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Research Article

Prospective evaluation of relationship between MRI findings and ASIA score to predict neurological recovery in acute traumatic spinal cord injury

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Abstract

Introduction: The role of MRI in evaluating the acutely injured spine is well established and contributes to assessment of ligamentous disruption, associated disc protrusions as well as exact site of maximal canal stenosis and nature of cord injury; and neurological assessment as per ASIA score is an internationally accepted method. It is not well established the MRI at any point of time correlates with ASIA score to prognosticate neurological recovery.

Aims: The present study aimed to evaluate relationship between MRI findings and ASIA score to predict neurological deficit and recovery in acute SCI patients.

Methods: Thirty-five patients of acute spinal cord injury with mean age of 31.34 ± 10.63 years (range 16 to 65 years), who have been presented within 48 hours of injury were included in the study. Complete neurological (ASIA grading) and MRI examinations were done at presentation, 3 months, and 6 months to evaluate the SCI. Statistical analysis of MRI (qualitative & quantitative) findings and clinical evaluation was done with ASIA scoring to find an agreement between MRI and neurological outcome.

Results: The statistically significant correlation was found to be with Maximum Canal Compromise (MCC) (-0.703) followed by lesion length (-0.678), Maximum Spinal Cord Compression (MSCC) (-0.661), stenosis (-0.577) and disc herniation (-0.420) to prognosticate the neural recovery as determined by ASIA score. The rest of MRI findings didn't have significant correlation with ASIA score at any point of time. However, decrease in edema significantly correlated with ASIA score at 3 and 6 months post injury. Statistically significant kappa agreement between neurological recovery diagnosed by ASIA score and MRI findings was found with MCC (k=0.211) and soft tissue injury (k=0.318).

Conclusions: The present study showed that significant correlation exist between MRI findings (MCC, MSCC, stenosis, and disc herniation) and ASIA score at different point of time post SCI. Furthermore, statistically significant kappa agreement between neurological recovery diagnosed by ASIA score and MRI findings (MCC and soft tissue injury) was found. We suggest that serial neurologic examination and neuroimaging complement each other in prognosticating neurological recovery after acute traumatic SCI.

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Introduction

Acute traumatic Spinal Cord Injuries (SCI) represent one of the commonest devastating injuries, more prevalent in the younger population (16-30 years) and creating physical, emotional, and economic burdens on both the individual as well as to the society. Recent demographics demonstrate a trend toward increasing average age at the time of injury and more violence-related events [1]. A Spinal Cord Injury (SCI) refers to any injury to the spinal cord that is caused by trauma instead of systemic or regional disease. Depending on the site where the spinal cord and nerve roots are damaged, the symptoms can vary widely, from pain to paralysis to incontinence [2]. Spinal cord injuries are described at various levels of "incomplete", which can vary from having no effect on the patient to a "complete'' injury which means a total loss of function [3-5]. Several radiological investigations including radiographs (x-rays) and Computed Tomogram (CT) scans are available but advent of Magnetic Resonance Imaging (MRI) has enabled the non-invasive visualisation of the spinal cord in both diagnostic as well as in prognostic purposes. MR imaging is indicated in the setting of spinal trauma when a neurologic deficit present or when there is clinical suspicion of a soft tissue or vascular abnormality. The role of MRI in evaluating the acutely injured spine is well established and contributes to assessment of ligamentous disruption, associated disc protrusions as well as exact site of maximal canal stenosis and nature of cord injury [6-13]. Present study aimed to evaluate relationship between MRI findings and ASIA score to predict neurological recovery in acute Spinal Cord Injury (SCI) patients. We further evaluated whether there was an agreement in these two to predict neurological prognosis.

Material and methods

Approval from Institutional Review Board and Ethical Committee was taken before enrollment of patients in the study, and written informed consent was obtained from all the patients. Thirty-five patients of acute spinal cord injury with mean age of 31.34 ± 10.63 years (range 16 to 65 years), who have been presented within 48 hours of injury to Orthopaedics emergency department in institute within period from June 2014 to November 2016, included in present prospective study. Patients having spinal cord injury either with non-traumatic etiology or with head injury/medically unstable condition or with previous implanted metallic devices or with claustrophobia, pacemakers and cochlear implants or presenting with previous neurological deficits and gunshot wounds were excluded from the study. There was male preponderance incidence [male: female; 29 (82.9%): 6 (17.1%)]. Most injuries were at the first lumbar vertebral level in 14 subjects (40.0%) followed by second lumbar and thoracic twelfth in 5 (14.3%) subjects each, while mode of injury was fall from height (34 subjects, 97.1%) followed by road side accidents (1 subject, 2.9%). The mean duration of time elapsed between injury and MR imaging was 18.97±4.86 hours (range 6 to 24 hours) with maximum (30 subjects, 85.7%), investigated between 13-24 hours. Thorough chronological history along with complete clinical assessment (sensory score, motor score and zone of partial preservation) was done at the time of admission, on 3rd day, on 7th day, at 3 months and at 6 months of injury as per international guidelines [14]. Plain radiographs of the spine were done on admission to diagnose the level and calculate sagittal index, Gardener Segmental Kyphotic Deformity, and regional kyphotic deformity as described by Farcy et al [15]. MRI was done in all cases for confirmatory diagnosis within 48 hours of injury and assessment of quantitative parameters [MSCC (Maximum Spinal Cord Compression), MCC (Maximum Canal Compromise) and lesion length] as well as qualitative parameters (cord edema, hemorrhage, Soft Tissue Injury (STI), disc herniation and posterior ligament complex injury) was done by the method described by Fehlings et al [16]. Plain radiographs and MRI were repeated at 3 and 6 months. Traumatic spinal cord injury was classified into five categories (score A with complete injury of spine, score B, C, D with incomplete injury and score E with no neural deficit) on the ASIA Impairment Scale [17]. Statistical analysis of MRI (qualitative & quantitative) findings and clinical evaluation was done with ASIA scoring to find an agreement between MRI and neurological outcome.

Statistical analysis

Normally distributed variables (means and standard deviation) were analysed using Student t-test and repeated measure analysis of variances (ANOVA). Chi-square test, Friedman ANOVA and Cochran's Q test were employed for categorical and ordinal data. Correlation between variables was assessed by Spearman coefficient of correlation. Standard

Table 1: Distribution of subjects according to their symptomatology (n=35).

Symptoms	Initial	3 months	6 months	Significance*
Pain	35 (100.0%)	13 (37.1%)	2 (5.7%)	p< 0.001
Swelling	35 (100.0%)	0 (0.0%)	0 (0.0%)	p< 0.001
Deformity	35 (100.0%)	17 (48.6%)	3 (8.6%)	p< 0.001
Weakness UL	2 (5.7%)	2 (5.7%)	1 (2.9%)	p=0.368
Weakness LL	33 (94.3%)	25 (71.4%)	17 (48.6%)	p< 0.001
Incontinence	0 (0.0%)	0 (0.0%)	5 (14.3%)	p=0.007
Retention	27 (77.1%)	20 (57.1%)	7 (20.0%)	p< 0.001

*Cochran's Q test

Table 2: Distribution of subjects according to their neurological assessment (n=35).

Neurological assessment	Initial	3 months	6 months	Significance
Decreased Muscle Tone	33 (94.3%)	27 (77.1%)	18 (51.4%)	p< 0.001*
MIS-UL	48.69 ±	49.57 ± 1.80	49.74 ±	p=0.232#
MIS-LL	13.34 ±	30.09 ±	40.91 ±	p<0.001#
Voluntary Anal Contraction	30 (85.7%)	22 (62.9%)	7 (20.0%)	p< 0.001*
SIS- Light touch	84.29 ±	106.11 ±	110.69 ±	p<0.001#
SIS- Pin prick	81.60 ±	102.17 ±	110.23 ±	p<0.001#
Temperature sense	18 (51.4%)	3 (8.6%)	0 (0.0%)	p< 0.001*
Deep Anal Pressure (DAP)	21 (60.0%)	11 (31.4%)	2 (5.7%)	p< 0.001*
Clonus (Absent)	35 (100.0%)	35 (100.0%)	35 (100.0%)	p=1.000*
Zone of partial preservation	35 (100.0%)	35 (100.0%)	35 (100.0%)	p=1.000*

*Cochran's Q test, #Repeated Measures ANOVA

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Statistical software (SPSS version 20.0) was used for statistical analysis and a p-value of <0.05 was considered statistically significant.

Results

Clinical parameters and neurology

Distribution of subjects according to their symptomatology is depicted in the table 1. Neurological assessment was done with different variables including muscle tone, Motor Index Score (MIS), Voluntary Anal Contraction (VAC), Sensory Index Scoring (SIS), temperature, Deep Anal Pressure (DAP), clonus and Zone of Partial Preservation (ZPP). These all variables are tabulated at different follow up of time in table 2.

The median neurological grade improved from score C to D in initial 3 months and score D to E in next 3 months. The neurological recovery was highly significant (p<0.001) by Friedman ANOVA test. At initial documentation, 20% (7) and 5.7% (2) subjects presented with complete injury and no deficit respectively (ASIA score A and E), whereas maximum subjects (20, 57.1%) were classified into grade C. At the end of 6 months, maximum subjects had no deficit (18 subjects, 51.4%).

MRI parameters

The difference in various quantitative and qualitative parameters on MRI findings observed have been tabulated in Table 3; and according to their neurological status at the time of admission in terms of severity of injury assessed by ASIA score have been represented in Table 4.

Table 3: Qualitative and quantitative findings on MRI observed initially and at subsequent follow-ups (n=35).

Findings	Initial	3 months	6 months	Significance
Qualitative Findings				
Edema	34 (97.1%)	27 (77.1%)	8 (22.9%)	p<0.001*
Hemorrhage	10 (28.6%)	6 (17.1%)	0 (0.0%)	p=0.004*
Cord swelling	1 (2.9%)	1 (2.9%)	1 (2.9%)	p=1.000*
Soft tissue injury	8 (22.9%)	7 (20.0%)	3 (8.6%)	p=0.015*
Stenosis	19 (54.3%)	19 (54.3%)	16 (45.7%)	p=0.050*
Disc herniation	25 (71.4%)	23 (65.7%)	20 (57.1%)	p=0.022*
Epidural hematoma	0 (0.0%)	0 (0.0%)	0 (0.0%)	p=1.000*
Body Fracture	34 (97.1%)	34 (97.1%)	34 (97.1%)	p=1.000*
Altered marrow signal	35 (100.0%)	35 (100.0%)	35 (100.0%)	p=1.000*
Posterior element fracture	8 (22.9%)	8 (22.9%)	8 (22.9%)	p=1.000*
Posterior ligament complex injury	8 (22.9%)	8 (22.9%)	4 (11.4%)	p=0.018*
Pre-vertebral edema	0 (0.0%)	0 (0.0%)	0 (0.0%)	p=1.000*
Subluxation	1 (2.9%)	0 (0.0%)	0 (0.0%)	p=0.368*
Spondylosis	0 (0.0%)	0 (0.0%)	0 (0.0%)	p=1.000*
Foreign body	0 (0.0%)	0 (0.0%)	0 (0.0%)	p=1.000*
Quantitative findings				
Maximum spinal cord compression	57.43 ± 29.05	32.83 ± 25.58	18.57 ± 17.43	p<0.001**
Maximal canal compromise	61.60 ± 29.70	37.91 ± 27.63	20.91 ± 18.07	p<0.001**
Lesion length	10.34 ± 9.31	7.30 ± 6.96	5.05 ± 5.47	p<0.001**

*Cochran's Q test ** Repeated measures ANOVA.

Table 4: Comparison of initial neurological status in terms of complete and incomplete injury with qualitative and quantitative parameters.

PARAMETERS	Severity of initial injury			Significance
	Complete SCI (ASIA Grade A) (n=7)	Incomplete SCI (ASIA Grade B,C,D) (n=26)	No deficit (ASIA Grade E) (n=2)	
QUALITATIVE				
Edema	7 (100.0%)	25 (96.2%)	2 (100.0%)	p=0.837*
Haemorrhage	3 (30%)	7(70%)	0 (0%)	p=0.021*
Cord swelling	0 (0.0%)	1 (3.8%)	0 (0.0%)	p=0.837*
Soft tissue injury	2 (28.6%)	5 (19.2%)	1 (50.0%)	p=0.560*
Stenosis	7 (100.0%)	12 (46.2%)	0 (0.0%)	p=0.011*
Disc herniation	7 (100.0%)	16 (61.5%)	2 (100%)	p=0.089*
Body Fracture	7 (100.0%)	25 (96.2%)	2 (100%)	p=0.837*
Posterior element fracture	3 (42.9%)	4 (15.4%)	1 (50.0%)	p=0.197*
Posterior ligament complex injury	3 (42.9%)	4 (15.4%)	1 (50.0%)	p=0.197*
Subluxation	0 (0.0%)	1 (3.8%)	0 (0.0%)	p=0.837*
QUANTITATIVE				
Maximum spinal cord compression	83.14 ± 2.04	54.04 ± 27.95	11.50 ± 0.71	p=0.002**
Maximal canal compromise	88.43 ± 2.15	58.00 ± 28.38	14.50 ± 2.12	p=0.002**
Lesion length	19.29 ± 7.00	8.73 ± 8.51	0.00 ± 0.00	p=0.005**

*Chi-square test ** One-way ANOVA.

Qualitative: There was statistically significant (p<0.001) improvement in neurological function of subjects who had edema initially (34 subjects) as seen on follow up visits with median ASIA score to be C initially, D at 3 months and E at 6 months with 7 (20.01%) patients showed no improvement on follow up and these patients were also having intramedullary haemorrhage. There were 10 patients with initial haemorrhage. Three patients had ASIA A and 7 patients had ASIA C neurological status; and neurological improvement was noted in 6 (60.0%) patients and rest of the 4 (40.0%) patients showed no improvement on follow up. There was statistical difference (*p*=0.014) in neurological outcome between patients who had haemorrhage and those not having haemorrhage. Cord swelling was observed in only single patient and it persisted throughout the final follow- up. STI was present initially in 22.9% (8) of subjects, persisted in only 8.6% (3) subjects after 6 months with statistically significant (*p*=0.014) improvement in neurological function with median ASIA score to be C initially, C at 3 months and D at 6 months. There was statistically significant (*p*<0.001) improvement in neurological function, who had stenosis initially (19 patients) with median ASIA score to be C initially, C at 3 months and D at 6 months, while 4 (21.1%) out of 19 patients showed no improvement.

Quantitative: Subjects with compression of MSCC > 50%, improved from median ASIA score from C to C at 3 months and D at 6 months, while for subject's compression ≤ 50% score to be D initially, D at 3 months and E at 6 months with significant neurological improvement (*p*<0.001).

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Similarly, mean MCC decreased significantly from (61.60%± 29.70) to (20.91% ± 18.07), (p<0.001) at final follow up. There was improvement in neurological function of subjects who had initial MCC ≤ 50% as seen on follow up visits with median ASIA score to be D initially, E at 3 months and E at 6 months. This improvement in neurological function was found to be statistically significant (*p*<0.001)

There was significant improvement in neurological function with initial lesion length ≤50mm, reflecting median ASIA score to be C initially, D at 3 months and E at 6 months, (*p*<0.001).

Correlation matrix of MRI findings and ASIA score (Spearman's correlation test) is shown in Table 5.

Statistically significant kappa agreement between neurological recovery diagnosed by ASIA score and MRI findings was found with maximum canal compromise (k=0.211) and soft tissue injury (k=0.318) only (Table 6).

Discussion

MRI is a gold standard for evaluation of SCI patients; and qualitative and quantitative parameter have been defined and evaluated in SCI. Most studies in the literature had registered the qualitative variables to examine the association between imaging parameters and neurological outcome in SCI [5,6,9,11-13,18-22]. There are only a few studies which evaluated the quantitative variables (degree of spinal canal compromise, cord compression and length of lesion) [11-13,23,24]. The present study used an objective method, which has previously been approved to be reliable, standardized and objective, to quantify MR images obtained from patients with SCI [16,25].

Qualitative MRI findings

Most of the subjective changes in spinal cord are related to secondary insults following the initial trauma, but the extent of cord damage is proportionate to the initial impact force [26,27]. Even minor injuries can also cause significant cord malfunction, while there is some resistant of the cord to direct physical disruption [13]. Intramedullary haemorrhage is associated with more neurological deficit and poor neurological prognosis. The present study also substantiate it; as there was statistical difference (p=0.014) in neurological outcome between patients who had haemorrhage and those not having haemorrhage at the time of presentation. Similar findings had also been reported in other studies [6,9,18,19,21,22,28-30].

Cord edema usually resolves with time and is associated with good neurological recovery. Significant (p<0.001)

Table 5: Correlation matrix of MRI findings and ASIA score (Spearman's correlation test).

	MRI findings									ASIA Score
	Maximum Spinal Cord Compression	Maximum Canal Compromise	Lesion length	Edema	Soft tissue injury	Stenosis	Disc Herniation	Post. Ligament complex injury	Subluxation	
Initial ASIA score	-.661**	-.703**	-.678**	-0.237	-0.105	-.577**	-0.420*	-0.207	-0.009	1.000
ASIA score at 3 months	-0.780**	-0.823**	-0.730**	-508**	-0.127	-0.613**	-0.575**	-0.278	0.000	1.000
ASIA score at 6 months	-0.740**	-0.700**	-0.591**	-0.607**	-0.228	-0.683**	-0.474**	-0.259	0.000	1.000

** Correlation is significant at 0.01 level (2-tailed) * Correlation is significant at 0.05 level (2-tailed).

Table 6: Agreement in neurological recovery according to ASIA score and MRI findings.

Neurological recovery by MRI findings		Neurological recovery by ASIA score: No	Neurological recovery by ASIA score: Yes	Kappa Agreement
Spinal cord compression	No	0	0	K=0.000
	Yes	7	28	p=1.000
Maximum canal compromise	No	1	0	K=0.211
	Yes	6	28	p=0.042
Lesion length	No	3	8	K=0.118
	Yes	4	20	p=0.466
Edema	No	3	5	K=0.237
	Yes	4	23	p=0.159
Soft tissue injury	No	2	1	K=0.318
	Yes	5	27	p=0.035
Stenosis	No	4	12	K=0.096
	Yes	3	16	p=0.497
Disc herniation	No	5	15	K=0.105
	Yes	2	13	p=0.393
Post. ligament complex injury	No	1	3	K=0.043
	Yes	6	25	p=0.791
Subluxation	No	0	0	K=0.000
	Yes	7	28	p=1.000

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neurological recovery was also noted in patients with resolving edema during follow up. Kulkarni et al. [6] and Rao et al. [22] observed in different studies patients with cord edema recovered significantly. Similar observations were found by Chandra et al. where signal changes with transient cord edema reverted to normal on follow up imaging, had a better outcome [5].

In the present study while comparing the patients with complete injury spinal injury (ASIA A), incomplete injury (ASIA B,C,D), and no deficit (ASIA E) for qualitative MRI parameters; there was significant difference in haemorrhage (p=0.021) and soft tissue injury (p=0.011) parameters only. Takahashi et al. also correlated the degree of cord compression with recovery of neurological function [29]. Singh et al. reported that patients with cord swelling and stenosis showed a trend towards severe neurological deficit at presentation (p=0.816) but post-operatively there was a significant improvement for edema (p=0.01) and spinal cord stenosis (p=0.001) [30]. Miyanji et al. documented that patients with complete SCIs also had higher frequencies of hemorrhage (p<.001), edema (p<0.001), cord swelling (p=0.001), stenosis (p=0.01), and STI (p=0.001). Cord swelling (p< .001) was correlated with baseline ASIA motor scores, while haemorrhage (p<0.001) and cord swelling (p=0.029) were predictive of the neurologic outcome at follow-up. Hemorrhage (p<0.001) and cord swelling (p=0.002) were correlated significantly with follow-up ASIA score when taking account, the baseline neurologic assessment [11].

Quantitative MRI findings

In present study, mean MSCC was found to be (83.14%±2.04) among subjects with complete injury initially whereas subjects with no deficit had mean MSCC to be (11.50%±0.71). MCC was found to be (88.43%±2.15) among subjects with complete injury initially whereas subjects with no deficit had mean MCC to be (14.50%±2.12). There was statistically significant difference in MSCC (p=0.002) and MCC (p=0.002); when we compared the difference between these two parameters in patients with complete injury spinal injury (ASIA A), incomplete injury (ASIA B,C,D), and no deficit (ASIA E). Singh at al. reported that patients with complete injury had significantly more MSCC (P< 0.001) and MCC(P< 0.001) in comparison to incomplete injury as well as in comparison to neurologically healthy patients (MSCC [P< 0.001], MCC [P<0.001] [30].

Meves et al. found that patients with neurological deficit had greater canal compromise [21]. Similar results were observed by Miyanji, et al. [11] (p=.005) and Haar, et al. [13] (p=0.009) in their studies with more substantial MCC in complete SCI than patients with incomplete SCIs or those with no SCI, while correlated with baseline ASIA motor scores in cervical spine. Greater canal compromise is significantly associated with severity of neurological deficit and prognosis as documented in literature [5-13,18-30].

The mean lesion length was found to be (19.29mm±7.00) among subjects with complete injury initially whereas subjects with no deficit had mean lesion length to be zero as they didn't had any lesion at all. Singh et al. noticed 28% improvement in lesion length from 25.25±29.55mm to 18.15±22.75 in first 3months, further increment by 19% in next 3 months and by 16.4% in next 6 months (at 1 year) follow up. Lesion length decreased in all patients on each follow up and it was statistically significant (p=0.001) [30]. Studies by Miyanji et al. [11] (p=0.005) and Haar, et al. [13] (p=0.001) revealed more substantial lesion length with complete motor and sensory SCIs than patients with incomplete SCIs or no SCI in cervical spine. The length of lesion (p=0.019) correlated with baseline neurology and was predictive (p=0.011) of a poor neurological outcome.

Correlation between MRI findings and ASIA score

Correlation between MRI findings and ASIA score were obtained by Spearman's correlation test at different point of time and explained in Table 5. The statistically significant correlation of ASIA score with MRI findings was found to be with MCC (-0.703) followed by lesion length (-0.678), MSCC (-0.661), stenosis (-0.577) and disc herniation (-0.420). The rest of MRI findings didn't have significant correlation with ASIA score at any point of time. However, decrease in edema significantly correlated with ASIA score at 3 and 6 months post injury. Extensive literature review did not reveal any study in English literature reporting agreement of neurological recovery according to ASIA scores and MRI findings at the time of start of present study in 2014. At the time of writing the article again literature search was done and we found one study by Matsushita et al. in 2017 in English literature reporting agreement of neurological recovery according to ASIA scores and MRI findings. They evaluated only the relationship between the vertical diameter of T2 high-intensity change in acute cervical spine cord injury, and observed a significant relationship 2–3 days after injury between the vertical diameter of T2 high-intensity area and the neurologic prognosis at discharge. There was correlation between intramedullary high-intensity changed area (ISI) and ASIA motor score at admission and at discharge (P< 0.05), but the correlation coefficient was low (0.3766 at admission and 0.4240 at discharge) in patients admitted 0-1 day after injury; while in patients admitted 2-3 days after injury, there was a significant correlation between the ISI and ASIA motor score at admission and at discharge (P< 0.05), and the correlation coefficient was very high (0.6840 at admission and 0.5293 at discharge) [31]. Present study is the first one to report relationship between multiple MRI findings and ASIA score over different point of time after discharge.

Agreement between neurological recoveries diagnosed by ASIA score and MRI findings

As shown in Table 6, statistically significant kappa agreement between neurological recovery diagnosed by ASIA score and MRI findings was found with maximum canal compromise (k=0.211) and soft tissue injury (k=0.318) only. We could not find in the literature any study reporting agreement between ASIA score and MRI features to predict neurological recovery for comparison purposes.

Conclusions

From the present study, it was observed that there is a significant correlation between MRI findings and ASIA score

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at different point of time post SCI. The statistically significant correlation was found to be with MCC (-0.703) followed by lesion length (-0.678), MSCC (-0.661), stenosis (-0.577) and disc herniation (-0.420) to prognosticate the neural recovery as determined by ASIA score. Furthermore, statistically significant kappa agreement between neurological recovery diagnosed by ASIA score and MRI findings was found with MCC (k=0.211) and soft tissue injury (k=0.318). We suggest that serial neurologic examination and neuroimaging complement each other in prognosticating neurological recovery after acute traumatic SCI.

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