CLINICAL ARTICLE

Patient Characteristics Following Surgery for Spinal Metastases: A Multicenter Retrospective Study

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Objectives: To summarize the epidemiological characteristics of patients following surgery for spinal metastases retrospectively and make a univariate analysis to identify independent variables that could affect the operation decision making.

Methods: This was a multicenter retrospective review of patients with spinal metastasis who were treated with surgery from 1 January 2007 to 31 July 2019. Basic clinical data were analyzed retrospectively by univariate analysis to identify independent variables that could affect the decision of operation modalities, including gender, age, spinal metastatic site, Frankel score, Karnofsky performance score (KPS), spinal instability neoplastic score (SINS), visual analogue scale (VAS), Tokuhashi score, urinary and fecal incontinence, spinal pathological fracture, primary tumor, extraspinal metastasis, visceral metastasis, and bone lesion (osteolytic, osteoblastic or mixed).

Results: A total of 580 patients including 332 males and 248 females were enrolled in the study with an average age of 58.26 years old (range, 13–86 years old). The most common spinal metastatic level was the thoracic vertebra (190 [32.76%]), followed by the lumbar vertebra (146 [25.17%]), cervical vertebra (47 [8.10%]), and sacral vertebra (35 [6.03%]). Metastases involving more than two sites of the cervical, thoracic, lumbar, and sacral vertebrae arose in 162 (27.93%) patients. For primary tumor, there were 198 (34.14%) cases of lung cancer, 41 (7.07%) cases of kidney cancer, 39 (6.72%) cases of breast cancer, 38 (6.55%) cases of gastrointestinal cancer, 35 (6.03%) cases of lymphoma and myeloma, 25 (4.31%) cases of prostate cancer, 24 (4.14%) cases of liver cancer, 23 (3.97%) cases of mesenchymal tissue sarcoma, 20 (3.45%) cases of thyroid cancer, and 84 (14.48%) cases were tumor with unknown origin. Sixty-three (10.86%) patients received minimally invasive surgery, 460 (79.31%) patients received palliative surgery, and the remaining 57 (9.83%) received tumor resection. According to the univariate analysis, the KPS score, SINS score, VAS score, Tokuhashi score, urinary and fecal incontinence, spinal pathological fracture, primary tumor, extraspinal metastasis, visceral metastasis, and bone lesion (osteolytic, osteoblastic or mixed) were independent and favorable factors affecting the surgery modalities.

Conclusions: Surgical treatment for spinal metastases was mainly to relieve pain, rebuild spinal stability, improve nerve function, control local tumors, and improve the quality of life of patients. For middle-aged and elderly patients with good general conditions, severe pain, spinal pathological fracture, spine instability and without urinary and fecal incontinence, early surgical treatment should be actively carried out.

Key words: Epidemiological study characteristics; Spinal metastases; Surgical treatment; Univariate analysis

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Introduction

Spinal metastases are the most common type of bone metastases with a prevalence of 30%–70% in cancer patients and 5%–10% metastases may be associated with epidural spinal cord compression (ESCC) leading to impaired mobility, neurologic deficits, and decreased quality of life.\(^1\)–\(^4\). In order to relieve pain, improve nerve function, control local tumors, and improve quality of life for patients, surgery is more and more widely performed, including minimally invasive surgery, palliative surgery, or radical surgery. In turn, the majority of studies report a significant clinical effect for carefully selected spinal metastatic patients. Flavio Tancioni \(^5\)–\(^7\) reported 25 consecutive patients with a diagnosis of ESCC from solid primary tumors. These patients were treated with minimally invasive surgery, with 96% clinical remission of pain and 88% improvement of neurological deficit after 2 weeks. Masuda \(^8\) et al. assessed the surgical outcomes of 44 patients treated with posterior decompression and stabilization and reported that the Frankel score and Eastern Cooperative Oncology Group performance status (ECOG-PS) improved in all patients after surgery, Boriani \(^9\) et al. also applied total en-bloc spondylectomy for 165 patients, and reported that all patients had neurologic deficits improvement and the local recurrences recorded were just 15.28% after 25 years.

However, there still remains some problems when treating spinal metastasis with surgery. Complications must be considered after surgery, such as intra-operation bleeding, spinal cord injury, and hematoma.\(^11\)–\(^12\). Furthermore, the purposes for spinal metastasis treatment are usually different from visceral metastases, which makes the treatment concept, preoperative evaluation, and treatment strategy of spinal metastasis become irregular and arbitrary.\(^13\)–\(^14\). At the same time as the rapid development of immuno-therapy, endocrine therapy, radiotherapy, and chemotherapy (especially targeted therapy), a multidisciplinary combined therapy of spinal metastasis has become a trend.\(^15\)–\(^17\). Therefore, indications and contraindications for spinal metastasis surgery treatment should be clearly understood.

Accordingly, a multicenter retrospective study was performed with the aim of: (i) summarizing the epidemiological characteristics of patients following surgery for spinal metastases; (ii) making a subgroup analysis to identify independent and favorable factors which could affect the surgery selection; and (iii) helping clinicians make a more appropriate surgery decision for patients with spinal metastasis.

Patients and Methods

Participants

This was a multicenter retrospective review of patients with spinal metastasis who were treated with surgery from 1 January 2007 to 31 July 2019. All patients met the following inclusion criteria: (i) patients diagnosed with spinal metastasis precisely by clinical imaging examination (CT, MRI, ECT or PET-CT) or pathological examination; (ii) patients with hematological malignancy spinal metastasis, including lymphoma and myeloma; (iii) patients who were treated by surgical intervention; and (iv) patients whose observation indicators below could be retrospectively analyzed.

Exclusion criteria for this review were: (i) patients with impaired spinal cord function due to other diseases, such as primary spinal tumors, spinal tuberculosis, or spinal degenerative diseases; (ii) outpatients; (iii) patients with another spinal surgery aside from the metastatic tumor; and (iv) patients undergoing biopsies as the only surgical intervention.

Operation Category

Operations applied for patients were mainly divided into minimally invasive surgery and aggressive surgery based on the operation invasiveness.

Minimally invasive surgery was defined as techniques which had lower associated soft tissue damage and shorter hospital lengths of stay, including percutaneous vertebroplasty (PVP) or percutaneous kyphoplasty (PKP).

For aggressive surgery, palliative surgery was applied for the purpose of improving impaired mobility, neurologic function, and quality of life, but the tumor was not resected completely. Posterior laminectomy decompression and subtotal corpectomy (combing with vertebroplasty and microwave ablation or not) were included.

For the purpose of removing the tumor completely, radical surgery was performed for patients, including total or piecemeal vertebrectomy, piecemeal or total en-bloc spondylectomy.

Observation Indicators

Indicators were collected including gender, age, primary malignancy type, spinal metastatic level, spinal pathological fracture, urinary and fecal incontinence, extraspinal metastasis, visceral metastasis, bone lesion, Frankel score, Karnofsky performance score (KPS), visual analogue scale (VAS), spinal instability neoplastic score (SINS), and Tokuhashi score.

Primary malignancy type was defined as the origin of spinal metastatic tumor, such as lung cancer, breast cancer, and kidney cancer, among others.

Spinal metastatic level was defined as the location where the metastatic tumor existed. Based on the anatomical structure of the spine, it was divided into the cervical vertebra, thoracic vertebra, lumbar vertebra, sacral vertebra, and trans-segmental metastasis.

Spinal pathological fracture was defined as vertebral body or appendix fractured due to the tumors based on examinations with X-rays, CT, or MRI.

Extraspinal metastasis was defined as patients with bone metastasis other than that occurring in the spine (such as rib, femur, tibia, fibula).

Bone lesion was identified based on the function of osteoblasts and osteoclasts, including osteolytic, osteoblastic, and mixed, through examinations with X-rays or CT.

Frankel score classification provided an assessment of spinal cord function, which was divided into five grades of A, B, C, D, and E based on the degree of spinal cord injury. Grade A meant complete neurological injury with no motor and
sensory function, Grade B meant preserved sensation only, Grade C meant preserved nonfunctional motor, Grade D meant preserved functional motor, and Grade E meant normal motor and sensory function\textsuperscript{18}. KPS score was used to assess the functional status of patients. From 0 to 100, patients with no symptoms were scored at 100, patients who died were scored at 0. Generally speaking, KPS score above 80 was considered to be self-care level, 50–70 was considered into half self-care level, and 50 was considered patients needing help from others\textsuperscript{19}.

VAS score was a measure of pain intensity and it was a continuous scale comprised of a horizontal (called horizontal visual analog scale) or vertical (called vertical visual analog scale) scale. For pain intensity, the scores could be from 0–10, which was determined by measuring the distance (mm) on the 10 cm line between the “no pain” anchor and the patient’s mark\textsuperscript{20}.

SINS score was applied for assessing the spinal instability. It contained the lesion location, mechanical pain, bone lesion, radiographic spinal alignment, vertebral body collapse, and postero-lateral involvement. The total score was 18 (1–6 meant stable, 7–12 meant potentially stable, and 13–18 meant unstable)\textsuperscript{21}. Tokuhashi score was a prognostic evaluation of patients which was based on KPS score, numbers of extraspinal metastasis, primary malignancy type, and spinal cord palsy. The score was from zero to 15, usually divided into 0–8 with overall survival less than 6 months, 9–11 with overall survival between 6 and 12 months, and 12–15 with overall survival more than 12 months\textsuperscript{22}. Statistical Analysis

Measurement data (age, intra-operation bleeding, and operation time) were expressed as their mean, with the minimum and maximum values compared with the \textit{t}-test. Counting data (gender, primary tumor, and neurological assessment etc.) were compared using the \textit{χ}²-test. All statistical analyses were performed using IBM SPSS Statistics 22.0, and a two-tailed \( P < 0.05 \) was considered significant difference statistically.

Results

Cohort Characteristics

As shown in Table 1, a total of 332 male and 248 female patients were enrolled in the study with an average age of 58.26 years old (range, 13–86 years old), an average intra-operation bleeding of 1334.98 mL (range, 5–9000 mL), and an average operation time of 216.31 min (range, 60–680 min).

The most common spinal metastatic level was the thoracic vertebra (190 [32.76%]), followed by the lumbar vertebra (146 [25.17%]), cervical vertebra (47 [8.10%]), and sacral vertebra (35 [6.03%]). Metastases involving more than two sites of the cervical, thoracic, lumbar, and sacral vertebrae arose in 162 (27.93%) patients. Among these patients, only one single segment metastasis was presented in 270 (46.55%) patients and two or more segment metastases were presented in 310 (53.45%) patients (Fig. 1).

For primary tumors, there were 198 (34.14%) cases of lung cancer, 41 (7.07%) cases of kidney cancer, 39 (6.72%) cases of breast cancer, 38 (6.55%) cases of gastrointestinal cancer, 35 (6.03%) cases of lymphoma and myeloma, 25 (4.31%) cases of prostate cancer, 24 (4.14%) cases of liver cancer, 23 (3.97%) cases of mesenchymal tissue sarcoma, 20 (3.45%) cases of thyroid cancer, and 84 (14.48%) cases were with unknown origin of tumor (Fig. 2). Four hundred and seventy one (81.21%) patients presented unbearable pain with an average VAS score of 7.12 (range, 0–9). As for neurological impairment, 90 (15.52%) patients presented paralysis including Frankel A in 27 patients, Frankel B in 13 and Frankel C in 50 patients. Furthermore, 485 (83.62%) patients presented spinal instability and the average SINS score of 8.02 (range, 7–18). More details were presented in Fig. 3.

Operation Category and Univariate Analysis

In this cohort study, 63 (10.86%) patients received minimally invasive surgery (including 58 PVP and five PKP). Four hundred and sixty (79.31%) patients received palliative surgery (including 290 posterior laminectomy, 155 subtotal corpectomy, 15 subtotal corpectomy combined with microwave ablation and vertebroplasty) and 57 (9.83%) patients received radical surgery (including 36 total vertebrectomy and 21 total en-bloc spondylectomy). The results of univariate analysis were shown in Table 2, with KPS score, SINS score, VAS score, Tokuhashi score, urinary and fecal incontinence, spinal pathological fracture, and bone lesion (osteolytic, osteoblastic or mixed) being independent and favorable factors affecting the surgery treatment.

KPS Score

The KPS score was divided into three groups (10–40, 50–70, 80–100) \((P = 0.017)\). For group 10–40, no patients received minimally invasive surgery, 30 (5.17%) patients received palliative surgery, and three (0.52%) patients received radical surgery. For group 50–70, 21 (3.62%) patients received minimally invasive surgery, 209 (36.03%) patients received palliative surgery, and 34 (5.86%) patients received radical surgery. For group 80–100, 42 (7.24%) patients received minimally invasive surgery, 221 (38.14%) patients received palliative surgery, and 20 (3.45%) patients received radical surgery.

SINS Score

Three groups (1–6, 7–12, 13–18) \((P < 0.001)\) were included for the SINS score. For group 1–6, eight (1.38%) patients received minimally invasive surgery, 84 (14.48%) patients received palliative surgery and three (0.52%) patients received radical surgery.
## TABLE 1 Characteristics of the studied cohort (n = 580)

| Gender          | Lung cancer | Kidney cancer | Breast cancer | Prostate cancer | Thyroid cancer | Liver cancer | Colorectal cancer | Gastric cancer | Myeloma and lymphoma | Mesenchymal tissue sarcoma |
|-----------------|-------------|---------------|---------------|-----------------|----------------|--------------|-------------------|----------------|------------------------|-----------------------------|
| Male            | 120         | 35            | 0             | 25              | 5              | 20           | 10                | 15             | 19                     | 9                           |
| Female          | 78          | 6             | 39             | 0               | 15             | 4            | 11                | 2              | 16                     | 14                          |
| **Age (year)**  |             |               |               |                 |                |              |                   |                |                        |                             |
| ≤44             | 24          | 3             | 10             | 0               | 2              | 1            | 1                 | 2              | 8                      |                             |
| 45–59           | 79          | 13            | 18             | 4               | 10             | 9            | 11                | 6              | 11                     | 6                           |
| 60–74           | 89          | 21            | 10             | 15              | 8              | 11           | 7                 | 8              | 8                      | 9                           |
| 75–89           | 6           | 4             | 1              | 6               | 2              | 0            | 1                 | 2              | 0                      | 0                           |
| **Spinal metastatic site** |         |               |               |                 |                |              |                   |                |                        |                             |
| Cervical vertebra |             |               |               |                 |                |              |                   |                |                        |                             |
| Single segment  | 14          | 5             | 0              | 2               | 1              | 4            | 0                 | 0              | 0                      | 1                           |
| Multiple segment| 5           | 0             | 2              | 0               | 1              | 1            | 0                 | 0              | 0                      | 0                           |
| **Thoracic vertebra** |         |               |               |                 |                |              |                   |                |                        |                             |
| Single segment  | 30          | 9             | 9              | 4               | 3              | 3            | 5                 | 5              | 8                      | 5                           |
| Multiple segment| 25          | 8             | 7              | 7               | 4              | 4            | 3                 | 3              | 5                      | 5                           |
| **Lumbar vertebra** |         |               |               |                 |                |              |                   |                |                        |                             |
| Single segment  | 39          | 6             | 5              | 2               | 6              | 3            | 6                 | 2              | 9                      | 6                           |
| Multiple segment| 16          | 2             | 2              | 1               | 0              | 1            | 1                 | 1              | 0                      | 5                           |
| **Sacral vertebra** |         |               |               |                 |                |              |                   |                |                        |                             |
| 8              | 1           | 0             | 3              | 1               | 3              | 1            | 3                 | 1              | 0                      | 3                           |
| **Trans-segmental metastasis** |         |               |               |                 |                |              |                   |                |                        |                             |
| 61             | 10          | 14            | 14             | 8               | 9              | 7            | 7                 | 14             | 6                      | 1                           |
| **Extraspinal metastasis** |         |               |               |                 |                |              |                   |                |                        |                             |
| Yes            | 96          | 17            | 14             | 14              | 8              | 9            | 7                 | 7              | 14                     | 6                           |
| No             | 102         | 24            | 25             | 11              | 12             | 15           | 14                | 10             | 21                     | 17                          |
| **Visceral metastasis** |         |               |               |                 |                |              |                   |                |                        |                             |
| Yes            | 31          | 6             | 3              | 2               | 5              | 6            | 9                 | 2              | 0                      | 5                           |
| No             | 167         | 35            | 36             | 23              | 15             | 18           | 12                | 15             | 35                     | 18                          |
| **Spinal pathological fracture** |         |               |               |                 |                |              |                   |                |                        |                             |
| Yes            | 69          | 15            | 21             | 9               | 6              | 8            | 8                 | 5              | 20                     | 9                           |
| No             | 129         | 26            | 18             | 16              | 14             | 16           | 13                | 12             | 15                     | 14                          |
| **Bone lesion** |             |               |               |                 |                |              |                   |                |                        |                             |
| Osteolytic     | 67          | 15            | 11             | 8               | 5              | 7            | 4                 | 8              | 24                     | 9                           |
| Osteoblastic   | 5           | 0             | 0              | 1               | 0              | 0            | 0                 | 0              | 0                      | 0                           |
| Mixed          | 1           | 0             | 0              | 1               | 0              | 0            | 0                 | 0              | 0                      | 0                           |
| Unknown        | 125         | 26            | 28             | 15              | 15             | 17           | 17                | 9              | 11                     | 13                          |

### Reproductive system tumors

| Unknown origin | Unknown reproduction system | Esophageal cancer | Bladder cancer | Pancreas cancer | Others | Totally (n) |
|----------------|-----------------------------|-------------------|----------------|----------------|--------|-------------|
| Gender          | Male                        | 48                | 2              | 7              | 3      | 5           | 9            | 332              |
|                | Female                      | 36                | 10             | 2              | 3      | 0           | 12           | 248              |
| **Age (year)** |                             |                   |                |                |        |             |               |                  |
| ≤44            | 8                          | 2                 | 0              | 1              | 1      | 7           | 1             | 70               |
| 45–59          | 27                         | 7                 | 2              | 2              | 2      | 2           | 10            | 217              |
| 60–74          | 38                         | 3                 | 7              | 3              | 2      | 3           | 2             | 359              |
| 75–89          | 11                         | 0                 | 0              | 0              | 0      | 0           | 1             | 34               |
| **Spinal metastatic site** |                   |                   |                |                |        |             |               |                  |
| Cervical vertebra |                             |                   |                |                |        |             |               |                  |
| Single segment  | 4                          | 0                 | 1              | 0              | 0      | 0           | 1             | 33               |
| Multiple segment| 2                          | 0                 | 0              | 0              | 0      | 0           | 0             | 14               |
| **Thoracic vertebra** |                   |                   |                |                |        |             |               |                  |
| Single segment  | 7                          | 2                 | 3              | 1              | 3      | 2           | 1             | 99               |
| Multiple segment| 14                         | 0                 | 1              | 1              | 1      | 1           | 6             | 91               |
| **Lumbar vertebra** |                   |                   |                |                |        |             |               |                  |
| Single segment  | 16                         | 3                 | 1              | 2              | 0      | 5           | 11            | 111              |
| Multiple segment| 7                          | 0                 | 0              | 0              | 0      | 0           | 0             | 35               |
| **Sacral vertebra** |                   |                   |                |                |        |             |               |                  |
| 8              | 2                          | 0                 | 0              | 1              | 0      | 3           | 35            | 385              |
| **Trans-segmental metastasis** |               |                   |                |                |        |             |               |                  |
| 26             | 5                          | 3                 | 1              | 1              | 4      | 1           | 162           | 1042             |
| **Extraspinal metastasis** |               |                   |                |                |        |             |               |                  |
| Yes            | 32                         | 3                 | 2              | 2              | 0      | 5           | 237           | 237              |
| No             | 52                         | 9                 | 7              | 4              | 5      | 16          | 344           | 344              |
| **Visceral Metastasis** |               |                   |                |                |        |             |               |                  |
| Yes            | 11                         | 0                 | 2              | 0              | 2      | 6           | 90            | 90               |
| No             | 73                         | 12                | 7              | 6              | 3      | 15          | 490           | 490              |
For group 7–12, 42 (7.24%) patients received minimally invasive surgery, 327 (56.38%) patients received palliative surgery, and 24 (4.14%) patients received radical surgery. For group 13–18, 13 (2.24%) patients received minimally invasive surgery, 49 (8.45%) patients received palliative surgery, and 30 (5.17%) patients received radical surgery.

**VAS Score**
The VAS score was divided into three groups (0–3, 4–6, 7–10) (*P* = 0.009). For group 0–3, six (1.03%) patients received minimally invasive surgery, 93 (12.41%) patients received palliative surgery, and five (0.86%) patients received radical surgery. For group 7–12, 26 (4.48%) patients received minimally invasive surgery, 223 (38.45%) patients received palliative surgery, and 36 (6.21%) patients received radical surgery. For group 13–18, 31 (5.34%) patients received minimally invasive surgery, 144 (24.8%) patients received palliative surgery, and 11 (1.90%) patients received radical surgery.

**Tokuhashi Score**
The Tokuhashi score was divided into three groups (0–8, 9–11, 12–15) (*P* = 0.021). For group 0–8, 15 (2.59%) patients received minimally invasive surgery, 72 (12.41%) patients received palliative surgery, and five (0.86%) patients received radical surgery. For group 9–11, 31 (5.34%) patients received minimally invasive surgery, 221 (38.10%) patients received palliative surgery, and 20 (3.45%) patients received radical surgery. For group 12–15, 17 (2.93%) patients received minimally invasive surgery, 167 (28.79%) patients received palliative surgery, and 32 (5.52%) patients received radical surgery.

**Urinary and Fecal Incontinence**
Among these 580 patients, 64 (11.03%) patients presented urinary and fecal incontinence including 58 (10.00%) patients...
receiving palliative surgery and six (1.03%) patients receiving radical surgery. The remaining 516 (88.97%) patients were with no urinary and fecal incontinence, 63 (10.86%) patients received minimally invasive surgery, 402 (69.31%) patients received palliative surgery, and 51 (8.79%) patients received radical surgery. The difference was significant among groups ($P = 0.028$).

**Spinal Pathological Fracture**
Two hundred and twelve (36.55%) patients presented spinal pathological fracture, and among these patients 35 (6.03%) patients received minimally invasive surgery, 155 (26.72%) patients received palliative surgery, and 22 (3.79%) patients received radical surgery. And while spinal pathological fracture did not occur in 368 (63.45%) patients, 28 (4.83%) patients received minimally invasive surgery, 305 (52.59%) patients received palliative surgery, and 35 (6.03%) patients received radical surgery. The difference was significant among groups ($P = 0.002$).

**Bone Lesion (Osteolytic, Osteoblastic, or Mixed)**
Totally, 192 (33.10%) patients presented with osteolytic lesions through imaging examinations and received surgery treatment. Thirty-one (5.34%) patients received minimally invasive surgery, 153 (26.38%) patients received palliative surgery, and eight (1.38%) patients received radical surgery. For patients with osteoblastic lesions, only eight (1.38%) patients received palliative surgery and one (0.17%) patient received radical surgery. For patients with mixed lesions, just one (0.17%) patient received minimally invasive surgery and two (0.34%) patients received palliative surgery. The difference was significant among groups ($P < 0.001$).

**Discussion**
Spinal metastases are the most common type of bone metastasis with a prevalence of 30%–70% in cancer patients; 5%–10% of metastases may be associated with ESCC leading to impaired mobility, neurologic deficits, and decreased quality of life. However, there is still no consensus regarding the best treatment modality for these lesions. In this multicenter study, a total of 580 patients with an average age of 58.26 years (range, 13–86 years old) were enrolled in the study to summarize and analyze the epidemiological characteristics and independent variables affecting surgical modalities for spinal metastases.

Among these 580 patients, the epidemiological characteristics were analyzed. Three hundred and thirty-two male and 248 female patients were enrolled with a ratio of 1.34:1, and most patients were at middle or elderly age between 45 years and 74 years. For primary lesion, the most common were lung cancer, followed by kidney cancer, gastrointestinal cancer, lymphoma and myeloma, prostate cancer, mesenchymal tissue sarcoma, and thyroid cancer. Especially, lung cancer was the top one leading to spinal metastasis either in males or females, which was different from data published abroad (prostate cancer in males and breast cancer in females). It may be due to the regional and cultural differences. The most common spinal metastatic site was the thoracic vertebra (190 [32.76%]), followed by the lumbar vertebra (146 [25.17%]), and metastases involving more than two sites of the cervical, thoracic, lumbar, and sacral vertebrae arose in 162 (27.93%) patients, that was the same as in the report by Bollen et al.

As shown in Table 2, the KPS score, SINS score, VAS score, Frankel score and KPS score in 580 patients treated with surgery. Tokuhashi score more than nine was shown in 488 (84.14%) patients; 485 (83.62%) patients presented spinal instability with SINS score more than 7; 471 (81.21%) patients presented pain with VAS score more four. As for neurological impairment, 90 (15.52%) patients presented paralysis.
vertebral body posterior wall and pedicle involvement, so further analyses were needed to determine minimally invasive surgery indications for different spinal metastatic sites.

Unlike primary spinal tumors, the goal of surgery for spinal metastases is not cure but an overwhelming improvement of symptoms. That is to say, surgeons must consider the patients' overall health, as well as the imaging examination of the vertebral metastases. In this study, 460 (79.31%) patients received palliative surgery including 290 posterior laminectomy, 155 subtotal laminectomy, and 15 other surgical interventions. The average operative time was 123.6 ± 56.8 minutes, and the average blood loss was 61.4 ± 95.2 ml. The average hospital stay was 5.4 ± 2.2 days. The mortality rate was 7.0% (33 patients).

### TABLE 2: Univariate analysis to identify independent variables that could affect the operation modality (P < 0.05 was identified with significant difference; n = number)

| Variable                      | Minimally invasive surgery (n = 63 (10.86%)) | Palliative surgery (n = 460 (79.31%)) | Radical surgery (n = 57 (9.83%)) | P value |
|-------------------------------|---------------------------------------------|--------------------------------------|---------------------------------|---------|
| Gender                        |                                             |                                      |                                 | 0.120   |
| Male                          | 36                                          | 258                                  | 36                              |         |
| Female                        | 27                                          | 202                                  | 21                              |         |
| Age (year)                    |                                             |                                      |                                 |         |
| ≤44                           | 6                                           | 59                                   | 3                               |         |
| 45–59                         | 21                                          | 167                                  | 31                              |         |
| 60–74                         | 32                                          | 203                                  | 23                              |         |
| 75–89                         | 4                                           | 31                                   | 0                               | 0.059   |
| Spinal metastatic site        |                                             |                                      |                                 |         |
| Cervical vertebra             | 0                                           | 42                                   | 5                               |         |
| Thoracic vertebra             | 17                                          | 152                                  | 21                              |         |
| Lumbar vertebra               | 16                                          | 122                                  | 8                               |         |
| Sacral vertebra               | 3                                           | 28                                   | 4                               |         |
| Trans-segmental metastasis    | 27                                          | 116                                  | 19                              | 0.078   |
| Frankel score                 |                                             |                                      |                                 |         |
| A–C                           | 3                                           | 75                                   | 12                              |         |
| D                             | 33                                          | 195                                  | 29                              |         |
| E                             | 27                                          | 190                                  | 16                              | 0.067   |
| KPS score                     |                                             |                                      |                                 | 0.017   |
| 10–40                         | 0                                           | 30                                   | 3                               |         |
| 50–70                         | 21                                          | 209                                  | 34                              |         |
| 80–100                        | 42                                          | 221                                  | 20                              |         |
| SINS score                    |                                             |                                      |                                 | <0.001  |
| 1–6                           | 8                                           | 84                                   | 3                               |         |
| 7–12                          | 42                                          | 327                                  | 24                              |         |
| 13–18                         | 13                                          | 49                                   | 30                              |         |
| VAS score                     |                                             |                                      |                                 | 0.009   |
| 0–3                           | 6                                           | 93                                   | 10                              |         |
| 4–6                           | 26                                          | 223                                  | 36                              |         |
| 7–10                          | 31                                          | 144                                  | 11                              |         |
| Tokuhashi score               |                                             |                                      |                                 | 0.021   |
| 0–8                           | 15                                          | 72                                   | 5                               |         |
| 9–11                          | 31                                          | 221                                  | 20                              |         |
| 12–15                         | 17                                          | 167                                  | 32                              |         |
| Urinary and fecal incontinence|                                             |                                      |                                 | 0.028   |
| Yes                           | 0                                           | 58                                   | 6                               |         |
| No                            | 63                                          | 402                                  | 51                              |         |
| Primary tumor                 |                                             |                                      |                                 | 0.335   |
| Slow growth                   | 16                                          | 113                                  | 12                              |         |
| Moderate growth               | 23                                          | 182                                  | 18                              |         |
| Rapid growth                  | 24                                          | 165                                  | 27                              |         |
| Extraspinal metastasis        |                                             |                                      |                                 | 0.385   |
| Yes                           | 30                                          | 185                                  | 22                              |         |
| No                            | 33                                          | 275                                  | 35                              |         |
| Visceral metastasis           |                                             |                                      |                                 | 0.971   |
| Yes                           | 0                                           | 70                                   | 9                               |         |
| No                            | 54                                          | 390                                  | 48                              |         |
| Spinal pathological fracture  |                                             |                                      |                                 | 0.002   |
| Yes                           | 35                                          | 155                                  | 22                              |         |
| No                            | 28                                          | 305                                  | 35                              |         |
| Bone lesion                   |                                             |                                      |                                 | <0.001  |
| Osteolytic                    | 31                                          | 153                                  | 8                               |         |
| Osteoblastic                  | 0                                           | 8                                    | 1                               |         |
| Mixed                         | 1                                           | 2                                    | 0                               |         |
| Unknown                       | 31                                          | 297                                  | 48                              |         |
corpectomy, and 15 subtotal corpectomy combined with microwave ablation and vertebroplasty. Most of them presented severe pain and spinal instability but the general conditions were good with KPS score more than 60 and Frankel score in D and E. The revised Tokuhashi score has suggested that surgery only be considered in patients with a life expectancy of more than 6 months\(^{29,31}\), meaning that patients, especially those with aggressive primary tumor metastasis, are ineligible for surgical symptom palliation\(^{29,32}\). However, in this multicenter case series, lung cancer was the most common metastasis, as seen in 198 patients. Rapid development of radiotherapy and chemotherapy, especially targeted therapy, may help to improve patients’ life expectancy.

Radical surgery was also performed for spinal metastasis, but the complex anatomical structure of the spine made the operation very difficult and bleeding occurs frequently during the operation. Therefore, indications and contraindications should be strictly clear. The indications for spinal metastatic tumor resection are generally as follows: single-level metastatic tumors of thoracic and lumbar vertebra with well-controlled primary lesions susceptible to chemotherapy or targeted therapy; without vital visceral metastasis; patients with longer life expectancy; no more than two adjacent segment lesions; Tokuhashi score at a range of 12–15\(^{33,34}\). Only 57 (9.83\%) patients who received tumor resection containing 36 total vertebrectomy and 21 total en-bloc spondylectomy were enrolled in this retrospective study, most of them were met with the indications above. In addition, univariate analysis identified that patients with spinal pathological fracture and spinal instability (SINS score at a range of 13–18) could also be treated with tumor resection which should be considered for indications. The limitations of this retrospective study include: lack of non-surgical patients enrolled as control group; spinal metastatic sites are just on the basis of cervical vertebra, thoracic vertebra, lumbar vertebra, sacral vertebra, and trans-segmental metastasis, however, another subgroup containing vertebral body and appendix should also be considered; and surgery modalities are not divided into the subgroup of operation combining with or without radiotherapy, chemotherapy and targeted therapy.

Conclusions
Surgical treatment for spinal metastases is mainly to relieve pain, rebuild spinal stability, improve nerve function, control local tumors, and improve the quality of life of patients. With the rapid development of radiotherapy, chemotherapy (especially targeted therapy), immunotherapy and endocrine therapy, the level of surgical treatment of spinal metastases has been greatly improved. For middle-aged and elderly patients with good general conditions, severe pain, spinal pathological fracture, spine instability and without urinary and fecal incontinence, early surgical treatment should be actively carried out.

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