Traumatic cervical cord injury at C3–4 without radiographic abnormalities: correlation of magnetic resonance findings with clinical features and outcome

M Takahashi, Y Harada, H Inoue
Department of Orthopaedic Surgery, School of Medicine, Okayama University, 2-5-1 Shikata-chou, Okayama City, Okayama 700-8558, Japan

K Shimada
Department of Orthopaedic Surgery, Okayama Rosai Hospital, 1-10-25 Chikkounidori-machi, Okayama City, Okayama 702-8055, Japan

ABSTRACT

Purpose. Clinical features and outcomes of 43 patients at the Department of Orthopaedic Surgery, Okayama Rosai Hospital, Okayama, were studied prospectively. These patients were not found to have radiographic abnormalities but magnetic resonance images showed acute cervical spinal cord trauma at the C3–4 disc level.

Methods. Magnetic resonance images were analysed at presentation (immediately after the injury) and subsequent follow-up visits (at subacute and chronic stages, respectively) in an attempt to correlate imaging findings to clinical features and outcomes, respectively.

Results. The injury mechanism was usually a hyper-extension of the cervical spine. The level of neurological involvement was assessed in 9 patients with complete tetraplegia: the motor level was C5 in 6 patients and C4 in 3, whereas the sensory level was C5 in 7 patients, C4 in one, and C3 in one. Respiratory dysfunction in patients with severe paralysis, or numb and clumsy hands in patients with incomplete paralysis were the characteristic clinical features of cervical spinal cord injury at these lesions. Three patterns of signal change on magnetic resonance images were observed in patients with spinal cord injury at C3–4. A low-intensity area on T2-weighted images in the acute stage indicated a poor prognosis, while a high-intensity area at 2 to 3 weeks after injury indicated some degree of permanent paralysis.

Conclusion. The serial signal changes of magnetic resonance images and the clinical severity or outcome seemed to be well correlated.

Key words: cervical cord injury; magnetic resonance imaging; treatment outcome

Address correspondence and reprint requests to: Dr M Takahashi, Department of Orthopaedic Surgery, Iwakuni National Hospital, 2-5-1 Kuroiso-chou, Iwakuni City, Yamaguchi 740-0041, Japan. E-mail: r-murbo@mx9.tiki.ne.jp
INTRODUCTION

Since the advent of magnetic resonance imaging (MRI), the level and extent of spinal cord damage can be clearly displayed in patients with traumatic acute spinal cord injury. Several studies have reported that the frequency of signal changes on MRI at the C3–4 disc level is significantly higher than at any other level in adult patients with traumatic cervical spinal cord injury without radiographic abnormalities.1,2 At our institution, the most common site of such signal changes in patients with cervical spinal cord injury without radiographic abnormalities was also at the C3–4 disc level (52% of all such patients).3 There is little published in the literature, however, about the clinical features and outcomes in patients with cervical spinal cord injury without radiographic abnormalities. This study investigated the clinical features and outcome among such patients, the characteristic MRI features of this type of injury over time, and correlations of MRI features with patients’ clinical features and outcomes.

MATERIALS AND METHODS

From January 1993 through December 2000, 82 patients presented to the Department of Orthopaedic Surgery, Okayama Rosai Hospital, Okayama, with cervical spinal cord injury but no radiographic abnormalities. Of these 82 patients, 43 (41 males and 2 females) had traumatic spinal cord injury at the C3–4 disc level on MRI. The mean patient age was 63.4 years (range, 26–89 years).

Paralysis at the time of injury was graded as A in 9 patients, B in 25, and C in 9, on the basis of the International Medical Society of Paraplegia (IMSOP) scale.4 The mechanism of injury comprised downfalls (n=17), motor vehicle accidents (n=13), falls (n=8), and other causes (n=5). Some of these patients had facial injury or lacerations to the face or scalp, which suggested that their injury had resulted from hyperextension of the cervical spine. All patients were treated conservatively, and were followed up for one year. MRI was first performed within 48 hours of injury, and it was subsequently performed after approximately 3 weeks, 3 months, 6 months, and one year. Images were obtained using a 1.5-T superconducting magnetic resonance scanner with a surface coil. T1-weighted images were obtained with an echo time of 17 ms and a pulse repetition time of 550 ms, and T2-weighted images were obtained with an echo time of 130 ms and a pulse repetition time of 3200 ms. The spin-echo technique was applied, with a slice thickness of 5 mm.

RESULTS

Characteristic findings and serial changes

The characteristic MRI findings and serial signal changes of the patients are shown in Table 1. Three characteristic patterns of MRI signal change were observed. Pattern one (Fig. 1) was characterised by the absence of any signal abnormalities on T1-weighted images from the acute to the chronic stage. In contrast,
T2-weighted images initially showed an indistinct high-intensity area (white arrow in Fig. 2b) that gradually localised to the main site of spinal cord injury, and almost completely disappeared after 2 to 6 weeks. In pattern 2 (Fig. 2), there were no acute signal abnormalities on T1-weighted images, but a circumscribed low-intensity area (white arrow in Fig. 2b) appeared at 3 to 6 weeks after injury. An extensive high-intensity area was observed from the acute to subacute stages on T2-weighted images, and this area decreased

Figure 1  Pattern one: MRI scan of a 64-year-old man with grade C paralysis in the acute stage. (a) T2-weighted images at 15 hours after injury, showing an indistinct high-intensity area (white arrow); (b) MRI at 3 weeks after injury, showing that the high-intensity area has almost disappeared; there were no signal changes on T1-weighted images from the acute to the chronic stage.

Figure 2  Pattern 2: a 35-year-old man with grade B paralysis in the acute stage. (a) T2-weighted images at 14 hours after injury, showing an extensive and indistinct high-intensity area at the C3–4 disc level (white arrow); (b) T1-weighted images show no signal changes; (b) T2-weighted images at 3 weeks after injury, showing an extensive and distinct high-intensity area; T1-weighted images show a circumscribed low-intensity area at the same level (white arrow); (c) The signal changes at 3 months after injury are more distinct on both T1- and T2-weighted images.
in size and became more distinct approximately 3 months after injury. Pattern 3 (Fig. 3) was characterised by a small low-intensity area (white arrow) within an extensive high-intensity area on acute T2-weighted images, despite the lack of visible signal changes on acute T1-weighted images. There was a distinct and extensive high-intensity area on T2-weighted images and a low-intensity area on T1-weighted images in the chronic stage of injury. The overall mean of anteroposterior diameter of the cervical canal at the C4 level was 12.2 mm; the mean canal diameter was 12.9 mm, 12.4 mm, and 6.5 mm in patterns one, 2, and 3, respectively.

Clinical features and outcomes

The clinical features and outcome of the patients in our series are shown in Table 2 and Fig. 4. The patients with pattern one MRI findings (n=10) experienced satisfactory resolution of motor paralysis, although slight dysfunction and numbness of the fingers were evident in 9 patients at the one-year follow-up; one patient showed complete recovery of paralysis.

Patients with pattern 2 (n=31) had variable outcomes. The deficit was unchanged in 9 of these patients, 3 of whom (2 were grade A and one was grade B on the IMSOP scale) underwent tracheotomy and received mechanical ventilation for several months. The other 22 patients with pattern 2 showed some degree of improvement of their paralysis, but had ‘numb’ hands and lacked fine motor control of the hands, or ‘clumsy’ hands, and they needed help with daily life. 14 patients in this group could walk without assistance after 6 months.

The 2 patients with pattern 3 had complete paralysis at the time of injury and showed no improvement of their neurological deficits. Both patients had severe respiratory dysfunction at the time of injury, and required emergency tracheotomy followed by mechanical ventilation—one for 8 weeks and the other for 10 weeks.

It was found that the patients with pattern one on MRI and grade B paralysis at the time of injury had better resolution of their paralysis than patients exhibiting pattern 2 and grade B signs (Fig. 4).

Neurological involvement

The level of neurological involvement was assessed in 9 patients with complete tetraplegia (grade A) using key muscle and sensory points. The motor level was at the level of C5 in 6 patients and C4 in 3, whereas the sensory level was at C5 in 7 patients, C4 in one, and C3 in one.

DISCUSSION

A clear picture of the location, extent, and severity of traumatic cervical spinal cord injury can be obtained with MRI, which also reflects the histological features of the intramedullary lesions. Features on MRI scans

Figure 3 Pattern 3: a 58-year-old man with OPLL at C3–5; paralysis was grade A at the time of injury. (a) T2-weighted images at 14 hours after injury, showing a small low-intensity area (white arrow) within a high-intensity area; no signal changes were observed on T1-weighted images; (b) T2-weighted images at 3 months after injury, showing more extensive high-intensity area; while T1-weighted images show a low-intensity area.
of the spinal cord injury have been investigated previously.\textsuperscript{5-7} In this study, the most common acute MRI pattern was no change of the signal intensity on T1-weighted images, but a blurred high-intensity area on T2-weighted images (Fig. 1a and 2a) subsequently became isointense (Fig. 1b) or else even more intense (Fig. 2b–c) in the subacute and chronic stages. At this stage, a low-intensity area began to appear on T1-weighted images (Fig. 2b–c). The characteristic finding in the chronic stage was usually an oval-shaped area of signal change at the C3–4 disc level (Fig. 2c).

Based on previous studies of the histopathological features of spinal cord injury,\textsuperscript{8-10} a blurred high-intensity area on T2-weighted images is thought to represent oedema or petechial haemorrhage. On the other hand, a more distinct high-intensity area in T2-weighted images, combined with a low-intensity area on T1-weighted images in the subacute and chronic stages, is thought to indicate necrosis, myelomalacia, or an intramedullary cyst. The injury is usually caused by hyperextension and localised force,\textsuperscript{4} but the severity and prognosis varies widely.

The anteroposterior diameter of the cervical canal is an important factor that influences the neurological severity and outcome. The diameter at the C4 level ranged from 6 mm to 15 mm (mean, 12.2 mm) among the patients of this series. In particular, the diameter of such 2 patients who showed pattern 3 MRI signs was narrow (6 mm and 7 mm, respectively), and ossification of the posterior longitudinal ligament (OPLL) was visible at the site. The standard anteroposterior diameter at C4 is 16.8 mm (standard deviation [SD], 1.4 mm) among Japanese men and 15.8 mm (SD, 1.5 mm) among women.\textsuperscript{11} The characteristic of acute signal change was a small low-intensity area within an extensive high-intensity area in T2-weighted images (Fig. 3a), which was thought to indicate more extensive intramedullary haemorrhage that is attributed to deoxyhaemoglobin.\textsuperscript{5,7,12} Such pattern of acute signal change has been reported to suggest a poor prognosis for neurological recovery.\textsuperscript{13,14}

Studying the neurological features of traumatic cervical cord injury, Hoppenfeld\textsuperscript{15} found that spinal

<table>
<thead>
<tr>
<th>Pattern of MRI signal change</th>
<th>No. of patients</th>
<th>Resolved (n)</th>
<th>Motor resolved (n)</th>
<th>Deficit remained (n)</th>
<th>Deficit unchanged (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pattern 1</td>
<td>10</td>
<td>1</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pattern 2</td>
<td>31</td>
<td>0</td>
<td>14</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Pattern 3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

**Figure 4** Correlation between MRI changes and clinical outcomes based on the IMSOP.
damage at the C3–4 level is associated with a neurological level of C3, and thus there is no function of the upper extremities, and the patient is unable to breathe independently because of dysfunction of the diaphragm. However, the C4 and C5 levels were functional in patients with complete paralysis in our series. Such difference of the neurological level between Hoppenfeld’s patients, and those in this cohort may be attributed to variation of the traumatic force at the time of injury. The force involved extension and was localised in our series, so damage to the spinal cord was confined to the C3–4 disc level (Fig. 2c).

Respiratory dysfunction was one of the characteristic features in both the acute and chronic stages in patients with severe paralysis of grades A and B. Respiratory dysfunction may occur in the acute stage at 2 to 3 days after injury because of temporary paralysis of the phrenic nerve due to spinal cord oedema. Six patients (5 grade A and one grade B, respectively) underwent acute tracheotomy, and mechanical ventilation was performed in 5 with weaning after 8 to 20 weeks (mean, 10.4 weeks). Diaphragmatic functions recovered to some degree by the subacute stage (usually about 3 weeks after injury), but respiratory function did not recover well (Fig. 5). Two patients (both of grade A, aged 83 and 74 years; both were smokers) died of respiratory complications at 4 and 14 months after injury, respectively. Such finding suggests that from the acute to chronic stage, respiratory management is necessary in patients with severe paralysis due to spinal cord injury, even if the neurological level is C4 or C5. The risk of respiratory complications is high and severe, especially in elderly smokers. Patients who have traumatic cervical spinal cord injury without radiographic abnormalities do not seem to be in such a serious condition at the time of injury because of the absence of fracture or dislocation of the spine. We should yet be careful because respiratory dysfunction may develop in patients with severe paralysis at the C3–4 level by 24 to 72 hours after their injury; such patients need intensive respiratory management.

Zancolli16 described the function of the elbow and forearm in patients with a neurological level at C5, but did not mention the finger function. All the patients with incomplete paralysis in our series complained of numbness, tingling, or dysaesthesia, and they lacked fine motor control of the hands. Furthermore, 18 patients were unable to recognise objects, and could not distinguish small objects such as coin or key, without directly seeing them. Eight patients (all were grade C) developed flexion contracture of the fingers. Assessment of hand symptoms in the patients with incomplete paralysis (grades C and D) revealed that another characteristic feature of this injury was ‘numb’ and ‘clumsy’ hands (Table 3). These symptoms seem to evolve over several years. Patients should be informed of these disabilities, and should consult with their employer and/or medical social worker about their return to work or new job training at an early stage. The hand symptoms seem to be due to dysfunction of the dorsal funiculus of the upper
cervical cord and ‘numb, clumsy hands’ have been previously described in reports of patients with tumours of the craniospinal junction or high cervical spine, and in reports of patients with cervical spondylotic myelopathy at the levels of C3–4 or C4–5.\textsuperscript{17,18}

CONCLUSION

Three patterns of signal change on MRI have been observed in patients with spinal cord injury at C3–4. T2-weighted images provided the most useful information, and the best times for prognostic imaging were at the time of injury and 2 to 3 weeks afterwards. A low-intensity area on T2-weighted images in the acute stage is thought to indicate a poor prognosis, while a high signal intensity area at 2 to 3 weeks after injury indicates that some degree of paralysis will be permanent.

Table 3

<table>
<thead>
<tr>
<th>Feature of injury</th>
<th>No. of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory</td>
<td></td>
</tr>
<tr>
<td>‘Numb’ hands</td>
<td>31</td>
</tr>
<tr>
<td>Tingling or dysesthesia in hands</td>
<td>24</td>
</tr>
<tr>
<td>Stereoanesthesia</td>
<td>18</td>
</tr>
<tr>
<td>Motor</td>
<td></td>
</tr>
<tr>
<td>‘Clumsy’ hands</td>
<td>28</td>
</tr>
<tr>
<td>Weakness</td>
<td>27</td>
</tr>
<tr>
<td>Finger deformity</td>
<td>8</td>
</tr>
</tbody>
</table>

* Grade C (n=8) and grade D (n=23).

REFERENCES