The Outcome of Surgical Management of Solitary Spinal Metastasis

Adel Mahmoud Hanafy (MD)[1], Nehad Abdo Zeid (MD)[2], Haitham El Beltagy Abd El-Kader (MD)[1], Mohamed Morsy Al Mashd (MD)[1], Mohamed Mahmoud Abo-Hussein (M.B.B.Ch)[1]

[1] Neurosurgery Department, Faculty of Medicine, Menoufia University, Egypt
[2] General Surgery Department, Faculty of Medicine, Menoufia University, Egypt
futuredoctor20132001@yahoo.com

Abstract: Spinal metastasis is common among cancer patients and it has great influence on their quality of life. It causes intractable pain, in addition to motor dysfunction. Surgery is an old widely acceptable treatment for solitary spinal lesions. It may serve as a palliative treatment as it helps to relieve pain, preserve or restore the neurological function. This study is to evaluate the effect of different surgical modalities on the improvement of the clinical status of patients with solitary spinal metastasis. We made a prospective study on 18 patients admitted to our neurosurgery department. Preoperatively, neurological status and pain were evaluated by the JOA scale, Frankel grade and VAS. MRI spine with contrast was done, and cord compression was assessed by ESCC scale. All patients were evaluated by Tokuhashi scoring system. Anterior approach was used in two patients, and Posterior approach was used in 16 patients with several surgical modalities. All the patients received post-operative radiotherapy and underwent follow up for 6 months. There is a significant statistical difference between pre and post-operative VAS and Frankel grade with (p-value=0.003) and (p-value=0.013) respectively. There is a significant correlation between pre-operative neurological status and the outcome. A strong factor influencing post-operative improvement of the patients was pre-operative neurological condition in this study.
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1. Introduction

Metastatic bone disease is common among cancer patients and can severely affect patient's quality of life. About 70 % of cancer patients develop bony metastasis, while the most common osseous site to receive metastasis is the spine by 40 % **(1, 2).** Thedorsal spine is the most common site of the disease (70%) followed by lumbar spine (20%) and cervical spine (10%). Metastasis can arise from the vertebral column (85%), the paravertebral region (10-15%) and rarely the epidural, subarachnoid or intramedullary space itself < (5%) **(3, 4, 5).** Usually the posterior half of the vertebral body is involved first, while the anterior body, lamina, and pedicles are invaded later**(6).** Spinal metastasis can be solitary or multiple.

The most common tumors that metastasize to the spine are breast, lung, renal, prostate, thyroid, melanoma, myeloma, lymphoma and colorectal cancer (7, 8). Metastatic spreadto the spine occurs either via direct infiltration, hematogenously either via paravertebral plexus (Batson plexus) or through aortic segmental arteriesor seeding through the cerebrospinal fluid (CSF)**(9, 10).**

The average age of the patients affected by spinal metastases is 55 – 60 years with male to female ratio 4:3**(11).**

Clinically, 80 % of the patients will suffer from axial or radicular pain which is constant, dull aching pain with night predominance, while 35–65 % of the patients will have motor dysfunction **(12).** Magnetic resonance imaging (MRI) is the gold standard in imaging of spinal metastasis, it can detect site, extent of spinal metastasis and degree of neural compression as well as paravertebral involvement **(13).**

There are many treatment modalities available after the administration of steroid including irradiation, surgery, bisphosphonates, and rarely chemotherapy and hormonal therapy as an adjuvant therapy in well-defined tumor types **(14).** The efficacy of treatment depends on the histological type, stage, spread and therapeutic control of the primary tumor **(15, 16)**.

2. Patients and methods

A prospective study was done on 18 patients with solitary spinal metastasis admitted to the neurosurgery department of Al-Menofia University. From January 2014 to June 2016, 11 males and 7 females with a mean age of 54.8±9.7 years (range, 43 – 77y) were included in the study. A written informed consent was obtained from all the subjects. The inclusion criteria were patients with Solitary spinal metastasis, with

neurological manifestations not responding to conservative treatment and medically fit for surgery. Excluded patients were those with multiple level spinal metastases and patients medically not fit for surgery.

Patients have undergone different surgical modalities with follow up for six months. The aim of surgery of spinal metastases was to relieve pain, to preserve or restore neurological function, and to obtain tissue for histological diagnosis.

All patients were subjected to full history taking, general examination and full neurological examination. There were 4 patients presented with intractable pain only (2 patients had neck pain and 2 had back pain), 10 patients presented with neurological deficit only, and 4 patients presented with both pain and neurological compromise.

Pre-operative evaluation included the assessment of pain and neurological status. Pain was assessed using the visual analogue scale (VAS) for pain **(22),** 5 patients had moderate pain while 3 had severe pain. Assessment of neurological status was via Frankel Grade **(23)**, and Japanese orthopaedic association score JOA scale **(24).** According to Frankel, 8 patients were grade (C), 4 patients were (D), 4 patients were (E) and 2 patients were (A). By JOA scale, 7 patients had normal function and 7 patients were grade 1 while 4 patients were grade 2.

All the patients made preoperative imaging of the spine by magnetic resonance imaging (MRI) with contrast and computed tomography (CT) scan. In addition, tumor markers, CT-scans of the chest and abdomen and nuclear scintography (Bone scan) were performed for all patients for identification of the primary tumors and assessment of secondary lesions.

No visceral or extra-spinal bone metastases were found in any patient.

The primary tumor was identified in 4 patients (3 breast cancer and 1 lung cancer); while in 14 patients the primary tumor was unidentified.

The dorsal spine was the mostly affected by metastasis (12 patients), while lumbar spine was affected in 4 patients and cervical spine in 2 patients. According to the surgical classification of vertebral tumors by Tomita et al**. (17)**, 4 tumors were considered as intracompartmental and 14 tumors were extracompartmental.

Cord compression was assessed by Epidural spinal cord compression (ESCC)grading scale **(19).** Thirteen patients had cord compression grade 2, three patients had grade 0, one patient had grade 1c and one had grade 3.

All the patients were evaluated using the revised Tokuhashi scoring system **(18).** The mean was 10.9±1.8 with a range (9- 15), and the life expectancy for all patients was exceeding 3 months.

Anterior approach was used in two patients. The first patient had C7 metastases confined to the vertebral body with no epidural compression, underwent total vertebrectomy of C7, reconstruction with titanium mesh cage and anterior fixation with cervical plate and screws.

Fig (1): post-operative neck CT showing corpectomy cage and cervical plate with screws.

The second patient had D10 metastases with cord compression grade 3. He underwent partial vertebrectomy of D10, radical excision of the tumor, reconstruction with Pyra mesh and anterior fixation with Z plate and screws.

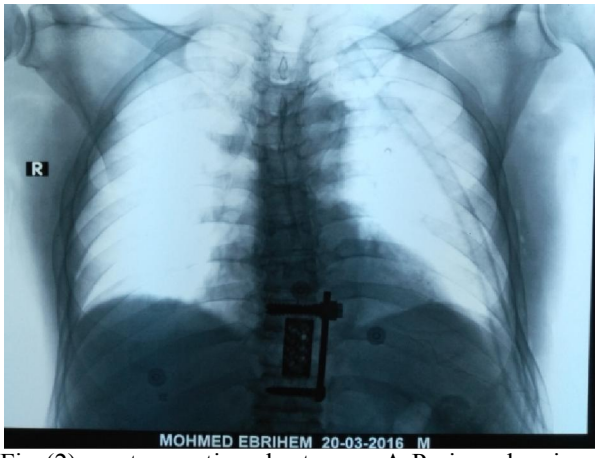

Fig (2): post-operative chest x-ray A-P view showing Pyra mesh with plate and screws.

Posterior approach was used in 16 patients, posterior decompression with transpedicular screw fixation was done for 13 patients, posterior transpedicular screw fixation without decompression was done for one patient, and posterior decompression with transpedicular screw fixation combined with vertebroplasty (hybrid construct) was done for one patient, while Occipito-cervical fixation was done for one patient.

Decompression was performed by wide laminectomy of the compressed area; Roots and dural sac were decompressed by removing the metastatic mass penetrating in the spinal canal.

Vertebroplasty was done by injection of radiopaque polymethylmethacrylate cement, Trocar and cannula systems were introduced using the biplane fluoroscopic guidance by a transpedicularapproach in L4 with combination of posterior transpedicular screw fixation of L3 and L5.

Occipito-cervical fixation of the occiput and the lateral mass of C3 and C4 was done for metastases confined to the body of C2 with no cord compression.

All the patients received post-operative adjuvant external beam palliative radiotherapy.

Follow up was done for 6 months for all patients in the outpatient clinic, clinically by JOA scale and radiological by MRI spine with contrast post-operative, at 3 months and at 6 months.


Fig (3): post-operative neck x-ray lateral view showing fixation of the occiput, C3 and C4 with plates and screws.

Statistical Analysis

Data was collected and entered to the computer using SPSS (Statistical Package for Social Science) program for statistical analysis, (version 20; Inc., Chicago. IL).

Two types of statistics were done:

❖ **Descriptive statistics:**

- Quantitative data was shown as mean, SD, and range.
- Qualitative data was expressed as frequency and percent.

❖ **Analytical statistics:**

- Chi- square test was used to measure association between qualitative variables.
- Fisher exact test was used for 2x2 qualitative variables when more than 25% of the cells have expected count less than 5.
- McNemar's test was used to compare two proportions that are related to each other.
- Mann Whitney was used to compare mean and SD of 2 sets of quantitative not normally distributed data.
- **P-value was considered statistically significant when it was less than 0.05.**

3. Results

Histopathological results of the excised specimens from all patients were small-cell lung carcinoma in 44.4%, Invasive duct carcinoma in 16.7%, rectal adenocarcinoma in 16.7%, Multiple myeloma in 11.1%, Hepato cellular adenocarcinoma in 5.6% and Non-Hodgkin's lymphoma in 5.6%.

Complications occurred in 27.8% of the studied patients. Two patients developed wound infection. One patient developed deep infection which subsided by following revision, debridement and wound drainage, the other patient developed superficial

wound infection which subsided by only antibiotics and daily dressing. Implant failure occurred in 2 patients due to malposition of the dorsal screws. Surgical revision and repositioning of the screws were performed successfully. Another patient developed transient Cerebrospinal fluid leakage (CSF) which stopped at day 5 post-operative.

There is a significant statistical difference between pre and post-operative VAS and Frankel grade with (p-value=0.003) and (p-value=0.013) respectively. **(Table 1)**

There is a significant correlation between pre-operative neurological status and the outcome. There is significant statistical difference between pre-operative Frankel grade and post-operative improvement (p-value=0.001) as 100% of non-improved patients were Frankel grade A. **Table (2)**

There is significant statistical difference between pre-operative JOA and post-operative improvement (p-value=0.019) as 100% of non-improved patients were JOA grade 2. **Table (3)**

There is no significant statistical difference between age of the studied groups regarding post-operative improvement (p-value=0.204).

There is no significant statistical difference between post-operative complication and post-operative improvement (p-value=0.834).

There is no significant statistical difference between the different used surgical techniques regarding post-operative improvement (p-value=0.46). **Table (4)**

There is a significant statistical difference between the different used surgical techniques regarding tumor residual on post-operative MRI (p-value <0.05). table (5)

Total excision of the tumor was done in 11.1% of the studied patients, while 88.9% had residual on post-operative MRI.

Regarding ESCC on post-operative MRI, cord compression G0 was found in 44.4%, G1a in 22.2 and G1 b in 33.3% of the studied patients.

Clinical status and imaging still the same as post-operative for all patients at 3 and 6 months.

Table (1): Comparison of neurological assessment of the studied group pre and post-operative:

	Pre		**Post**		**Mac nemer test**	**P value**
	N0	**%**	**N0**	**%**		
• **JOA**						
Normal function (16+17)	7	38.8	13	72.2	4.07	0.13
Grade 1(12-15)	7	38.8	3	16.6		
Grade 2(8-11)	4	22.2	2	11.1		
•VAS						
None) 0-4)	10	55.6	13	72.2		
Mild (5-44)	0	0.0	5	27.8	13.39	0.003
Moderate(45-74(	5	27.8	0	0.0		
Severe (75-100)	3	16.7	0	0.0		
•frankel						
A	2	11.1	**2**	11.1		
C	8	44.4	**0**	0.0	**10.7**	**0.013**
D	4	22.2	**9**	50.0		
E	4	22.2	**7**	38.9		

Table (2): Correlation between pre-op frankelgrade and the outcome:

pre-op frankel	IMPROVEMENT				Test	P VALUE
	YES (16)		NO(2)			
	NO	%	NO	%		
• A	0	0.0	2	100.0	18.0	0.001
• C	8	50.0	0	0.0		
• D	4	25.0	0	0.0		
• E	4	25.0	0	0.0		

Table (3): Correlation between pre-op JOA and the outcome:

Pre-op JOA	IMPROVEMENT				Test	P VALUE
	YES (16)		NO(2)			
	NO	%	NO	%		
• Normal function	7	43.8	0	0.0		
• Grade 1	7	43.8	0	0.0	7.8	0.019
• Grade 2	2	12.5	2	100		

Table (4): Correlation between surgical techniques and the outcome:

Clinical status	Anterior approach		Posterior approach								test	P value
	Corpectomy +reconsruction		Occipito-cervical fixation		Fixation+decompression		Fixation+verte-broplasty		Fixation without decompression			
	NO	%	NO	%	NO	%	NO	%	NO	%		
Not improved	1	50.0	0	0.0	1	7.7	0	0.0	0	0.0	3.59	0.464
Improved	1	50.0	1	100.0	12	92.3	1	100.0	1	100.0		

Table (5): relation between surgical techniques and tumor residual:

	Technique										test	P value
	Decompression+ fixation		corpectomy+ reconstruction		L4 vertebrolasty +fixation		occipito-cervical fixation		fixation without decompression			
	N0	%	N0	%	No	%	No	%	No	%		
•imaging residual												
No	0	0.0	2	100.0	0	0.0	0	0.0	0	0.0	18.00	0.001
Yes	13	100.0	0	0.0	1	100.0	1	100	1	100.0		

4. Discussion

The aim of surgical management of spinal metastases is to relieve local pain, to preserve or restore neurological function, and to obtain tissue for histological diagnosis. These goals can be achieved by decompression of neural structures, reduction of tumor mass and rigid stabilization of the spine **(20).** Total surgical removal of metastatic mass should not be the primary goal of the surgery as it is often impossible **(21).**

In this study the mean age of the studied patients was 54.8 years. These data cope with Wise et al. **(25)**, who reported that the mean age was 56 years. Also, 61.1% of the studied patients were males and 39.9 were females(Male to female ratio is 1.6:1)which came in agreement with the literature **(26)**, which mentioned that the likelihood is reportedly four times greater for men and three times greater for women(Male to female ratio of 1.36:1).

Spinal metastases was found in dorsal spine in 66.7% of the studied patients, lumbar spine in 22.2% and cervical spine in 11.1%, the most commonly affected level was dorsal vertebrae number 10 which was affected in 22.2% of the studied patients, these results came in agreement with the literatures **(27, 28, 29),** which reported that The thoracic spine is the most common site of disease (70%), followed by the lumbar spine (20%), and cervical spine (10%).

According to tomita anatomical classification, spinal metastases were intravertebral (type 1-3) in 22.2% and perivertebral (type 4-5) in 77.8% of the studied patients while type 6 and 7 were excluded in this study, these data came in agreement with the literature **(30)**, which mentioned that perivertebral involvement occurred in 43.5% while intravertebral involvement occurred in 4.3%.

In this study the primary tumor was Small-cell lung carcinoma (44.4%), invasive duct carcinoma (16.7%), rectal adenocarcinoma (16.7%), multiple

myeloma (11.1%), hepatocellular adenocarcinoma (5.6%) and non-Hodgkin's lymphoma (5.6%) which came with agreement with the literature**(31, 32)**, which reported that The commonest tumours that involve the spine are breast, lung, renal, prostate, thyroid, melanoma, myeloma, lymphoma and colorectal cancer.

In this study 22.2% of the studied patients were presented with intractable pain, 55.6% was presented with neurological deficit and 22.2% was presented with both pain and deficit, Liang, et al. **(30)**, reported that Preoperative pain was found in 89 patients (97%) while Preoperative neurologic dysfunction occurred in 73 patients (79%).

In this study the mean revised tokuhashi score was 10.9 ranging from 9 to 15 with life expectancy exceeding 6 months, Melcheret al. **(33),** reported that pretreatment evaluation using the revised Tokuhashi-score revealed a score range between 11 and 15 in all patients, thus predicting a 1-year survival period in more than 95% and suggesting excisional surgery.

In this study posterior approach was used in 88.9% of the studied patients, Trans pedicular screws Fixation + decompression was the commonly used technique which was used in 72.2% of the studied patients, Liang, et al.**(30)**, reported that a posterior approach was used in 68.5%, an anterior approach was used in 15.2% and a combined anterior and posterior approach was used in 16.3%, a posterior tumor resection and bone graft or bone cement fusion plus pedicle screw fixation was the commonly used technique which was used in 65.2% of the studied patients.

In this study Total excision of the tumor was done in 11.1% of the studied patients which was achieved with anterior approach, while 88.9% had residual on post-operative MRI.

In this study neurologic dysfunction was improved after surgery in 85.7% of the studied patients. The improvement in overall neurologic function therefore was substantial, which is consistent with findings from other studies **(34, 35, 36).**

And we found pain levels decreased after surgery in 8 of the studied patients for a pain relief rate of 100%, which is similar to reductions in pain in 89% to 100% of patients reported in the literature **(34, 35, 36).**

The complication rate reported for patients undergoing surgery for spinal metastases is up to 20-30%, the most common being wound infection **(37, 38, 39, 40, 41)**. In this study we observed surgical complications in 5 patients, giving a complication rate 27.8%, the most common was wound infection occurred in 22.2% of the studies patients, which is acceptable.

In this study we found that there is no significant correlation between the age of the studied groups and post-operative improvement.

But we found that there is a significant correlation between pre-operative neurological status and the outcome as 100% of non-improved patients were frankel grade A and JOA grade 2.

We found that there is no significant correlation between the different used surgical techniques and post-operative improvement.

In this study surgical complication did not affect the outcome.

In this study the post-operative follow up for 6 months showed that there was no change in clinical status of the studied patients regarding pain relief and neurological improvement, also no local recurrence was reported.

Conclusion

Surgery for symptomatic solitary spinal metastases represents efficient and relatively safe therapeutic modality. A strong factor influencing post-operative improvement of the patients was pre-operative neurological condition in this study.

References

1. Harrington K. Metastatic tumors of the spine: diagnosis andtreatment. J Am Acad Orthop Surg 1993;1:76-86.
2. Bohm P, Huber J. The surgical treatment of bony metastasesof the spine and limbs. J Bone Joint Surg Br 2002;84:521-529.
3. Byrne TN. Spinal cord compression from epidural metastases. N Engl J Med 1992;327:614-619.
4. Gerszten PC, Welch WC. Current surgical management ofmetastatic spinal disease. Oncology (Huntingt) 2000;14:1013-1024; discussion 1024, 1029-1030.
5. Gilbert RW, Kim JH, Posner JB. Epidural spinal cordcompression from metastatic tumor: diagnosis and treatment. Ann Neurol 1978;3:40-51.
6. Adams M, Sonntag VKH. Surgical treatment of metastaticcervical spine disease. Contemp Neurosurg 2001;23:1-5.
7. Jacobs WB, Perrin RG (2001) Evaluation and treatment of spinal metastases: an overview. Neurosurg Focus 11 (article 10).
8. Ibrahim AG, Crockard HA, Antonetti P et al (2005) Does spinal surgery improve the quality of life for those with extradural (spinal) osseous metastases? An international multi-centre prospective observational study of 223 patients. J Neurosurg Spine 8:271–278.

9. Scuibba DM, Petteys RJ, Dekutoski MB, Fisher CG, Fehlings MG, et al. Diagnosis and management of metastatic spine disease. A review. J Neurosurg Spine. 2010;13:94-108..
10. Schick U, Marquardt G, Lorenz R (2001) Intradural and extradural spinal metastases. Neurosurg Rev 24:1–5.
11. Aebi M. Spinal metastasis in the elderly. Eur Spine J. 2003;12 (suppl 2): S202–213.
12. Van der Linden YM, Dijkstra SPDS, Vonk EJA, Marijnen CAM, Leer JWH: Prediction of survival in patients with metastases in the spinal column: results based on a randomized trial of radiotherapy. Cancer; 103(2):320–328, 2005.
13. Laufer I, Sciubba DM, Madera M, Bydon A, Witham TJ, et al: Surgical Management of Metastatic Spinal Tumors;19(2):125, 2012.
14. Smith MR, Malkowicz SB, Chu F, Forrest J, Price D, et al: Toremifene Increases Bone Mineral Density In Men Receiving Androgen Deprivation Therapy For Prostate Cancer. J Urol; 179(1): 152–155, 2008.
15. Wai EK, Finkelstein JA, Tangente RP, Holden L, Chow E, et al: Quality of Life in Surgical Treatment of Metastatic Spine Disease. Spine 28:508–512, 2003.
16. Dürr HR, Wegener B, Krödel A, Müller PE, Jansson V, et al: Multiple myeloma: surgery of the spine. Spine 27:320–325, 2002.
17. Tomita K, Kawahara N, Kobayashi T, Yoshida A, Murakami H, et al: Surgical strategy for spinal metastases. Spine 26:298–306, 2001.
18. Tokuhashi Y, Matsuzaki H, Oda H, Oshima M, Ryu J: A revised scoring system for preoperative evaluation of metastatic spine tumor prognosis. Spine 30:2186–2191, 2005.
19. Bilsky M and Smith M. Surgical approach to epidural spinal cord compression. Hematol Oncol Clin North Am; 20(6):1307-1317, 2010.
20. Steinmetz MP, Mekhail A, Benzel EC (2001) Management of metastatic tumors of the spine: strategies and operative indications. Neurosurg Focus 11(6): Article 2: 1–6.
21. Sen C, Eisenberg M, Casden AM, Sundaresan N, Catalano PJ (1995) Management of the vertebral artery in excision of extradural tumors of the cervical spine. Neurosurgery 36(1): 106–115; discussion 115–116.
22. HAWKER GA, MIAN S, KENDZERSKA T, FRENCH M: Measures of Adult Pain. Arthritis Care & Research; 63: S240 –S252, 2011.
23. Frankel HL, Hancock DO, Hyslop G, et al. The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. I. *Paraplegia* 1969;7:179-92.
24. Vitzthum HE, Dalitz K: Analysis of five specific scores for cervical spondylogenic myelopathy. European Spine Journal; 16(12): 2096–2103, 2007.
25. Wise JJ, Fischgrund JS, Herkowitz HN, Montgomery D, Kurz LT. Complication, survival rates, and risk factors of surgery for metastatic disease of the spine. Spine (Phila Pa 1976). 1999;24:1943–1951.
26. Aebi M. Spinal metastasis in the elderly. Eur Spine J.2003;12 (suppl 2): S202–213.
27. Byrne TN. Spinal cord compression from epidural metastases. N Engl J Med 1992;327:614-619.
28. Gerszten PC, Welch WC. Current surgical management of metastatic spinal disease. Oncology (Huntingt) 2000;14:1013-1024; discussion 1024, 1029-1030.
29. Gilbert RW, Kim JH, Posner JB. Epidural spinal cord compression from metastatic tumor: diagnosis and treatment. Ann Neurol 1978;3:40-51.
30. Liang T, Wan Y, Zou X, Peng X, Liu S: Is Surgery for Spine Metastasis Reasonable in Patients Older Than 60 Years? Clin Orthop Relat Res (2013) 471:628–639.
31. Jacobs WB, Perrin RG (2001) Evaluation and treatment of spinalmetastases: an overview. Neurosurg Focus 11 (article 10).
32. Ibrahim AG, Crockard HA, Antonetti P et al (2005) Does spinalsurgery improve the quality of life for those with extradural (spinal) osseous metastases? An international multi-centre prospective observational study of 223 patients. J Neurosurg Spine 8:271–278.
33. Melcher I, Disch AC, Khodadadyan-Klostermann C, Tohtz S, et al: Primary malignant bone tumors and solitary metastases of the thoracolumbar spine: results by management with total en bloc spondylectomy. Eur Spine J (2007) 16: 1193.
34. Hussein AA, El-Karef E, Hafez M. Reconstructive surgery in spinal tumours. Eur J Surg Oncol. 2001;27:196 199.
35. Siegal T, Siegal T. Current considerations in the management of neoplastic spinal cord compression. Spine (Phila Pa 1976). 1989;14:223–228.
36. Weigel B, Maghsudi M, Neumann C, Kretschmer R, Muller FJ, Nerlich M. Surgical management of symptomatic spinal metastases: postoperative outcome and quality of life. Spine (Phila Pa 1976). 1999;24:2240–2246.
37. Choi D, Crockard A, Bunger C, et al. Review of metastatic spine tumour classification and indications for surgery: the consensus statement

of the Global Spine Tumour Study Group. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society* 2010;19:215-22.

38. Patchell RA, Tibbs PA, Regine WF, et al. Direct decompressive surgical resection in the treatment of spinal cord compression caused by metastatic cancer: a randomised trial. *Lancet* 2005;366:643-8.
39. Moon KY, Chung CK, Jahng TA, et al. Postoperative survival and ambulatory outcome in metastatic spinal tumors: prognostic factor analysis. *J Korean Neurosurg Soc* 2011;50:216-23.
40. Quraishi NA, Rajagopal TS, Manoharan SR, et al. Effect of timing of surgery onneurological outcome and survival in metastatic spinal cord compression. *Eur Spine J* 2013;22:1383-8.
41. Wise JJ, Fischgrund JS, Herkowitz HN, et al. Complication, survival rates, and risk factors of surgery for metastatic disease of the spine. *Spine* 1999;24:1943-51.

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