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The value of a new method for assessing the separate functions of the long tracts and involved segments in patients with cervical myelopathy

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Abstract In order to assess accurately lesions of the spinal cord in patients with cervical myelopathy we have developed a new method of examination, which is based on the Japanese Orthopaedic Association (JOA) scoring system. The method attempts to assess separately the functions of the long tract and any involved cord segments in respect to the period after treatment. It was used in 117 consecutive patients who were divided into 2 groups based on whether or not there was a T2-high-intensity lesion within the spinal cord, as revealed by a preoperative magnetic resonance imaging scan (MRI). The results of this method correlated well with the MRI findings. It was assumed that the degree of function of the upper limbs in patients with a T2-high-intensity lesion revealed more about a segment than about the long tract.

Résumé Pour évaluer les lésions médullaires dans la myélopathie cervicale, nous avons développé une méthode d'examen basée sur la classification de l'Association Orthopédique Japonaise (JOA). La méthode essaie d'évaluer les fonctions de l'ensemble médullaire et du segment concerné après une période de traitement. 117 malades consécutifs ont été divisés en deux groupes selon qu'il y avait ou non un signal d'hyper-intensité en T2 sur l'IRM pré-opératoire. Les résultats selon cette méthode ont été en corrélation avec les résultats IRM.

Introduction

In cervical myelopathy, which is often caused by spondylosis or by ossification of the posterior longitudinal ligament (OPLL), the cervical spinal cord is compressed to various degrees. Consequently, an assortment of neurological symptoms and signs occurs in the upper and lower limbs and in the trunk, which can be explained anatomically. The white matter containing myelinated nerve fibres (the long tracts) is located peripherally in the spinal cord, and innervates the upper and lower limbs and the trunk. The central portion of the cervical spinal cord contains the grey matter consisting mainly of nerve cells, which segmentally innervate the upper limbs. In cervical myelopathy the symptoms and signs in the trunk and lower limbs result from involvement of the long tracts at the cervical level, and providing there are no nerve lesions in the thoracic and lumbar region. Therefore, function of the trunk and the lower limbs results from function of the long tracts, and long tract signs may appear when the white matter is damaged. In contrast the symptoms and signs in the upper limbs can result from lesions either affecting a segment and/or the long tracts. Thus, loss of activity of the upper limbs may result from involvement of a segment or of the long tract, or of both, and it is often difficult to determine which is responsible. Long tracts and the segments of the spinal cord can be affected to various degrees and this can result in the appearance of various kinds of neurological problems that have been divided or classified by Crandall and Batzdorf [1] into 5 groups. The prognosis for a myelopathy is different for each neurological condition and presumably relates to the viability of the spinal cord.

Ideally it would be more accurate when assessing the neurological situation in cervical myelopathy to be able to separate the function of the long tracts from that of the segments rather than by considering them together. However, there are currently no methods available to do this [2,3,5]. When considering any recovery of spinal cord function, improvement of the neurological condition must be recorded in relation to the speed of improvement.

We have developed a new method of assessment (the TS/T method) for patients with cervical myelopathy. Our goal was to try to assess separately the functions of the long tracts and of one or more segments and the speed of

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Table 1 The Japanese Orthopaedic Association scoring system for cervical myelopathy

I	Motor function of the upper limbs
4	Normal
3	Able to feed using chopsticks with slight difficulty
2	Able to feed using chopsticks with difficulty
1	Able to feed using a spoon only
0	Unable to feed unaided
II	Motor function of the lower limbs
4	Normal
3	Able to walk without support with slight difficulty
2	Able to walk up and down stairs only with support
1	Requires support to walk even on level ground
0	Unable to walk
III	Sensory function (same in upper and lower limbs, and trunk)
2	Normal
1	Slight sensory disturbance or numbness
0	Distinct sensory disturbance
IV	Bladder function
3	Normal
2	Slight urination difficulty (pollakisuria, retardation)
1	Serious urination difficulty (residual urine, dysuria)
0	Urine retention

recovery. TS/T is defined as: T, the long tract; S, the segment; and T, the time. The TS/T method is based on the Japanese Orthopaedic Association (JOA) scoring system for cervical myelopathy (Table 1). The aim of the present study was to examine the usefulness of the TS/T method by comparing scores obtained by this method with the findings of preoperative magnetic resonance imaging (MRI) in patients who underwent tension-band laminoplasty [6].

Patients and methods

We examined 117 consecutive patients with cervical myelopathy who underwent tension-band laminoplasty from 1994 to 1996 at our hospital. Eighty-six patients were male, and 31 female. Age at the time of operation ranged from 41 to 81 years, with an average of 56 years. Follow-up period ranged from 1 to 3 years, with an average of 1 year and 9 months. Before operation, all the patients had been followed for at least 3 months at our hospital. Patients with an acute spinal cord injury arriving at our hospital within 24 h after their accident were excluded.

As already explained, in this study we used the term “function of the upper limbs” instead of “function of a segment”, as opposed to “function of the long tracts”, which represents the function of the trunk and the lower limbs.

In the TS/T method the function of the long tracts is represented by the sum of the JOA score of motor function of the lower limbs, sensory function of both the lower limbs and the trunk and bladder function. The maximum scores are 4, 2, 2 and 3, respectively. The maximum possible score, therefore, is 11. Function of the upper limbs is assessed by the sum of the JOA score of motor (4) and of sensory (2) function in these limbs; thus, giving a possible maximum score of 6.

Changes in function are presented individually as recovery indices in relation to the response to treatment. In the post-treatment period, each unit of measurement represents 3 months. The recovery indices are the differences between the sum of the JOA scores

$$\text{RECOVERY INDEX} = \frac{\text{POST} - \text{PRE}}{\text{TIME}}$$

POST = sum of JOA scores at follow-up
PRE = sum of JOA scores before treatment
TIME = time after treatment

Fig. 1 New method of assessment (TS/T method)

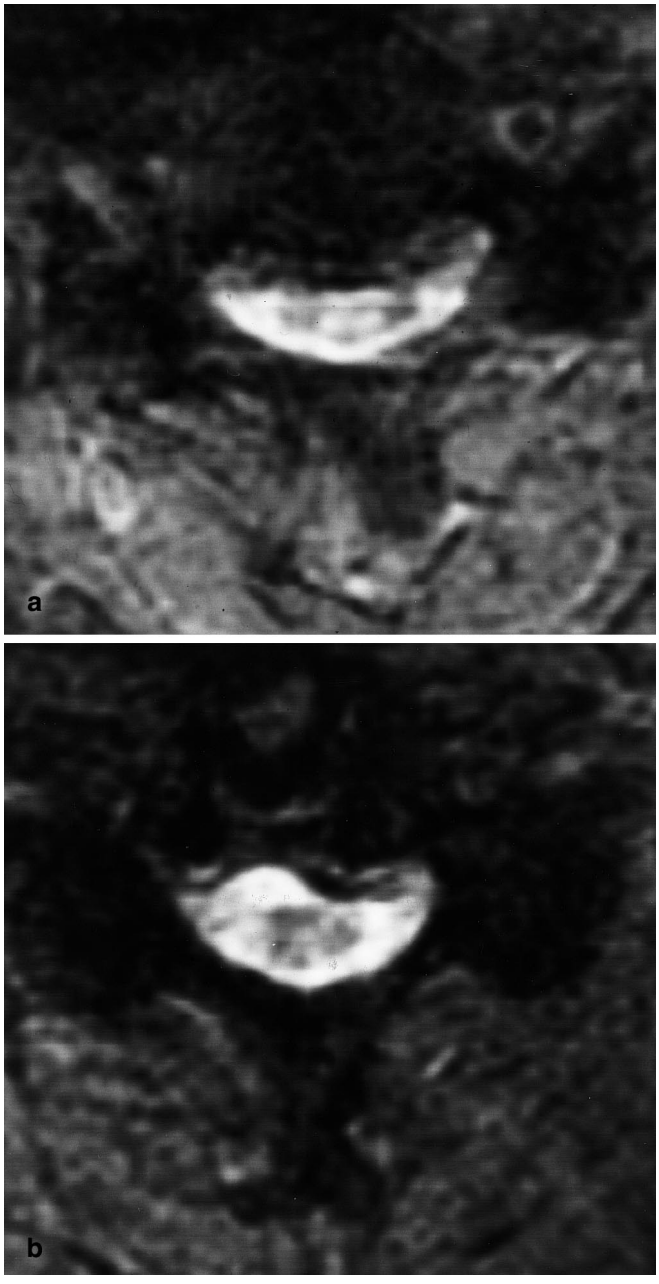

Fig. 2a,b Axial views of MRI in a patient with a T2-high-intensity lesion located mainly at the central portion of the spinal cord (**a**), and a patient with a T2-high-intensity lesion mainly at the peripheral portion (**b**)

at the time of follow-up and before treatment, divided by the time units after treatment (Fig. 1).

On a preoperative MRI the presence of a T2-high-intensity lesion within the cervical spinal cord was assessed by doctors who had not taken part in the operation. The patients were then divided into 2 groups based on whether there was a T2-high-intensity lesion within the spinal cord or not. In patients with a T2-high-intensity lesion the lesions were further divided into 2 groups using the axial view of the MRI showing whether the lesion was located mainly at the central portion of the spinal cord, or mainly in the peripheral (Fig. 2). Magnetic resonance imaging was performed with a 1.5-T superconductive unit (Shigna, Wisconsin, USA). Imaging was performed with fast spin-echo sequences in 1.5-T unit. The pulse sequence used was 5,000 ms in repetition time and 100 ms in echo time in order to give T-2 weighted images. The section thickness used was 10 mm.

Statistical analysis was performed using the Mann-Whitney method.

Results

Fifty-one patients had no T2-high-intensity lesions in their spinal cord on preoperative MRI (group 1). Sixty-six patients had T2-high-intensity lesions on their preoperative MRI (group 2). Of the 66 patients in group 2, 64 had T2-high-intensity lesions mainly in the central portion of the spinal cord, and 2 patients in the periphery. In each patient, the T2-high-intensity lesion was located at a single segment.

The preoperative scores of the long tract showed no significant differences between groups 1 and 2. But there were significant differences in the scores of the upper limbs and the total scores of both the long tract and the upper limbs ($P<0.0001$, $P<0.001$, respectively) (Table 2).

The postoperative scores of the long tract, the upper limbs, and the sum scores of both the long tract and the upper limbs showed significant differences between the 2 groups ($P<0.05$) (Table 3).

In the recovery indices of the long tract there was no significant difference between the 2 groups. Meanwhile, in the indices of the upper limbs there was a significant difference ($P<0.05$) (Table 4), the rate of group 2 being better than that of group 1.

Table 2 Average pre-operation JOA scores in each group

	Long tract	Upper limbs	Long tract + upper limbs
Group 1	7.10	3.89	11.5
Group 2	6.41	2.56	9.0
P value	NS	$P<0.0001$	$P<0.001$

NS, Not significant

Table 3 Average post-operation JOA scores in each group

	Long tract	Upper limbs	Long tract + upper limbs
Group 1	9.10	4.64	13.7
Group 2	8.34	3.96	12.3
P value	$P<0.05$	$P<0.05$	$P<0.05$

Table 4 Average recovery indices in each group

	Long tract	Upper limbs
Group 1	0.43	0.13
Group 2	0.80	0.43
P value	NS	$P<0.05$

NS, Not significant

Table 5 Average scores of motor function of the upper limbs

	Before operation	After operation
Group 1	2.8	3.3
Group 2	1.9	2.8
P value	$P<0.0001$	$P<0.05$

Table 6 Average scores of motor function of lower limbs

	Before operation	After operation
Group 1	2.2	2.8
Group 2	1.7	2.5
P value	$P<0.05$	NS

NS, Not significant

With regard to the motor function the preoperative scores of the upper limbs in group 2 was significantly lower than that of group 1 ($P<0.0001$). After operation, although the differences continued to exist between the 2 groups, the level of difference decreased ($P<0.05$) (Table 5).

In the lower limbs the preoperative score in group 2 was also significantly lower than that in group 1 ($P<0.05$), while after operation there was no significant difference between them (Table 6).

Discussion

At present there are a number of methods used to assess the effectiveness of treatment for cervical myelopathy. Their main purpose is to determine the degree to which the symptoms and signs improve after treatment. However, these previous methods of assessment [2,3,5] do not include the duration of any recovery after treatment. In assessing recovery of spinal cord activity, information about the time period involved is important because it is natural to assume that a patient whose symptoms and signs improve rapidly has a more viable spinal cord than a patient with slow recovery. For that reason it is difficult to assess fully the viability of the spinal cord by the previous methods of assessment, as these do not take any account of the speed of recovery.

In 1998 we developed a new method of assessment that involves “the post-treatment time-course”, the M/T method [4]. This was mainly used in patients with cervi-

cal myelopathy in whom presenting muscle weakness was restricted to the upper limb. In this method the function of the spinal cord is represented by the degree of manual muscle test (MMT) of individual muscles. The M/T index is the difference between the degree of MMT at the time of follow-up and that before treatment, divided by the time units after treatment.

In the present study we developed another method of assessment (the TS/T method), which can be applied to patients with various kinds of neurological problems. One of the features of the TS/T method is to try to assess separately the functions of the long tract and segment, and another is to assess these in relation to the time-course after treatment (as in the M/T method). Consequently, the function and viability of the spinal cord can be assessed more accurately. The function of the long tract is represented by the function of the trunk and the lower limbs. However, the true function of the segment in the upper limbs is more difficult to assess because the function of the upper limbs implies the functioning not only of the segment but also of the long tract. Therefore, in this study we used the term "function of the upper limbs" as opposed to "function of the long tract".

In T2-high-intensity lesions within the spinal cord in patients with acute spinal cord injury it has been reported that a T2-high-intensity MRI lesion within the spinal cord indicates edema and/or a hemorrhage. This may help in making a prognosis for the neurological condition from both the degree and extent of T2-high-intensity lesions. However, in patients with cervical myelopathy in whom the spinal cord has been chronically compressed, the relationship between T2-high-intensity lesions and the neurological condition has not been well studied. The form of T2-high-intensity lesions is thought to differ between acute spinal cord injury and slowly developing cervical myelopathy. It is unclear whether the T2-high-intensity lesion in cervical myelopathy is due to edema, hemorrhage, congestion, necrosis or ischemia. Although the precise pathology is unclear, we regard regions with T2-high-intensity and the neighboring regions as seriously affected areas. Therefore, in the present study we investigated these lesions in relation to the neurological findings.

There was a significant difference in the preoperative scores of the upper limbs between group 1 and group 2, with the score of group 2 being significantly lower than that of group 1. On the other hand, there was no significant difference in the long tract scores. Therefore, the significant difference in the total scores of both the long tracts and the upper limbs was assumed to result from the difference in the scores of the upper limbs.

In the postoperative score, although the differences in the upper extremities and the total scores of both the long tract and the upper limbs continued to exist between the 2 groups, the level of difference decreased. This result was assumed to arise from the improvement in the score of the upper limbs in group 2. This assumption was confirmed from the recovery index results, with the recovery index in the upper limbs of group 2 being significantly better. There was no significant difference in the recovery index of the long tract. These results indicate that the final operative outcome is influenced by the preoperative neurological condition especially that of the upper limbs. The recovery of function in the spinal cord is more strongly demonstrated by the recovery of function of the upper limbs than by that of the long tract.

In the present study T2-high-intensity lesions located mainly in the central portion of the spinal cord were found in almost all patients in group 2. Anatomically the grey matter is located in the central portion of the spinal cord, and the long tract at the periphery. It can therefore be assumed, in general, that a T2-high-intensity lesion in the central portion of the spinal cord suggests a lesion of the segment rather than that of the long tract. In the present study the preoperative score of the upper limbs in group 2 was significantly lower, while there were no significant differences between the 2 groups in the score of the long tract. From these results it can be assumed that function of the upper limbs in group 2 possibly revealed more about the segment than about the long tract, and as a result functions of the upper limbs in group 2 were related to the function of the segment. It seems that this assumption has been confirmed from the motor function results. In other words the results of the TS/T method of assessment correlated well with the findings on MRI.

We found that the recovery rate of the upper limbs in group 2 was better than in group 1. A T2-high-intensity lesion in group 2 suggests that function significantly decreases with compression and recovers after decompression. Wada et al. [7] reported that a T2-high-intensity lesion of several segments represents either spinal cord atrophy or cavity formation and results in less recovery. Our study, however, indicates that a T2-high-intensity lesion at a single segment has a better prognosis.

In conclusion, the TS/T method proved to be valuable in assessing function and viability of the spinal cord. Comparison of the function in the upper limbs between patients with and without preoperative T2-high-intensity lesions within the spinal cord may lead to more precise information of the function of the long tract and that of the segments.

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