Prognostic significance of magnetic resonance imaging in the acute phase of cervical spine injury

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Fifty-seven patients with acute cervical spine injuries and associated major neurological deficit were examined within 2 weeks of injury by magnetic resonance (MR) imaging. All patients had abnormal scans, indicating intramedullary lesions. This study was undertaken to determine if the early MR imaging pattern had a prognostic relationship to the eventual neurological outcome. Three different MR imaging patterns were observed in these patients: 21 patients had patterns characteristic of intramedullary hematoma (Group 1); 17 had intramedullary edema over more than one spinal segment, but no hemorrhage (Group 2); and 19 had restricted zones of intramedullary edema involving one spinal segment or less (Group 3).

The neurological state was determined using standard motor index scores at admission and at follow-up examination. Characteristically, the patients in Group 1 had admission motor scores significantly lower than the other two groups. At follow-up examination, the median percent motor recovery was 9% for Group 1, 41% for Group 2, and 72% for Group 3.

These studies suggest that the MR imaging pattern observed in the acutely injured human spinal cord has a prognostic significance in the final outcome of the motor system. It is only when an accurate prognosis can be given at the outset that useful treatment data might be collected for homogeneous injury groups, and accurately based long-term planning made for the best patient care.

KEY WORDS • spinal cord injury • magnetic resonance imaging • cervical spine • vertebral fracture

Injuries to the cervical spine are commonly associated with devastating spinal cord injuries. Early in the course of traumatic spinal cord dysfunction, concern is given to the eventual capabilities of the patient, and long-term goals need to be established early for effective rehabilitation. Currently, the treating physician has only the physical examination to assist him in judging the long-term consequences of the injury, and can only speculate at the eventual outcome. Indeed, some patients recover far beyond that anticipated by the initial examination. Conversely, some patients improve very little from what at first appears to be a minor injury. In the awake, cooperative patient, much can be said regarding the potential for recovery based on the physical examination alone. This is particularly true if the examination remains consistent when repeated over a period of 72 hours. Those patients who have complete motor and sensory loss distal to their injury after 72 hours have little or no chance of distal motor recovery, although they may recover some function around the zone of injury.²,⁵-⁸,₁₀,₁₅,₁₈,₁⁹ It is less clear how much neurological recovery occurs distal to the zone of injury when the initial examination shows an incomplete injury.

Often, the physical examination is not reliable during the acute phase of the injury due to associated injuries, chemical intoxication, or multisystem involvement. In these patients it is difficult to evaluate the extent of the acute injury, much less make any judgment about eventual outcome. In this study, we have evaluated an objective imaging technique, magnetic resonance (MR) imaging, as a potential prognostic indicator of eventual motor outcome, and compared the lesion found on the initial study to the percent of motor recovery.

Clinical Material and Methods

This study included 57 patients with closed cervical spinal cord injuries who were admitted to the Regional Spinal Cord Injury Center of the Delaware Valley between September, 1987, and January, 1989. Patients
Prognostic value of MR imaging in cervical spine injury

Fig. 1. Magnetic resonance T2-weighted images of the cervical spine, sagittal view. Left: Image obtained 1 day following a motor-vehicle accident in a Group 1 patient demonstrating extensive intramedullary hemorrhage at C5-6 with a surrounding zone of edema. The admission motor score for this patient was 1, with a follow-up motor score of 10 at 13 months. This patient underwent posterior interspinous process wiring and fusion for ligamentous instability. Center: Image obtained in a Group 2 patient showing a traumatic disc herniation at C5-6. Centered around this disc herniation is an extensive zone of intramedullary edema extending from C-4 to C-7. There is also evidence of disruption of the interspinous ligaments between C-5 and C-6. This patient had an initial motor score of 28. Nineteen months following an anterior C5-6 discectomy and fusion and subsequent posterior C5-6 fusion, his motor score had improved to 98. Right: Image obtained 4 days after a bicycle accident in a Group 3 patient. A focal area of edema is apparent in the spinal cord adjacent to the C5-6 disc, and is restricted to one spinal segment. This patient was treated nonsurgically. Motor score improved from 31 on admission to 88 after 6 months.

with penetrating spinal injuries were excluded because the mechanism of injury to the cord is quite different from that of closed injury, and the metallic fragments from these injuries cause large signal artifacts. All patients had an abnormal neurological examination associated with their injury, and all underwent MR imaging during the acute phase of the injury on a 1.5-tesla GE scanner* with sagittal T1- and T2-weighted and proton density images. Axial gradient recall acquisition in the steady state (GRASS) images were obtained in most cases. For diagnostic purposes, we found the T2-weighted images to be most valuable. The T1-weighted images tend to understate pathology in the cord, particularly the presence of cord edema. This is likely because, in this pulse sequence, water density tends to be almost indistinguishable from the surrounding spinal cord. Intramedullary hemorrhage can occasionally be seen as high signal intensity on this sequence. In all cases, MR imaging was obtained as soon as feasible after the patient had been admitted, the spine stabilized, and life-threatening injuries had been ruled out. Since some patients are initially admitted to an outside hospital prior to transfer to our institution, the average time from injury to MR imaging in this series was 6.5 days. Patients admitted directly to our hospital typically undergo MR imaging within the first 24 hours. All patients with spine dislocations had closed reduction of their dislocation via skull-tong traction prior to MR imaging. Those patients with unstable injuries were maintained in an MR-compatible halo vest during the scanning process. One patient was manually ventilated during the procedure. There were no instances of neurological worsening attributable to this process.

The presence of traumatic myelopathy was judged according to the classification of Frankel, et al. All patients with Frankel E injuries (normal neurological examination or root involvement only) were excluded from the study.

Three categories of intramedullary signal were determined according to the presence of intramedullary hematoma or spinal cord edema. Patients were divided into the three groups based on intramedullary spinal characteristics in the spinal cord using patterns previously described by Schaefer and coworkers. The 21 Group 1 patients had intramedullary lesions of low signal intensity on T2-weighted images that corresponded to areas of intramedullary hematoma (Fig. 1 left). Group 2 consisted of 17 patients with intramedullary lesions of high signal characteristics on T2-weighted images that corresponded to areas of edema without focal hemorrhage; in these patients this lesion extended for greater than one spinal segment (Fig. 1 center). Patients in Group 3 had similar high signal lesions on T2-weighted images, but the lesions were restricted to a single spinal segment or less (Fig. 1 right).

Total motor scores, allotted based on the criteria of the American Spinal Injury Association, were obtained for each patient at admission and at follow-up examination, and were analyzed for statistical significance in regard to neurological improvement. Motor scores were determined by grading each of the major motor nerve

* Scanner manufactured by GE Signa, Milwaukee, Wisconsin.
groups in each extremity on a 0 to 5 scale, and totaling the score for each patient. Neurological improvement was based on percent recovery as described by Lucas and Ducker.\textsuperscript{13} Statistical differences for percent recovery within groups was determined using a Kruskal-Wallis test, with between-group analysis determined with a Mann-Whitney U test. Results were analyzed at a 95% confidence level.

<table>
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<th>Group 2</th>
<th>Group 3</th>
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* Magnetic resonance appearance: Group 1 = intramedullary hematoma; Group 2 = intramedullary edema extending > one segment; Group 3 = intramedullary edema extending ≤ one segment. For further description see text.

Results

The study population included 48 males and nine females, with an average age of 27.2 years for Group 1, 43.5 years for Group 2, and 38.4 years for Group 3. There were no significant differences among the groups in regard to length of hospital stay or interval from injury to admission. The decision for surgical treatment was based on mechanical stability of the spine as well as the presence of persistent neural compression by bone, vertebral disc, ligament, extra-axial hematoma, or other compressive elements. Operative treatment of the different groups is summarized in Table 1. Magnetic resonance imaging was useful in determining the surgical approach, particularly in view of its ability to image acute disc herniation. Indeed, because of the accuracy of MR imaging in demonstrating disc pathology, cord compression, and intrinsic cord injury, we have virtually eliminated myelography as a diagnostic tool in acute spinal cord injuries; however, computed tomography remains superior for diagnosing fractures, particularly complex fractures of the posterior arch.

Motor scores were calculated at the time of admission, and again at the last follow-up examination, and the percent recovery was calculated. It was of interest that statistical differences existed in regard to age between Groups 1 and 2 (p < 0.02) but not between the remainder of the groups, and that admission motor scores for Group 1 were significantly lower than for the other two groups (p < 0.005) (Table 2). Follow-up periods ranged from 2 to 18 months (mean 7.8 months). Follow-up duration is somewhat misleading since patients were followed until they had achieved normal or nearly normal motor recovery, so those patients who had rapid return of motor function had short follow-up periods. In those patients who had little motor recovery, the follow-up data were obtained at the latest possible date.

Group 1

Of the 21 patients who had intramedullary hematoma on their initial MR image (Group 1), one patient regained a functional level of motor recovery distal to the level of his injury and another regained movements...
that were nonfunctional. Both patients had very small focal hematomas in the cord surrounded by a zone of edema (Fig. 2). All other patients had extensive intramedullary hemorrhage. The median admission motor score for this group was 7 (mean 12.1). The average follow-up period for this group was 9 months with a mean follow-up motor score of 14. There was no statistical difference between admission and follow-up motor scores. The median percent recovery for the patients in this group was 9% (Table 3).

Group 2

The group of 17 patients with intramedullary signal characteristics that corresponded to extensive zones of edema (> one spinal segment) fared better, with a median admission motor score of 25. This is statistically significant from the median admission motor score in Group 1 (p < 0.005). Median follow-up motor score for this group was 40 with a median percent recovery of 41% (Table 3). This difference in median recovery is also significant with respect to Group 1 (p < 0.02).

Group 3

The group of 20 patients who had small focal areas of edema in the cord fared much better than either of the other two groups. The median admission motor score for this group was 32, which was significantly different when compared to Group 1 (p < 0.001) but not when compared to Group 2. This group of patients had a median percent recovery of 72% (Table 3), with a mean of 62.5%. The percent recovery for this group is significant when compared to both Group 1 (p < 0.001) and Group 2 (p < 0.01). It is of interest that, while Groups 2 and 3 had little difference between the median admission motor scores, there was significant difference in median percent recovery between the two groups. It is clear from the data that those patients who suffer spinal cord injury severe enough to cause extensive intramedullary hematoma are unlikely to achieve significant recovery distal to the zone of injury. The results of analysis of the percent recovery among the three groups are summarized in Table 4.

Discussion

Evaluation of recovery in quadriplegic patients is generally judged in the literature in terms of functional capacities. Little has been written regarding the actual motor outcome from traumatic quadriplegia. In most reported series, eventual outcome is based on motor classifications such as the systems of Frankel, et al.,7 or Klose, et al.,11 which tend to group patients into similar categories of function. Other classification systems exist based on indices of function, for example the Barthel index.14 Only sporadic reports of the percentage of motor recovery have been published15-13 and, in these, no report to date has used objective imaging techniques to quantify the probability of percent motor recovery.

Lucas and Ducker14 described an equation for determining motor index recovery. In their series of patients with complete injuries, 85% remained complete and 11% to 15% regained some motor function in the lower extremities, with less than 3% eventually able to walk independently. These data correlate well with other published reports on recovery rates. Their patients were evaluated clinically at admission and again at follow-up examination, and the percent recovery rates were obtained for a variety of groups based on clinical syndromes. No determination was made, however, as to which patients would be likely to improve and might therefore benefit from aggressive early therapy.

In our series, of the patients who had intramedullary hematoma on their admission MR image, only one patient regained useful motor function distal to the zone of injury. Another regained nonuseful function distal to the zone of injury. Each of these patients had a very small focal hematoma in the cord, surrounded by a localized zone of edema that correlates well with the Type III lesion described by Kulkarni, et al.12 The remaining patients in this group had rather extensive hemorrhage in the cord and none regained useful motor function distal to the zone of injury. It seems, therefore, that not all hematomas in the cord have a dismal prognosis for recovery, and that a small focal hematoma such as that seen in these two patients may well be associated with a different and possibly much higher rate of recovery. Since this type of lesion is seen relatively infrequently, sufficient numbers for statistical analysis are not available at this time, but it seems that these patients should be considered as a separate subgroup in terms of prognosis. Ideally, serial MR imaging would be helpful in order to follow the evolution of
cord injury and recovery, both prior to and following operative decompression and fusion. Unfortunately, surgical management of these injuries invariably involves the use of metallic internal fixation devices, rendering postoperative MR imaging virtually useless for interpretation of cord changes due to signal artifact from the metal. We have not used titanium or other MR imaging-compatible internal fixation devices at our institution.

Current treatments for spinal cord injury center primarily on treatment of the vertebral column. Little advance has been made in the treatment of the injured cord itself. Even with the results of the recent National Acute Spinal Cord Injury Study on the efficacy of large doses of methylprednisolone, improvement in recovery, while statistically significant, is not dramatic. Prior to the development of MR imaging, no modality was available to depict accurately the injury to the cord itself. Because of this, patients were categorized into groups based on clinical syndromes and this was the basis for clinical research. It is now clear that MR imaging, with its accurate delineation of the spinal cord injury, will improve the way we categorize patients with traumatic spinal cord injuries and may have significant bearing on the initial management of these patients. Certainly, new treatments can best be tested for efficacy when applied within a homogeneous patient injury group.

Intramedullary lesions following acute closed spinal cord injuries have been described. It is known that, within hours of the injury, small petechial hemorrhages appear in the central gray matter surrounded by extensive zones of edema. These petechial hemorrhages are sufficiently small that, even with high-resolution MR imaging, they are not distinguishable and only the signal characteristics of edema are discernible. It is likely that, as methods are developed to improve the resolution of MR imaging, such a distinction may be seen radiographically and a clearer understanding of the injury process may be obtained.

Conclusions

We have demonstrated that MR imaging in the acute phase of cervical spine injury can be predictive of the eventual motor recovery of the patient. Because previous studies have categorized patients into nonhomogeneous groups, it is not surprising that current studies report similar results in terms of recovery compared with studies of several decades ago. To date, the study groups have been defined on a clinical basis related to degree of muscle weakness or sensory loss on clinical examination. Magnetic resonance imaging offers a very precise method of identifying the magnitude of the anatomical injury, therefore patients with similar types of intrinsic cord lesions can be grouped with apparently very different rates of recovery based on these lesions. It is clear from the data that those patients with extensive intramedullary hemorrhage have a very poor prognosis, while those with no hemorrhage have a much higher rate of recovery. This remains true in spite of the initial neurological examination. We believe that MR imaging can currently augment the clinical examination in estimating the prognosis for recovery. This imaging technique also provides a very specific method of categorizing patients into homogeneous groups that is independent of the cooperation of the patient, and is therefore likely to be more desirable for research purposes.

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References

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