 41-60 group had 13 males (36.1%) and 5 females (35.7%), accounting for 36.0% of the total. The 61+ age group contained 3 males (8.3%) and no females, making up 6.0%. Overall, males constituted 72% (n=36) and females 28% (n=14) of the total sample (n=50). These age distribution trends align with those observed in other studies, such as Naik B *et al.* [6], Srinivas B *et al.* [7], and Gupta R *et al.* [8], where the 21-40 age group was the most prevalent, with a high male predominance.

Regarding MRI findings, our study revealed that cord hemorrhage was present in 18.0% of cases, cord edema (less than 3 cm) in 32.0%, and cord edema (greater than 3 cm) in 34.0%, with epidural hematoma found in 6.0%. These findings were consistent with the results of Naik B *et al.* [6],

Srinivas B *et al.* [7], Gupta R *et al.* [8], and Ramon S *et al.* [9], who also identified a high prevalence of cord edema and hemorrhage, with varying degrees of spinal cord injury correlating with the MRI patterns.

In terms of neurological outcomes, our study showed improvement in 38.0% of cases, with no improvement in 30.0%. Sensory function improvements were observed in 10.0% of cases. These results were similar to those of Naik B *et al.* [6], where 49% of patients showed neurological improvement. Studies by Gupta A *et al.* [10] and Miyanji F *et al.* [11] highlighted the prognostic significance of cord hemorrhage and edema, with spinal cord hemorrhage being associated with poor neurological recovery, while edema offered potential for improvement. Furthermore, Srinivas B *et al.* [7] observed that the degree of injury correlated with the extent of neurological recovery, reinforcing the prognostic value of early imaging and clinical evaluation.

In the current study, the distribution of AIS scores upon admission showed varying levels of neurological impairment: A (22.0%), B (8.0%), C (16.0%), D (22.0%), and E (32.0%). However, at discharge, the distribution shifted: A (12.0%), B (2.0%), C (4.0%), D (40.0%), and E (42.0%), with a significant change observed ($p = 0.037$), indicating improvements in neurological function. These results highlight the effectiveness of treatment in enhancing AIS scores.

Srinivas B *et al.* reported that no patients with ASIA Grade A improved postoperatively at 6 months, with 41.6% succumbing to their condition. ASIA Grades D and C showed higher improvement rates, with Grade D at 83% and Grade C at 78%, underscoring the variability in recovery across different grades [7]. Similarly, Khorasanizadeh M *et al.* observed the highest recovery in Grade C, followed by Grade B, D, and A [12].

In the present study, patients with cord hemorrhage showed a shift in AIS scores from A (66.7%) to A (55.5%) and D (33.3%) at discharge, suggesting some recovery. Naik B *et al.* found that no improvement occurred in their cord hemorrhage cases, with all patients remaining at ASIA A [6]. Gupta R *et al.* and Ramon S *et al.* observed similar trends, with no change in neurological status for cord hemorrhage cases [8, 9].

In cases with cord edema less than 3 cm, the distribution of AIS scores shifted from a majority of Grade D at admission to a notable increase in Grade D (50%) and Grade E (25%) at discharge, highlighting dynamic changes in neurological impairment. This suggests a possible correlation between cord edema and improvement in AIS scores, warranting further investigation [8].

Srinivas B *et al.* found that 65.2% of patients with cord edema showed improvement, with statistical significance ($p = 0.004$) [7]. In the present study, cord edema greater than 3 cm showed a shift from A (29.4%) to D (58.8%) at discharge, emphasizing the importance of monitoring this condition for its impact on neurological outcomes.

Lastly, in cases with epidural hematoma, AIS scores improved from A (100%) to E (33.3%) at discharge, suggesting some neurological recovery. Naik B *et al.* observed similar findings, with improvement in two out of three patients with epidural hematoma [6]. Dziedzic T *et al.* also noted that most epidural hematoma cases were initially categorized as AIS A, with slight recovery observed during follow-up [13].

In the present study, a significant association was found

between the presence of cord hemorrhage and neurological outcomes. Among cases without cord hemorrhage, 41.5% showed neurological improvement, while 19.5% showed no improvement. In contrast, only 22.2% of cases with cord hemorrhage showed improvement, with 77.8% showing no improvement, indicating a negative impact of cord hemorrhage on neurological recovery ($p = 0.002$). These findings are consistent with Naik B *et al.*, where patients with cord hemorrhage did not demonstrate neurological improvement based on MRI findings [6].

Similarly, in cases of cord edema (<3 cm), a significant association was observed between its presence and neurological improvement ($p = 0.004$). Neurological recovery was seen in 56.3% of patients with cord edema, while only 29.4% of patients without cord edema showed improvement. This supports Srinivas B *et al.*, who reported that 75% of patients with cord edema (<3 cm) showed improvement [7].

Cord edema (>3 cm) also showed a positive impact on neurological outcomes ($p = 0.002$), with 58.8% of patients improving compared to 27.3% in the absence of edema. Naik B *et al.* similarly found that 56.5% of patients with cord edema showed improvement [6].

Regarding epidural hematoma, no significant association with neurological outcomes was found ($p = 0.29$), as only 33.3% of patients with epidural hematoma showed improvement, while the majority did not. These findings align with Naik B *et al.*, where some patients with epidural hematoma showed improvement, but the overall impact was minimal [6].

In terms of sensory improvement, cord hemorrhage significantly influenced sensory recovery ($p = 0.001$), with 22.2% of patients with cord hemorrhage showing sensory improvement, while most cases without cord hemorrhage were categorized as "not applicable." This is consistent with Parashari U *et al.*'s findings, where a significant number of patients with sizable cord hemorrhage showed no sensory improvement [14].

Cord edema (<3 cm) did not significantly influence sensory improvement ($p = 0.18$), with only a small proportion of patients showing improvement. Parashari U *et al.* found similar results, reporting that 42% of patients with cord edema (<3 cm) showed sensory improvement [14].

Lastly, cord edema (>3 cm) had no significant impact on sensory recovery ($p = 0.62$), as improvement was observed in only 11.8% of patients with edema. This aligns with Parashari U *et al.*, who reported that 14% of patients with cord edema (>3 cm) showed sensory improvement [14].

Conclusion

In conclusion, this study highlights the positive recovery trends in both neurological and sensory outcomes among patients with spinal cord injuries. A significant proportion of participants showed improvements in their ASIA Impairment Scale classification from admission to discharge, with a marked reduction in severe impairments (ASIA A and B) and an increase in patients classified as ASIA D and E. Spinal pathologies, including cord hemorrhage and cord edema, were notably associated with better neurological recovery, whereas epidural hematoma showed no significant impact on neurological outcomes. Sensory recovery was less frequent, with only a small percentage of patients showing improvement, especially in cases of cord hemorrhage and epidural hematoma. Overall, the findings suggest a favorable

trend in recovery, particularly for those with milder spinal pathologies, underscoring the importance of early intervention and management in spinal trauma cases.

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