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Analysis of the Relationship Between the Epidural Spinal Cord Compression (ESCC) Scale and Paralysis Caused by Metastatic Spine Tumors

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Study Design. A retrospective, single-institute, and radiographic study.

Objective. To evaluate the relationship between the epidural spinal cord compression (ESCC) scale and the severity of metastatic spine tumor–induced paralysis.

Summary of Background Data. The ESCC scale is used to evaluate the grade of spinal cord compression on T2-weighted magnetic resonance imaging (MRI). However, few studies have investigated the relationship between such MRI findings and paralysis.

Methods. The subjects were 467 patients with metastatic spine tumors and grade 1b or worse spinal cord compression according to the ESCC scale. Evaluations using this scale were performed by three spine surgeons, and results that were obtained by two or more surgeons were adopted. We also examined patients whose spinal cord compression deteriorated by one grade or more to American Spinal Injury Association (ASIA) grade C or worse within the first 3 weeks after MRI.

Results. The kappa coefficients for inter- and intraexaminer variability were 0.90 and 0.95, respectively. ASIA grade D or worse paralysis developed in at least 50% of the patients with ESCC grade 1b or worse spinal cord compression at the C1-T2 and at least 50% of those with ESCC grade 1c or worse spinal cord compression at the T3-L5. The frequency of ASIA grade C or worse paralysis was high among the patients with ESCC grade 2 or worse spinal cord compression at the C7-L1. Nineteen patients experienced rapid deterioration of one grade or more to ASIA grade C or worse paralysis within the first 3 weeks after MRI. Of these, paralysis occurred in at least 30% of the patients with anterolateral or circumferential cord compression combined with ESCC grade 2 or 3 compression at the C7-L1.

Conclusion. The severity of paralysis was not correlated with the ESCC scale. Patients with anterolateral or circumferential ESCC grade 2 or 3 cord compression at the C7-L1 are at high risk of rapidly progressive paralysis.

Key words: epidural spinal cord compression scale, magnetic resonance imaging, metastatic spinal tumors, paralysis, paraplegia.

Level of Evidence: 4

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Metastatic spine tumors induce paralysis through spinal cord compression or spinal instability. Therefore, treatment must be considered in cases in which spinal cord compression is encountered. In addition, the incidence of spinal cord compression is high, that is, it occurs in 5% to 14% of all cancer patients.[1,2] Spinal paralysis can occur depending on the grade of spinal cord compression; thus, the optimal treatment must be selected promptly in cases of spinal cord compression. However, the relationship between the grade of spinal cord compression and spinal paralysis has not been sufficiently evaluated. Bilsky *et al*[3] proposed the epidural spinal cord compression (ESCC) scale as a tool for evaluating the severity of spinal cord compression on cross sections obtained with T2-weighted magnetic resonance imaging (MRI). This scale consists of 6 grades, and it has been validated and used in research.[4] Currently, MRI is the standard method for diagnosing spinal metastasis,[5] and its sensitivity and specificity are high.[6]

However, the MRI findings of spinal cord compression are not always correlated with the severity of paralysis, which depends on the level of the affected site. Paralysis

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often progresses rapidly, leading to severe conditions in many cases. However, the signs of rapid progression remain to be clarified.

Few studies have investigated the relationship between MRI findings of spinal cord compression and the severity or progression of paralysis with respect to the level of the affected spinal cord site. In this study, we examined the severity or progression of paralysis with respect to the level of the affected spinal cord site using the ESCC scale.[3]

MATERIALS AND METHODS

Patients

The subjects were 467 patients with metastatic spine tumors in whom the grade of spinal cord compression was evaluated to be 1b or worse according to the ESCC scale during examinations of cross-sections obtained using T2-weighted MRI. All subjects were treated at a single institution between January 1, 2001, and December 31, 2016.

There were 289 males and 178 females, and their mean age was 62.4 years (range: 15–92 years). The primary foci consisted of lung cancer in 128 patients, liver cancer in 49 patients, prostate cancer in 42 patients, kidney cancer in 38 patients, breast cancer in 37 patients, multiple myeloma in 25 patients, stomach cancer in 18 patients, colorectal cancer in 14 patients, thyroid cancer in 11 patients, malignant lymphoma in 10 patients, uterine cancer in 8 patients, rectal cancer in 7 patients, osteosarcoma in 7 patients, gallbladder cancer in 5 patients, renal pelvic cancer in 5 patients, pharyngeal cancer in 5 patients, bladder cancer in 4 patients, and pancreatic cancer in 4 patients. There were 23 patients in which the nature of the primary foci was unclear.

All except 19 patients (4.1%) received treatment. Surgery was performed in 216 patients (46.2%), including anterior decompression and stabilization (palliative surgery) in 26 patients, posterior decompression alone in 9 patients, posterior stabilization alone in 54 patients, posterior decompression and stabilization in 119 patients, and vertebroplasty in 1 patient. Total en-bloc spondylectomy was carried out in 7 patients. Two hundred 32 patients were given conservative treatment (one or more procedures), including the abovementioned patients who underwent surgery. Radiotherapy was administered to 198 patients (46.5%), and 118 (25.3%) patients were given chemotherapy. Furthermore, bisphosphonate therapy was administered to 128 patients (27.4%), and 44 (9.4%) patients were given antireceptor activator of nuclear factor kappa-B ligand (RANKL) antibody therapy.

Epidural Spinal Cord Compression Scale[3]

The ESCC scale consists of six grades: grade 0, bone involvement alone; grade 1, epidural impingement; grade 2, the retention of cerebrospinal fluid is visible despite spinal cord compression; and grade 3, cerebrospinal fluid is not visible due to marked spinal cord compression. Grade 1 is classified into three subgroups: grade 1a, epidural impingement without deformation of the thecal sac; grade 1b, compression of the thecal sac without spinal cord abutment; and grade 1c, deformation of the thecal sac with spinal cord abutment in the absence of spinal cord compression (Figures 1A–C and 2).

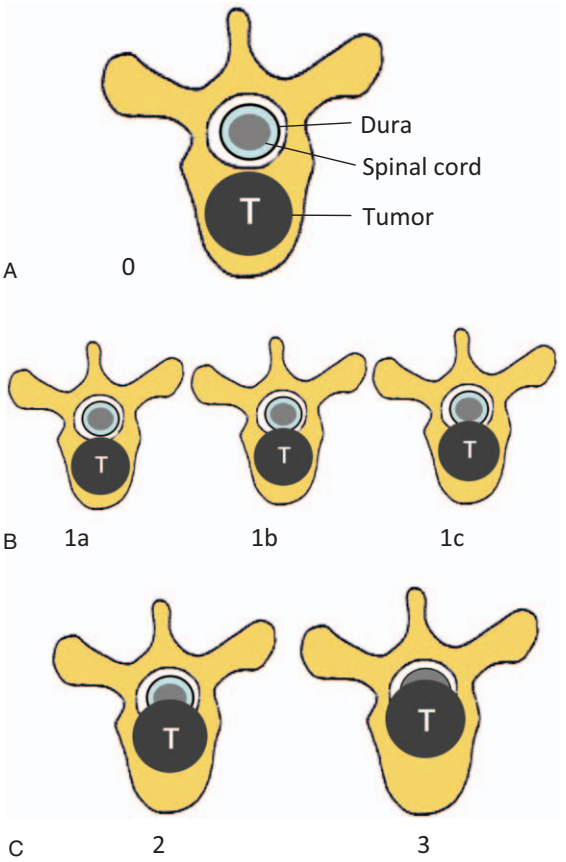

Figure 1. Schematic representation of the six-point ESCC grading scale. **A**, Grade 0, bone disease alone. **B**, Grade 1, epidural impingement. 1a, epidural impingement without deformation of the thecal sac; 1b, deformation of the thecal sac without spinal cord abutment; 1c, deformation of the thecal sac with spinal cord abutment, but without cord compression. **C**, Grade 2, spinal cord compression, but with cerebrospinal fluid (CSF) visible around the cord; grade 3, spinal cord compression, no CSF visible around the cord.

At the L2 or lower cauda equina level, it was difficult to differentiate grade 1c compression from grade 2 compression, and all such cases were regarded as grade 1c.

The ESCC scale evaluations were performed by three spine surgeons, and results that were obtained by two or more surgeons were adopted. After 4 weeks, re-evaluations were conducted by the same examiners. We also calculated kappa coefficients for the interexaminer variability among the examiners and intraexaminer variability after 4 weeks.

Transverse Localization of the Tumors

Although the grade of metastatic spine tumor-related spinal cord compression can be evaluated using the ESCC scale, this scale does not take the transverse localization of the tumor into account. Therefore, we also categorized the

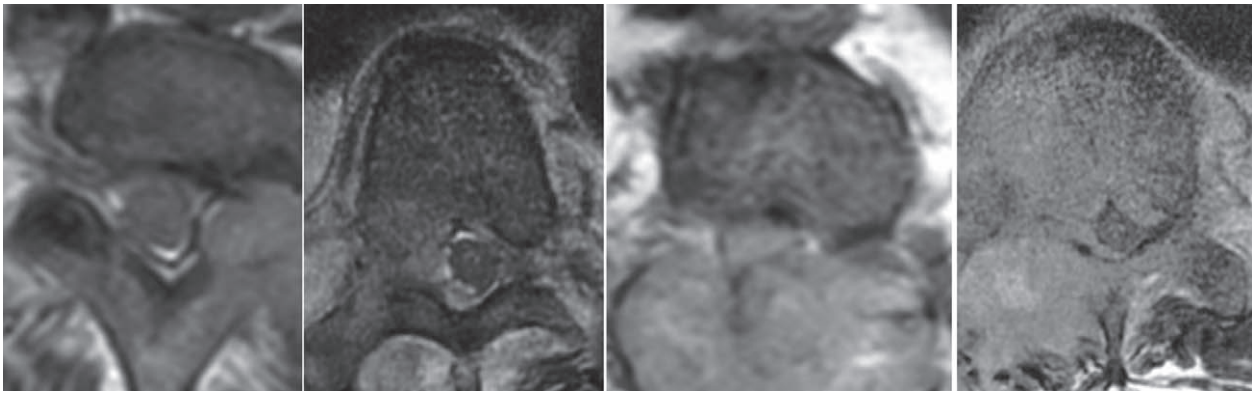

Figure 2. Typical examples for selected ESCC grades. Grade 1b at the T1/T2 level, grade 1c at the T9 level, grade 2 at the T9/T10 level, and grade 3 at the T10 level.

tumor locations into 4 segments (Figure 3): (1) anterior (A), (2) anterior + posterior (A + P), (3) anterior + lateral (A + L), and (4) anterior + posterior + lateral (A + P + L).

American Spinal Injury Association Classification[7]

We used the American Spinal Injury Association (ASIA) classification to evaluate the severity of the subjects' spinal paralysis. It consists of five grades (A to E): (A) complete paralysis (sensory/motor functions are absent from the S4-S5 sacral segments); (B) incomplete paralysis (complete motor paralysis is observed at a neurological level or lower, and sensory function remains in the S4-S5 sacral segments); (C) incomplete paralysis (motor function remains at a neurological level or lower, but less than three of the key muscles exhibit strength levels of at least 50% [C5: elbow flexors, C6: wrist extensors, C7: elbow extensors, C8: finger flexors, T1: finger abductors, L2: hip flexors, L3: knee extensors, L4: ankle dorsiflexors, L5: long toe extensors, S1: ankle plantar flexors]); (D) incomplete paralysis (motor function remains at a neurological level or lower, and three or more of the key muscles display strength levels of ≥50%); and (E) normal (sensory/motor functions are normal). According to these criteria, the severity of paralysis was evaluated on MRI. In addition, the spinal cord level responsible for the patient's paralysis was assessed based on the maximal severity of their spinal cord compression, which was evaluated using the ESCC scale, and the subjects' neurological findings.

Using the above criteria, we investigated the grade of spinal cord compression, the transverse localization of the tumor, and the severity of paralysis in each case.

We also examined the above three items in patients whose ASIA grades deteriorated by one grade or more to ASIA grade C or worse within the first 3 weeks after MRI, that is, those with rapidly progressive paraplegia.

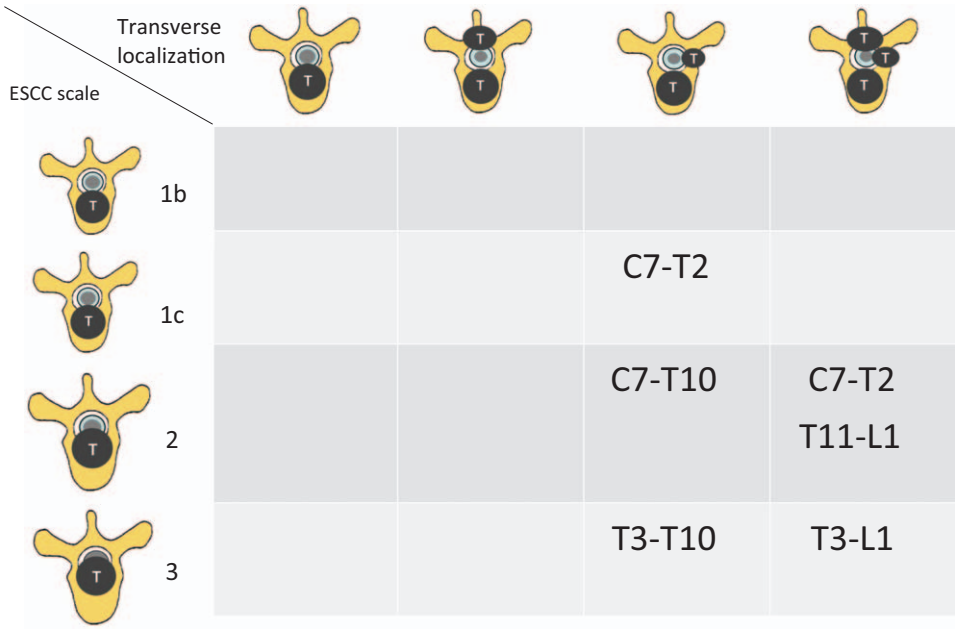

Figure 3. High-risk group for progressive severe paralysis. ESCC scale, transverse localization of tumors, and spinal level.

TABLE 1. C3-C7 Lesions

ESCC	ASIA	A	A + P	A + L	A + P + L
1b (n = 18)	E	8	2	3	
	D	1		4	
	C				
	B				
	A				
1c (n = 23)	E	2	2	2	2
	D	2	1	7	2
	C			3	
	B				
	A				
2 (n = 19)	E				
	D	2	1	4	5
	C		1	3	3
	B				
	A				
3 (n = 5)	E				
	D			1	2
	C				2
	B				
	A				

A indicates anterior lesions; A + L, anterior and lateral lesions; A + P, anterior and posterior lesions; A + P + L, anterior, posterior, and lateral lesions (circumferential lesions); ASIA, American Spinal Injury Association; ESCC, epidural spinal cord compression scale.

RESULTS

Inter- and Intraexaminer Agreement on the Epidural Spinal Cord Compression Scale

Interexaminer Agreement

There were no patients in which the results of the ESCC scale evaluation differed among the three surgeons. The mean consistency rate was 96.1% (range: 95.0%–96.8%), and the mean kappa coefficient was 0.89 (range: 0.86–0.91).

Intraexaminer Agreement

The mean intraexaminer consistency rate was 97.4% (range: 96.8%–97.9%), and the mean kappa coefficient was 0.95 (range: 0.93–0.96).

Evaluation of the Spinal Cord Level Responsible for Paralysis

The three surgeons obtained consistent results during the evaluations of the spinal cord level responsible for each patient's paralysis (consistency rate: 100%). The following spinal cord levels were found to be responsible for the patients' paralysis: C1-C2 in 12 patients, C3-C6 in 65 patients, C7-T2 in 41 patients, T3-T10 in 149 patients, T11-L1 in 80 patients, L1-L5 in 113 patients, and S1 in 9 patients.

Grade of Spinal Cord Compression With Respect to the Level of the Affected Site, Transverse Localization of the Tumor, and Paralysis Severity

The MRI findings of spinal cord compression (according to the ESCC scale) were not correlated with the severity of paralysis (ASIA classification) at any spinal cord level (Tables 1–4).

At levels C1-C2, ASIA grade A–C paralysis occurred in 7 of 12 patients (58.3%). ASIA grade A–B paralysis developed in three patients, all of whom were classified as having ESCC 1b spinal cord compression.

Of the 113 patients with L2-L5 lesions, there were 52 patients (46.0%) who exhibited dural compression without paralysis, which was indicative of ASIA grade E paralysis. There were 18 patients (15.9%) with ASIA grade C paralysis, and there were only 3 patients (2.7%) with ASIA grade B paralysis. Also, three patients with L2-L5 lesions and ESCC grade 3 spinal cord compression did not develop paralysis.

At the S1 level (n = 9), there were five patients (55.6%) with dural compression who did not develop paralysis, which was indicative ASIA grade E. There were no patients with ASIA grade C or worse paralysis.

On the contrary, the incidence of ASIA grade C or worse paralysis was high among the patients with ESCC grade 2 or worse spinal cord compression at the C7-L1 level (Tables 1–4).

ASIA grade D or worse paralysis developed in at least 50% of the patients with ESCC grade 1b or worse spinal cord compression at the C1-T2 level (Tables 1 and 2), whereas it arose in at least 50% of the patients with ESCC grade 1c or worse spinal cord compression at the T3-L5 level (Tables 3 and 4).

Examinations of the Patients Who Suffered Rapidly Progressive Paralysis

There were 19 patients who suffered deterioration of one grade or more to ASIA grade C or worse within the first

TABLE 2. C7-T2 Lesions

ESCC	ASIA	A	A + P	A + L	A + P + L
1b (n = 10)	E	5		1	
	D	1		1	1
	C			1	
	B				
	A				
1c (n = 15)	E	1			2
	D	2	2	5	
	C			1	1
	B				1
	A				
2 (n = 9)	E				2
	D				1
	C	1		2	3
	B				
	A				
3 (n = 7)	E				1
	D				1
	C				1
	B			3	
	A				1

A indicates anterior lesions; A + L, anterior and lateral lesions; A + P, anterior and posterior lesions; A + P + L, anterior, posterior, and lateral lesions (circumferential lesions); ASIA, American Spinal Injury Association; ESCC, epidural spinal cord compression scale.

3 weeks after MRI (C3-C6, one patient; C7-T2, four patients; T3-T10, eight patients; T11-L1, five patients; and L2-L5, one patient). The primary foci consisted of lung cancer in six patients; liver cancer in three patients; bladder cancer in two patients; and breast cancer, prostate cancer, colorectal cancer, gastric cancer, gallbladder cancer, neuroblastoma, and uterine cancer in one patient each. The nature of the primary focus was unclear in one patient. Of these,

TABLE 3. T3-T10 Lesions

ESCC	ASIA	A	A + P	A + L	A + P + L
1b (n = 32)	E	17	6	5	2
	D			1	
	C			1	
	B				
	A				
1c (n = 23)	E	3		6	2
	D	2	1	1	1
	C	1	1		5
	B				
	A				
2 (n = 48)	E				1
	D		1	5	2
	C	1		13	20
	B			2	3
	A				
3 (n = 44)	E				1
	D				2
	C			7	12
	B			11	9
	A				2

A indicates anterior lesions; A + L, anterior and lateral lesions; A + P, anterior and posterior lesions; A + P + L, anterior, posterior, and lateral lesions (circumferential lesions); ASIA, American Spinal Injury Association; ESCC, epidural spinal cord compression.

TABLE 4. T11-L1 Lesions

ESCC	ASIA	A	A+P	A+L	A+P+L
1b (n=23)	E	17	2	1	1
	D	1		1	
	C				
	B				
	A				
1c (n=19)	E	4	2	1	2
	D	3		3	2
	C			2	
	B				
	A				
2 (n=17)	E	1		1	1
	D			4	2
	C	1		3	4
	B				
	A				
3 (n=21)	E				
	D			2	
	C				8
	B			1	8
	A				2

A indicates anterior lesions; A+L, anterior and lateral lesions; A+P, anterior and posterior lesions; A+P+L, anterior, posterior, and lateral lesions (circumferential lesions); ASIA, American Spinal Injury Association; ESCC, epidural spinal cord compression scale.

rapidly progressive paralysis occurred in at least 30% of the patients who exhibited anterolateral or circumferential ESCC grade 2 or 3 spinal cord compression at the C7-T2, T11-L1, or T3-T10 level on MRI cross-sections (Table 5, Figure 3).

DISCUSSION

Bilsky *et al* reported that the ESCC scale, which consists of four grades, is useful for selecting the optimal treatment for spinal cord compression.[8] In 2010, they indicated that T2-weighted axial images were more useful than T1-weighted axial images for discriminating between the grades of the ESCC scale.[3] In this study, the use of T2-weighted axial MRI for ESCC scale–based evaluations of spinal cord compression resulted in favorable inter- and intraexaminer agreement.

In clinical practice, the MRI findings of spinal cord compression are not always correlated with the severity

TABLE 5. Patients That Suffered Rapidly Progressive Paralysis

Lesion	ESCC Grade	Transverse Localization	Deterioration	Number of Subjects	Frequency (%)
C3-C6 (n=1)	1c	A+L	1	8	12.5
C7-T2 (n=4)	1c	A+L	1		50
	2	A+L	1	2	100
	2	A+PF	2	1	66.7
T3-T10 (n=8)	1b	A+L	1	3	20
	2	A+L	2	5	40
	2	A+P+L	1	5	12.5
	3	A+L	2	8	50
	3	A+P+L	2	4	33.3
T11-L1 (n=5)	2	A+P+L	1	6	33.3
	3	A+P+L	4	3	80
L2-L5 (n=1)	3	A+L	1	5	20
		Total	19	467	4.1

Deterioration: patients whose ASIA grade deteriorated by one grade or more to ASIA grade C or worse within the first 3 weeks after magnetic resonance imaging (MRI).

A indicates anterior lesions; A+L, anterior and lateral lesions; A+P, anterior and posterior lesions; A+P+L, anterior, posterior, and lateral lesions (circumferential lesions); ESCC, epidural spinal cord compression scale.

of paralysis, which depends on the level of the affected spinal cord site. Paralysis often progresses rapidly, leading to severe conditions in many cases. However, no previous studies have reported the grade of spinal cord compression at which neurological symptoms appear or paralysis rapidly progresses.

In addition, few studies have investigated the relationship between the MRI findings of spinal cord compression and the severity or extent of paralysis with respect to the level of the affected spinal cord site. Recently, Oshima *et al*[9] conducted a retrospective study of T2-weighted axial MR images and reported that postoperative gait function could be predicted based on the circumferential ratio of cord compression (CRCC). They also indicated that there was no relationship between the compression site (the direction of the compression) and pretreatment paralysis/post-treatment gait function. In addition, they emphasized that nerve function depended on the grade of circumferential spinal cord compression and that spinal cord compression does not involve a simple mechanical compressive force.

Oshima *et al* also reported that a CRCC of more than 50% was correlated with poor ambulatory function, suggesting that the CRCC is a useful MRI finding for assessing the risk of metastatic spine tumor–induced paralysis. In our study, circumferential spinal cord compression and spinal deformity were seen in some, but not all, cases of severe paralysis.

In the present study, at least 50% of the patients with ESCC grade 1b or worse spinal cord compression at the C1-T2 level developed ASIA grade D or worse paralysis (Tables 1 and 2). In addition, at least 50% of the patients with ESCC grade 1c or worse spinal cord compression at the T3-L5 level developed ASIA grade D or worse paralysis (Tables 3 and 4). This difference might have been caused by dynamic factors associated with the cervical spine or cervical-thoracic transition area. Neurological symptoms might appear even if the grade of spinal cord compression or entrapment is low.

With respect to patients that are at high risk of the rapid progression of paralysis to a severe condition, it is difficult to predict paralysis based on T2-weighted axial MRI alone unless the relationship between the timing of MRI examinations and the stage of paralysis could be elucidated. In this study, we retrospectively reviewed the cases of patients whose paralysis deteriorated by one grade or more to ASIA grade C or worse within the first 3 weeks after MRI. The frequency of lung cancer patients was high among these patients, but lung cancer did not account for a significant percentage of all subjects. When we examined our T2-weighted axial MRI findings for each same spinal cord level, we found that the patients that exhibited anterolateral or circumferential ESCC grade 2 or 3 spinal cord compression at the C7-T2, T11-L1, or T3-T10 level constituted a high-risk group for the deterioration of paralysis, that is, they demonstrated a paraplegia incidence of at least 30% within the first 3 weeks after MRI (Figure 3). Although MRI results might depend on the timing of MRI with respect to the stage of paralysis, treatment should be started promptly in patients who fall into the abovementioned group.

The limitations of this study were as follows: (1) the craniocaudal direction of the patients' spinal cord compression was not taken into account, although the examiners exhibited 100% consistency with respect to their ability to identify the level of each paralysis-inducing lesion; (2) no dynamic factors were examined[10]; and (3) the timing of MRI with respect to the stage of paralysis was unclear.[11] Concerning tumor-related mechanical compression, we could not investigate the duration of compression, primary tumor rigidity, or the intraspinal circulation under compression. A prospective study involving these factors should be conducted in future.

Furthermore, some patients with severe paralysis or whose paralysis had deteriorated rapidly at the time of the MRI examination were already operated on within the next 3 weeks. Therefore, the rate of rapidly deteriorating paralysis may increase further.

➢ Key Points

- ❑ The severity of paralysis was not correlated with the ESCC scale.
- ❑ More than 50% of patients with ESCC grade 1b or worse spinal cord compression at the C1-T2 level or ESCC grade 1c or worse spinal cord compression at the T3-L5 level developed ASIA grade D or worse paralysis.
- ❑ The high-risk group for rapidly progressive paralysis, which was identified based on deterioration of one grade or more to ASIA grade C or worse within the first 3 weeks after the MRI, consisted of patients with anterolateral or circumferential ESCC grade 2 or 3 spinal cord compression at the C7-T1 level.

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