



## Original Articles

### POST-TRAUMATIC CHRONIC SPINAL CORD INJURY: ASSESSMENT WITH MRI

FARHOOD SAREMI, M.D.

*From the Department of Radiology, Imam Khomeini Hospital, Tehran University of Medical Sciences,  
Tehran, Islamic Republic of Iran.*

#### ABSTRACT

The initial experience concerning the use of magnetic resonance imaging in 94 patients who had sustained chronic cord injury showed its specific advantages over traditional imaging modalities. A variety of 84 cord abnormalities were identified including myelomalacia in 47%, cord cysts in 37%, focal atrophy in 11% and cord transection in 5%. Canal stenosis was seen in twenty-five patients, eleven of which were associated with herniated nucleus pulposus. The time interval post-injury varied from 5 months to 10 years which was independent of the type of injury. Myelopathy was usually observed at the site of initial injury. Although the majority of patients had cervical spine injuries (56%), the thoracic spinal cord appeared more susceptible to cyst development (40%).

**Key Words:** Spinal injury, MRI, traumatic cord cysts, myelomalacia.

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#### INTRODUCTION

A certain number of spinal injury patients experience neurological deterioration months or years after initial trauma. Deterioration may result from instability, persisting cord pathologies, or from the development of a syrinx.<sup>1,2,3</sup> There are now many disabled survivors of spinal injury in Iran, and with the increasing longevity due to new therapeutic methods, this number is increasing. A skeletal survey and even CT myelogram does not provide much information to assess the soft tissue structures and the spinal cord. MRI is considered to be the examination of choice for the chronically-injured spinal cord.<sup>5,6,7</sup> It is found to be of value in determining the extent of cord injury, continued cord compression,

unexpected lesions and follow-up syringes.\* This article reviews a variety of cord lesions, demonstrated by MRI in three different MR centers with newly-installed machines.

#### MATERIAL AND METHODS

Magnetic resonance images of 94 patients who had sustained spinal injuries during the past years were analysed. The study was performed between January 1992 and March 1994. The age, level of injury, length of time post-injury, type of cord lesion and signal characteristics were recorded. The patients ranged in age from 18 to 71 years with a mean of 38 years. They were referred either because of clinical deterioration or because of the development of new clinical symptoms and signs. Some were referred for an opinion regarding their prognosis. The time interval post-injury ranged from 5 months to 10 years. Both complete and

**Address for correspondence:** Farhood Saremi, M.D.,  
Associate Professor of Diagnostic Radiology, Imam Khomeini  
Hospital, Tehran University of Medical Sciences, Tehran, Islamic  
Republic of Iran.

## MRI in Chronic Spinal Cord Injury

Table 1. Cord pathologies according to the site of injury

Level of injury	Myelomalacia	Cyst < 2 cm	Cyst > 2 cm	Atrophy	Transection	Total
Cervical	23	13	2	6	3	47
High Thoracic	9	5	-	1	1	16
Low Thoracic	6	5	2	1	-	14
Lumbar	2	2	1	1	-	6
Total	40	25	5	9	4	83

A single patient with a holocord syrinx was not included.

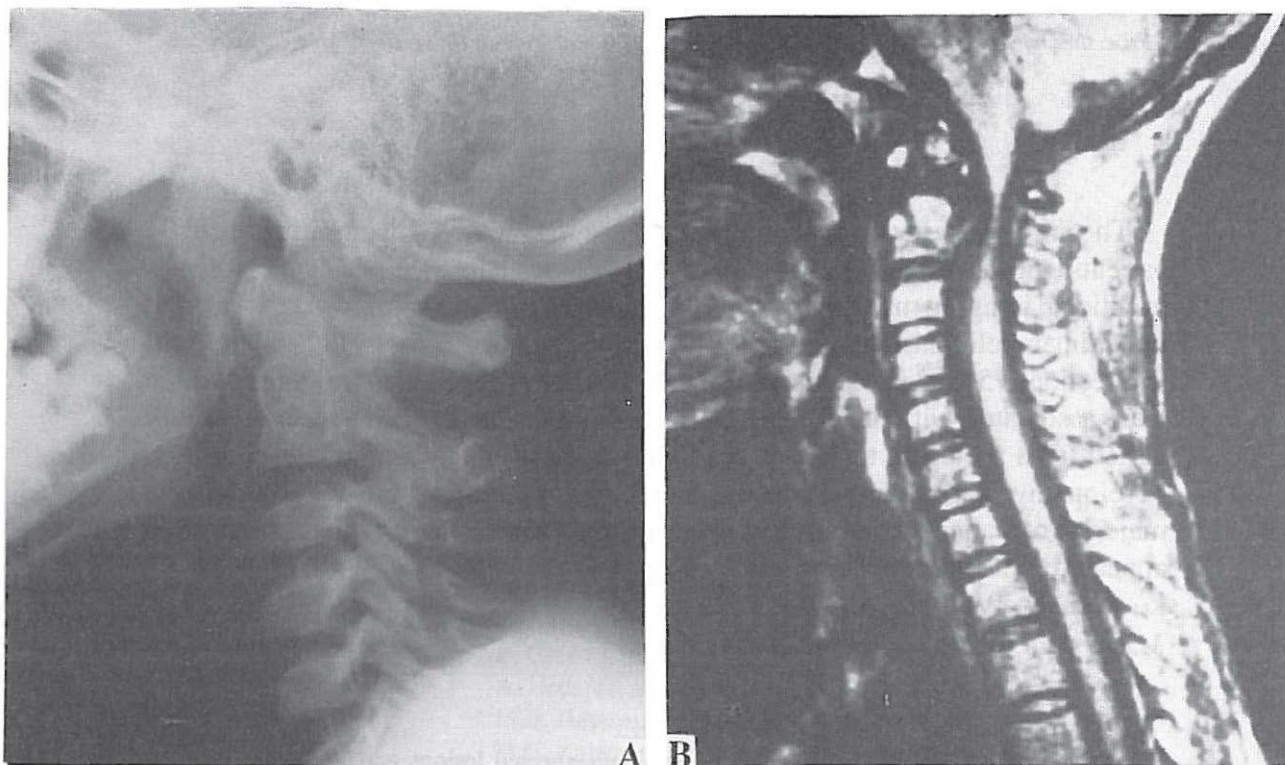
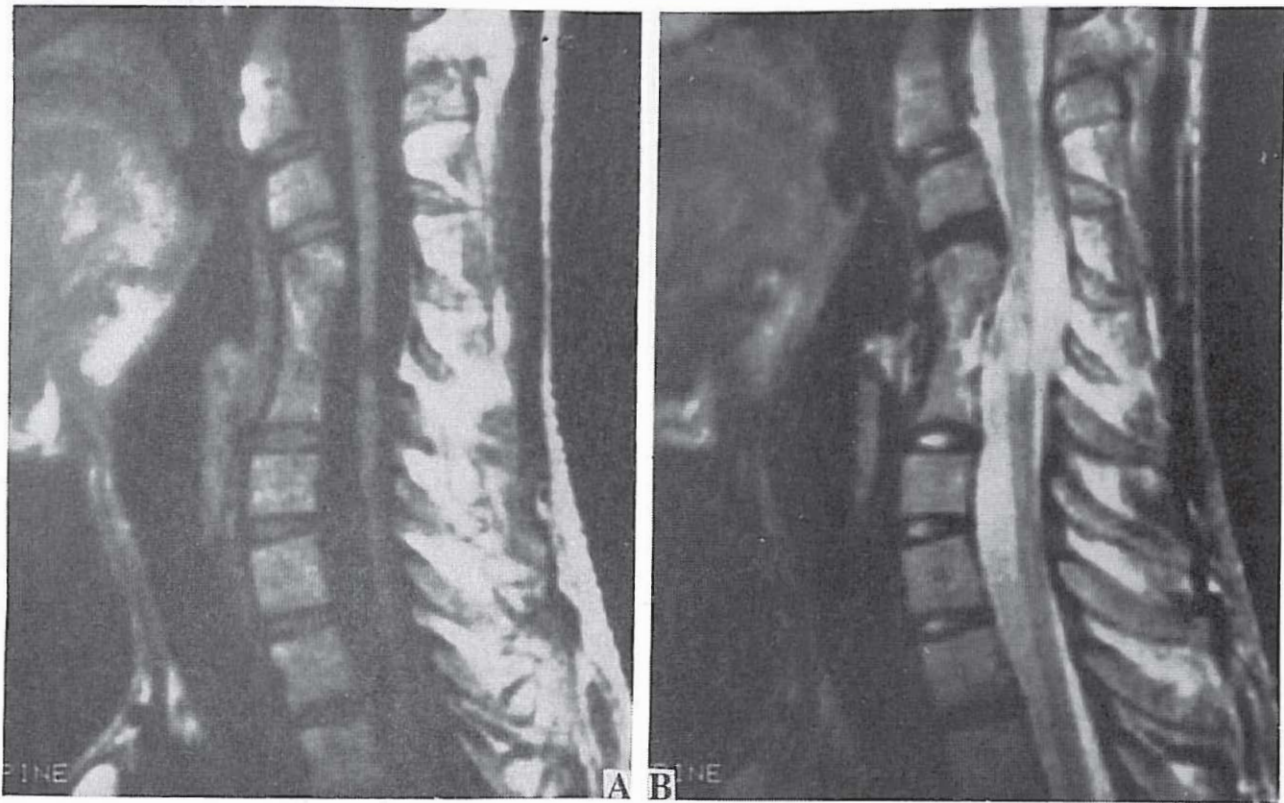


Fig. 1. (a) Normal lateral plain radiograph of cervical spine in a young patient with prior motor vehicle accident. (b) Sagittal T1-weighted MR image demonstrates marked cord atrophy at C2 segment. No signal deterioration was found on T2 images (not shown).

incomplete paraplegias and quadriplegias were seen. 15 patients had been initially treated by regular surgical techniques such as anterior fusion, laminectomy, or posterior stabilization. Most patients had been evaluated by different diagnostic procedures such as plain radiographs, CT, or myelograms. 79 patients were studied with a resistive 0.38-Tesla system, 5 with an 0.5-Tesla superconducting magnet and the remaining 10 patients with a permanent 0.064-Tesla machine at three different centers. Images 5 to 10 mm thick were obtained by using the spin-echo technique. Image sequences consisting of T1, T2-weighted and proton-density were acquired in sagittal views. Appropriate axial images were obtained in some cases. The images were acquired and

displayed on a 128×286 matrix and reconstructed with a 2D Fourier transformation.

A well-defined area of low-signal intensity similar to cerebrospinal fluid on T1W views which becomes high-intensity on T2W images was considered to be a cyst. Lesions with poorly-defined borders and presence of high-signal intensity compared to the cord on T2 and PD-weighted images were interpreted as myelomalacia. In some cases, it was difficult to distinguish a small cyst from myelomalacia because of partial volume averaging. These lesions were differentiated by a special MR myelographic technique incorporated in the resistive magnet operating console.



**Fig. 2.** Association of focal cord atrophy with signal deterioration consistent with myelomalacia in a patient with prior spinal cord injury. (a) Sagittal T1 view, (b) corresponding T2 image.

## RESULTS

The most common cause of injury was motor vehicle accidents and the most common type and level of injury was fracture and/or subluxation from C4 through C6. Motor and sensory loss, increase in spasticity and local pain were common signs and symptoms. The results suggest that post-traumatic progressive myelopathy is independent of the severity of injury. The time interval until development of new symptoms was also independent of the type of cord lesion. Of 94 patients who were assessed with MRI, 84 cases were associated with medullary lesions.

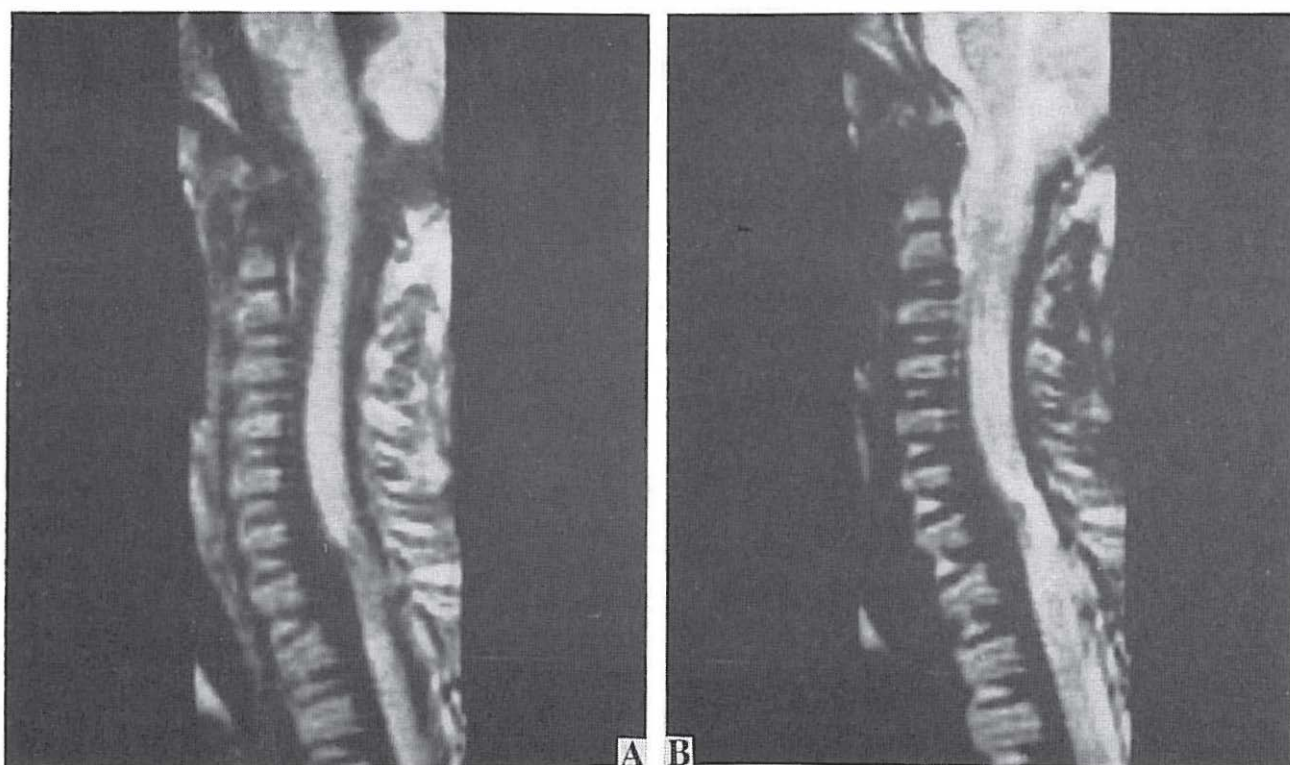
Table I summarizes different pathologies according to the site of injury. A variety of pathological findings were detected. They include myelomalacia in 40 (47%), cord cysts in 31 (37%), focal cord atrophy (Fig. 1) in 9 (11%), and cord transection in 4 (5%) cases. Persisting canal stenosis with variable degrees of cord compression were noted in 25 patients. In 11 out of 25 patients herniated nucleus pulposus was shown to be the causative factor for stenosis. In the remaining patients arachnopathy, fibrosis, retropulsed bony fragment, or subluxation was observed. In two patients, the MRI disclosed odontoid fracture with the fracture fragment causing compression of the cord and canal narrowing. The lesions had not been visualized by conventional radiographs

taken at the time of initial injury. The location and size of cystic lesions are listed in Table II. The majority of patients had a single cyst. In a single patient two separate small cysts were noted. In all cases the cysts appeared to have originated at the level of spinal injury. Although the majority of patients had cervical spine injuries (56%), the thoracic cord appeared more susceptible to cyst development (45%) than other levels. There was a total of 31 cysts, of which 15 were cervical, 12 thoracic, 3 within the conus and one involved the entire cord. Small cysts usually less than 2 cm were identified in 25 patients. 6 patients had large syringes more than 2 cm in size, one of which extended through the whole length of the spinal cord. In this single case the clinical status was far better than that which was expected from the MRI. MRI showed a double-barrelled syrinx in one case. The cord

**Table II.** Location of post-traumatic cysts

Level	< 1 cm	1- 2 cm	> 2 cm	Total
Cervical	5	8	2	15
Thoracic	4	6	2	12
Conus	1	1	1	3
Total	10	15	5	30

A single patient with a holocord syrinx was not included.



**Fig. 3.** Myelomalacic cord damage in a patient with a prior spinal cord injury and a C4 to C6 interbody fusion. Myelomalacic tissue is identified as a focus of low signal-intensity on a sagittal T1-weighted image (a) that becomes high-intense on a matching T2 image (b). It would be difficult in this patient to exclude small cyst cavity without using the MR myelographic technique.

was focally enlarged by the cyst in 8 cases. The cysts were characterized on T1-weighted images as well-defined intramedullary regions of low signal intensity. The signal from the cysts was usually homogenous. Two syringes showed foci of signal void inside their cavity on T2-weighted images indicating pulsatile flow. Mixtures of cyst, atrophy, myelomalacia, or focal stenosis were not unusual. Cord atrophy below the cyst was present in one patient. In six patients MRI suggested the presence of myelomalacia surrounding a small intramedullary cyst. Three cases were classified in cyst groups as shown in Table II. Two cases showed myelomalacia with associated cord atrophy (Fig. 2).

### DISCUSSION

Tremendous progress has been made in the diagnosis of spinal injuries<sup>9</sup> and the challenge, in the next decade, is to prevent further deterioration. It is now believed that progressive neurological deterioration is a common finding in chronic spinal injury. Piepmeyer et al.<sup>10</sup> have found this to be around 12.5% over 5 years. 10% of spinal cord injuries deteriorate from Frankel grading B to A in the first year.<sup>11</sup> This represents a significant number of patients if the

existing number of disabled persons from spinal cord injury is taken into account. For example, in the United States there are now 250,000 disabled survivors of spinal injury.<sup>12</sup> Therefore, the ability to clarify the type of myelopathy in such patients is of great significance. Deterioration may result from instability, persisting compressive pathologies or from the development of syrinx.

A large number of imaging techniques are available for studying the spine and its contents. Conventional investigations and even CT myelography has been found to be inadequate in predicting the patients who are likely to deteriorate. Stevens et al.<sup>13</sup> demonstrated that contrast accumulated after CT myelography in only 58% of surgically-proven cysts. It is also now well recognized that contrast may be taken up in areas of myelomalacia giving false-positive results.<sup>4</sup> MRI has been shown to be more specific than delayed MCT in evaluating myelomalacia and cysts. In the study of Quencer et al.<sup>14</sup> the results of MRI were compared with delayed metrizamide CT. It was found that MRI demonstrated the intramedullary abnormalities in the injured spinal cord more accurately than did delayed metrizamide CT because the former could separate myelomalacia from a post-traumatic spinal cord cyst, a differentiation which was frequently difficult with CT.

There has been considerable interest in the role of MR of

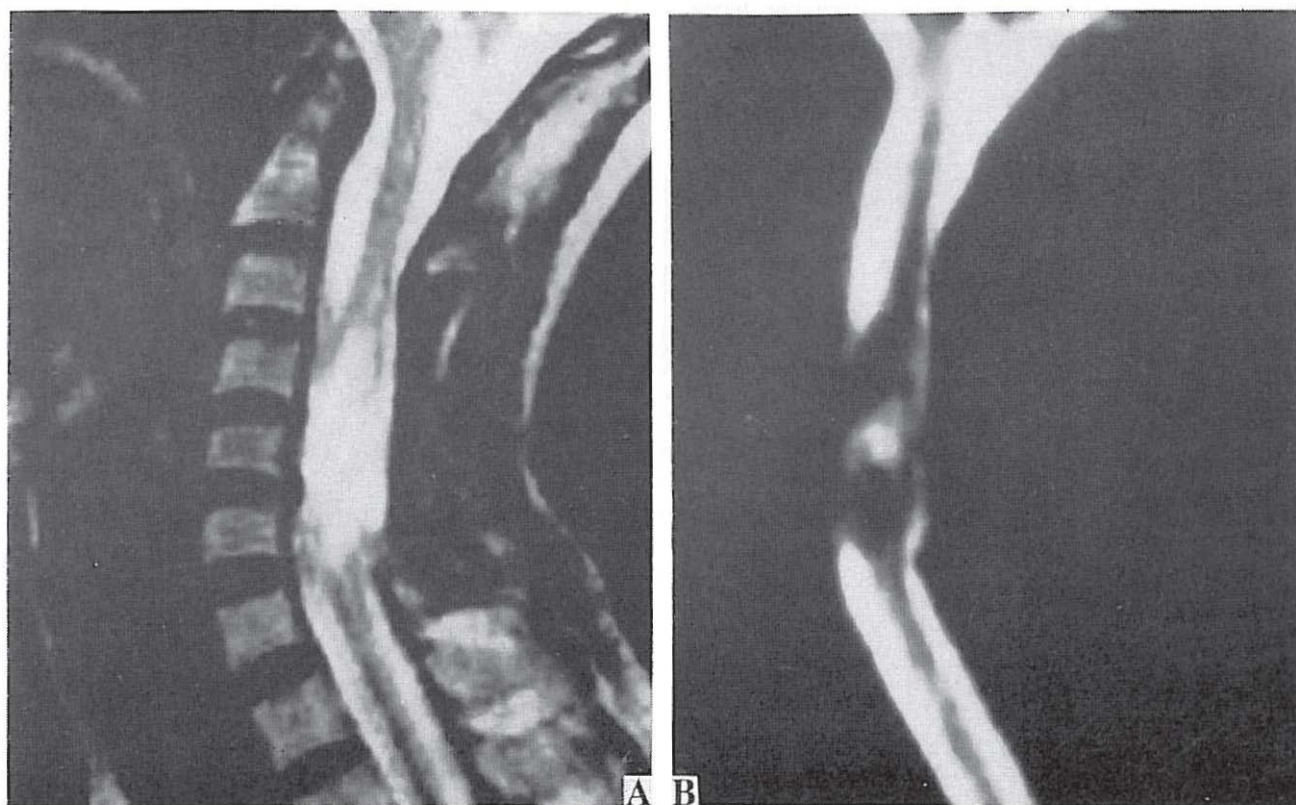


Fig. 4. Value of MR myelogram for differentiation of myelomalacia from cord cyst. (a) Sagittal T2-weighted image in a patient with chronic cord damage and laminectomies reveals marked abnormal increased cord signals from C3 to C6 levels. It would not be easy to distinguish myelomalacia from cyst. (b) MR myelogram clearly demonstrates the presence of a small high-signal cyst within the signal-void of myelomalacic tissue.

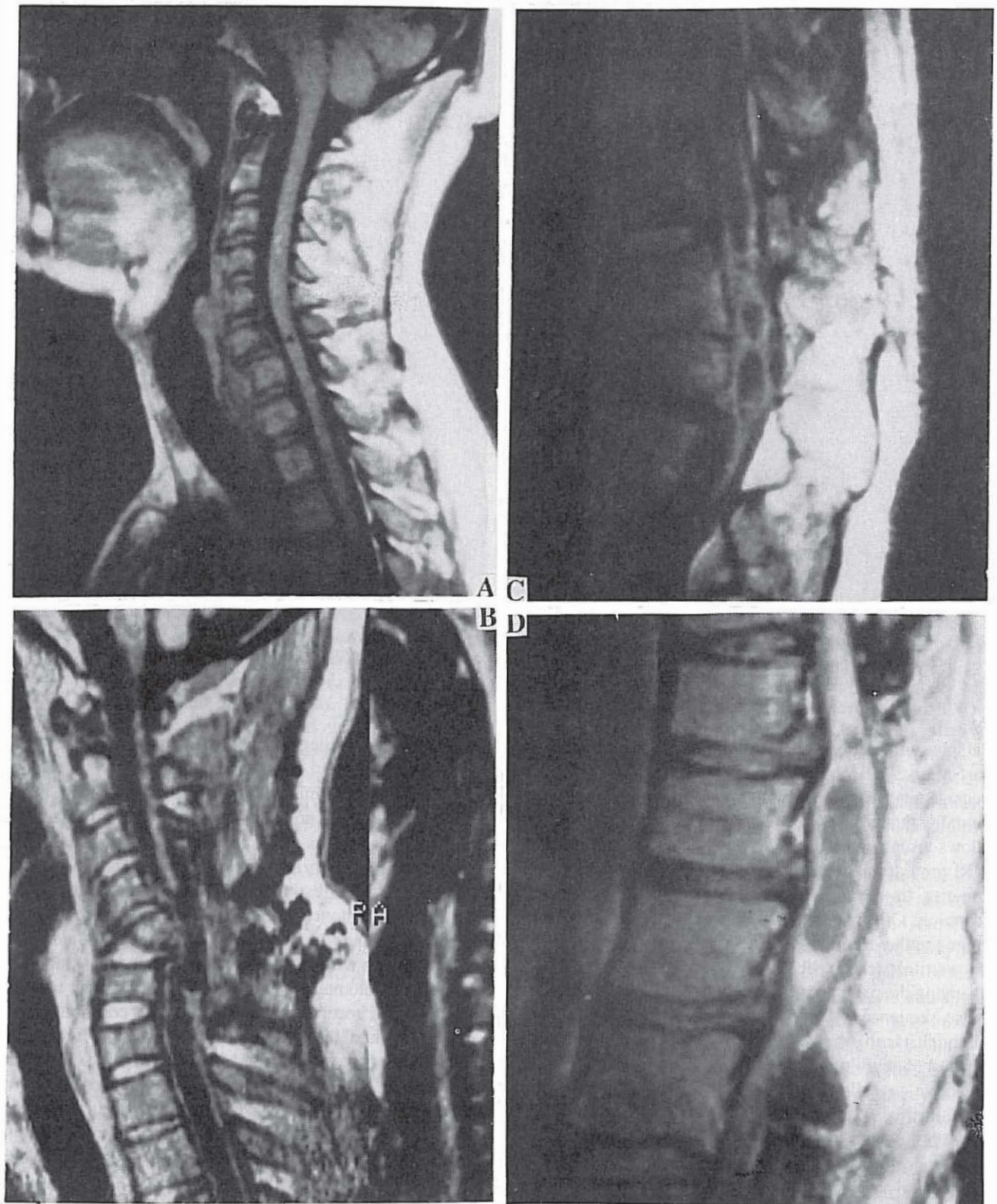
the spine with respect to other imaging modalities during the past years. MRI has been considered essential in the management of patients with spinal injury. It is the only modality that provides a direct image of the spinal cord and allows visualization of the intramedullary disease process. MRI provides accurate delineation of anatomic detail and superior tissue characterization as compared with CT scanning. Other advantages for evaluation of an injured spine are the excellent contrast resolution, the absence of bone artifacts, the feasibility of multiplane imaging without changing the patient's position, and the choice of different pulse sequences.<sup>15,16</sup> No ionizing radiation is used and although it is an expensive procedure, when we bear in mind the cost of neurological deterioration, it is much more cost-effective to follow-up spinal injury patients with this modality.<sup>12</sup>

While axial MR images in this series of patients provided poor spatial resolution, sagittal images were of excellent quality and provided all the necessary information regarding the myelopathies.

Patients with spinal cord injuries may have ferromagnetic stabilization implants, but some of these devices may be sufficiently nonferromagnetic so that no significant artifact will occur. The presence of wire sutures produced MR

artifacts in one patient in this study but did not degrade the picture of the spinal cord.

A common clinical and radiologic problem is the preoperative differentiation of myelomalacia from intramedullary cysts. MRI, with its proven ability to detect cystic intramedullary abnormalities is the obvious radiologic study of choice to distinguish myelomalacia from cord cyst. Although hematomyelia may later break down and become cystic, explaining the initial stage of development of cord cysts, trauma without resultant cord hemorrhage may also create a myelomalacic core of tissue which may undergo necrosis and become cystic.<sup>1,4</sup> Factors that contribute to the development of this myelomalacic area include ischemia in the regions of marginal blood supply, the action of released lysosomes on the cord tissue and increased levels of norepinephrine which cause diminished perfusion of the spinal cord. Rossier et al.<sup>17</sup> believed that the dorsal columns are the most susceptible areas. Whatever the cause, pathologic studies show surrounding edema in the region of myelomalacia with varying degrees of gliosis and microcytic changes which contribute to prolongation of T1 and T2 relaxation times. The result of these changes is decreased signal intensity on T1-weighted images and a bright signal area on T2-weighted views (Fig. 3). Myelomalacia will be



**Fig. 5.** Various shapes of post-traumatic spinal cord cyst in different patients. A cord cyst is usually seen on T1 views as a low-signal area similar to the CSF signal. (a) Small well-defined intramedullary cyst at C6-7 level. (b) Caudal extension of a large intramedullary syrinx from the site of a C5 burst fracture. (c) Rostral extension of a holocord syrinx from the level of T12-L1 discectomy is noted. (d) Expansile cyst in a patient with prior thoracic spine injury and laminectomies. The cyst is limited by herniated discs on both sides.

relatively hyperintense compared to the normal spinal cord on proton density images. Cysts, on the other hand, will be hypointense or isointense relative to the spinal cord on proton density views and hyperintense on T2-weighted images.<sup>2</sup> With increasing T2-weighting, CSF-containing structures including cord cysts become hyperintense compared to both the normal spinal cord and myelomalacia. This is the basis of the MR myelogram, in which a heavily T2-weighted technique is used, showing only the fluid containing structures including CSF and cord cysts. The author has found this myelographic technique to be the best procedure in order to exclude small cysts from myelomalacia, a differentiation which may be difficult to accomplish by the usual sequences due to the partial volume-averaging phenomenon and signal characteristics of the fluid as well (Fig. 4).

The most important and interesting sequel to spinal injury is the development of post-traumatic syringomyelia. It is believed that any new symptoms developing in a patient with spinal cord injury should alert the clinician to the possibility of a developing syrinx.<sup>4</sup> The increasing amounts of fluid within the cyst may be produced by cells of gliotic tissue that line the cyst wall, or CSF may enter the cyst from enlarged Virchow-Robin spaces.<sup>2,4</sup> The quoted incidence of the development of a cyst within a previously damaged spinal cord ranged from 0.9% to 3.2%.<sup>1,4,15</sup> With the introduction of MR, it is certainly being recognized more frequently. Backe et al.<sup>2</sup> found the incidence of post-traumatic cyst to be around 50%. In the study presented here it was detected in 30 of 82 (36.5%) patients with MR-proven cord lesions. The onset of symptoms in a post-traumatic syrinx is extremely variable; Lyons et al.<sup>18</sup> stated 18 months as being the average. Quencer et al.<sup>14</sup> noted in their series that it varied from one month to two years. In the author's study this was found to be totally unpredictable and ranged from 5 months to 10 years. This indicates that cysts may begin to form shortly after the original injury. It is therefore advisable that MRI studies be performed before symptoms appear in order to prevent further cord damage.

The length and width of the cysts vary considerably (Fig. 5). In this study 10 cysts were observed which measured less than 1 cm in length and one which extended the entire length of the cord. The majority of cysts in this study were found in the dorsal cord as had been stated by Quencer et al.<sup>14</sup> 32% of cervical cord lesions were shown to be cystic, while in the thoracic area this was calculated around 40%. The rich capillary blood supply to the gray matter, particularly the dorsal horns, makes this a likely location for post-traumatic hemorrhage and secondary cystic changes.<sup>2</sup>

It is suggested that a cyst-subarachnoid shunt is indicated if a significant cyst is present in an accessible intramedullary location.<sup>16</sup> Conservative treatment is acceptable if the disability is tolerable.<sup>2</sup> Quencer et al.<sup>4,14</sup> advocated shunting of cysts which were symptomatic, as well as large and asymptomatic syringes. The cyst can be observed with

serial and yearly MR imaging. If there is any further increase in size of the cyst suggesting the development of a syrinx, then a drainage operation should be performed.<sup>5</sup>

In summary, it seems that with the continuing technologic advances in the field of MR imaging, particularly with the introduction of new surface coils and fast scanning techniques,<sup>19</sup> many would agree that MRI is the only preoperative study needed to distinguish different types of cord lesions in patients with progressive neurologic symptoms who have sustained prior severe cord injury.

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