THE PROGNOSIS OF SURGERY FOR CERVICAL COMPRESSION MYELOPATHY

AN ANALYSIS OF THE FACTORS INVOLVED

KEIJU FUJIWARA, KAZUO YONENOBU, SOHEI EBARA, KAZUO YAMASHITA, KEIRO ONO

From Osaka University Medical School, Japan

We have studied the morphometry of the spinal cord in 50 patients with cervical compression myelopathy. Computed tomographic myelography (CTM) showed that the transverse area of the cord at the site of maximum compression correlated significantly with the results of surgery. In most patients with less than 30 mm² of spinal cord area, the results were poor; the cord was unable to survive.

Several factors, such as chronicity of disease, age at surgery and multiplicity of involvement are said to influence the results of surgery, but the transverse area of the cord at the level of maximum compression provides the most reliable and comprehensive parameter for their prediction.

The results of surgery for cervical compression myelopathy are difficult to predict. Various factors, such as chronicity of disease, age at surgery, and anteroposterior canal diameter have been said to influence the results, but their influence has not been proved. A clinicopathological study reported by one of the present authors (Ono et al. 1977), showed that the grade of pathological change in the spinal cord correlated well with the degree of neurological impairment during life; it also correlated well with the transverse area or the anteroposterior compression ratio (Fig. 1) of the spinal cord (Fujiwara et al. 1988). We wondered if it was possible, with simple but sensitive parameters, to predict the results of surgery in patients with cervical compression myelopathy.

Recent advances in imaging techniques, such as computed tomographic myelography (CTM), have made it possible to visualise the cross-sectional size and shape of the spinal cord. We have used this technique in an attempt to predict the prognosis of chronic compression myelopathy and to discover how the results compared

with those of the clinical methods previously believed to provide reliable prognosis.

PATIENTS AND METHODS

Fifty patients with cervical myelopathy treated surgically in our department during the past three years were the subject of this study. The series consisted of 19 patients with cervical spondylotic myelopathy (CSM), 20 with myelopathy due to cervical soft disc herniation (hernia) and 11 with ossification of the posterior longitudinal ligament (OPLL).

The severity of the myelopathy was graded by the function assessment score proposed by the Japanese

Fig. 1

$$\text{Compression ratio} = \frac{\text{sagittal diameter}}{\text{transverse diameter}} \times 100(\%)$$

K. Fujiwara, MD
K. Yonenobu, MD
S. Ebara, MD
K. Yamashita, MD
K. Ono, MD, Professor and Chairman
The Department of Orthopaedic Surgery, Osaka University Medical School, Fukushima-Ku, Osaka 553, Japan.

Correspondence should be sent to Dr K. Ono.

© 1989 British Editorial Society of Bone and Joint Surgery
0301-620X/89/3115 \$2.00
J Bone Joint Surg [Br] 1989;71-B:393-8.

Orthopaedic Association (JOA score) (Table I). Recovery after surgery was evaluated using the formula suggested by Hirabayashi et al. (1981):

$$\text{rate (\%)} = \frac{\text{post-op score} - \text{pre-op score}}{17 (\text{full}) - \text{pre-op score}} \times 100$$

We selected our surgical procedure as follows: for single level CSM or hernia, anterior interbody fusion by Smith-Robinson's technique was employed; for two or three level CSM or hernia, we used subtotal corpectomy and fusion; and for four level involvement or more with CSM or OPLL, laminectomy or laminoplasty was indicated.

Table I. Criteria adopted by the Japanese Orthopaedic Association for evaluation of the results of operation for cervical myelopathy

I Upper extremity function	
0	Impossible to eat with either chopsticks or spoon
1	Possible to eat with spoon, but not with chopsticks
2	Possible to eat with chopsticks, but inadequately
3	Possible to eat with chopsticks, but awkwardly
4	Normal
II Lower extremity function	
0	Impossible to walk
1	Needs cane or aid on flat ground
2	Needs cane or aid only on stairs
3	Possible to walk without cane or aid, but slowly
4	Normal
III Sensory function	
A Upper extremity	
0	Apparent sensory loss
1	Minimal sensory loss
2	Normal
B Lower extremity	
Same as A	
C Trunk	
Same as A	
IV Bladder function	
0	Complete retention
1	Severe disturbance
(1) Inadequate evacuation of the bladder	
(2) Straining	
(3) Dribbling of urine	
2	Mild disturbance
(1) Urinary frequency	
(2) Urinary hesitancy	
3	Normal

Morphometry of the spinal cord. One or two hours after injection of metrizamide via a lumbar spinal puncture, the CTM study was carried out, using a General Electric CT/T 8800. The gantry angle was carefully adjusted to be perpendicular to the spinal canal. The window level was set at 100 to 250 and the window width at 1000 to 2000. The morphometric parameters employed were the transverse area, the compression ratio and the shape at the maximum compression segment. The transverse area and compression ratio were measured by means of a computerised digitiser. The cross-sectional shape of the spinal cord was classified into three types: diffusely compressed, centrally compressed, and unilaterally compressed (Fig. 2).

Fig. 2a

Fig. 2b

Fig. 2c

Types of spinal cord compression: (a) diffuse, (b) central, (c) unilateral.

RESULTS

Spinal cord size and neurological function. The compression ratio at the level of maximum compression did not correlate with the pre-operative JOA score nor with the postoperative neurological recovery. The transverse area at the maximum compression level did not correlate with the pre-operative neurological status, but it showed a significant positive correlation ($p < 0.01$) with the post-

operative JOA score and the recovery rate. Of 13 patients with a poor prognosis (less than 40% of recovery rate), 11 had less than 30 mm² of transverse area (Figs 3a and b). The correlation between the transverse area of the cord and the recovery rate differed according to the cause of the compression myelopathy: a significant positive correlation was found with disc hernia and OPLL ($p < 0.05$), but not with CSM, though this exhibited a similar tendency (Table II).

Clinical features, surgical results and spinal cord size. The following six items were evaluated for their relation to surgical results and to spinal cord size: original cause of compression, age at surgery, type of cord compression, multiplicity of involvement, presence or absence of canal stenosis, and chronicity of disease.

Original cause of compression. With regard to the pre-operative JOA score, there was no significant difference between the three diseases (CSM, disc hernia, and OPLL). Judging from the postoperative JOA score and the recovery rate, the best results were obtained in the disc hernia group, followed by OPLL and CSM. There was a significant difference ($p < 0.05$) between the disc hernia and CSM groups with regard to these parameters. The compression ratio at the level of maximum compression showed no difference among the three groups, but the transverse area was greatest in the disc hernia group; it was approximately the same in CSM and OPLL.

Table II. Correlation between the transverse area of the cord and the recovery rate

Disease	Number	Correlation	
CSM	19	0.383	
Disc hernia	20	0.510	$p < 0.05$
OPLL	11	0.639	$p < 0.05$
Total	50	0.549	$p < 0.01$

Age at surgery. There was a significant negative correlation between the age at surgery and the recovery rate: as the age increased the surgical result worsened ($Y = -0.89X + 103.81$, $r = -0.394$, $p < 0.01$ where Y = transverse area at the maximum compression level and X = age at surgery). The transverse area at the maximum compression level tended to decrease as the age at surgery advanced ($Y = -0.28X + 51.69$, $r = -0.260$).

Type of cord compression. Most cases (31) were of the diffuse compression type, followed by unilateral (12) and central (seven) compression types. The pre-operative JOA score showed no significant difference between the three compression types. The postoperative JOA score and the recovery rate for the diffuse compression type were significantly inferior to those of the other two types ($p < 0.05$). Judging from the compression ratio, the central type was most compressed, followed by the diffuse and then the unilateral type, with significant differences between each. The spinal cord transverse area was significantly ($p < 0.05$) decreased in the diffuse compression type as compared with the other two types; the diffuse type had the greatest decrease in spinal cord transverse area, and the worst prognosis.

Multiplicity of involvement. Single level involvement was the most common (21 cases), followed by two level (11), three level (10) and four level involvement (eight). There was no correlation between the pre-operative JOA score and multiplicity of involvement. The single involvement group had the best postoperative result, followed by the two level group; three and four level groups had the worst results, but there was little difference between them. The compression ratio showed no significant difference between the four groups. The transverse area tended to decrease as multiplicity of involvement increased. A significant difference in size ($p < 0.05$) was observed between the single and triple involvement groups.

Spinal canal stenosis. The sagittal diameter of the spinal canal was measured on a standard lateral radiograph.

Fig. 3a

Fig. 3b

Figure 3a – Correlation between transverse area at the maximum compression level and postoperative JOA score. Figure 3b – Correlation between transverse area at the maximum compression level and recovery rate.

Spinal canals with a diameter below 13 mm were classified as 'stenotic' (there were 18 of these) and those above 13 mm as 'non-stenotic' (32). There was no significant difference in pre-operative JOA score between the two types; with regard to recovery rate, however, the stenotic group was significantly inferior ($p < 0.05$). The compression ratio showed no significant difference between the two groups. The transverse area in the stenotic group was significantly reduced ($p < 0.05$), as compared to the non-stenotic.

Chronicity of disease. It is impossible to determine exactly when spinal cord compression begins, but we defined the onset of cervical myelopathy as the time when lower limb symptoms developed, and the interval from onset to operation as indicating the degree of chronicity. This chronicity had a negative correlation with the recovery rate ($Y = -1.79X + 73.66$, $r = -0.623$, $p < 0.01$ where Y = recovery rate and X = chronicity of disease) and with the transverse area ($Y = -0.68X + 43.59$, $r = -0.529$, $p < 0.01$ where Y = transverse area, and X = chronicity of disease). As compression of the spinal cord continues, the transverse area decreases, spinal cord function becomes impaired and finally the damage is irreversible.

The most significant factor for surgical prognosis. While selecting the postoperative JOA score and the recovery rate as our criterion variables, we also estimated the 11 variables shown in Table III using the technique of analysis of co-variants for this purpose. For predicting the postoperative JOA score, the transverse area at the maximum compression level was the most significant factor, followed by the age at surgery and the pre-operative JOA score (Table IV). With regard to recovery rate, again the transverse area was the most significant factor (Table V).

Alteration of cord size and shape after surgery. Postoperative CTM was performed on 11 cases (six CSM, four disc hernia, one OPLL). In those cases where the transverse area was reduced below 30 mm², restoration of spinal cord size and shape and functional recovery after surgery were both poor. On the other hand, in those cases where the transverse area was preserved above 30 mm², restoration of the spinal cord morphology and functional recovery were both favourable (Fig. 4).

ILLUSTRATIVE CASES

Case 1. A 51-year-old woman with cervical disc herniation presented with a pre-operative JOA score of eight points. The maximum compression level was C5/6, and the compression was of the diffuse type. Although the cord was severely compressed (compression ratio 31%), the transverse area was well preserved at 59.2 mm². On CTM imaging one month after surgery, which consisted of anterior spinal fusion at C5/6, the transverse area was 65.3 mm² and slight compression remained, with a ratio of 46.0%. The spinal cord

Fig. 4

Relationship between transverse area and recovery rate.

Table III. The variables used in analysis of co-variance

1	Original disease: CSM; disc hernia; OPLL
2	Sex
3	Age at surgery
4	Surgical method: anterior; posterior
5	Multiplicity of involvement
6	JOA score before operation
7	Chronicity of disease
8	Spinal canal stenosis: presence; absence
9	Compression ratio at maximum compression level
10	Transverse area at maximum compression level
11	Spinal cord compression type: diffuse; central; unilateral

morphology showed good restoration to its original status, with a high postoperative JOA score (15) and recovery rate (78%): functional recovery was satisfactory (Fig. 5).

Case 2. A 38-year-old man with cervical disc herniation presented with a pre-operative JOA score of 12 points. The maximum compression level was at C4/5 and the spinal cord was markedly compressed as compared with the previous case; with a compression ratio of 30.5% and a transverse area of 28.1 mm², the decrease was remarkable. One year after surgery, which consisted of

Fig. 5a

Fig. 5b

Case 1. A 51-year-old woman with a disc hernia at C5/6 level. Figure 5a - Before surgery: JOA score = 8 points; transverse area = 59.2 mm²; compression ratio = 31.0%. Figure 5b - After surgery: JOA score = 15 points; recovery rate = 78%; transverse area = 65.3 mm²; compression ratio = 46.0%. The spinal cord shape is restored almost to normal and neurological recovery is satisfactory.

Fig. 6a

Fig. 6b

Case 2. A 38-year-old man with a disc hernia at C4/5 level. Figure 6a - Before surgery: JOA score = 12 points; transverse area = 28.1 mm²; compression ratio = 30.5%. Figure 6b - After surgery: JOA score = 13 points; recovery rate = 20%; transverse area = 38.1 mm²; compression ratio = 29.0%. The subarachnoid space has been decompressed completely but the spinal cord shape remains unchanged. Neurological recovery is poor.

Table IV. JOA score after operation

Factor	Degrees of freedom	F-value	Significance level
Transverse area	1	10.42	0.0025
Age at surgery	1	10.08	0.0029
Pre-operative	1	9.00	0.0047
Multiplicity of involvement	1	7.10	0.0112
Original disease	2	4.54	0.0169
Spinal canal stenosis	1	4.44	0.0415

Table V. Recovery rate

Factor	Degrees of freedom	F-value	Significance level
Transverse area	1	7.52	0.0092
Spinal canal stenosis	1	7.07	0.0113
Multiplicity of involvement	1	6.59	0.0142
Age at surgery	1	6.17	0.0174
Original disease	2	3.78	0.0317

anterior spinal fusion at C4/5, CTM imaging showed a compression ratio of 29.0% and a transverse area of 38.1 mm²; the cord morphology showed little restoration despite the fact that the decompression was adequate as judged by the increase of the subarachnoid space. The postoperative JOA score was 13, and functional recovery was unsatisfactory (Fig. 6).

DISCUSSION

CTM using metrizamide was first reported by Di Chiro and Schellinger in 1976. In 1979, Thijssen et al. and Resjö et al. measured normal spinal cord morphology using CTM. In our present study, the transverse area and the compression ratio of the spinal cord were used to assess the extent of spinal cord deformity. In patients with cervical compression myelopathy, the relation between spinal cord deformity and function was also studied. Before this clinical study we had confirmed by cadaveric studies that CTM could provide an exact image of the spinal cord (Fujiwara et al. 1988).

We have found that recovery of the activities of daily living after surgery correlated closely with the size and shape of the spinal cord. Various clinical features which had been claimed to aid in determining prognosis also proved to be in close correlation.

Neither the transverse area nor the compression ratio at the maximum compression level could be used to determine the pre-operative neurological status. However, the transverse area correlated well with the postoperative JOA score and with the recovery rate. The cases in which, despite marked deformity of the spinal cord, the transverse area was well preserved, showed good recovery from paresis. In such cases, the postoperative cord morphology was almost completely restored to normal. However, when the transverse area was less than

30 mm² before operation, the postoperative results were unsatisfactory and spinal cord morphology was not sufficiently restored. Thus, 30 mm² proved to be the critical point below which the spinal cord was unable to survive.

Although several factors, such as the type of disease, the age at surgery, multiplicity of involvement, the type of cord compression, the presence or absence of stenosis and chronicity of disease, are known to influence surgical prognosis in this condition, their influence proved to be effected through the alteration in the transverse area of the spinal cord. For example, the longer the interval from onset of paresis to surgery, the more reduced was the transverse area. We conclude therefore that the transverse area is the most comprehensive and useful factor in predicting the result of surgery.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES

- Di Chiro G, Schellinger D. Computed tomography of spinal cord after lumbar intrathecal introduction of metrizamide (computed assisted myelography). *Radiology* 1976;120:101-4.
- Fujiwara K, Yonenoba K, Hiroshima K, Ebara S, Yamashita K, Ono K. Morphometry of the cervical spinal cord and its relation to pathology in cases with compression myelopathy. *Spine*: in press.
- Hirabayashi K, Muiakawa J, Satomi K, Maruyama T, Wakano K. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. *Spine* 1981;6:354-64.
- Ono K, Ota H, Tada K, Yamamoto T. Cervical myelopathy secondary to multiple spondylotic protrusions: a clinicopathologic study. *Spine* 1977;2:109-25.
- Resjö IM, Harwood-Nash DC, Fitz CR, Chuang S. Normal cord in infants and children examined with computed tomographic metrizamide myelography. *Radiology* 1979;130:691-6.
- Thijssen HO, Keyser A, Horstink MW, Meijer E. Morphology of the cervical spinal cord on computed myelography. *Neuroradiology* 1979;18:57-62.