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Comparison of Diagnostic Accuracy of MRI With and Without Contrast in Diagnosis of Traumatic Spinal Cord Injuries

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Abstract: Acute spinal cord injury (SCI) is one of the most common causes of severe disability and mortality after trauma. Magnetic resonance imaging (MRI) can identify different levels of SCI, but sometimes unable to detect the associated soft tissue injuries. The role of MRI with contrast in patients with SCI has not been studied. This is the first study in human to compare the efficacy of MRI with and without contrast in diagnosis and prognosis evaluation of SCIs.

In this cross-sectional diagnostic study, MRI with and without contrast was performed on 40 patients with acute spinal injury. In these patients, 3 different types of MRI signal patterns were detected and compared.

The most common cases of spinal injuries were accident (72.5%) and the after fall (27.5%). The prevalence of lesions detected includes spine fracture (70%), spinal stenosis (32.5%), soft tissue injuries (30%), and tearing of the spinal cord (2.5%). A classification was developed using 3 patterns of SCIs. Type I, seen in 2 (5.0%) of the patients, demonstrated a decreased signal intensity consistent with acute intraspinal hemorrhage. Type II, seen in 8 (20.0%) of the patients, demonstrated a bright signal intensity consistent with acute cord edema. Type III, seen in 1 (2.5%) of the patients, demonstrated a mixed signal of hypointensity centrally and hyperintensity peripherally consistent with contusion. In the diagnosis of all injuries, MRI with contrast efficacy comparable to noncontrast MRI, except in the diagnosis of soft tissue, which was significantly higher sensitivity ($P < 0.05$).

So given that is not significant differences between noncontrast and contrast-enhanced MRI in the diagnosis of major injuries (hematoma, edema, etc.) and contrast-enhanced MRI just better in soft tissues. We recommend to the MRI with contrast only used in cases of suspected severe soft tissue injury, which have been ignored by detection MRI without contrast.

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Abbreviations: MRI = magnetic resonance imaging, SCI = spinal cord injury.

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INTRODUCTION

Acute spinal cord injury (SCI) is one of the most common causes of severe disability and mortality after trauma.[1] Trauma can be associated with significant neurologic damages such as quadriplegia, paraplegia, and even death,[2] and causes low quality of life, cost of care for individual patients, and ultimately be short-lived.[3] On the contrary, the importance of correct and timely diagnosis of patients with incomplete SCI, to prevent progression to complete SCI, has led to early detection and treatment of fractures, hematomas, and other compressive lesions on cord which is very important.

Diagnostic imaging, particularly magnetic resonance imaging (MRI), plays a vital role in the assessment and diagnosis of SCI.[4]

Subtle abnormalities in the bone marrow, the soft tissue, and the spinal cord may not appear on the other imaging techniques, but can be easily detected on MRI.[5]

Early and correct identification of SCI often leads to diagnosis in a timely manner, and avoids unnecessary surgery and medical procedures.[5] Many advantages of MRI, such as high resolution, no bone artifacts, multidimensional capabilities, and select several different plus sequence, provide more accurate diagnosis of SCI. As well as using this method get the more appropriate information about the need of surgical intervention for spinal cord damage and related spinal canal structures, for example significant disc protrusion and the epidural hematoma. In cases of edema, bruising, hemorrhage, and ischemia, MRI findings may be used as a predictive index.[5]

The role of gadolinium-based contrast agents in MRI has been fixed for >20 years. The contrast agents were useful to improve confidence of radiologists about interpreting the images and diagnosis, visualize, and describe the extent of the damage.[6]

More importantly, imaging techniques based on simple morphological data from MRI with contrast agents instead of conventional, are more accurate physiological data from the study hemodynamic processes the central nervous system.[7]

The use of MRI with contrast will provide better diagnosis from the hide lesions of acute phase (eg, edema, infarction, or contusion without hemorragia) which will later associate with severe mylomalacia and severe complications and with timely intervention can prevent from next sever complications (plegia).

Despite the role of MRI with contrast in patients with SCI has not been studied,[8] this is the first study to compare the efficacy of MRI with and without contrast in diagnosis and prognosis evaluation of SCIs.

MATERIALS AND METHODS

The study was approved by the local Institutional Ethics Committee (Code: IR. MAZUMS. REC.94-680). Informed consent was obtained from each patient or his or her relations.

This is a cross-sectional diagnostic study. A total of 40 patients with SCI following a road accident or falling from height were selected. Neurological examinations were performed for patients in the early stages.

For evaluation of SCI in patients with suspected vertebra and spinal cord damage (including cervical spine, thoracic, and lumbar), asked for MRI protocol including MRI with and without contrast in acute phase of injury (first 24 hours). MRI was obtained as our routine center scadjule content of sagittal T 1 and T2 MRI sequence. All patients underwent MRI acquisition on the same 1.5 Tesla System (Signa Excite, GE medical systems, Milwaukee, WI) using the spine coil to maximize the signals.

In this study, Dutarm (gadoterate meglumine) was used as a contrast agent. Two different radiologists independently reviewed and reported the imaging. Only the reports that are consistent with each other were selected.

Inclusion criteria included: the clinical diagnosis of trauma related to the spine and such, limb paralysis, parapelegia, quaderi plegia, and sphincter dysfunction, was evidence on examination, and radiologic finding of vertebral fracture in plain x-ray and computed tomography scan. All patients were in ASIA (American Spinal Injury Association) A, B, C, D classifications of SCI. Exclusion criteria included: pregnant and lactating women, patients who were injured within 2 weeks after liver transplant, patients with pace makers or metal inside the body, and patients who had renal failure (glomerular filtration rate <30). We described the study to the patients and their family, and they signed the consent form. Demographic data, informations about MRI findings included level of spine involvement, type of traumatic injury (fracture-canal stenosis-soft tissue-cord injury), type of cord injury (edema-hemorrhagia-combined),[9,10] and percentage of cord injury (>50%–50% to 75%–<75%) were recorded. All data analyzed with SPSS software. Descriptive statistics methods such as mean used for age and frequency table was used for other variables. We used sensitivity, specificity, positive predictive value, negative predictive value, and positive and negative likelihood for the power of diagnosis. McNemar test used to compare the diagnostic accuracy of MRI in 2 groups.

We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this research

RESULTS

In this study, 40 patients attended, including 25 men (62.5%) and 15 women (37.5%). The average age of men was 43.56 ± 1 8.82 years and women was 48.47 ± 20.45 years. In 29 case (72.5%) accidents and in 11 case (27.5%) falling from the height due to the spine and spinal cord trauma. For these people, MRI with and without contrast was performed in 2 stages. Six patients had edema pattern in MRI images without contrast and 8 patients had edema pattern in MRI with contrast. This difference was not statistically significant (McNemar test: $P = 0.500$). The mean sagittal size of the edema before contrast injection was 142.75 ± 111.63 mm^2 and after contrast injection was 334.87 ± 212. 63 mm^2. The increase in size of the edema after contrast injection was statistically significant ($P = 0.030$) (Table 1) (Fig. 1A,).

Comparison of spinal cord involvement with Transverse parameters and quality measurements also showed no statistically significant difference (Pearson χ^2 test: $P = 0.735$).

The hemorrhage pattern was observed in 2 patients before use of MRI contrast. However, hemorrhage pattern was recorded only in 1 of these 1 patients after the use of contrast.

TABLE 1. The Conflict Has Been Detected in People With Spinal Cord Edema Before and After Contrast Injection

	MRI Methods	
Conflict	**Without Contrast**	**With Contrast**
<50%	**3**	**2**
75% to 50%	**1**	**2**
<75%	**1**	**3**
None	**1**	**1**

MRI = magnetic resonance imaging.

This difference for diagnosis accuracy between MRI with and without contrast was not statistically significant (McNemar test: $P = 1.000$).

The average sagittal size of the hemorrhage before contrast injection on MRI was 166.38 ± 92.80 mm^2 and was 119 mm^2 after use of contrast only in 1 patient. Paired *t* test showed no significant statistically difference ($P = 0.55$). Of this 2 patients the involvement of the spinal cord in a patient, it was impossible to detect. And other patients were diagnosed between 50% and 75% before and after contrast injection.

However, before the use of contrast, the combination pattern was not observed; but after using contrast, a patient was diagnosed. This differences was not statistically significant (McNemar test: $P = 1.000$).

The sagittal size of the lesion was 196 mm^2, and transverse involvement was 50% to 75%. Only 1 case of rupture of the spinal cord was seen in patients with noncontrast MRI and confirmed in MRI with contrast. Both methods recognized the amount of this rupture >50 % (Fig. 2A, B).

The fracture on MRI was diagnosed in 28 (70%) of the patients before contrast injection, and was diagnosed in 27 (67.5%) of the patients after contrast injection (Table 2). This difference was not statistically significant (McNemar test: $P = 1.000$). The number of cases of spinal stenosis was quite similar in the MRI images before and after contrast injection, and equivalent to.[13] The soft tissue injury was observed in 4 cases (10%) before contrast injection and 12 cases (30%) after contrast injection. Although the difference was statistically significant (McNemar test: $P = 0.008$).

The results of affected area of the spine in patients before and after injection of contrast agent in MRI images are shown in Table 2. This difference was not statistically significant (Pearson χ^2 test: $P = 0.996$).

The amount of sensitivity, specificity, positive predictive value, negative predictive value, and positive and negative likelihood in the diagnosis of 3 pattern of SCI by using MRI with and without contrast is shown in Table 3.

The amount of sensitivity, specificity, positive predictive value, negative predictive value, and positive and negative likelihood in the diagnosis of traumatic rupture of the SCI, vertebral fractures, spinal stenosis, and soft tissue damage by using MRI with and without contrast is shown in Table 4.

DISCUSSION

The use of contrast in MRI is useful for detection, sculpture, and description of the extent of the damage, and improves reliability of radiologist about the interpretation of images.[6] So

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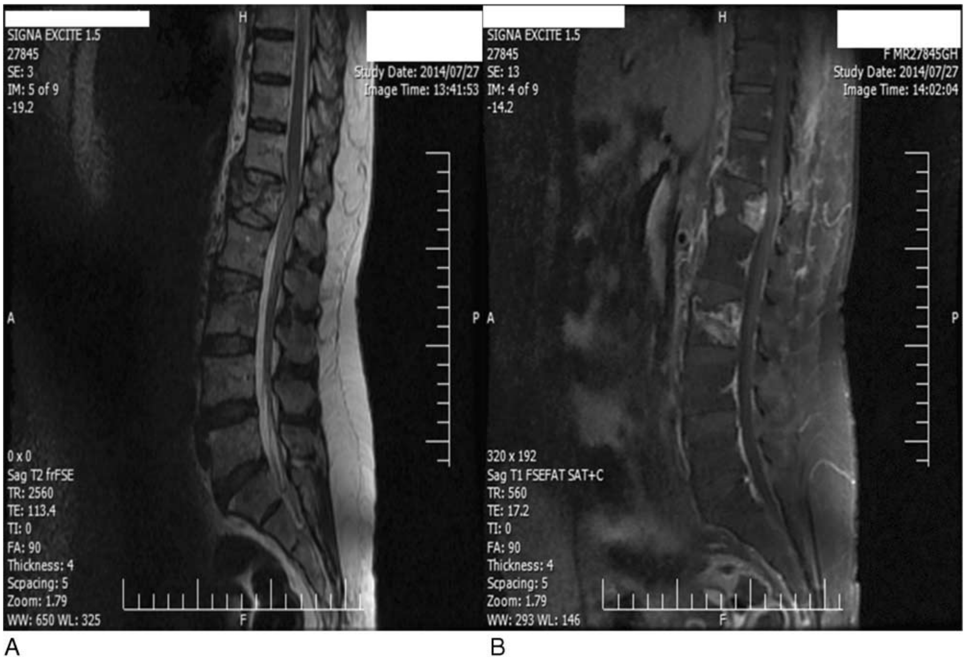

FIGURE 1. (A) Sagittal T2-weighted MRI without contrast. L1 and L3 fractures: size of edema was measured 3.12 mm. (B) Sagittal T1-weighted MRI with contrast. L1 and L3 fractures: size of edema was measured 5.20 mm. MRI = magnetic resonance imaging.

can to better identify the hide lesions of acute stages (eg, edema, infarction, or contusion without bleeding) that associated with later severe complications and mylomalacia, and intervene early prevent the next complications (hemiplegia). Therefore, the choice of imaging sequences as well as a suitable contrast agent can be improved to better contrast imaging and pathological processes involved in acute SCI, including SCI, soft tissue, and ligaments.[9]

Perhaps the most important use of MRI in spinal trauma is noninvasive visualization of the spinal cord. Three models of

FIGURE 2. (A) Sagittal T2-weighted MRI without contrast. Fracture of T11: size of edema was measured 30.8 mm, and spinal cord rupture >50%. (B) Sagittal T1-weighted MRI with contrast. Fracture of T11: size of edema was measured 42.13 mm, and spinal cord rupture >50%. MRI = magnetic resonance imaging.

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TABLE 2. The Number of Patients With Vertebral Fractures in the Area of the Spine, Before and After Contrast Injection

	MRI Methods		
Region	Without Contrast	With Contrast	P
Cervical	**3**	**3**	**996/0**
Thoracic	**9**	**9**	
Lumbosacral	**14**	**13**	
Thoracolumbosacral	**3**	**4**	
Uneffected	**11**	**11**	

MRI = magnetic resonance imaging.

SCI due to trauma have been identified: type 1 representing acute spinal cord bleeding; type 2 represents an edema; and type 3 showed combination of edema and hemorrhage, and is known in many cases as spinal cord contusion.

In this study, were detected spinal cord edema without bleeding in 20%, bleeding or hemorrhage in the spinal cord at 5%, and combination pattern in 2.5% of the cases.

Kulkarni et al reported in the 1987 incidence of this injury patterns study on 37 patients with suspected SCI. Imaging was done in patients from 1 day to 6 weeks after the damage. Spinal cord disorders and abnormalities were observed in 19 patients. In this study, spinal cord injuries had 3 patterns on MRI signal. Acute interaspinal hemorrhage was seen in 5 patients with acute SCI. And a decrease in signal intensity was visible well in the T2 obtained within 24 hours of injury. In 12 of the patients with SCI were diagnosed Spinal cord edema and contusion in high signal intensity on the T2.

Neurological improvement identified in 16 patients, in patients with interaspinal hemorrhage was minimal but patients with spinal cord edema showed significant neurological improvement. They showed MRI 1.5 tesla is also very useful to diagnosis of acute injury, and also very useful to predict the potential of neurological improvement.[10,11]

Bondurant et al in 1990 showed the incidence of this injury patterns using T1 and T2 images in 37 patients with acute SCI, was 43.2% (16 patients) in edema pattern with hyperintensy, 27% (10patients) in hemorrhagic pattern with hypointensy, and 8.1% in contusion or combination pattern with hypointensy in center and hyperintensy around.[12]

Although Parashari et al[5] in 2011 found in 62 patients, with SCI, there is spinal cord edema without hemorrhage in (41.5%)

TABLE 3. The Amount of Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value, and Positive and Negative Likelihood in the Diagnosis of 3 Pattern of Spinal Cord Injury by Using MRI With and Without Contrast

Spinal Pattern Damage	Sensitivity, %	Specificity, %	Positive Predictive Value, %	Negative Predictive Value, %	Positive Likelihood, %	Negative Likelihood, %
Edema	MRI without contrast	75	100	100	94.11	68.4
	MRI with contrast	100	100	100	100	0
Hemorrhagia	MRI without contrast	100	100	100	100	0
	MRI with contrast	50	100	100	.4397	13.0
Combination	MRI without contrast	0	100	0	.597	06.0
	MRI with contrast	100	100	100	100	0

MRI = magnetic resonance imaging.

TABLE 4. The Amount of Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value, and Positive and Negative Likelihood in the Diagnosis of Traumatic Rupture of the Spinal Cord Injury, Vertebral Fractures, Spinal Stenosis, and Soft Tissue Damage by Using MRI With and Without Contrast

Spinal Pattern Damage	Sensitivity, %	Specificity, %	Positive Predictive Value, %	Negative Predictive Value, %	Positive Likelihood, %	Negative Likelihood, %
Spinal cord rupture	MRI without contrast	**100**	**100**	**100**	**100**	**0**
	MRI with contrast	**100**	**100**	**100**	**100**	**0**
Bone fracture	MRI without contrast	**100**	**100**	**100**	**100**	**0**
	MRI with contrast	**42.96**	**100**	**100**	**30.92**	**44.19**
Spinal canal stenosis	MRI without contrast	**100**	**100**	**100**	**100**	**0**
	MRI with contrast	**100**	**100**	**100**	**100**	**0**
Soft tissue damage	MRI without contrast	**33.33**	**100**	**100**	**77.77**	**4.12**
	MRI with contrast	**100**	**100**	**100**	**100**	**0**

MRI = magnetic resonance imaging.

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and areas of bleeding in the spinal cord in (33%), epidural hematoma in (5%), and the normal spinal cord in (26%). Patients with spinal cord edema and hemorrhage areas had more neurological damage and poor prognosis.

So all these studies as well as our study are reported the higher incidence of edema in patients with acute SCI. Then, when we compare the diagnostic accuracy of MRI with and without contrast to detection these 3 patterns of injury, MRI without contrast diagnosed only 6 cases of traumatic spinal cord edema in these patients but after contrast injection, number of patients with this injury increased to 8 patients. That suggests higher sensitivity of MRI with contrast in edema (100% vs 75% MRI without contrast).

In addition to higher sensitivity of the diagnosis, what is the importance of using contrast enhanced, this is exacerbated resolution and higher image clarity. As we have seen, the size of the lesion after injection was significantly greater than the state before the injection on the sagittal images. The higher resolution and larger size image was also observed in 2 other models of SCI, the hemorrhage and contusion or combination pattern. Although hemorrhage pattern of the 2 cases observed by MRI imaging without contrast, only 1 case was observed after injection of contrast, but in the same case, not only the larger size of the lesion, but also its association with the combined pattern was observed. Although we use MRI without contrast, any combination pattern was not seen. As in most studies, including the study of MV Kullkarni, Bondurant, and S. Ramon has been shown, more than 70% of patients with spinal cord edema and contusion will face with an incomplete neurological damage in the future. Therefore, early diagnosis of the lesions is important until to prevent the progress it toward complete and incurable nerve damage.

Although in this study sensitivity for MRI with contrast in the diagnosis of hemorrhage was less than without contrast MRI (50% vs 100%). But it should be noted that the appearance of intensified lesions, in particular, depends on the dose of contrast agent used and the time delay after injection of imaging and imaging sequence.

Usually an increase in lesions recovery achieved with a standard dose of the contrast agent (1.0 mmol/kg) and a delayed imaging technique (taking pictures for 20–40 minutes after injection).[6]

On the one hand, the increasing of delay time shown a higher resolution than the first 5 to 10 minutes after injection.[6] On the other hand, a significant improvement in contrast intensified was found when the higher doses of gadolinium-based contrast agents were used in imaging (2.0–3.0 mmol/kg). This will not only improve the detection of brain and spinal cord tumors and metastatic lesions as small or extremely weak, but as it had been expected the extent of involvement of primary tumors of the CNS is improved and thus it has caused more accurate guidance for the surgical removal and better mark the target volumes for radiation surgery.[6]

So decide on the applicability and advantages of MRI with contrast against noncontrast MRI for SCI patterns, require more studies to learn more and optimize the technique in humans.

Few studies have used the effects of MRI with contrast intensification for traumatic SCI and often use it for investigate and follow-up blood-brain barrier dysfunction of the spinal cord after injury.

However, Ilkan Tatar, in one of the limited studies that we found, using dynamic contrast MRI in postinjury period of induced SCI on 5 C57BL/6 female mice, demonstrated the feasibility of quantitatively mapping regional BSCB dysfunction in injured cord in mouse, and concluded that capability is expected to play an important role in characterizing the neurovascular changes and reorganization following SCI in longitudinal preclinical experiments, but with potential clinical implications.[17]

However, few studies have been recorded in the area of damage to the regional blood spinal cord barrier dysfunction in patients with SCI in humans.

One of the studies with contrast in the traumatic spine lesion was conducted by Terae et al. The study included 15 MRI image with exacerbate gadolinium of cervical spine in 8 patients with SCI. In this study signal the intensification of border intramedullary lesions proved in 3 patients, 1 to 14 weeks after the injury. They concluded that this escalation may reflect new granulation of vessel in a recovery phase. So they suggested this method to be considered in the differential diagnosis of intramedullary spinal cord lesions.[14]

Similar to Terae, Ross et al studied the period and mechanisms of intense gadolinium in diagnosing of lumbar epidural fibrosis, 6 months after SCI surgery. Resonance contrast revealed the enhances of contrast can be differentiated scar tissue from recurrent disk herniation of failed back surgery.[15]

Sze[16] used this method in the detection of intramedullary and intradural lesions, vascular malformations, or demyelination.

We compared the ability of MRI techniques with and without contrast to detect the patterns of spinal cord, also compared the ability of these 2 methods in the diagnosis and prevalence of other disorders of the spine trauma.

In this study, most frequently observed in the spine fracture with a prevalence of 70% and then prevalence of the spinal canal stenosis was 32.5%, soft tissue damage was 30%, and the rupture of spinal cord was 2.5%. Ramon et al[17] were diagnosed patterns of spinal compression in 9 of the 55 patients (16.36%), and the pattern of spinal transsection in 2 cases (3.36%) on MRI.

There is the sensitivity of MRI without contrast in the diagnosis of bone fractures was more than MRI with contrast (96.42 %vs 100%). Although showed the same sensitivity in the diagnosis of spinal stenosis and spinal cord ruptures.

But one of the remarkable results was the high sensitivity of MRI with contrast against MRI without contrast to the diagnosis of soft tissue damage (33/33% vs 100%). Soft tissue damage was diagnosed in 4 patients by without contrast method, whereas in contrast method, it rose to 12 patients and showed the ability of MRI with contrast to exacerbation of soft tissue defects that somehow confirmed findings of Sze about importance of MRI with contrast for difference soft tissue lesions, particularly in the intramodulary and intradural space, vascular malformations, or demyelization.

CONCLUSION

So there is no significant difference between noncontrast and contrast-enhanced MRI in the diagnosis of major injuries (hematoma, edema, etc.), and MRI with contrast is better in soft tissues. And on the other, with considering the economic conditions of the patient and the drug price, we suggest MRI with contrast used only in cases of suspected severe soft-tissue injury. In this case, we had hoped the incidence of disability following SCI in these patients, mostly young people, would be minimal and return to live and work in these patients could be promising heal their and more active communities. One of the limitations our study is small number of samples is the limitations of our study. We recommended to design a prospective study with larger sample numbers.

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