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ORIGINAL RESEARCH

Pulmonary Function in Patients with Solitary Spinal Metastases: A Hospital-Based Cross-Sectional Study

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Background: This study aimed to evaluate the pulmonary function of patients with solitary spinal metastases with the intention of providing a data-driven basis to evaluate cardiopulmonary function in patients with spinal metastases in the future.

Methods: This was a retrospective analysis of 157 patients with solitary spinal metastases in our hospital from January 2010 to December 2018. This study analyzed the influence of different stages of solitary spinal involvement on respiratory function, based on the spinal segment invaded by the metastases.

Results: The highest proportion of solitary spinal metastases occurred at the thoracic level (49.7%), with the lowest proportion at the sacral level (3.9%). The largest number of patients were in the 60–69-year age group (34.6%). There was no significant difference in pulmonary function among patients with spinal metastases at different segments (all $P > 0.05$). The highest vital capacity (VC), forced expiratory volume in one second (FEV_1), and forced vital capacity (FVC) were observed in patients who were overweight (all $P < 0.05$). There were no significant relationships between pulmonary respiratory function and body mass index (BMI) groups in male patient with spinal metastases. In female patients, the highest VC, FEV_1, FVC, and maximum voluntary ventilation were observed in patients who were overweight (all $P < 0.05$).

Conclusion: Thoracic vertebral metastasis was the main type of solitary spinal metastatic tumor. Spinal metastases were more common at ages 60–69 years. There was no significant difference in pulmonary function among patients with spinal metastasis at different segments. Lung function was better in patients with spinal metastases who were overweight, especially in female patients.

Keywords: spinal metastases, pulmonary function, clinical features

Introduction

With the significant increase in the overall incidence of malignant tumors, the incidence of spinal metastases is also increasing annually.[1] Overall, 30–50% of patients with advanced cancer develop spinal metastases, second only to lung and liver metastases.[2,3] Often, these tumors can significantly impact a patient's quality of life due to pain, compression, and even paralysis from spinal cord injury.[4,5] For patients with spinal metastases, the primary goal of treatment is to prolong the patient's overall survival and improve the quality of the remaining life as much as possible. In general, it is critical to assess a patient's overall performance and life expectancy to guide patients in choosing the best treatment option. Previous studies have shown that the primary cancer site, Karnofsky Performance Scale, albumin level, number of visceral metastases, and analgesic use will affect survival expectations in patients with spinal metastases.[6–9] Cardiopulmonary function can seriously affect the intraoperative status and long-term prognosis of cancer patients.[10,11] However, few studies have assessed respiratory function in patients with spinal metastases.

Therefore, this study recruited patients with solitary spinal metastases and evaluated the pulmonary function of these patients, with the intent to provide a data-driven basis for the evaluation of cardiopulmonary function of spinal metastases in the future.

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Methods

Patients

The clinical data of 157 patients undergoing surgical treatment for spinal metastases were collected from 2010 to 2018. The collected data included age, sex, metastatic site, blood loss, blood test indexes, and pulmonary function indexes. All data were collected by two experimenters, and the collected data were cross-checked.

Given some of chemotherapeutic agents cause potentially pulmonary function injury for long time systemic chemotherapy, so the authors recruited the subjects from SMIG (spinal metastasis intergroup of China) data base of 1706 cases to meet the criteria (Figure 1). Inclusion criteria: (i) All patients had a single vertebral tumour and had an indication for surgery to be treated with vertebral surgery. The indication of the patients were as followed: spine instability associated with mechanical pain, pain or paralysis caused by spinal cord and/or nerve compression due to tumor extension from involved vertebral body. (ii) All patients underwent dynamic MRI of the thoracolumbar spine using the same type of MRI scanner in our hospital to identify the affected cone. (iii) Patients were treated surgically by total en bloc spondylectomy (TES) or vertebral tumour resection.

Exclusion criteria: (i) Patients were treated with systemic chemotherapy or radiotherapy prior to surgery. (ii) Patients who underwent surgical treatment in the form of simple dissection or minimally invasive embolization or who underwent resection of more than one vertebral body. (iii) Patients with incomplete follow-up data. (iv) Patients with asthma, chronic obstructive pulmonary disease (COPD), scoliosis, atelectasis and neuromuscular diseases that affect lung function in the past.

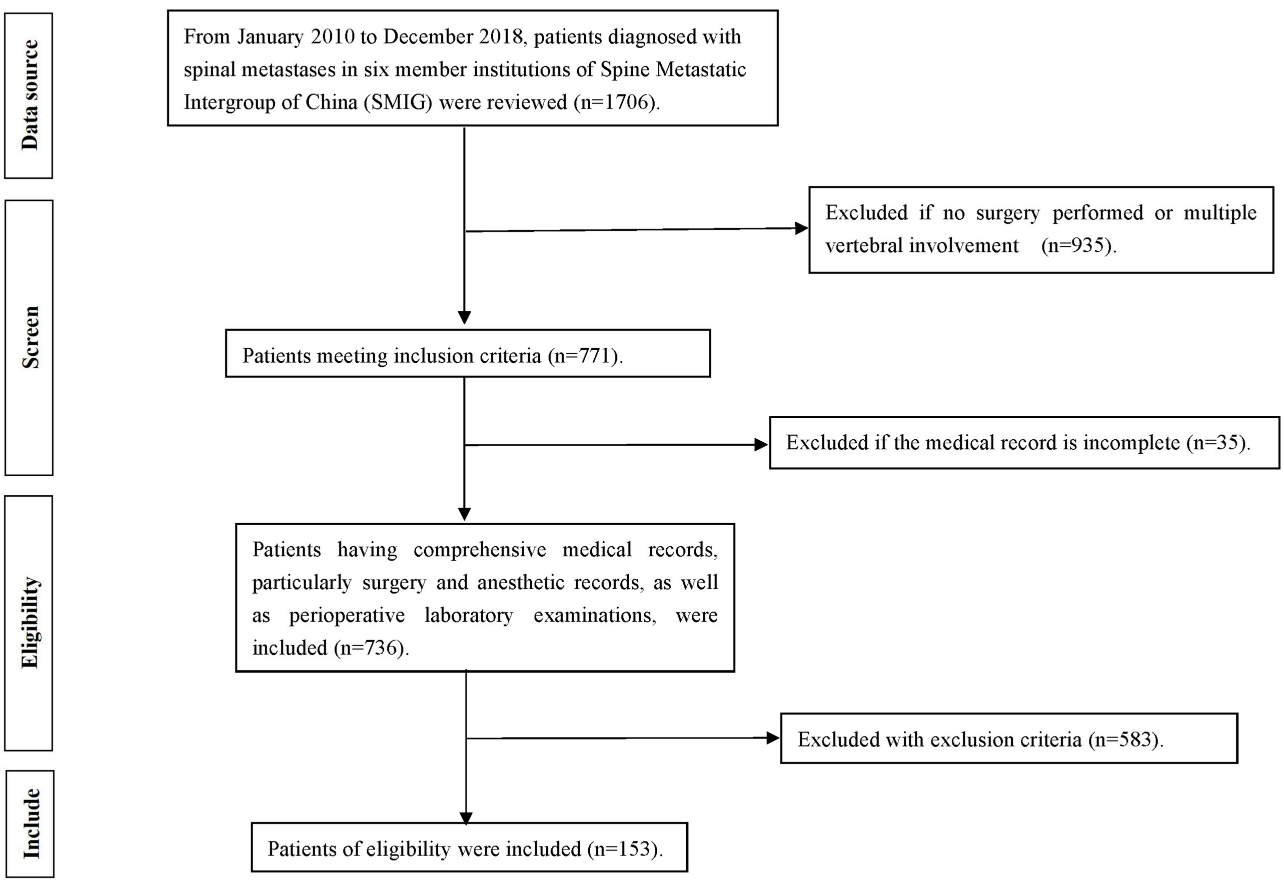

Figure 1 Flowchart of patients' selection. From January 2010 to December 2018, patients diagnosed with spinal metastases in six member institutions of Spine Metastatic Intergroup of China (SMIG) were reviewed (n=1706). 771 patients were meeting inclusion criteria, after excluded those no surgery performed or multiple vertebral patients (n=935). Of these, there were 736 patients having comprehensive medical records, particularly surgery and anesthetic records, as well as perioperative laboratory examinations removing those without medical record (n=35 cases). Excluded those patients with exclusion criteria (n=583), 153 patients were included in this study.

Pulmonary Function Tests

All patients were tested for pulmonary function with the patient in a resting, seated position. Patients' noses were pinched close, allowing breathing only through the mouth into the pulmonary function testing equipment (CareFusion Germany 234 GmbH, MasterScreen), which recorded all values. Patients were instructed to breathe evenly and calmly, then to inhale as deeply as possible following a normal tidal expiration to the point of maximum inhalation, then to exhale as forcefully as possible, and finally to rapidly inhale deeply from the point of maximal expiration to the point of maximum inhalation. At least three measurements of each value were obtained for each patient, and the highest value was used for each measurement. Tests include forced vital capacity (FVC), expiratory volume in one second (FEV_1), rate of forced expiration in one second (FEV_1/FVC), and maximum voluntary ventilation per minute (MVV).

Statistical Analysis

Continuous variables (age, BMI, hemoglobin, lymphocyte percentage, and total albumin) are presented as means and standard deviations (SDs); comparison between groups of these values were performed using Student's *t*-test. Categorical variables (age group: <50, 50–59, 60–69, and ≥70 years; BMI group: low body weight group, normal weight group, overweight group, and obesity group)[12] are presented as numbers and frequencies; comparison between groups were performed using chi-squared tests. All analyses were conducted using SPSS for Windows (version 25.0; SPSS, Chicago, IL, USA); $P < 0.05$ was considered statistically significant.

Results

Patient Data

A total of 153 patients with solitary spinal metastases were included in this study and consisted of 70 (45.8%) male patients and 83 (54.2%) female patients. The highest proportion of spinal metastases was 34.6% in the 60–69-year age group. The highest proportion based on location was thoracic spinal metastasis (49.7%). The mean VC, FEV_1, FVC, FEV_1/FVC, and MVV in male patients were 2.86 ± 0.89 L, 2.35 ± 0.84 L, 2.82 ± 0.9 L, 82.69 ± 11.13, and 117.92 ± 14.26 L, respectively. The mean VC, FEV_1, FVC, FEV_1/FVC, and MVV in female patients were 2.18 ± 0.59 L, 1.84 ± 0.52 L, 2.13 ± 0.59L, 86.39 ± 7.27, and 93.89 ± 10.91 L, respectively. Moreover, the preoperative hemoglobin level in male and female patients was 142.59 ± 19.63 g/L and 125.61 ± 13.13 g/L, respectively (Table 1).

Table 1 Characteristics of Participants in This Study

Category	Men	Women	Total	P
Total	70(45.8)	83(54.2)	153	
Age, means±SD	56.31±14.62	59.59±13.1	58.09±13.87	
Age group, n (%)				0.390
< 50	16(22.9)	13(15.7)	29(19.0)	
50 ~59	22(31.4)	21(25.3)	43(28.1)	
60 ~69	20(28.6)	33(39.8)	53(34.6)	
≥70	12(17.1)	16(19.3)	28(18.3)	
Surgical site:				0.424
Cervical spine	6(8.6)	10(12)	16(10.5)	
Thoracic	37(52.9)	39(47)	76(49.7)	
Lumbar spine	26(37.1)	29(34.9)	55(35.9)	
Sacral spine	1(1.4)	5(6)	6(3.9)	
VC, means±SD (L)	2.86±0.89	2.18±0.59	2.49±0.81	<0.001
FEV1, means±SD (L)	2.35±0.84	1.84±0.52	2.07±0.73	<0.001
FVC, means±SD (L)	2.82±0.9	2.13±0.59	2.44±0.82	<0.001
FEV1/FVC, means±SD	82.69±11.13	86.39±7.27	84.7±9.39	0.015
MVV, means±SD (L)	117.92±14.26	93.89±10.91	104.89±17.34	<0.001

(*Continued*)

Table 1 (Continued).

Category	Men	Women	Total	P
Preoperative laboratory indicators, means±SD:				
Hemoglobin	142.59±19.63	125.61±13.13	133.38±18.44	<0.001
Lymphocyte percentage	25.22±9.7	28.57±11.43	27.04±10.77	0.055
Total albumin	39.46±5.13	39.67±4.25	39.58±4.66	0.785
Postoperative laboratory indicators, means±SD:				
Hemoglobin	110.73±18.1	108.41±18.57	109.52±18.32	0.469
Lymphocyte percentage	11.09±6.54	11.96±6.73	11.54±6.63	0.450
Total albumin	29.54±5.42	30.33±5.64	29.94±5.52	0.417

Abbreviations: VC, Vital capacity; FEV1, Forced Expiratory Volume in the first second; FVC, Forced vital capacity; MVV, Maximal voluntary ventilation.

Analysis of Characteristics of Metastatic Tumors in Different Sites

Table 2 shows that patients with cervical (n = 6, 37.5%) and lumbar (n = 18, 32.7%) metastatic tumors comprised the highest proportions in the 50–59-year age group. The highest proportion among groups was thoracic spinal metastasis in the 60–69-year age group (n = 33, 43.4%). There were no significant differences between different spinal segments with regard to VC, FEV_1, FVC, FEV_1/FVC, or MVV (all $P > 0.05$). Moreover, there were no significant differences between different spinal segments with regard to hemoglobin level, lymphocyte percentage, or total albumin level (all $P > 0.05$).

Relationship Between BMI and Respiratory Function in Patients with Spinal Metastases

Table 3 shows the relationship between BMI and respiratory function in patients with spinal metastases. The highest VC, FEV_1, and FVC were observed in patients who were overweight (all $P < 0.05$). There were no significant differences in BMI groups with regard to FEV_1/FVC or MVV (all $P > 0.05$).

Table 2 Analysis of Characteristics of Metastatic Tumors in Different Sites

Category	Cervical Spine	Thoracic	Lumbar Spine	Sacral Spine	P
Age group, n (%)					0.512
< 50	3(18.8)	11(14.5)	13(23.6)	2(33.3)	
50 ~59	6(37.5)	18(23.7)	18(32.7)	1(16.7)	
60 ~69	4(25.0)	33(43.4)	15(27.3)	1(16.7)	
≥70	3(18.8)	14(18.4)	9(16.4)	2(33.3)	
VC	2.59±1.07	2.37±0.76	2.65±0.76	2.26±0.45	0.223
FEV1	2.19±0.98	1.95±0.68	2.22±0.68	1.96±0.45	0.172
FVC	2.53±1.09	2.33±0.76	2.6±0.76	2.23±0.49	0.244
FEV1/FVC	85.51±8.69	83.7±9.77	85.52±9.77	87.62±5.34	0.579
MVV	102.39±16.48	105.08±15.36	106.46±15.36	94.55±13.07	0.406
Preoperative laboratory indicators:					
Hemoglobin	137±20.24	132.09±18.79	135.09±18.79	124.33±19.26	0.410
Lymphocyte percentage	28.61±7.39	26.18±11.35	27.7±11.35	27.65±13.42	0.792
Total albumin	41.31±3.29	38.82±5.18	40.13±5.18	39.32±2.93	0.173
Postoperative laboratory indicators:					
Hemoglobin	121.31±17.85	107.49±18.95	109.89±18.95	104.17±24.32	0.078
Lymphocyte percentage	11.11±4.93	10.94±5.86	12.84±5.86	9.35±7.66	0.386
Total albumin	32.95±4.32	29.28±5	29.69±5	32.25±10.83	0.115

Abbreviations: VC, Vital capacity; FEV1, Forced Expiratory Volume in the first second; FVC, Forced vital capacity; MVV, Maximal voluntary ventilation.

Table 3 Relationship Between BMI and Respiratory Function in Patients with Spinal Metastases

Category	VC		FEV1		FVC		FEV1/FVC		MVV	
	Mean±SD	P	Mean±SD	P	Mean±SD	P	Mean±SD	P	Mean±SD	P
Total										
BMI group:		0.028		0.026		0.026		0.284		0.623
Low body weight group	1.66±0.62		1.27±0.70		1.59±0.67		78.41±21.36		104.31±28.59	
Normal weight group	2.38±0.79		2.01±0.66		2.35±0.79		86.06±9.48		103.09±17.01	
Overweight group	2.65±0.78		2.20±0.71		2.60±0.79		84.44±7.78		106.83±17.11	
Obesity group	2.42±0.90		1.98±0.84		2.35±0.92		83.44±10.35		102.87±16.58	
Man		0.304		0.341		0.321		0.621		0.863
BMI group:										
Low body weight group	2.03±0.47		1.62±0.71		2.02±0.44		77.54±23.74		120.96±23.35	
Normal weight group	2.77±0.82		2.3±0.72		2.74±0.83		84.25±10.49		117.83±13.25	
Overweight group	3±0.96		2.49±0.9		2.97±0.96		82.9±10.65		118.7±14.81	
Obesity group	2.87±0.83		2.25±0.88		2.77±0.9		79.77±10.72		114.64±13.89	
Woman		0.005		0.005		0.003		0.429		0.029
BMI group:										
Low body weight group	1.1±0.25		0.74±0.21		0.94±0.04		79.72±26.31		79.32±9.84	
Normal weight group	2.09±0.62		1.79±0.53		2.05±0.61		87.46±8.52		91.68±8.80	
Overweight group	2.35±0.42		1.97±0.38		2.30±0.43		85.71±3.88		97.04±11.95	
Obesity group	1.97±0.76		1.71±0.74		1.93±0.77		87.12±9.01		91.11±8.96	

Abbreviations: VC, Vital capacity; FEV1, Forced Expiratory Volume in the first second; FVC, Forced vital capacity; MVV, Maximal voluntary ventilation.

When stratified by sex, there was no significant relationship between pulmonary respiratory function in male patients according to BMI group. In female patients, the highest VC, FEV_1, FVC, and MVV were observed in patients who were overweight (all $P < 0.05$).

Discussion

This study describes the main demographic characteristics and pulmonary function of patients with solitary spinal metastases. In this study, thoracic vertebral metastasis was the most common type of spinal metastatic tumor. In addition, the largest number of patients were in the 60–69-year age group. There was no significant difference in pulmonary function among patients with spinal metastasis at different segments. In addition, respiratory function indicators were higher in patients who were overweight, especially in female patients.

Spinal metastasis is the most common spinal tumor. The improvement of treatment standards and targeted systemic treatment have significantly increased the life expectancy of tumor patients, which in turn has led to an increase in the incidence rate of metastatic spinal cord compression (MSCC). It is reported that the incidence rate of MSCC was 5% - 14%.[13] MSCC patients often have not only pain, but also nerve function defects and functional autonomy impairment.[4,14] Previous studies have examined the influencing factors of postoperative lung function in patients undergoing spinal surgery. A study on the incidence and risk factors of aspiration pneumonia in patients with cervical spine surgery showed that the incidence of postoperative aspiration pneumonia was 5.3 per 1000 cases, and patients ≥ 65 years of age were twice as likely to develop aspiration pneumonia.[15] In a retrospective study, 9734 adult patients undergoing surgery for spinal deformities were evaluated, and spinal deformities were found to be an independent risk factor for postoperative respiratory failure due to pneumonia.[16] Using the National Inpatient Sample database, a retrospective cohort study of patients who had undergone cervical spine surgery found that after multivariate logistic regression analysis, patients with heart failure had a three-fold increased risk of post-aspiration pneumonia. Heart failure was also found to be an independent risk factor for postoperative venous thromboembolism in patients undergoing thoracolumbar fusion surgery.[15] Another study investigated a cohort in the NIS database that showed that patients undergoing thoracic or thoracolumbar fusion had the highest risk of postoperative venous thromboembolism.[17]

Postoperative impaired lung function in patients undergoing spinal surgery may be due to preoperative risk factors. The identification of risk factors helps to guide clinicians through preoperative patient consultation and provides information on the risks and benefits of surgery. The present study focused on assessing the preoperative assessment of lung function for different spinal segment metastases and found no significant difference between different spinal segments, which differs from the findings of previous studies.

Currently, the medulla oblongata is believed to be the basic center for regulating breathing. Diaphragmatic motor neurons and intercostal motor neurons in the cervical and thoracic segments of the spinal cord can excite spinal motor neurons innervating inspiratory muscle through downward conduction, while lateral branches inhibit spinal motor neurons innervating expiratory muscle through inhibitory intermediate neurons. Impairment of respiratory function is more severe when the damaged segment of the spinal cord is at higher levels.[18,19] Spinal cord compression is the most terrible complication of spinal pyramidal metastasis. Respiratory function may not be affected when uncomplicated vertebral body transfer does not cause spinal cord compression. This may explain why there are no significant differences in lung function in patients with spinal metastases at different segments.

Previous studies have found a complex relationship between BMI and lung function, with unclear results. One study showed an inverted U-shaped correlation between BMI and lung function,[20] and others have reported no association.[21,22] Few studies have positively correlated lung function with obesity. These studies have been conducted in different ethnic groups, and there are few correlational studies in China, particularly concerning the relationship between BMI and lung function in patients with cancer. A Chinese study that included 8284 general adults found that obesity was negatively associated with lung function, which was more pronounced in women than in men. However, the study focused only on obesity and did not include more detailed groupings based on BMI.[23] A recent Chinese study involving 32,033 subjects showed that underweight and severe obesity are associated with reduced lung function, while slight obesity was a protective factor for lung function in people at risk of chronic obstructive pulmonary disease.[24] This is consistent with the current results, wherein values of lung function indicators showing the best function were found in patients who were overweight; this may be related to the nutritional status of patients with cancer. As patients with cancer are more likely to be malnourished, BMI may reflect the nutritional status of the patients to some extent, and there may be a non-linear correlation. Follow-up studies with an expanded study population are needed.

There were some limitations in the present study. First, this study did not provide a detailed information about primary tumor location, type, manifestation and stage, which may affect the results. Second, the sample size of this study is small, and it will continue to be expanded to supplement the results. Finally, patient history information was not collected in this study and may bias the results.

Conclusion

In the present study, thoracic vertebral metastasis was the main type of spinal metastatic tumor. In addition, solitary spinal metastases were most frequent in the 60–69-year age group. However, there was no significant difference in pulmonary function among patients with spinal metastasis at different segments. These findings can help doctors better understand the clinical baseline characteristics of respiratory function in patients with spinal cord metastasis. In addition, patients with spinal metastases who were overweight, in particular female patients, manifested better lung function. Therefore, when spinal surgery is performed on patients with spinal metastases, the surgeon can make a more comprehensive assessment of the patient's postoperative respiratory function based on age, gender and BMI. Further studies can be conducted to investigate the relationship between the nutritional status of patients and respiratory function.

Abbreviations

VC, vital capacity; FEV_1, forced expiratory volume in one second; FVC, forced vital capacity; BMI, body mass index; TES, total en bloc spondylectomy; FEV_1/FVC, rate of forced expiration in one second; MVV, maximum voluntary ventilation per minute; SDs, standard deviations.

Data Sharing Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Informed Consent

The present study was approved by the Ethics Committee of Tianjin Hospital and conducted in accordance with the Declaration of Helsinki. A written informed consent was obtained from all patients.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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