CLINICAL ARTICLE

Minimally Invasive Percutaneous Fixation Techniques for Metastatic Spinal Disease

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Objective: Surgical treatment of spinal metastasis is generally a palliative procedure. Although minimally invasive surgical (MIS) techniques are supposedly less morbid than open techniques, there is a lack of stratification of MIS techniques based on anticipated longevity. A simple stratification into three percutaneous surgical techniques based on modified Tokuhashi score is here proposed.

Methods: Patients recommended for spinal surgery for metastatic spinal disease between 2009 and 2012 and operated on by the senior author (RJM) were retrospectively reviewed. One of three MIS techniques was offered based on estimated survival using a modified Tokuhashi score. Technique #1 is suitable for patients with predicted short longevity (<6 months). Using a mini-open midline or paramedian decompression and percutaneous screw fixation, the goal here is for rapid mobilization and minimization of hospitalization. Technique #2 is suitable for patients with predicted medium longevity (6–12 months). They are suitable for decompression and/or cement vertebral body replacement and a two levels stabilization. Technique #3 is suitable for patients with predicted long term survival survival (>12 months). In these patients, the primary goal of surgery is a wide local or marginal resection of tumor, decompression of the neurological elements and a robust stabilization construct. They are suitable for an open 360°decompression, vertebral body reconstruction and a multilevel stabilization.

Results: The study included eight patients with a mean age of 59 years (range, 36–72 years). Mean modified Tokuhashi score was 10 (range, 7–13) with three patients in the short term, two in the medium term and three in the long term survival category. Mean blood loss was 700 mL (range, 100–1200 mL), mean operating time 280 min (range, 120–360 min) and length of stay in the hospital was on average 13 days (range, 3–30 days).

Conclusion: The authors present three minimally invasive technique options for the management of spinal metastatic disease corresponding to three clinical prognostic categories. In this small series, MIS techniques resulted in speedy recovery, minimal morbidity and no mortality.

Key words: Metastases; Minimally invasive; Morbidity; Percutaneous; Spine

Level of Evidence: Therapeutic Level IV.

Introduction

Surgical approaches for the management of metastatic spine disease have long been debated. There is a lack of published reports with class 1 evidence concerning whether certain approaches are superior to others in terms of surgical morbidity. Neoplasms of the spine are typically secondary tumors; the skeletal system is the third most common site of metastases and the spine the most common site within this system[1].

In most patients with cancer, spinal metastases are present at autopsy[2,3], approximately 30% of them having experienced symptomatic metastatic spinal disease[4]. Although only a minority (10%) of these progress to epidural spinal cord, conus or cauda equina compression, because of the large numbers involved, metastatic compression of the neural elements is a common occurrence in clinical practice[4]. Spinal metastases can cause instability manifesting as neurological

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TABLE 1 Studies reporting MIS techniques for spinal metastatic disease: operative data, outcomes and complication rates[19–32]

Author	No of patients	MBL (mL)	MOT (min)	LOS (d)	MNI (%)	MPA (%)	MCR (%)
Lin *et al*.[22]	25	1047	324	NA	76	68	4
Tancioni *et al*.[23] (Prospective)	25	NA	NA	6	88	96	12
Zairi *et al*.[20] (Prospective)	10	400	170	6	100	100	10
Rosenthal *et al*.[21]	4	1450	390	7.5	100	100	0
Huang *et al*.[25]	41 (VAST)	775	190	NA	NA	NA	54
Huang *et al*.[24]	29 (MASS)	1100	179	—	70.8	—	24
Le Huec *et al*.[28]	2	350	156	NA	100	100	50
McLain *et al*.[31]	8	1677	360	6.5	100	100	0
Mobbs *et al*.[26]	1	—	—	—	100	100	0
Deutsch *et al*.[34]	8	227	132	4	62.5	62.5	0
Muhlbauer *et al*.[29]	5	1120	360	NA	100	100	0
Kan and Schmidt[27]	5	610	258	6.25	100	100	0
Payer and Sottas[30]	11	711	NA	—	91	NA	18
Taghva *et al*.[32]	1	1200	420	5	100	100	0

LOS, length of stay; MASS: minimal access spine surgery; MBL, mean blood loss; MCR, mean complication rate; MNI, median neurologic improvement; MOT, mean operating time; MPA: median pain alleviation rate; VAST, video-assisted thoracosopic surgery.

symptoms and pain, which impact significantly on the patients' quality of life[2,5]. Finkelstein *et al*. reported a median survival time of 227 days for metastatic spine cancer of all primary types[6].

Surgical treatment of spinal metastases is largely palliative, the exception being solitary metastases with certain favorable histologies[7]. The aim of palliative surgery in such cases is to reduce or eliminate neurologic deficits and improve pain control, thus improving the patient's quality of life. The role of surgery is adjuvant to radiotherapy and/or chemotherapy as indicated by the primary cancer pathology. Surgery for spinal metastases is a contentious issue related largely to the fact that it involves performing significant surgical procedures on those nearing death. Published reports have shown that laminectomies were no more successful historically than radiotherapy, conversely direct decompressive surgery followed by radiotherapy is superior to radiotherapy alone in patients with common metastatic histologies[8].

However, the surgery performed must be tailored to the patient's condition and the degree of palliation varies from patient to patient[9–11]. For patients with medium-term prognoses, such as renal or breast cancer primaries, more aggressive surgical techniques, which may entail more radical resections and definitive stabilization, are recommended[11]. For patients in whom *long-term control* is the goal of surgery, Tomita *et al*. suggest wide excision such as total en bloc spondylectomy[11]. *Medium-term control* may require intra-lesional excision or perhaps even wide excision. *Short-term* or palliative surgery

TABLE 2 Consecutive cases with spine metastases treated with MIS techniques

Case	Primary	Age (years)	Preoperative Tokuhashi score	pP	PP	AL	PL	MIS	BL	OT	LOS	C	Survival (months)
1	**Lung**	58	9	2	4	T_9	$T_{7–11}$	2	800	220	5	Nil	11
2	**MM**†	72	8	2	4	T_{12}	T_{11}-L_1	1	20	300	30	Nil	56*
3	**Breast**	62	7	4	4	T8	$T_{7–9}$	1	20	120	8	Nil	3
4	**Breast**	46	10	4	4	$T_{4–6}$	$T_{3–7}$	2	1000	300	3	Nil	43*
5	**GIST**	72	7	0	4	T_9	$T_{8–10}$	1	800	180	14	Nil	13
6	**RCC**	68	13	4	4	$T_{6,7}$	$T_{5–8}$	3	600	360	10	Nil	30
7	**HP**	56	12	0	4	$T_{2–4}$	$T_{2–4}$	3	1200	330	20	Nil	41
8	**RCC**	36	12	2	4	L_3	T_{12}-L_4	3	1000	330	11	Inf	28

Note: AL, affected level; HP, hemangiopericytoma; Inf, wound infection; MM, multiple myeloma; PL, percutaneous level; PP, post- operative power; pP, pre-operative power; RCC, renal cell carcinoma. *, patient still alive; †, patient did not receive chemotherapy and radiotherapy.

will generally be limited to spinal decompression and stabilization, followed by palliative radiotherapy.

Because of the poor general condition of many of these patients, open spinal decompression with stabilization surgery may be associated with high morbidity rates[12–14]. According to published reports, MIS and open techniques have similar effectiveness (neurological recovery and pain alleviation); however, there are no studies of MIS techniques with class 1 evidence (Table 1). In patients with metastatic spine disease, open surgery and complete vertebrectomy may not be necessary: the goal is surgical decompression and stabilization to relieve pain and improve neurological function. More importantly, MIS techniques are associated with reduced operative times, blood loss, length of hospital stay and complication rates, all of which may lead to lower morbidity rates in patient who are in poor general condition. Unfortunately, no studies directly comparing the two techniques have been published.

Although there are various scoring systems for predicting prognosis and determining optimal extent of resection[5,11], these systems are generalized and not specific to minimally invasive surgical (MIS) techniques. We here propose a simplified means of guiding surgical decisions in patients with spinal metastases that is based on predicted survival and utilizes percutaneous stabilization techniques. We propose stratifying patients into three groups based on predicted survival according to modified Tokuhashi score[5]; namely, predicted short term (ST; <6 months); medium term (MT; 6–12 months) and long term survival (LT; >12 months). We argue that simple decompression with one level stabilization is appropriate for those in with ST survival, decompression and/or cement vertebral body replacement and two levels stabilization for those with predicted MT survival and comprehensive decompression/radical resection of the tumor and multi-level stabilization for those with predicted LT survival. We demonstrate this proposal with a small case series and examples of each survival category.

Patients and Methods

Eight patients who had been recommended for spinal surgery for metastatic spinal disease at neuro-oncology multidisciplinary meetings between 2009 and 2012 and operated on by the senior author (RJM) were retrospectively reviewed (Table 2). One of three MIS techniques was offered based on estimated survival using a modified Tokuhashi score[5]. Clinical data, particularly neurological status, were compared pre and post operatively, and operative details such as operating time in minutes (OT), blood loss in mL (BL), complications (C), and length of stay in days (LOS) were documented. Survival (S) in months from the time of surgery was also assessed.

We will demonstrate these MIS techniques with case examples for each.

Technique #1

Technique #1 is suitable for patients with predicted short longevity (<6 months). In these patients, the primary goal of

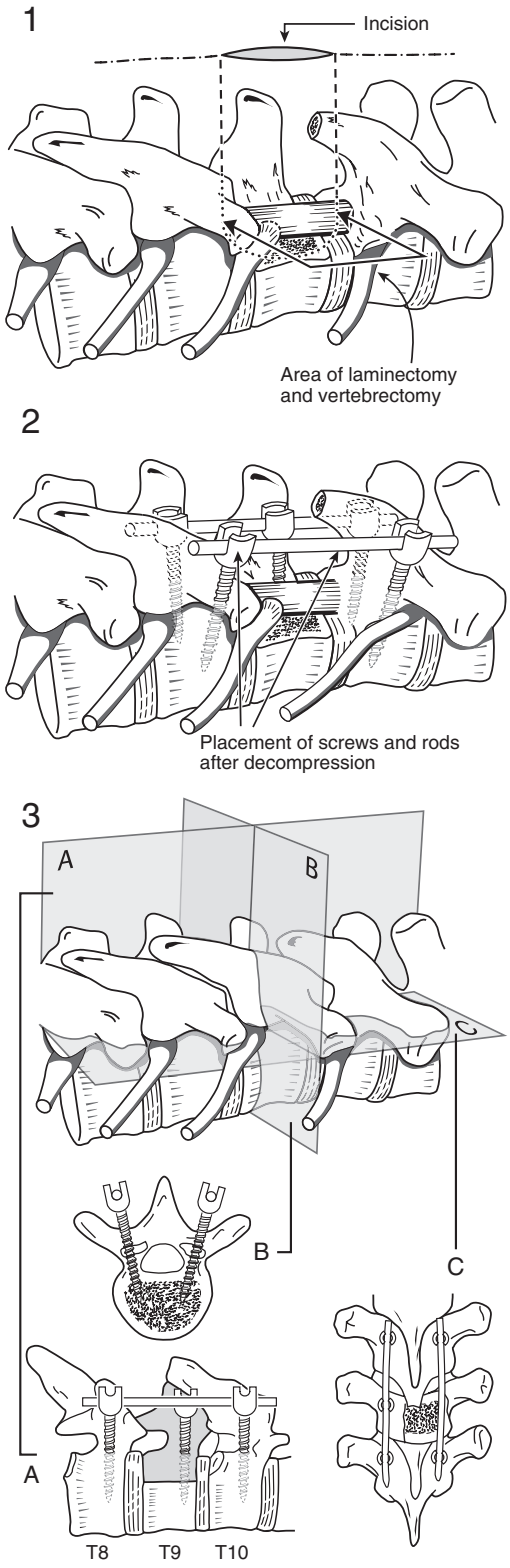

Fig. 1 Technique # 1 involves a mini-open decompression (Part 1) without anterior reconstruction, with a stabilization one level above and below the decompression (Part 2). A, Coronal section; B, Transverse section; C, Sagittal section.

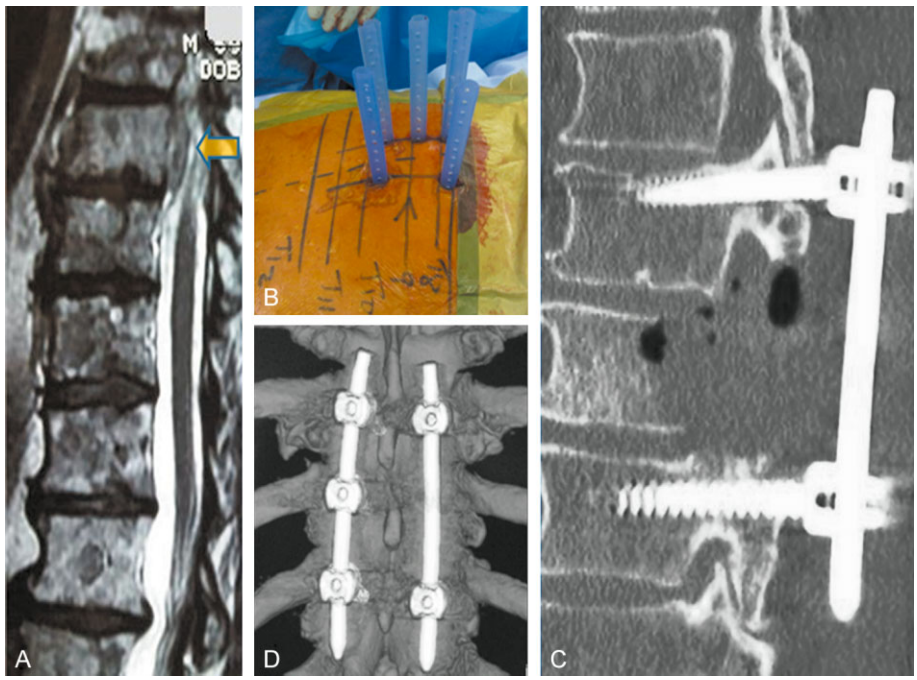

Fig. 2 A 72-year-old man presented with a gastrointestinal stromal tumor (GIST) with multiple metastases. He developed a paraparesis rapidly over 2 weeks. (A) MRI scan image showing cord compression caused by anterior epidural disease. (B) Intraoperative photograph showing percutaneous sleeves in situ. (C) Post unilateral pediculectomy and decompression. (D) Post-operative CT scan image.

surgery is decompression of the neurological elements and mechanical stabilization. Using a mini-open midline or paramedian decompression and percutaneous screw fixation, the goal here is for rapid mobilization and minimization of hospitalization (Fig. 1).

Case #1

A 72-year-old man presented with a gastrointestinal stromal tumor (GIST) with multiple metastases, including in the liver, lung and spine. He developed a paraparesis rapidly over 2 weeks (Fig. 2A). According to the oncology team, his likely survival was less than 6 months, based on modified Tokuhashi score[5]. Surgery was performed at the request of both patient and oncology team. A mini-open decompression including a unilateral pediculectomy and partial vertebral body resection (Fig. 2B–D) was performed with stabilization one segment above and below the decompression. The patient's neurological status improved and he was able to mobilize with minimal assistance. His length of stay was 3 days. The patient died 13 months post-procedure from cerebral metastases.

Technique #2

Technique #2 is suitable for patients with predicted medium longevity (6–12 months). In these patients, the primary goal of surgery is a decompression of the neurological elements and strong stabilization construct. They are suitable for decompression and/or cement vertebral body replacement and a two levels stabilization (Fig. 3).

Case #2

A 58-year-old woman with lung cancer presented with mid-thoracic pain of 2 months duration, and rapidly developing paraplegia with power 1–2/5 (Medical Research Council [(MRC] grade)[14]. Investigations revealed a metastatic lesion in T_9 with significant cord compression (Fig. 4A,B). Based on discussions with oncologists and assessment of her prognosis[5], she was predicted to have MT survival. Therefore the surgical technique aimed at decompressing the affected level, with vertebrectomy plus a two levels stabilization. A mini-open midline linear incision was made and bilateral pediculectomy and vertebrectomy performed (Fig. 4C). Vertebral reconstruction with cement augmentation was performed (Fig. 4D) and the midline wound closed. Percutaneous pedicle screw stabilization was performed two levels above and below the affected vertebra (Fig. 4E). A postoperative CT scan revealed satisfactory decompression and stabilization (Figs 4F,G). The patient improved to MRC strength 4/5 and was she discharged on postoperative day 5. She underwent radiotherapy and chemotherapy and survived for 11 months.

Technique #3

Technique #3 is suitable for patients with predicted LT survival (>12 months). In these patients, the primary goal of surgery is a wide local or marginal resection of tumor, decompression of the neurological elements and a robust stabilization construct. They are suitable for an open 360° decompression, vertebral body reconstruction and a multilevel stabilization (Fig. 5).

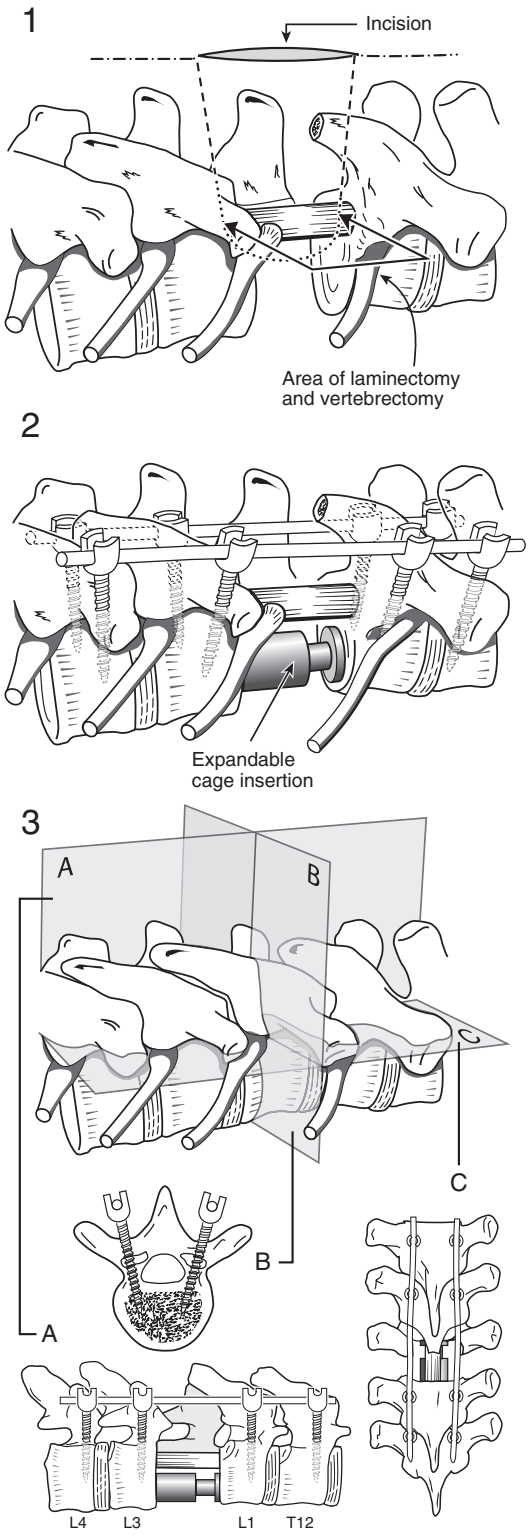

Fig. 3 Technique #2 involves a mini-open decompression and vertebrectomy with or without anterior cement augmented reconstruction (Part 1), with a stabilization two levels above and below the decompression (Part 2). A, Coronal section; B, Transverse section; C, Sagittal section.

Case 3#

A 32-year-old woman presented with mid back pain and leg weakness over 3 weeks. A large renal lesion was identified and removed, the pathological diagnosis being renal cell carcinoma. She had several metastases including in the L_3 vertebra and liver. Because of her potential LT survival, a decision was made to perform an L_3 vertebrectomy and stabilization. Autologous bone graft and tri-calcium phosphate bone graft substitute was placed within an L_3 expandable cage. Her back pain and leg weakness improved and she returned to independent living. She died of widespread metastatic disease 28 months postoperatively (Fig. 6).

Results

The study included eight patients (five women and three men) with a mean age of 59 years (range, 36–72 years). Renal cell carcinoma and breast carcinoma were the primary malignancies in two patients each and there was one case each of lung carcinoma, hemangiopericytoma, GIST and malignant melanoma. The mean modified Tokuhashi score was 10 (range, 7–13) with three patients in the ST survival, two in the MT survival and three in the LT survival category. The technique used was type 1 in ST, type 2 in MT and type 3 in LT. The mean blood loss was 700 mL (range, 100–1200 mL), mean operating time 280 min (range, 120–360 min) and mean length of hospital stay 5 days (range, 3–30 days). In the ST group survival was 3 months, 13 months and 56 months, in the MT group 11 and 43 months and in the LT group 28 months, 30 months and 41 months. In three patients preoperative power improved from 2 to 4 (MRC), whereas in one GIST patient it improved from 0 to 4; in the remaining patients it was unchanged at 4 (Table 2).

Discussion

Minimally invasive techniques for spinal fusion have evolved from the original descriptions of lumbar interbody fusion in the 1930's and Cloward's description of posterior lumbar interbody fusion in the 1950's[16]. Over time innovative procedures such as the transforaminal lumbar interbody fusion and extreme lateral lumbar interbody fusion techniques have aimed to improve access to the lumbar spine while avoiding significant anatomical structures, thus reducing complications. Similarly, the minimally invasive approach aims to reduce the amount of muscle dissection required, therefore reducing post-operative pain and duration of hospital stay[17,18]. In our experience, there is a reduction in blood loss and reduced need for wound drains[17]. We have also found that the minimally invasive method for percutaneous pedicle screws achieves a higher degree of screw accuracy[19]. In addition, the duration of exposed and open wounds is shorter, potentially decreasing infection rates, and the wounds are shorter, potentially making radiotherapy safer. All these factors may contribute to an overall improved quality of life, which is particularly important for those with poorer prognoses as described in published reports which lack class I evidence (Table 1)[20–33].

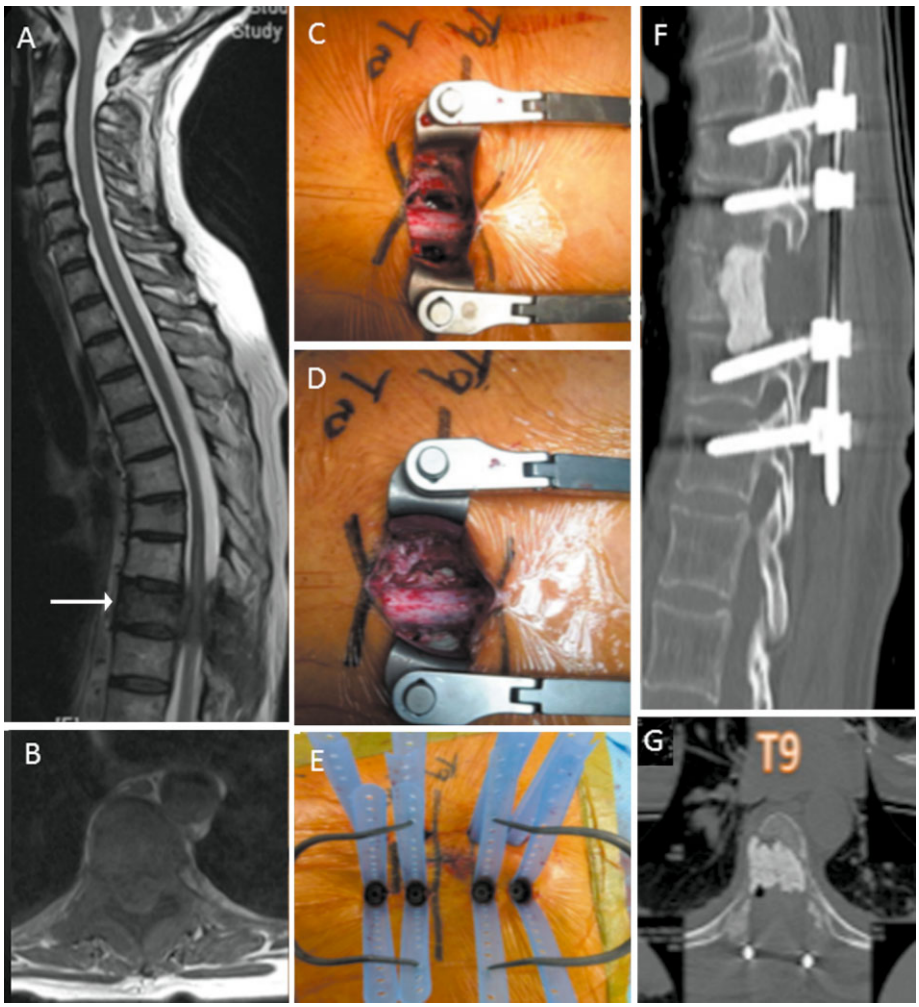

Fig. 4 A 58-year-old woman with lung cancer presented with midthoracic pain of 2 months duration. (A) and (B) MRI images showing circumferential spinal cord compression at T_9 level. (C) Intraoperative photograph showing mini-open midline linear incision with bilateral pediculectomy and vertebrectomy. (D) Post vertebroplasty with cement augmentation. (E) Intraoperative photograph showing percutaneous sleeves in situ. (F) and (G) Post-operative CT scan images.

Spinal metastases are common among patients with cancer and their consequences can significantly affect the quality of life. Radiotherapy is used to treat almost all patients with symptomatic spinal metastases; the response of any given lesion to radiotherapy being predictable based on histology. However, radiation therapy cannot restore mechanical integrity to a spine compromised by pathologic fracture or impending instability; however, it can ameliorate pain. Once neurologic signs are present, there is level I evidence for the superiority of direct decompressive surgery followed by radiotherapy over radiotherapy alone in patients with common metastatic histologies[8]. Some authors have reported surgical categorization, particularly in regard to relating aims of surgery to prognosis; the usual surgical categories are palliative, limited excision and wide excision[5,11]. However, there is little evidence to support specific surgical techniques. We propose that, because of the associated reduced muscle dissection and subsequent reduced pain and blood loss, greater accuracy, smaller wounds and reduced duration of stay, MIS techniques be prescribed for the treatment of spinal metastases, and that these be placed in three categories based on prognosis.

There are a number of variables relevant to selecting treatment options in patients with symptomatic metastatic spinal disease: diversity of primary tumors, varied metastatic vertebral disease, varied visceral metastasis, a wide range of performance status determined by tumor burden and previous treatments, varied neurological deficits and a wide range of radio-chemo sensitivity of the tumor itself. Prognostication scores are helpful for guiding surgical treatment[5,11]; however, the accuracy of such prediction is around 80% in most series. Hence the decision to operate and the extent of

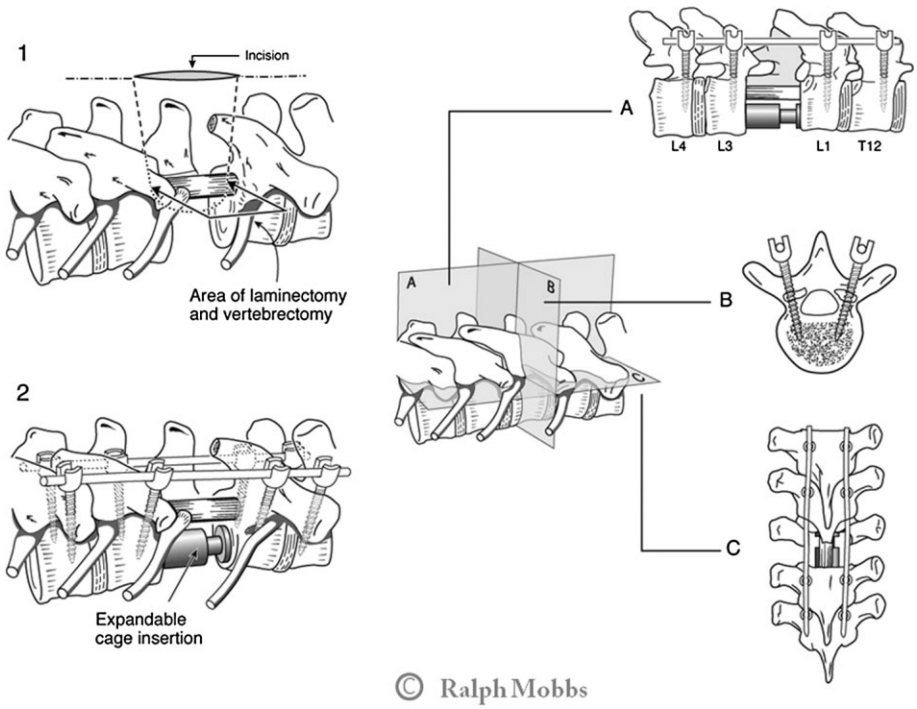

Fig. 5 Technique # 3 involves an open decompression and vertebrectomy with anterior vertebral reconstruction (expandable cage) (Part 1), with a stabilization two levels above and below the decompression (Part 2). A, Coronal section; B, Transverse section; C, Sagittal section.

surgery must tailored for each individual patient and their circumstances.

Our preference for MIS techniques is based on our own experience with MIS and open lumbar fusions[17] and on published reports concerning MIS for metastatic spine lesions (Table 1). Although there is neither published direct comparisons between MIS and open techniques for metastatic spine disease nor class I evidence for MIS, available reports are biased towards MIS because of the reduction in peri-operative morbidity and faster recovery.

MIS techniques have several important advantages for spinal decompression and stabilization of epidural spinal cord compression caused by metastases. In such cases, the goals of surgery (open or MIS) are tumor debulking, neuronal decompression and mechanical stabilization, all of which can be achieved readily via MIS procedures. Definitive treatment of these patients relies on chemo-radiotherapy, which can be started earlier in patients who have undergone MIS because wound and general recovery are quicker than with open procedures. Although circumferential compression is common, metastatic disease usually occurs in the vertebral body. The commonest MIS approach is posterior, however anterior or lateral approaches can be utilized either as a standalone or in combination with percutaneous posterior pedicle screw stabilization. Another advantage of MIS techniques is faster wound healing that is more resilient to radiotherapy-induced wound breakdown. It is commonly acknowledged that prolonged operative time is associated with increased infection rates and blood loss. In addition, blood transfusion is associated with risk of systemic infection, gastrointestinal complaints, and hemolytic reactions[34]. Thus, with the minimal exposed surgical corridor in MIS procedures, blood loss is reduced and the need for transfusion lessened. Additionally, although historically a criticism of MIS technique has been longer operating times, because of the minimal exposure operating times are in fact reduced[35,36]. Therefore, the morbidity of spine surgery in patients with metastasis-related neuronal compression can be minimized by using MIS techniques that reduce operating time, blood loss, need for blood transfusion and iatrogenic muscle injury and encourage wound healing, thus allowing patients to resume life-saving adjuvant therapies earlier than after conventional open surgery.

The "minimization" here is based on the prognosis of the patient (modified Tokuhashi score) and the goal(s) of surgery. Patients with predicted short longevity (<6 months) can be offered simple decompression followed by two-level stabilization. With predicted medium longevity (6–12 months), we recommend more rigorous decompression and attempts to reconstruct anteriorly with minimal effort but a stable construct. In patients with a reasonably long prognosis (>12 months), we recommend making every effort to resect the tumor and provide a robust stabilization construct. The aims are as follows: for short longevity patients to improve quality of life in terms of pain and mobility while minimizing operative

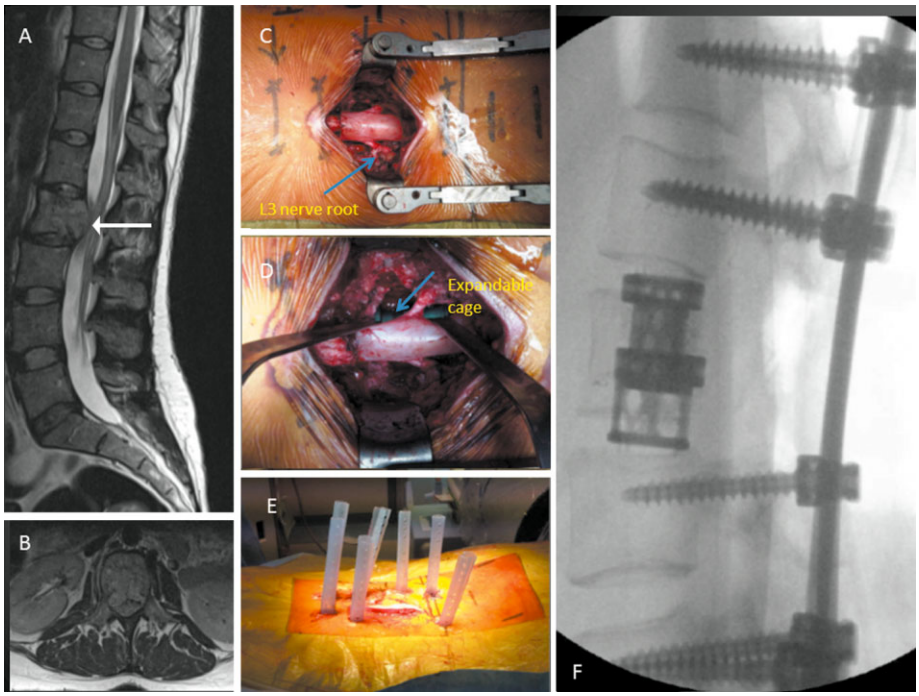

Fig. 6 A 32-year-old woman presented with mid back pain and leg weakness over 3 weeks. (A) and (B) MRI images showing solitary L_2 lesion causing circumferential cauda equina compression. (C) Intraoperative photograph showing midline incision with circumferential decompression and vertebrectomy. Decompressed L_3 nerve roots are displayed (arrow). (D) Intraoperative photograph showing expandable cage (arrow) assisted vertebral body reconstruction. (E) Intraoperative photograph showing midline wound closure and percutaneous fixation two levels above and below the vertebrectomy. (F) Post-operative radiograph.

morbidity and mortality, whereas for predicted long-term survivors surgery is aimed at good local tumor control and robust stability capable of withstanding stresses for a long time.

In this small series there was no perioperative mortality, as compared with open surgical series with surgical mortality of 4%–7.6%[8,12,13,15]. Morbidity rates in open surgery are reportedly 20%–25% across various studies[12,13,15]: in our series the rate was 1/8 (wound infection). Mean operative times were 280 min and mean blood loss 700 mL, similar to other MIS studies[20]. Short hospital stays in this series (13 days average) is also similar to other MIS studies[20] indicating that patients universally recover rapidly, which is one of the goals of palliative but effective surgery. Modified Tokuhashi scores were accurate in 5/8 patients. One malignant melanoma patient survived longer than 56 months and, at the most recent follow-up, a patient with metastasis from breast cancer was still alive 43 months after surgery.

Limitations

The proposed stratification can serve as a guide; further validation in terms of effectiveness and outcomes is required. As previously mentioned, the pathology of metastatic spine disease, patients' performance status and sensitivity to adjuvant treatment varies, as do patient preferences. Hence, bias is unavoidable in any stratification involving such a varied cohort unless well powered prospective studies are undertaken. This case series is small and hence too underpowered to make any definitive conclusions.

Conclusions

The authors present several minimally invasive options for managing spinal metastatic disease, using percutaneous fixation techniques combined with mini-open approaches to decompress neurological structures. We propose a simple stratification into three percutaneous surgical techniques corresponding with three clinical prognostic categories. The techniques are tailored to the expected longevity of the patient and attempt to reach a balance between invasiveness and effectiveness to manage each patient's unique presentation.

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