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.

INTRODUCTION

Aacute spinal cord injury (SCI) is one of the most common causes of severe disability and mortality after trauma. Trauma can be associated with significant neurologic damages such as quadriplegia, paraplegia, and even death, and causes low quality of life, cost of care for individual patients, and ultimately be short-lived. 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.

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.

Early and correct identification of SCI often leads to diagnosis in a timely manner, and avoids unnecessary surgery and medical procedures. 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.

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.

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.

The use of MRI with contrast will provide better diagnosis from the hide lesions of acute phase (eg, edema, infarction, or contusion without hemorrhagia) which will later associate with severe myelomalacia 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, 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 T 2 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, paraplegia, quadri 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 mm2 and after contrast injection was 334.87 ± 212. 63 mm2. 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 χ2 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. 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 mm2 and was 119 mm2 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 mm2, 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 χ2 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.2 So
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.

Perhaps the most important use of MRI in spinal trauma is noninvasive visualization of the spinal cord. Three models of
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 interspinal 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 hyperintensity, 27% (10 patients) in hemorrhagic pattern with hypointensity, and 8.1% in contusion or combination pattern with hypointensity in center and hyperintensity around.12

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

| Region           | MRI without contrast | MRI with contrast | P  |
|------------------|----------------------|-------------------|----|
| Cervical         | 3                    | 3                 | 996/0 |
| Thoracic         | 9                    | 9                 |     |
| Lumbosacral      | 14                   | 13                |     |
| Thoracolumbosacral | 3                  | 4                 |     |
| Unaffected       | 11                   | 11                |     |

MRI = magnetic resonance imaging.

| 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.

| 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 | 42.96          | 100                           | 100                          | 30.92                 | 44.19                  |
|                       | MRI with contrast    | 100            | 100                           | 100                          | 100                   | 0                      |
| Spinal canal stenosis | MRI without 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.
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 detect 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 Kulkarni, 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 tumors of the CNS is improved and thus it has caused more tumors and metastatic lesions as small or extremely weak, but as based contrast agents were used in imaging (2.0–3.0 mmol/kg). The higher 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 Kulkarni, 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.

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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.

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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