

An exploration on the radiological features associated with motor deficits in patients with metastatic epidural spinal cord compression

Y.-S. LIU, S.-B. LIU, D.-F. LI, H.-T. FAN, J.-Y. HUAI, J. GUO

Department of Orthopaedics, the No. 307 Hospital of People's Liberation Army, Beijing, China.

Abstract. – OBJECTIVE: This study was designed to explore the radiological features associated with the motor deficits in patients with metastatic epidural spinal cord compression (MESCC).

PATIENTS AND METHODS: The patients with MESCC admitted in our department from July 2006 to December 2008 were included in this analysis. The data on the radiological features of affected vertebrae showed by computed tomography or magnetic resonance imaging scan and the motor deficits level assessed as paralysis or non-paralysis according to Frankel Classification Grading System were collected. A multiple regression model was established to identify the radiological features associated with the paralysis status of MESCC patients.

RESULTS: A total of 56 patients with MESCC were included in this study. All patients had invasion of vertebral body, main affected vertebrae was consecutive in 75% (8/12) of patients with lesions of upper thoracic spine and/or cervicothoracic junction and 18.18% (8/44) of patients with lesions of cervical spine, middle thoracic spine, lower thoracic spine, and lumbar spine. The paralysis status was consisted with the finding of epidural space involvement. A linear relationship between paralysis status and the radiological features including lamina involvement, retropulsion of posterior wall, and location in upper thoracic spine and/or cervicothoracic junction was detected by the “optimal” regression equation, of them lamina involvement has the greatest impact on paralysis status.

CONCLUSIONS: The radiological features including lamina involvement, retropulsion of posterior wall, and location in upper thoracic spine and/or cervicothoracic junction were significantly associated with the motor deficits of patients with MESCC, which might be helpful to identify these patients who were susceptible to motor deficit, especially lamina involvement.

Key words:

Metastatic epidural spinal cord compression, Spinal metastases, Motor deficit, Radiological feature.

Abbreviations

Metastatic epidural spinal cord compression (MESCC); Magnetic Resonance Imaging (MRI); Spinal cord compression (SCC); Metastatic spinal cord compression (MSCC);

Cervical spine (CS); Upper thoracic spine (T 1-4) and/or cervicothoracic junction (UTSCT); Middle thoracic spine (MTS) (T5-8); Lower thoracic spine (LTS) (T 9-12);

Lumbar spine (LS); Lamina involvement (X_1); retropulsion of posterior wall (X_2); Consecutive main affected vertebra (X_3); Pedicle involvement (X_4); Fracture of anterior column (X_5); Fracture of posterior wall (X_6).

Introduction

Metastatic epidural spinal cord compression (MESCC) is the secondary compression of the spinal cord occurred when or subsequently after cancer metastasizes to the spine or epidural space¹. MESCC is one of most dreaded complications of malignancy that affects about 5% of patients with cancer. With findings of Magnetic Resonance Imaging (MRI), MESCC can be divided into “overt SCC”, defined as the involvement or compression of either the spinal cord or the cauda equina by an epidural or intramedullary mass lesion; and “occult SCC”, defined as metastatic disease causing impingement, indentation or loss of definition of the thecal sac². MESCC is a medical emergency that needs rapid diagnosis and treatment to prevent permanent paralysis^{3,4}. The natural course of the spinal metastases progression suggests that patients with apparent occult spinal cord compression diagnosed by MRI may develop neurological deficits if left untreated⁵. Time to development of symptom or motor deficits and ambulatory status prior treatment has been established as the independent prognostic factor of functional outcomes and survival factors for patients with known or unknown primary lesions in several recent studies⁶⁻⁹. However, a significant number of patients

with metastatic spinal cord compression (MSCC) had radiological evidence of spinal cord compression, but normal motor impairment, i.e. occult MSCC¹⁰. Thus, the early diagnosis and active management is important to prevent motor deficits and to improve the overall outcomes and survival of patients with MESCC⁷.

This study was designed to explore the radiological features associated with motor deficits in patients with MESCC, which were expected to be helpful to identify the MESCC patients susceptible to motor deficits.

Patients and Methods

Patients

The patients with MESCC admitted in our department from July 2006 to December 2008 who had radiological findings of main affected vertebrae on computed tomography (CT) or magnetic resonance imaging (MRI) scan and data of motor deficits determined by Frankel scores were included in this analysis. According to Frankel Classification Grading System¹¹, the level of motor deficits was assessed as paralysis defined by Frankel grades of A-C or non-paralysis defined by Frankel grades of D-E. Retrospective review of radiology reports was performed to collect the data on the radiological features of main affected vertebrae, including vertebral segment with lesions that was classified as cervical spine (CS), upper thoracic spine (T 1-4) and/or cervicothoracic junction (UTSCT), middle thoracic spine (MTS) (T5-8), lower thoracic spine (LTS) (T 9-12), lumbar spine (LS), lamina involvement (X_1), retropulsion of posterior wall (X_2), consecutive main affected vertebra (X_3), pedicle involvement (X_4), fracture of anterior column (X_5), fracture of posterior wall (X_6).

Statistical Analysis

A multiple linear regression model was used to evaluate the relationship between the motor deficits and radiological features. Fourfold table Chi-square test was used to compare the incidence of consecutive main affected vertebrae. The $p < 0.05$ was considered to indicate a statistically significant difference. All statistical analyses were conducted using SPSS software (SPSS, Inc., Chicago, IL, USA) version 16.5 for Windows.

Results

A total of 56 patients with MESCC were included in this study. The paralysis status and radiological features of main affected vertebrae were shown in Table I. Main affected vertebrae was consecutive in 75% (8/12) of patients with lesions of UTSCT and 18.18% (8/44) of patients with lesions of CS, MTS, LTS, and LS ($\chi^2 = 8.405$; $p = 0.004$) (Table II).

For all 56 MESCC patients, the multiple regression analysis showed a significant correlation between the paralysis status (Y) and radiological features ($p < 0.0001$) (Table III). The adjusted coefficient of determination (R_c^2) of this regression model was 0.548 ($0 \leq R_c^2 \leq 1$) (Table IV), which indicated that radiological features when served as independent variables could interpret the percentage of paralysis status (Y) which served as dependent variable.

The correlation analysis of MESCC patients' paralysis status (Y) and radiological features (X) showed that the radiological features of main affected vertebrae significantly associated with the paralysis status included lamina involvement (X_1), retropulsion of posterior wall (X_2), consecutive main affected vertebra (X_3), fracture of posterior wall (X_6), location in UTSCT (X_7). In addition, consecutive main affected vertebra (X_3) was

Table I. Paralysis status and radiological features of main affected vertebrae of the 56 MESCC patients included.

Patients number		
Paralysis status after admission	16	
Invasion of the epidural space	16	
Invasion of vertebral body	56	
Segment of affected vertebra		
CS	4	
UTSCT	12	
MTS	4	
LTS	12	
LS	24	
Lamina involvement	14	
Retropulsion of posterior wall	28	
Consecutive main affected vertebra		
Pedicle involvement	38	
Fracture of anterior column	42	
Fracture of posterior wall	22	

Table II. Incidence of consecutive main affected vertebrae in different spinal segment of 56 MESCC patients.

Location of main affected vertebrae	N	Consecutive main affected vertebrae	N	χ^2	p
UTSCT	12	UTSCT	8	8.405	
0.004					
CS	4	CS	2		
MTS	4	MTS	4		
LTS	12	LTS	2		
LS	24	LS	0		

UTSCT, upper thoracic spine and/or cervicothoracic junction; MTS, middle thoracic spine; LTS: lower thoracic spine; CS: cervical spine; LS: lumbar spine.

significantly related with lamina involvement (X_1), fracture of anterior column (X_5), and location in UTSCT (X_7); fracture of posterior wall (X_6) was significantly related with retropulsion of posterior wall (X_2), pedicle involvement (X_4), and fracture of anterior column (X_5) (Table V). So a regression analysis was warranted to further screen the independent variables.

As shown in Table VI, the “optimal” regression equation, contained three independent variables after excluding the most non-significant variable individually via backwards stepwise regression, showed a linear relationship between MESCC patients’ paralysis and the radiological features including lamina involvement (X_1), retropulsion of posterior wall (X_2), and location in UTSCT (X_7). According to the standardized coefficients for the regression model, among the three radiological features, lamina involvement (X_1) had the greatest impact on MESCC patient's paralysis status.

Discussion

MESCC is the common complication of malignant tumor, account for 5% of patients with cancer¹. The mechanisms of spinal compression caused by MESCC might related with intramedullary edema resulted from damage to vertebral venous system in early, and irreversible

myelonecrosis due to spinal cord ischemia in later.

Motor deficits occurred in 35-75% of patients with MESCC, and about 50-68% of patients with MESCC have lost the walking ability when they are first diagnosed with MESCC¹. MESCC is an emergency of patients with cancer, which needs to be rapidly diagnosed and treated before development of permanent paralysis^{1,12}. It has been established that better functional outcome after treatment was associated with pre-treatment ambulatory status^{6,13}, the same to the improved survival^{7,8}. Therefore, to explore and identify the correlation between motor deficits and the radiological features of patients with MESCC, which will in turn be helpful for early identifying the MESCC patients who are susceptible to motor deficits, is crucial for the prognosis¹⁴.

Spinal metastases can invade into epidural space and then result in direct spinal cord compression by growing into the spinal canal of paraspinal tumors through the intervertebral foramen which is common for lymphoma and neuroblastoma, or indirect spinal cord compression invasion into epidural space subsequent to hematogenous vertebral body metastasis^{1,4}. In our study, the paralysis statuses were exactly consisted with the radiological features indicating the invasion of intraspinal epidural tissue, all the 16 patients with invasion of intraspinal epidural tissue by main affected vertebrae developed motor deficits with strength grade 0-2, which suggested

Table III. Variance analysis of regression model for paralysis status (Y) and radiological features (X) of 56 MESCC patients.

Source of variation	SS	df	MS	F	p
Regression sum of squares	7.031	7	1.004	10.965	0.000
Residual sum of squares	4.598	49	0.094		
Total sum of squares	11.429	55			

SS: sum of squares; df: degree of freedom; MS: mean square.

Table IV. The coefficient of determination of regression model for paralysis status (Y) and radiological features (X) of 56 MESCC patients.

Model	R	R ₂	Ra ₂	SE
Regression	0.784 ^a	0.615	0.559	0.30267

R: multiple correlation coefficient; R²: coefficient of determination; R_a²: adjusted coefficient of determination; SE: standard error.

that severe motor deficits were inevitable if the radiological finding showed invasion of intraspinal epidural tissue by metastasis in patients with MESCC¹⁰. Therefore, it was a delay to predict the paralysis development of patients with MESCC by radiological findings of intraspinal epidural tissue invasion.

In our study, the patients with lamina involvement had the highest paralysis incidence of 75%. Consistently, the multiple regression analysis showed that lamina involvement was significantly associated with paralysis status of patients with MESCC ($p = 0.000$). The “optimal” regression equation established via backwards stepwise regression showed a linear regression relationship between MESCC patients’ paralysis and lamina involvement. The standardized coefficients also indicated that lamina involvement provided the greatest impact on MESCC patient’s paralysis status. In study by Yasushi etc, 55% patients with lamina involvement developed motor deficits at the initiation of radiation therapy (RT) compared to 5% of patients without lamina involvement ($p = 0.0001$)¹⁵. In addition, 93% of lesions resulted in motor deficits at the initiation of RT had lamina involvement. The patients with metastasis affected lamina were susceptible to infiltration of epidural

space and developed MESCC relatively early. All these findings were similar to ours. Therefore, the lamina involvement might be a predictor of motor deficit in MESCC patients.

Retropulsion of posterior wall was another radiological feature identified in our study that might be helpful for identifying the MESCC patients susceptible to motor deficit. According to the results of multiple regression correlation analysis, retropulsion of posterior wall (X_2) and fracture of posterior wall (X_6) were both significantly associated with the paralysis status of MESCC patients. However, it’s important to note that fracture of posterior wall (X_6) was highly correlated with retropulsion of posterior wall (X_2) ($p = 0.000$). Thus, further backwards stepwise regression was conducted to screen the independent variables to establish an “optimal” regression equation, which then showed a linear regression relationship between MESCC patients’ paralysis and the radiological feature of retropulsion of posterior wall. In previous study, Abdi et al¹⁶ found that collapse involving the posterior vertebral body was associated with the potency of spinal instability, which could be more evident when there was angular or translational deformity. The author proposed that significant collapse of the vertebral body with retropulsion of the posterior wall indicated middle column involvement and spinal instability. Based on the previous findings and our results, infiltration of vertebral body would have a large effect on paralysis status of MESCC patients when it was accompanied with retropulsion of the posterior wall, even without marked mechanic instability, which indicated that retropulsion of the posterior wall predicted the neurological instability.

Moreover, the level of consecutive main affected vertebrae was also associated with the paralysis status of MESCC patients. Jacobs et al¹⁷ reported

Table V. Partial results of correlation analysis of regression model for paralysis status and radiological features of 56 MESCC patients.

		Y	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇
Pearson correlation	Y	1.000	0.730	0.316	0.411	0.097	-0.183	0.301	0.440
	X ₃	0.411	0.309	0.076	1.000	-0.181	-0.309	0.073	0.759
	X ₆	0.301	0.211	0.658	0.073	0.397	0.296	1.000	0.115
Significance level	Y		0.000	0.009	0.001	0.239	0.089	0.012	
	X ₃		0.001	0.010	n.s.	n.s.	0.010	n.s.	0.000
	X ₆		0.012	n.s.	0.000	n.s.	0.001	0.014	n.s.
N		56	56	56	56	56	56	56	56

Y: paralysis status; X₁: lamina involvement; X₂: retropulsion of posterior wall; X₃: consecutive main affected vertebra; X₄: pedicle involvement; X₅: fracture of anterior column; X₆: fracture of posterior wall; X₇: location in upper thoracic spine and/or cervicothoracic junction; n.s., non significant.

Table VI. Parameter estimation and standardized regression coefficients of final stepwise regression model for paralysis status and radiological features of 56 MESCC patients.

Variance	b_j	Sb_j	b_j	t value	p value
Constant term	-0.009	0.059		-0.148	0.883
X_1	0.639	0.098	0.612	6.528	0.000
X_2	0.149	0.081	0.165	1.841	0.071
X_7	0.282	0.100	0.256	2.813	0.007

X_1 : lamina involvement; X_2 : retropulsion of posterior wall; X_7 : location in upper thoracic spine and/or cervicothoracic junction; b_j : coefficient of regression; Sb_j : standard error; b_j : standardized regression coefficients. Significance level: $p < 0.05$. The optimal regression equation of regression model for paralysis status (Y) and radiological features (X) of MESCC patients: $Y = -0.009 + 0.639X_1 + 0.149X_2 + 0.282X_7$.

that 40-70% of MESCC patients had multi-segmental spinal metastases. In our study, 46.4% of the patients had consecutive vertebra involvement, and main affected vertebra was consecutive in 17/56 patients, more than half of them (9 patients) occurred in level of UTSC. According to the results of multiple regression correlation analysis, affected vertebra located in UTSC and consecutive vertebra involvement were both significantly associated with the paralysis status of MESCC patients; however, it should be noted that consecutive vertebra involvement was highly correlated with the location of UTSC ($p = 0.000$). Then the “optimal” regression equation showed the radiological feature of affected vertebra located in UTSC was significantly associated with the paralysis status of MESCC patients. Similar, Yasushi etc. found that in patients with symptomatic MESCC, most of the affected vertebra located in the thoracic spine (70%), especially in the upper thoracic and thoracolumbar spine¹⁵. So we believed that MESCC patients with lesions occurred in UTSC might be susceptible to motor deficits.

However, the small number of patients included in our study might limit the generalization of these results. Further large, prospective trials are warranted to confirm the ability of these three radiological features to predict the paralysis status of MESCC patients. In addition, no MRI, but only CT scans were obtained in some patients.

Conclusions

Our study showed that the radiological features including lamina involvement, retropulsion of posterior wall, and location in UTSC were significantly associated with the motor deficits of patients with MESCC, which might be helpful to identify the MESCC patients who were susceptible to mo-

tor deficits, especially lamina involvement. However, further large studies with a long follow-up are warranted to establish the radiological features that can predict the motor deficits of these patients.

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Conflict of Interest

The Authors declare that there are no conflicts of interest.

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