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Clinical Studies

Expected motor function change following decompressive surgery for spinal metastatic disease

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ABSTRACT

Background: Motor function in patients with spinal metastatic disease (SMD) directly impacts a patient's ability to receive systemic therapy and overall survival. Spine surgeons may be in the challenging position to advise a patient on expected motor function outcomes and determine a patient's suitability as a surgical candidate. We present this study to provide this critical information on anticipated motor function change to spine surgeons.
Methods: Consecutive patients undergoing spinal surgery for SMD at a National Cancer Institute-designated cancer institute were prospectively enrolled. Patient motor function status before and after surgery was assessed using the standard 0 to 5 five-point muscle strength grading scale. The difference in presurgical and postsurgical motor function (proximal and distal) was used to assess motor function changes following surgery.
Results: A total of 171 patients were included. The mean age was 62.7±10.46 years and 40.9% (70) were female. Common primary malignancy types were lung (49), kidney (28), breast (25), and prostate (23). The average proximal and distal motor function difference was 0.38 (standard deviation=1.02, p<.0001) and 0.32 (standard deviation=0.91, p<.0001) respectively showing an improvement following surgery. Patients with proximal presurgical motor function of 2, 3, and 4 had an improved motor function in 73%, 77%, and 73% of the patients. Patients with distal presurgical motor function of 2, 3, and 4 had an improved motor function in 80%, 89%, and 70% of the patients.
Conclusions: Most patients undergoing surgery for SMD have a modest improvement in motor function following surgery. The degree of improvement in most instances is less than 1 point on a 0 to 5 motor function scale. This is critical knowledge for a spinal surgeon when evaluating SMD patients with significant preoperative motor function deficits. These results aid spinal surgeons in setting expectations and evaluating the need for rapid spinal decompression.

Introduction

The spinal column is the most frequent site of metastatic bone disease and the third most common site of solid tumor metastatic disease, after the lung and the liver [1,2]. More than 90% of spinal tumors are the result of metastases from the lung, breast, prostate, or kidney to the spinal column [3–5]. Spinal metastases can cause neural compression and spinal fracture, which can adversely impact the quality of life and result in neurological symptoms due to spinal cord compression [6,7] Motor dysfunction is the second most common presenting complaint following back pain, affecting 35% to 75% of patients [8].

Surgical decompression and spinal stabilization are essential components of spinal metastatic disease (SMD) treatment [9]. Surgical decompression for SMD can result in an improved ability to ambulate,

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Short summary sentence: Few studies exist reporting on the expected motor function change in patients following decompressive surgery for SMD. In our study of 171 patients, most patients had a modest improvement in motor function following surgery at 4 to 6 weeks follow-up rather than a dramatic motor function improvement.

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decreased pain and opioid medication usage, and prolonged survival [10,11]. Surgical decompression is part of a multimodal approach to spinal metastases, along with chemotherapy, radiation, and systemic therapy to treat primary cancer pathology [12]. Patient motor function in this population is critical, as overall function directly impacts a patient's ability to receive systemic therapy and overall survival [10]. Surgical patient selection is paramount in this population, and numerous studies exist to advise surgeons on factors affecting patient outcomes in SMD [13–15]. Spine surgeons may be in the challenging position of attempting to advise a patient on expected neurologic outcomes and determining a patient's suitability as a surgical candidate based on expected neurologic outcomes. Despite this challenge, few studies exist reporting on the expected motor function change in patients with SMD [16]. This study will provide this critical information to spine surgeons on motor changes expected after surgical decompression for SMD.

Methods

Patient population

Consecutive patients undergoing spinal surgery at a National Cancer Institute-designated cancer institute were prospectively enrolled from September 2010 to November 2021 in an IRB-approved study. Research electronic data capture system was used to manage the data. Patients with primary spinal column tumors including chordoma, chondrosarcoma, and multiple myeloma were excluded. All included patients were diagnosed with spinal metastatic disease and underwent decompressive spinal separation surgery by 2 neurosurgeons.

Study design

The STROBE guidelines were used [17]. Demographic characteristics such as sex, age at the time of surgery, primary carcinoma origin, and vertebral metastasis region were obtained from each patient's electronic medical record. Patient motor function status before and after surgery was obtained from clinical documentation and assessed using the standard 0 to 5-point grading scale [18]. The postsurgical motor function was assessed between 4 and 6 weeks follow-up after surgery due to variability of follow-up time. This time frame of postsurgical motor function assessment provides the optimal time after surgery for recovery and initiation of systemic therapy.

Muscle groups were categorized as proximal or distal in the upper and lower extremities. Upper extremity proximal muscle function was the worst score of the deltoid, biceps, and triceps motor function. Upper extremity distal muscle function was the worse score of the wrist flexors/extensors, wrist abductors/adductors, and hand grip motor function. Lower extremity proximal muscle function was the worst score of the muscles of hip flexors and hip adductors/abductors motor function. Lower extremity distal muscle function was the worst score of the knee flexors/extensors, foot dorsiflexors/plantar flexors, and foot evertors/invertors motor function. Patients with initial motor function weakness (motor function score 0–4) were separately analyzed to evaluate their motor function change following surgical decompression. Patients with intact initial motor function weakness (motor function score 5) were analyzed to evaluate their motor function change following surgical decompression as well. The grading of motor function strength was assessed by the 2 neurosurgeon attendings.

Statistical analysis

The difference in presurgical and postsurgical motor function was used to assess motor function changes after surgery with standard deviations (SD). Paired *t*-test was performed to access the statistical significance of the difference between overall presurgical and postsurgical motor function as well as for motor changes by primary malignancies. Subgroup analyses based on the most common primary malignancy type were performed. All statistical tests were 2-tailed, and a p-value<.05 was deemed significant. GraphPad software (https://www.graphpad.com/) was utilized to conduct all statistical analyses.

Table 1
Patient demographics.

Variable	Population (N=171)
Gender	
Male	101 (59%)
Female	70 (41%)
Age in y, (mean±SD) (range)	62.7±10.5 (29–86)
Location	
Cervical	18 (0.6%)
Thoracic	117 (0.6%)
Lumbar	35 (0.6%)
Sacrum	1 (0.6%)
Primary site	
Adrenal	1(0.6%)
Bladder	2 (1.2%)
Breast	25(14.6%)
Cervix	1 (0.6%)
Chondrosarcoma	1 (0.6%)
Colon	4(2.3%)
Esophagus	4 (2.3%)
Gastrointestinal	1 (0.6%)
Kidney	28 (16.4%)
Liver	2 (1.2%)
Lung	49(28.7%)
Lymphoma	6(3.5%)
Neuroendocrine	1 (0.6%)
Peripheral nerve sheath	3 (1.8%)
Prostate	23(13.5%)
Salivary gland	1 (0.6%)
Skin	10 (5.8%)
Thyroid	2(1.2%)
Tongue	1(0.6%)
Tonsil	1(0.6%)
Unknown origin	5 (2.9%)

Results

A total of 171 patients were included in the study. Mean age was 62.7±10.46 years and 40.9% (70) were female (Table 1). The most common primary malignancy types were lung (49 patients, mean age 63.4±8.25 years), kidney (28 patients, mean age 62.9±7.97 years), breast (25 patients, mean age 63.1±10.70 years), and prostate (23 patients, mean age 68.6±9.22 years; Table 1).

The average presurgical motor function of the overall study population was 4.28±1.14. The average postsurgical motor function of the overall study population was 4.63±0.88. The average motor function difference of the overall study population was 0.35±0.96. In the overall study population, patients with presurgical motor function of 2, 3, and 4 had an improved motor function in 77%, 83%, and 72.5% of the patients in those categories, respectively. Patients with presurgical motor function of 2, 3, 4, and 5 had a maintained motor function in 9%, 13%, 25.5%, and 92% of the patients in those categories, respectively. The average proximal motor function difference for all patients was 0.38 points (SD=1.02, p<.0001; Table 2) on a 0 to 5-point scale showing an improvement after surgery whereas for the average distal motor function difference was an improvement of 0.32 (SD=0.91, p<.0001; Table 3).

For primary malignancy type, the average proximal motor function difference for lung, breast, kidney, and prostate were improvements of 0.44 (p=.0009), 0.32 (p=.0026), 0.36 (p=.0224) and 0.22 (p=.1705) respectively (Table 2). The average distal motor function difference for lung, breast, kidney, and prostate were improvements of 0.31 (p=.0205). 0.28 (p=.0054), 0.04 (p=.0503), and 0.17 (p=.2130) respectively (Table 3). For the overall study population, patients with proximal presurgical motor function of 2, 3, and 4 had an improved motor function in 73%, 77%, and 73% of the patients in those categories respectively (Table 4). Patients with proximal presurgical motor function of 2,

Table 2
The average proximal motor difference by primary malignancy type.

Average motor function difference (0–5-point scale)			
Primary cancer site	Proximal motor function change (Average±SD)	p-value	Range
Overall population (N=171)	0.38±1.02	<.0001	(-2,4)
Kidney (N=28)	0.36±0.78	.0224	(-1,3)
Breast (N=25)	0.32±0.47	.0026	(0,1)
Lung (N=49)	0.44±0.89	.0009	(-1,4)
Prostate (N=23)	0.22±0.74	.1705	(-2,2)

SD = standard deviation; N = number of patients; Range = the spread of the difference between pre-surgical and post-surgical motor function of patients, negative = decreased motor stats after surgery, positive = improved motor status after surgery.

Table 3
The average distal motor difference by primary malignancy type.

Average motor function difference (0–5-point scale)			
Primary cancer site	Distal motor function change (Average±SD)	p-value	Range
Overall population (N=171)	0.32±0.91	<.0001	(-2,4)
Kidney (N=28)	0.04±0.33	.0503	(-1,3)
Breast (N=25)	0.28±0.46	.0054	(0,1)
Lung (N=49)	0.31±0.89	.0205	(-1,4)
Prostate (N=23)	0.17±0.65	.2130	(-2,2)

SD = standard deviation; N = number of patients; Range = the spread of the difference between pre-surgical and post-surgical motor function of patients, negative = decreased motor stats after surgery, positive = improved motor status after surgery.

Table 4
Percent of patients that had an improved motor function.

Improved motor function (%)						
	Presurgical motor function					
	2		3		4	
Primary cancer site	Proximal %, (N)	Distal %, (N)	Proximal %, (N)	Distal %, (N)	Proximal %, (N)	Distal %, (N)
Overall population (N=171)	73 (11)	80 (5)	77, (13)	89, (9)	73, (40)	70, (47)
Kidney(N=28)	100, (2)	-	100, (1)	100, (2)	62.5, (8)	75, (8)
Breast (N=25)	-	-	100, (1)	50, (2)	78, (9)	86, (7)
Lung (N=49)	50, (4)	50, (2)	100, (3)	100, (1)	92, (12)	94, (17)
Prostate (N=23)	-	-	100, (2)	100, (1)	60, (5)	50, (6)

% represents percentage of patients that had maintained and/or improved motor function after surgery; N = number of patients in each category.

3, 4, and 5 had a maintained motor function in 9%, 15%, 25%, and 93% of the patients in those categories respectively (Table 5). Patients with distal presurgical motor function of 2, 3, and 4 had an improved motor function in 80%, 89%, and 70% of the patients in those categories respectively (Table 4). Patients with distal presurgical motor function of 3, 4, and 5 had a maintained motor function in 11%, 26%, and 90% of the patients in those categories respectively (Table 5). The rest of Tables 4 and 5 showed the improved and maintained motor function respectively by the primary malignancy site. Figs. 1 and 2 visualizes the percentage of patients that had maintained and improved proximal and distal motor function after surgery respectively.

Discussion

Summary and highlights

Preoperative prediction of postoperative outcomes is a subject of major interest and study in SMD [15–19]. Despite extensive studies on the topic, limited results exist on the expected motor function change following decompressive surgery for SMD [13]. Bach et al. [20] found that after decompressive surgery for SMD 79% of ambulatory patients remained ambulatory and 18% of nonambulatory patients regained walking ability. Gokaslan et al. [21] reported improved motor function following vertebrectomy for SMD. A recent article by Amelot et al. [22] showed that patients with poor ECOG-PS could benefit from surgery through the preservation of their neurological function making ambulation possible and reducing pain. Expected postoperative motor function is critically important to patients with SMD and to the spinal surgeon selecting operative candidates. The purpose of this study is to define expected motor function changes in patients undergoing surgery for SMD in the present era of intraoperative imaging and spinal instrumentation.

The present study evaluated 171 patients undergoing surgical decompression for spinal metastatic disease and found an overall expected motor function change of positive 0.35 in all muscle groups. The motor improvement following operative decompression was statistically significant. Detailed subanalysis found an overall expected motor function change of positive 0.38 in proximal muscle groups and positive 0.32 in distal muscle groups. We chose to categorize muscle strength into proximal and distal muscle groups based on known patterns of spinal cord

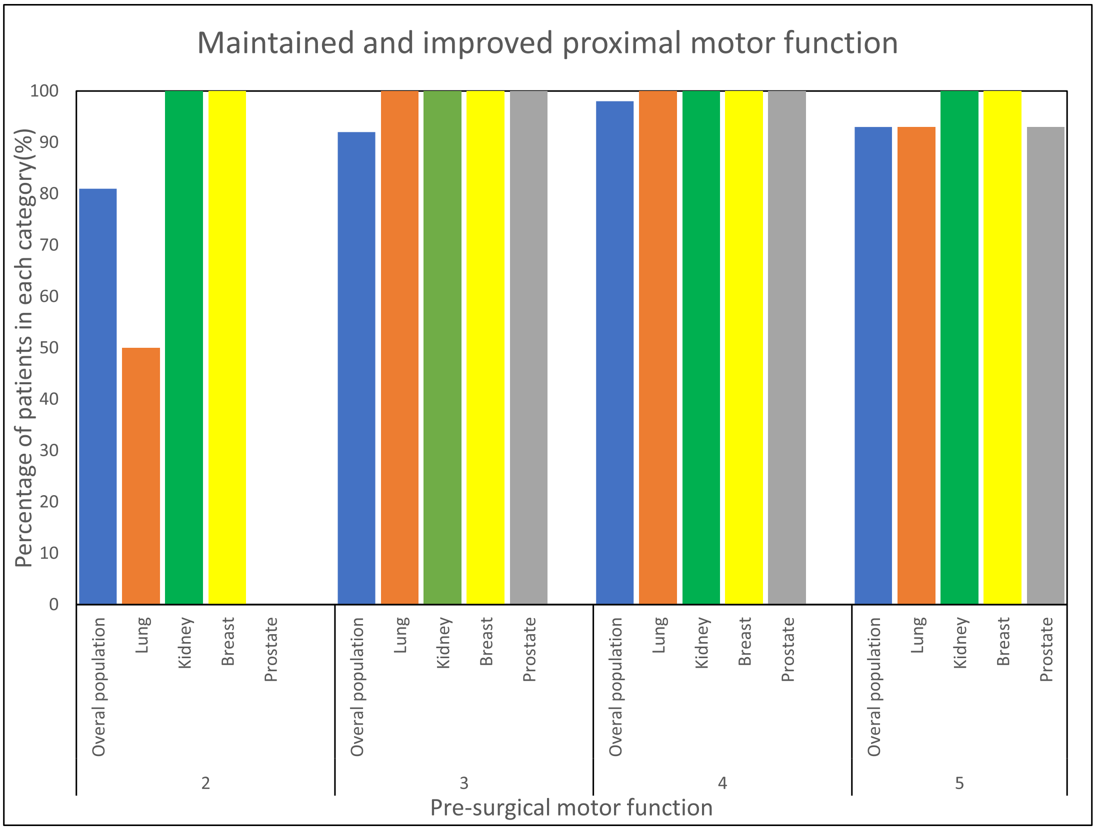

Fig. 1. Bar chart representing the percentage of patients that had maintained and/or improved proximal motor function after surgery (Note: Only maintained motor function in pre-surgical motor function of 5).

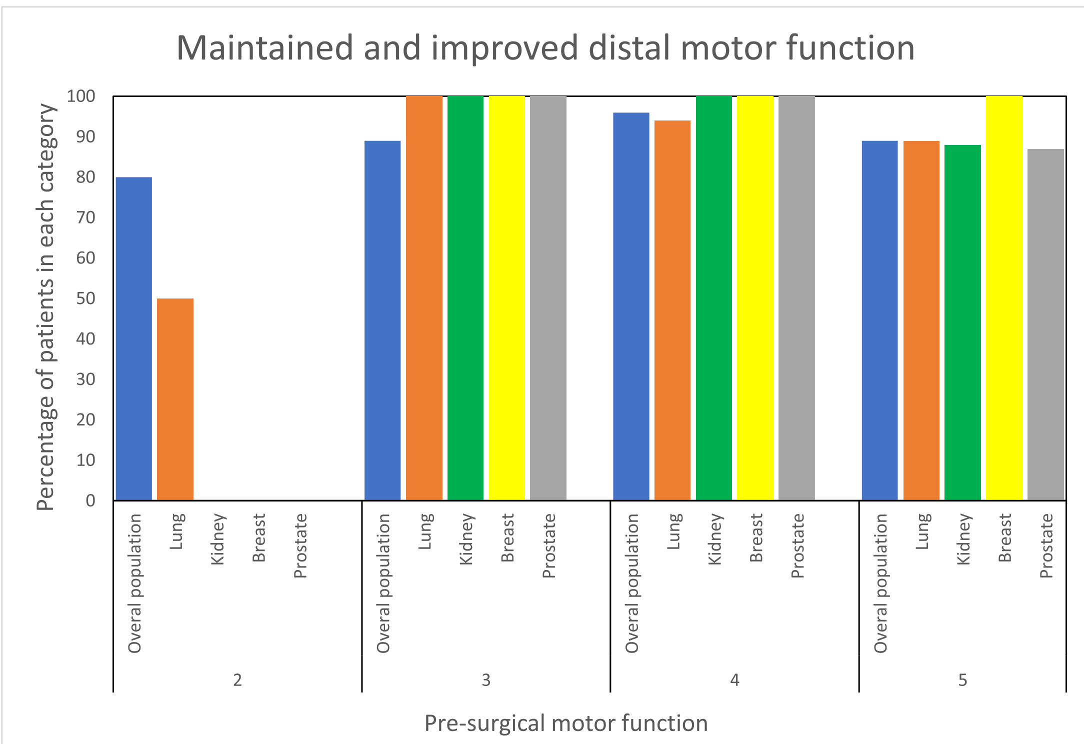

Fig. 2. Bar chart representing the percentage of patients that had a maintained and improved distal motor function after surgery (Note: Only maintained motor function in pre-surgical motor function of 5).

Table 5
Percent of patients that had a maintained motor function.

Maintained motor function (%)								
	Presurgical motor function							
	2		3		4		5	
Primary cancer site	Proximal %, (N)	Distal %, (N)	Proximal %, (N)	Distal %, (N)	Proximal %, (N)	Distal %, (N)	Proximal %, (N)	Distal %, (N)
Overall population (N=171)	9 (11)	-	15, (13)	11, (9)	25, (40)	26, (47)	93, (100)	90, (102)
Kidney(N=28)	-	-	-	-	37.5, (8)	25, (8)	94, (16)	88, (17)
Breast (N=25)	100, (1)	-	-	50, (2)	22, (9)	14, (7)	100, (14)	100, (16)
Lung (N=49)	-	-	-	-	8, (12)	24, (17)	93.3, (30)	89.2, (28)
Prostate (N=23)	-	-	-	-	40, (5)	50, (6)	93.3, (15)	86.7, (15)

% represents percentage of patients that had maintained and/or improved motor function after surgery; N = number of patients in each category

compression and weakness in SMD [1,23]. Further, we aimed to define results in a manner easily applicable to a given preoperative patient. Lung cancer patients showed the most postoperative improvement, but still less than 1 point on the 0 to 5-point scale. Patients with more severe preoperative motor deficits were less likely to improve postoperatively. This study supports a conclusion that patients with spinal metastatic disease of varying primary tumor types and varying preoperative motor deficits are expected to have a mild, but not profound, motor strength improvement following decompressive surgery for SMD that is less than 1 point on the 0 to 5-point muscle strength scale. A study of 101 SMD patients by Younsi A et al. [24] showed that 61% of patients could walk at discharge compared to 20% who were able to ambulate preoperatively. Over 70% of our study population had an improved motor function in all presurgical categories. Yaari LS et al. [25] showed that in their cohort of 61 SMD patients, their patients did not show any significant difference in their Frankel score and walking capability postoperatively. This is comparable to our results because most patients did not have a motor change greater than 1 point in our patients with presurgical motor function of 2 and 3. This information is vital for the spinal surgeon to select candidates for operative decompression for SMD.

A hallmark tenet when treating central nervous system disorders is the primary purpose of intervention is to maintain present function with no guarantee of improved neurologic function. The modest improvement in motor function demonstrated in the present study has implications for spinal surgeon decision-making. The typical weak SMD patient has a slow decline in motor function over a period of weeks or months and often will have motor function stabilization or improvement with the initiation of corticosteroids [24]. Given our results, the rare SMD patient with rapid neurologic decline refractory to corticosteroids would warrant urgent operative decompression, as postoperative improvements in strength may be modest rather than exceptional.

The observed follow-up time of 4 to 6 weeks is appropriate given the patient population studied. For patients with SMD, they must be well enough to receive postoperative radiotherapy and systemic therapy. Thus, early follow-up strength is of primary importance. It is possible that motor function improved further for our studied patients in a delayed fashion, yet ultimately the ability to recover to receive systemic therapy has the greatest impact on overall prognosis and survival in patients with SMD [26–28].

Strengths/Limitations

A limitation of this study is the selection bias related to including only operative patients. Presumably, those patients determined to have a poor likelihood of neurologic improvement would not be surgical candidates. This can be identified by the lack of patients with preoperative motor function of 0 and 1 point. Additional factors such as Karnofsky's performance scale and systemic oncologic prognosis impact the decision to operate in SMD, and these factors were not independently evaluated due to the lack of uniform data. The study still provides useful information on the expectations for surgeons and patients for motor function change in patients selected for surgery.

An additional limitation of the study is that no PROMS data such as VAS, ODI, SF-12, or SF-36 were included due to the heterogeneity of patient records. Multiple enrolled patients were hospital transfers to our tertiary referral center taken for urgent surgery. As a result, preoperative inpatient data were not uniform as it is for those patients evaluated preoperatively in the neurosurgical clinic where standard data sets are obtained. This limits our study as we were unable to include objective measures of performance that are valuable, particularly for comparison to other similar studies. Other variables such as duration of symptoms, time to surgery, number of levels decompressed, and complications during surgery were not assessed in this study. The purpose of this study was to provide a broad understanding of expected motor improvement following decompressive surgery in SMD. Further analysis into subgroups may provide insights into categories of patients with outlying outcomes, but the present study seeks to provide results inclusive for most SMD patients.

The population studied provides a useful representative sample of operative candidates with SMD. The study size is large relative to published clinical studies in SMD, and tumor type distribution is reflective of pathologies seen in clinical practice [10,14,19,29,30]. The group studied can be reasonably compared to the SMD patient seen in clinical practice. The similarity of results across presenting motor function and primary pathology groups allows extrapolation of the results to a variety of patient presentations.

The postoperative period for assessment of motor function was 4 to 6 weeks following surgery. We chose this time point as this is the time at which patients have typically completed their postoperative recovery and postoperative radiotherapy and are ready to begin systemic treatment. Additionally, we have uniform data on patient motor strength in this postoperative period. As a tertiary referral center, patients from distant geographic areas may begin to follow up with their local oncologists at greater time intervals. Patients would potentially continue to improve neurologically over a greater length of time. However, we do believe this information is valuable as it provides an assessment of motor strength as it directly impacts the period for postoperative initiation of systemic therapy.

While a modest improvement of motor function is seen, perhaps most important to the spinal surgeon is the lack of major motor function improvement in the groups studied. This means dramatic motor function improvement is not expected for most patients undergoing operative decompression for SMD. In patients with preoperative motor deficits, the likelihood of persistent neurologic motor dysfunction following surgery is high. Before undergoing surgery, the surgeon and patient ought to consider the likely persistent motor deficit in the context of adjuvant therapies, systemic treatments, overall prognosis, and quality of life.

Conclusions

Most patients undergoing surgery for SMD have an improvement in motor function following surgery. However, the degree of improvement in most instances is less than 1 point on a 0 to 5 motor function scale This is critical knowledge for a spinal surgeon when evaluating SMD patients with significant preoperative motor function deficits, as patients may not gain any major motor changes after surgical decompression. The results of this study can guide the spinal surgeon when selecting candidates for operative decompression in SMD and help set realistic patient expectations.

Declarations of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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