Clinical Investigations on Metastatic Epidural Spinal Cord Compression Treated by Separation Surgery Versus Separation Surgery Combined with Vertebroplasty Combined with Interstitial Implantation of 125I Seeds

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Research article

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Abstract

Objective Metastatic epidural spinal cord compression (MESCC) seriously affects the life span and quality of life of patients. Separation surgery combined with vertebroplasty combined with interstitial implantation of 125 I seeds (SSVPI) is a novel treatment for MESCC patients. To investigate the safety, feasibility and clinical efficacy on metastatic epidural spinal cord compression treated by SSVPI. Method Prospective analysis of 56 patients diagnosed with metastatic epidural spinal cord compression (MESCC) and receiving Separation surgery (SS) or separation surgery combined with vertebroplasty combined with interstitial implantation of 125 I seeds. Fifty-six patients were randomly divided into the SS group (26 patients) and SSVPI group (30 patients), and the differences in intraoperative bleeding, postoperative pain visual analog scale scores (VAS), Karnofsky performance scores (KPS) and American Spinal Injury Association grades were compared. Results There was no significant difference in intraoperative bleeding between the SS group and the SSVPI group ($P > 0.05$). There was no significant difference at 1 week after surgery ($P > 0.05$); there were significant differences in VAS scores at 2, 6 and 12 months after surgery ($P < 0.05$). There was no significant difference in the KPS score 1 week after surgery ($P > 0.05$); there were statistically significant differences in the KPS scores at 2, 6 and 12 months after surgery ($P < 0.05$). In the SS group, there were 20 patients (76.92%) with an improvement in ASIA grades from pre- to postoperation. In the SSVPI group, there were 24 patients (80%) with improved ASIA grades from pre- to postoperation. Conclusion SSVPI is a safe, feasible, less invasive and effective treatment for MESCC patients.

Background

The spine is a common metastatic site for bone metastases, and spinal metastases account for approximately 39% of bone metastases [1]. Tumors invade the vertebral body resulting in varying degrees of vertebral destruction, collapse, pathological fracture, soft tissue mass formation, and even tumors protruding into the spinal canal, which compress the dural sac, nerve roots, and spinal cord. Approximately 5-10% [2-3] of patients with bone metastases will develop MESCC, resulting in incomplete or complete paralysis. It seriously affects the life span and quality of life. Treatment of MESCC mainly includes traditional tumor resection, such as laminectomy and decompression, partial vertebral body resection, and total en-bloc spondylectomy [4-5]. With advancements in surgical techniques, many patients who had been completely paralyzed can now recover their postoperative neurological function. Report retrospectively reviewed 135 patients with complete paralysis due to neoplastic cord compression, 52 (38.5%) postoperatively reached the American Spinal Injury Association impairment D or E, and the maximum paraplegia time is up to 210 days[6]. Although traditional methods can completely remove the tumor, problems still exist, such as large trauma, hemorrhage, long recovery time and high technical requirements. In recent years, Bilsky et al [7] proposed performing separation surgery combined with stereotactic radiotherapy (SBRT) in MESCC patients. This treatment has certain clinical effects including relieving the compression of the dural sac and cauda equina nerves, relieving pain, and improving local antitumor ability and spinal cord protection. However, in this treatment, residual tumor tissue may continue to invade the vertebral body, and despite SBRT, recurrence may occur in the field or the dural space [8-10], which may cause vertebral fracture, leading to decreased stability of the anterior and middle column and radiation osteonecrosis. Percutaneous vertebroplasty combined with interstitial implantation of ^{125}I seeds (PVPI) for the treatment of patients with spinal metastases has had positive clinical efficacy in relieving pain, reconstructing spinal stability and controlling the progression of locally metastatic lesions. However, this technique is not suitable for patients with spinal metastases with spinal cord compression [11]. To emphasize the advantages and lessen the disadvantages, we intended to combine the two methods in the treatment of patients with MESCC.

Materials And Methods

The study was approved by the ethics committee of Yunnan Cancer Hospital. Prospective analyzed 56 patients who were diagnosed with MESCC and received SS or SSVPI from July 2016 to March 2019 in Yunnan Cancer Hospital (the Third Affiliated Hospital of Kunming Medical University). We randomly divided the 56 patients into the SS group consisting of 26 patients and the SSVPI group consisting of 30 patients. By comparing the intraoperative hemorrhage associated with the different surgical methods and changes in the visual analog scale (VAS) score, Karnofsky performance score (KPS), and American Spinal Injury Association (ASIA) grade, the safety, feasibility and clinical efficacy of the two surgical methods were explored in our study.

1 Inclusion and exclusion criteria

1.1 The inclusion criteria were as follows:

(1) Patients were clinically, radiologically, and pathologically diagnosed with spinal metastases and spinal compression;

(2) Patients were evaluated with an expectancy life ≥ 3 months according to the modified Tokuhashi score [12];

(3) Patients with spinal cord nerve function injury were classified as A-D according to ASIA spinal cord injury grading system;

(4) Patients can tolerate surgery and KPS ≥ 30;

(5) Patients and their families agreed to the surgery and signed the informed consent for the surgery;

(6) Patients were treated with chemotherapy, targeting, endocrine, and other comprehensive treatments according to the treatment plan before and after surgery; and

(7) Patients returned to the hospital on time for review and telephone follow-up after treatment.

1.2 The exclusion criteria were as follows:

(1) The ASIA of patients with spinal metastases was E;

(2) Patients with life expectancy3 months according to the modified Tokuhashi score;

(3)Patients not eligible for surgery because of general conditions;

(4) Patients and their families refused to undergo surgical treatment;

(5) Patients who failed to complete the comprehensive treatment as planned after surgery, such as patients who forgo subsequent chemotherapy, radiation, and other treatments;

(6) Patients who refused or were unable to cooperate with the completion of clinical data collection or follow-up.

2 Surgical techniques

2.1 SS

Under general anaesthesia, the patient was placed in the prone position. A C-arm X-ray machine was used to locate the diseased vertebrae. A posterior median incision on the back fully exposed the diseased vertebrae and 2 to 3 upper and lower segments and exposed the spinous process, lamina and superior and inferior articular processes of the vertebral body. With the C-arm X-ray machine, pedicle screws of suitable lengths were placed and posterior fixation was performed; then the lesions of the spinous process, lamina, posterior longitudinal ligament, and compressed spinal canal were resected, and decompression of the total spinal canal was performed (keeping at least 2-3 mm safe distance between tumor tissue and dura mater), but whole or block resection of the tumor was not performed. Attention was paid to the protection of the spinal cord during decompression. Generally, the segmental nerves were preserved on both sides of the dura mater as much as possible. If the tumor was resected, bilateral T_2 and below intercostal nerves could be ligated and resected. In general, the reconstruction of the anterior column was not required, but if the vertebral resection exceeded 50%, reconstruction with bone cement + titanium cage, titanium mesh, titanium plate or metal with bone trabecula was required [13]. (Fig. 1)

2.2 SSVPI

Under general anaesthesia, the patient was placed in the prone position. First, the separation surgery was performed, and the diseased vertebral body was punctured under direct vision. Using lateral X-ray fluoroscopy to confirm that the puncture needle had entered the junction of the anterior middle 1/3 vertebrae, and the tip of the puncture needle was as close to the central area of the vertebral body as possible after the puncture was completed, the needle core was removed, the vertebral vessels were displayed with contrast agent, and the residual contrast agents and blood from the vertebral body were suctioned out to reduce pressure in the vertebral body. The number of ^{125}I seeds to be implanted in the target area was calculated by a treatment planning system (TPS) before surgery. The ^{125}I seeds were implanted into the target area of the vertebral body along the puncture needle tract with the particle implantation needle. According to the position of the vertebral body tumor, the three-dimensional spatial distribution of ^{125}I seeds in the diseased vertebral body was realized by using two or more puncture needles to insert ^{125}I seeds or by constantly adjusting the direction of the puncture needles. Intravenous dexamethasone (10 mg) was injected to prevent an allergic reaction after seed implantation. Polymethymethacrylate (PMMA, Tianjin Institute of Synthetic Materials Industry, China) with suitable consistency was mixed with contrast agent and pushed into the diseased vertebral body under low pressure during the "toothpaste period". A continuously rotated needle tip was used during injection to achieve satisfactory bone cement filling. Leakage of bone cement to the posterior edge of the vertebral body was observed under direct vision, and the leaked bone cement was removed in a timely manner. The leakage of paravertebral and paraspinal veins in the bone cement was monitored with a C-arm X-ray machine. When the injection was complete, the needle core was again inserted and rotated to pull it out. (Fig. 2) In cases of multiple vertebral metastases, vertebroplasty combined with interstitial implantation of ^{125}I seeds (VPI) should be performed based on the patient's condition. (Fig. 3)

2.3 Postoperative treatment

All patients received prophylactic antibiotic therapy for 1-2 weeks after surgery, and the patients were observed for motor and sensory recovery of the lower limbs. The patients were instructed to turn over axially and pat their backs at regular intervals to prevent the formation of bedsores and the occurrence of progressive pneumonia. Early postoperative functional exercises of lower extremities were performed to prevent deep venous thrombosis of lower extremities. A postoperative digital radiography (DR) of the spine review was conducted to evaluate the internal fixation position, looseness and fracture. Two weeks after surgery, follow-up treatment was conducted according to the plan with the original tumor. For SSVPI patients, postoperative radiographs and computed tomography (CT) were reviewed to assess distribution of bone cement and ^{125}I seeds, postoperative nursing care related to protective measures from the ^{125}I seeds was taken, the surgical site was covered with a lead blanket to reduce the radiation of ^{125}I, and the patients and their families were informed of matters needing attention after ^{125}I seed implantation.

3 Observation indicators and follow-up

The following information was collected for all included patients: intraoperative blood loss, intraoperative seed implantation and bone cement injection, VAS scores, KPS scores and ASIA grades at 1 week, 2 months (1 half-life of ^{125}I seed) and 6 months (3 half-lives of ^{125}I seed) after surgery.

4 Statistical methods

SPSS 21.0 software was used for data analysis. Data with a normal distribution were expressed as the mean ± standard deviation (±S). Chi-square tests were used for the different tests of the enumerated data, t-tests and analyses of variance were used for the different tests of the measurement data. The 0.05 threshold of p-value was considered statistically significant

Results

1 Clinical data

Clinical data and comparative results from the two groups showed that the patients in the SS group and the SSVPI group had no significant differences in age, sex, primary tumor, number of diseased vertebral bodies, size of pathological vertebral, preoperative VAS score, preoperative KPS score, and preoperative ASIA grade (P>0.05), which is consistent with the statistical characteristics and is comparable. (Table 1)

2 The number of seeds and the amount of bone cement in SSVPI group

In SSVPI group, 20-29 ^{125}I seeds were implanted in the thoracic spine, with an average of 24.9, and 28 to 39 ^{125}I seeds were implanted in the lumbar spine, with an average of 34.9. The amount of bone cement injected was 2.3-5.5 ml, with an average of 3.85 ml.

3 Intraoperative bleeding

The intraoperative blood loss in the SS group was 2803.84±1142.45 ml and that in the SSVPI group was 2833.33±1189.71 ml. The statistical analysis results showed that there was no significant difference in intraoperative blood loss between the two groups ($P > 0.05$). (Table 1)

4 Changes in pain and functional status

4.1 VAS scores

The VAS score for the SS group before the operation was 7.61±1.55 points and that for the SSVPI group was 7.83±1.34 points. The statistical analysis results showed that there was no significant difference in the VAS scores between the two groups before the operation ($P > 0.05$). One week after surgery, the VAS score for the SS group was 1.92±1.57 points and that for the SSVPI group was 1.93±1.62 points. The statistical analysis results showed that there was no significant difference in the VAS scores between the two groups ($P > 0.05$). Two months after the surgery, the VAS score for the SS group was 3.27±2.14 points and that for the SSVPI group was 2.13±1.68 points. The statistical analysis results showed that there was a statistically difference in the VAS scores between the two groups (P < 0.05). Six months after surgery, the VAS score for the SS group was 3.73±2.01 points and that for the SSVPI group was 2.53±1.63 points. The statistical analysis results showed that there was a statistically significant difference in the VAS scores between the two groups ($P < 0.05$). Twelve months after surgery, the VAS score for the SS group was 4.67± 0.73 points and that for the SSVPI group was 4.15 ±0.92 points. The statistical analysis results showed that there was a statistically significant difference in the VAS scores between the two groups ($P < 0.05$). (Table 2)

4.2 KPS scores

The preoperative KPS score for the SS group was 43.08±7.88 points and that of the SSVPI group was 43.67±9.28 points. Statistical analysis results showed that there was no significant difference in the preoperative KPS scores between the two groups ($P > 0.05$). One week after surgery, the KPS score for the SS group was 74.23±18.15 points and that for the SSVPI group was 75.67±16.54 points. Statistical analysis results showed that there was no significant difference in the preoperative KPS scores between the two groups (P > 0.05). Two months after the operation, the KPS score for the SS group was 61.92±16.98 points and that for the SSVPI group was 72.00±17.50 points. The statistical analysis results showed that the difference in KPS scores between the two groups was statistically significant ($P < 0.05$). Six months after surgery, the KPS score for the SS group was 57.69±16.57 points and that for the SSVPI group was 68.00±17.50 points. The statistical analysis results showed that the difference in the KPS scores of the two groups was statistically significant ($P < 0.05$). Twelve months after surgery, the KPS score for the SS group was 53.33± 1.44 points and that for the SSVPI group was 58.46±1.81 points. The statistical analysis results showed that the difference in the KPS scores of the two groups was statistically significant ($P < 0.05$). (Table 2)

5 ASIA grade change

In the SS group, there were 4, 4, 8 and 10 patients in the A, B, C and D grades, respectively; in the SSVPI group, there were 4, 6, 8 and 12 patients in these grades, respectively. The statistical analysis results showed that there was no significant difference in ASIA grade between the two groups ($P > 0.05$). (Table 1)

Among the 4 patients with preoperative grade A in the SS group, there were 2 patients with grade A, 1 patient with grade B and 1 patient with grade D after the surgery. Among the 4 patients with preoperative grade B, there was 1 patient that was graded B, 1 patient that was graded C, and 2 patients that were graded D after the surgery. Among the 8 patients with preoperative grade C in ASIA, there was 1 patient with grade C, 6 patients with grade D and 1 patient with grade E after the surgery. Among the 10 patients with preoperative grade D in ASIA, there were 2 patients with grade D and 8 patients with grade E after the surgery. (Table 3)

Among the 4 patients in the SSVPI group with preoperative ASIA grade A, was 1 patient with ASIA grade A, 1 patient with ASIA grade B and 2 patients with ASIA grade D after the surgery. Among the 6 patients with a preoperative grade B in ASIA, 2 patients were graded B, 2 patients were graded C, 1 patient was graded D, and 1 patient was graded E after the surgery. Among the 8 patients with a preoperative grade C in ASIA, there was 1 patient with grade C, 5 patients with grade D and 2 patients with grade E after the surgery. Of the 12 patients with preoperative grade D in ASIA, 2 patients had grade D and 10 had grade E after the surgery. (Table 3)

6 Complications

In SS group, the postoperative complications included postoperative incision infection in 2 patients, cerebrospinal fluid leakage in 1 patients, pulmonary infection in 1 patients. And in SSVPI group the postoperative complications included postoperative incision infection in 1 patients, cerebrospinal fluid leakage in 2 patients, pulmonary infection in 1 patients and paravertebral cement leakage in 1 patient.

Discussion

MESCC patients have a variety of available treatments, including surgical treatment, radiation therapy, glucocorticoid therapy, bisphosphonate therapy, denosumab treatment, endocrine therapy, biological immunotherapy, etc [14]. Annular decompression is better than radiotherapy only in pain relief and limb function recovery [15-16]. It is necessary to reconstruct the stability of the anterior column in patients who have had more than 50% of the vertebral body removed [17]. Bilsky et al [7] put forward the concept of separation surgery in 2013; that is, resecting the spinous processes, lamina, and posterior longitudinal ligament, relieving compression of the spinal canal, and performing a complete spinal decompression without performing a whole tumor or en-bloc resection. Total en-bloc spondylectomy can be performed for some isolated metastases with a good prognosis (such as kidney cancer and thyroid cancer) [18].

Patients with MESCC need early surgical intervention to relieve the spinal cord and cauda equina nerves as soon as possible to save the function of the spinal cord. The Tomita score [19] and the modified Tokuhashi score [12] can help to assess the patient's expected survival time, the SINS score [20] can help to assess the stability of the spine, and the NOMS assessment system [21] can help to guide the treatment options. These evaluation systems play an important role in the systematic evaluation of diseases, the formulation of treatment plans, and the choice of surgical methods. Most MESCC patients are older, with basic illnesses and metastases involving important organs. The treatment plan of these patients typically involves preoperative imaging, pathology, intraoperative anesthesia, blood transfusion, postoperative ICU monitoring, treatment, etc. Preoperative multidisciplinary cooperation is mandatory for an optimal treatment for MESCC patients.

Blood loss was similar between the two groups The postoperative complications are consistent with the complications after spinal tumor resection reported by Roser et al [17]. In the comparison of VAS scores, the postoperative VAS scores of the two groups were significantly reduced compared with those before surgery. VAS scores was similar between the two group 1 week after the operation and it were differences between the two groups at 2, 6 and 12 months after surgery. With regard to the ^{125}I brachytherapy, it has been proven that local control of the tumor after ^{125}I brachytherapy is effective. Results consistent with this were obtained based on the comparison of the KPS scores. In the paraplegia classification, paraplegia symptoms were improved to different degrees in the SS and SSVPI groups.

Compared with total or subtotal vertebral resection, separation surgery has the advantages of less trauma, less bleeding and shorter postoperative recovery time. However, there are some limitations to this operation method. The local tumor is not completely removed after the operation, and severe damage to the anterior column of the partial vertebral body may cause further collapse, which requires follow-up treatment after surgery. From 2002 to 2011, Laufer et al treated 186 patients with spinal metastatic cancer with SS combined with stereotactic radiosurgery (SSSRS), including multiple radiotherapies with a large fraction and single high-dose radiotherapy [7]. The results showed that regardless of the type of tumor, the local tumor was well controlled by SRS supplementation after surgery. The median survival time of patients with local tumor progression was 4.8 months, accounting for 18.3% of the patients; the median survival time of patients without tumor progression before death was 5.6 months, accounting for 55.6% of the sample; and the median survival time of patients surviving the tumor was 7.1 months, accounting for 26.1% of the sample. Local tumor progression was 16.4% in 1 year. The incidence of SSSRS complications was relatively low, among which 4 patients received revision surgery due to failure of internal fixation, and 1 patient had local tumor progression. This treatment has certain clinical efficacy in relieving spinal cord compression, relieving pain, protecting the spinal cord and improving local tumor control ability. However, radionecrosis may occur, residual tumor tissue may continue to invade the vertebral body, secondary fracture of the vertebral body may occur due to radiation field recurrence or dural space recurrence, and pain may recur, even leading to decreased spinal stability. Additionally, the wound healing time after separation surgery is longer, and the interval between SS and SRS is longer, which affects the efficacy of SRS. Moreover, the artifact of the postoperative fixation affects the delineation of the radiotherapy target area and dose calculation, which are also shortcomings of SSSRS.

This study showed that SSVPI also achieved good clinical efficacy for MESCC patients. Intraoperative VPI can enhance the strength of the anterior column of the vertebral body and avoid the risk of further compression and collapse of the affected vertebral body. The cytotoxic effect, thermal effect, and hardening of bone cement can kill tumors and stop bleeding by blocking the blood supply, etc. Additionally, the thermal effect plays a beneficial role in pain relief by denaturation and necrosis of nerve endings in the diseased vertebrae [22]. Under direct vision, injecting bone cement can avoid the leakage of bone cement to the epidural space and the nerve root hole through the tumor destruction area of the posterior wall of the vertebral body and allows the timely removal of any leaking bone cement. Compared with PVPI alone, safety is significantly improved. Intraoperative combined with VPI allows multiple needle punctures in the same vertebral body, making the three-dimensional distribution of ^{125}I seeds and bone cement more reasonable. SSVPI is also suitable for MESCC patients with adjacent multiple vertebral metastases. ^{125}I seeds can control tumor progression after surgery [23-25]. ^{125}I seed brachytherapy can also avoid the occurrence of radiation dermatitis, radiation enteritis, and other complications[11]. However, the study was deficient in that there were few patients, a short follow-up time and no survival analysis. Therefore, patients will continue to be assessed in future studies for large-sample analysis and long-term follow-up to obtain more reliable research results.

Conclusion

SSVPI is a safe, feasible, less invasive and effective treatment for MESCC in comparison with SS alone. SSVPI has a cumulative effect and complementary advantages. It can relieve the compression of the spinal cord and cauda equina nerves, enhance the stability of the vertebral body, and relieve pain but also improve the effect over the local tumor control and reduce the risk of secondary compression of the spinal cord in tumor progression.

Abbreviations

MESCC: metastatic epidural spinal cord compression; SS: separation surgery; SSVPI: separation surgery combined with vertebroplasty combined with interstitial implantation of ^{125}I seeds; SBRT: separation surgery combined with stereotactic radiotherapy; PVPI: percutaneous vertebroplasty combined with interstitial implantation of ^{125}I seeds; VAS: visual analog scale; KPS: Karnofsky performance score; ASIA: American Spinal Injury Association; VPI: vertebroplasty combined with interstitial implantation of ^{125}I seeds; DR: digital radiography; CT: computed tomography; MRI: magnetic resonance imaging; TPS: treatment planning system; PMMA: polymethymethacrylate; SINS: spinal instability neoplastic score; ICU: intensive care unit; SSSRS: separation surgery combined with stereotactic radiosurgery; SRS: stereotactic radiosurgery.

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Availability of data and materials

The dataset supporting the conclusions of this article is included within

Additional file 1: Table S1.

Authors’ contributions

Y.Z.Z., Y.Y.H., Y.T. conceived the idea. C.J.H., W.T.Y., L.Y. collected the clinical data. T.H.B., L.D.Q. collected the image information. C.X.W., W.C. statistical analysis data. Y.Y.H., W.L., S.Z.J., S.K. drafted the paper. Y.Z.Z., Y.T., Z.J. modified the manuscript. All authors approved the final version of thepaper.

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Competing interests

The authors declare that they have no conflicts of interests.

Consent for publication

The authors declare that they agree to publish in the journal.

Ethics approval and consent to participate

The study was performed in accordance with the Declaration of Helsinki. The protocol of this study was approved and supervised by the Ethics Committee of Yunnan Cancer Hospital. All individuals provided written informed consent to participate in the study.

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Tables

Table 1 Clinical data of 56 patients with MESCC and comparison of intraoperative bleeding

	SS group (n=26)	SSVPI group (n=30)	*P* value
Age (year)	60.23±11.23	61.37±9.35	0.680
Gender			
Male	15	16	0.743
Female	11	14	
Site of primary tumor			
Lung	7	10	0.624
Breast	5	6	
Prostate	4	4	
Thyroid	3	3	
Liver	3	4	
Others	4	3	
Number of diseased vertebral bodies			
1	16	18	0.979
2	7	8	
≥3	3	4	
Site of pathological vertebral			
Cervical	3	4	0.973
Thoracic	23	28	
Lumbar	16	18	
Average preoperative VAS score	7.61±1.55	7.83±1.34	0.575
Average preoperative KPS score	43.08±7.88	43.67±9.28	0.800
Preoperative ASIA grading			
A	4	4	0.960
B	4	6	
C	8	8	
D	10	12	
Intraoperative bleeding (ml)	2803.84±1142.45	2833.33±1189.71	0.925

Table 2 Comparison of VAS and KPS scores of patients before and after surgery

	VAS			KPS		
	SS	SSVPI	*P*	SS	SSVPI	*P*
erative	7.61 ±1.55	7.83 ± 1.34	0.575	43.08 ± 7.88	43.67 ± 9.28	0.800
1 week	1.92 ±1.57	1.93 ± 1.62	0.981	74.23± 18.15	75.67± 16.54	0.758
months	3.27 ±2.14	2.13 ± 1.68	0.031	61.92± 16.98	72.00± 17.50	0.034
months	3.73 ± 2.01	2.53 ±1.63	0.017	57.69± 16.57	68.00 ±17.50	0.028
months	4.67± 0.73	4.15 ±0.92	0.039	53.33± 1.44	58.46±1.81	0.032

Figures

Table 3 Change of ASIA classification of patients before and after surgery

preoperative	SS group (26 cases)						SSVPI group (30 cases)					
	The number of cases	A	B	C	D	E	The number of cases	A	B	C	D	E
A	4	2	1	0	1	0	4	1	1	0	2	0
B	4	0	1	1	2	0	6	0	2	2	1	1
C	8	0	0	1	6	1	8	0	0	1	5	2
D	10	0	0	0	2	8	12	0	0	0	2	10

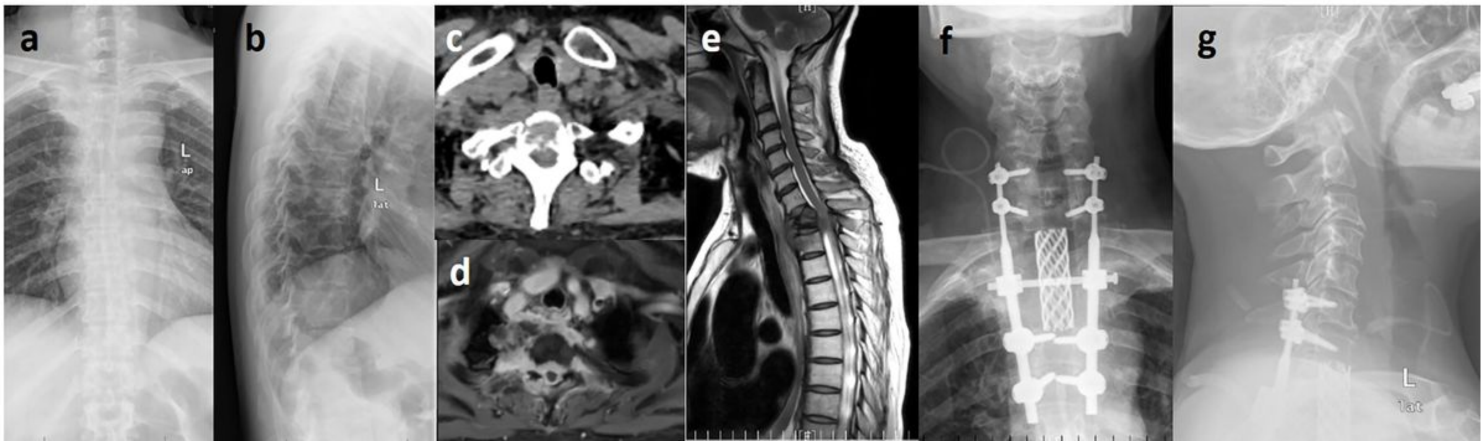

Figure 1

patient is a 49 years old female with right lung cancer with bone metastasis. a-e Preoperative DR, CT, and MRI, they suggest T1-3 vertebral metastasis with spinal cord compression; f-g SS postoperative DR.

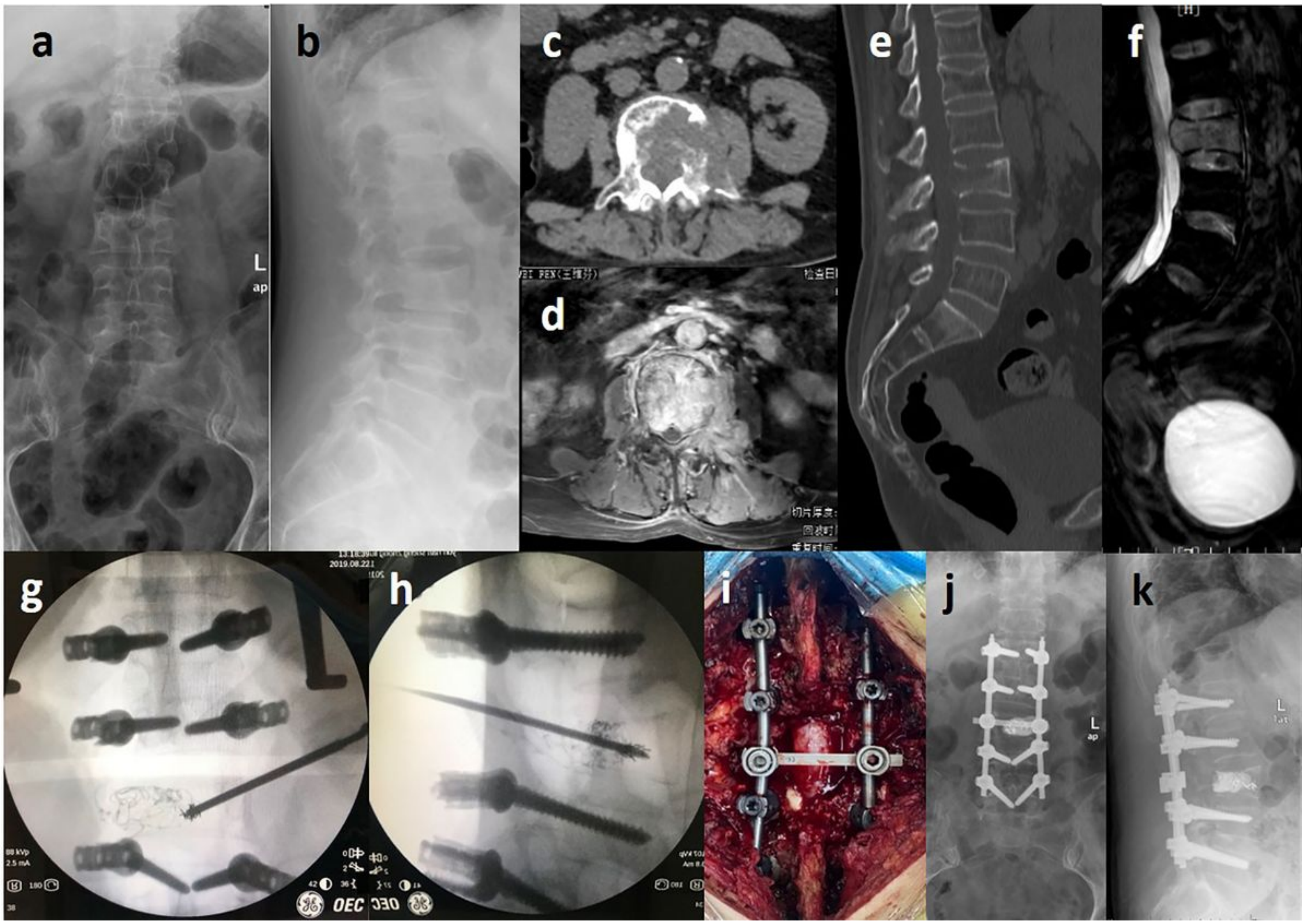

Figure 2

patient is a 63 years old female with right kidney cancer with bone metastasis. a-f Preoperative DR, CT, and MRI, they suggest L3 vertebral metastasis with spinal cord compression; g-h Intraoperative VPI; i intraoperative view; j-k SSVPI postoperative DR.

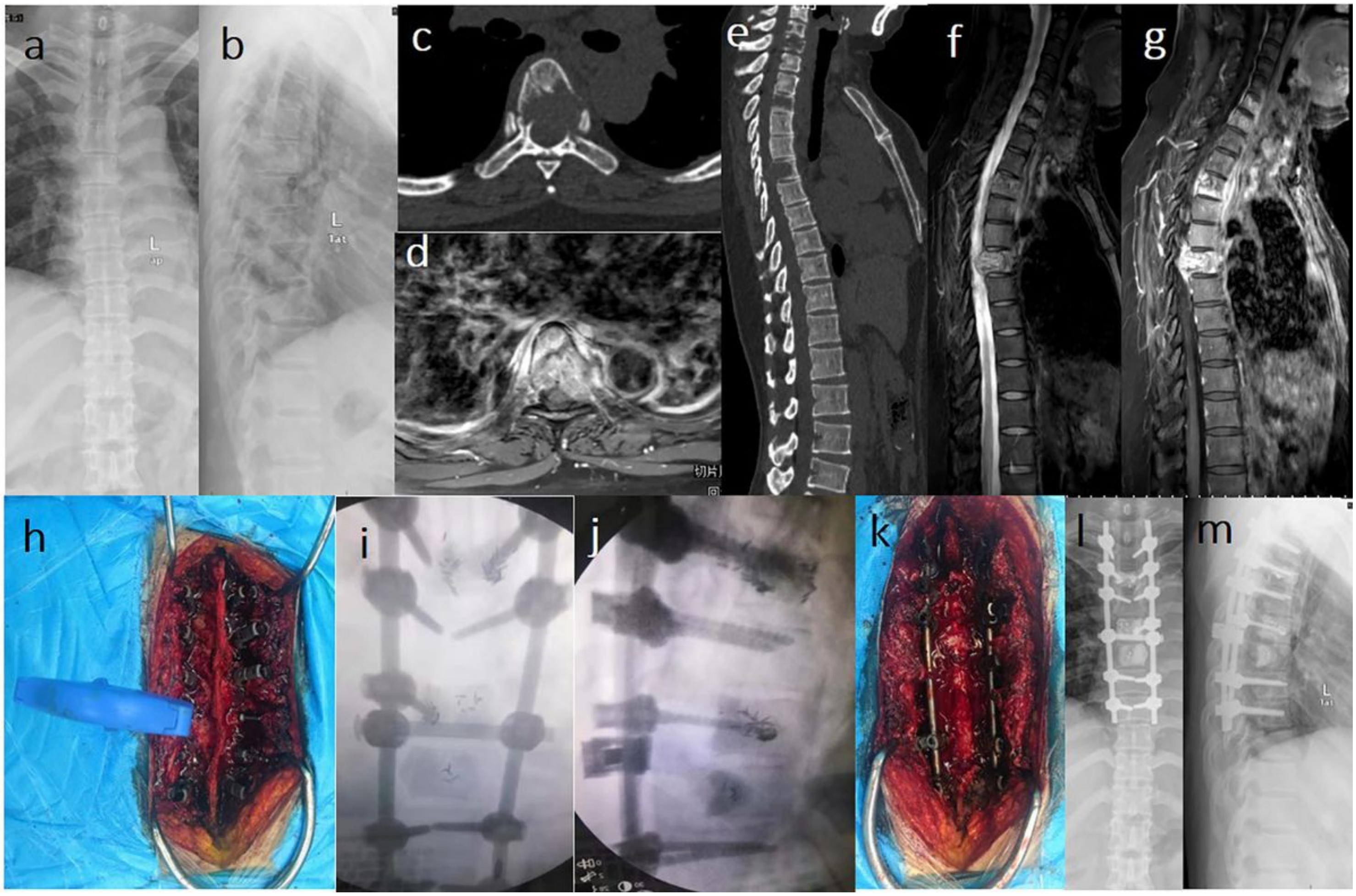

Figure 3

patient is a 46 years old female with adenocarcinoma of the transverse colon with bone metastasis. a-g Preoperative DR, CT, and MRI, they suggest T3□T5-6 vertebral metastasis with spinal cord compression, and the T6 vertebra was serious; h Intraoperative puncture of diseased vertebrae was performed; i-k intraoperative situation; l-m Multiple vertebral SSVPI postoperative DR.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- NewTableS1Dataset.xlsx