

# Preliminary establishment of a spinal stability scoring system for multiple myeloma

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## Research

**Keywords:** SINS scoring system, MM patients, Human Research Ethics Committee, data analysis

**Posted Date:** January 8th, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-139112/v1>

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# Abstract

**Background:** Multiple myeloma is an incurable malignant plasma cell disorder that represents the most common primary malignant bone tumor. It commonly involves bone metastasis in multiple vertebral bodies, which SINS scoring system may not be fully applicable to MM patients. We designed a stability evaluation system to evaluate the spinal stability of patients with MM spinal involvement in order to guide clinical treatment. **Methods:** By using Delphi method, information was collected and extracted through a series of questionnaires and improved via feedback and we preliminary establishment of a spinal stability scoring system for multiple myeloma. **Results:** Fifteen clinicians completed a second round of questionnaires and compared their answers with those of the first round of questionnaires to identify significant comments or changes that required group discussions. As a result, no further feedback was used to improve the scoring system. After integrating the information from the expert consultation questionnaire, we established the initial scoring system for MM spine stability and used the scoring system to assess a series of representative clinical cases. The scoring system consisted of the following six components. The MM spinal stability scoring system was created by calculating the scores of the six separate components: Location, Pain, Number of segments, Physiological curvature, Comorbidities and Neurological function. The minimum value was '0', and the maximum value was '24'. A score of '0-10' indicated 'spine stability', a score of '11-17' indicated 'potential instability', and a score of '18-24' indicated 'spine instability'. Patients with a score of '11-24' need an intervention such as surgery. **Conclusions:** The initial establishment of the MM spine stability scoring system provides a vital theoretical basis for the evaluation of spine stability in individuals with MM. **Trial registration:** The conducted study contains a retrospective analysis of medical records of our hospital database. Beijing Chao-yang Hospital Human Research Ethics Committee classifies this as a retrospective audit. The ethics approval and consent was given for the conducted retrospective data analysis.

## Background

Multiple myeloma (MM) is an incurable malignant plasma cell disorder that represents the most common primary malignant bone tumor. Older patients, with a median age of 59 years, are more likely to develop MM, but the exact incidence rate of the disease is unknown<sup>[1-4]</sup>. As the aging process in China accelerates, it is predicted that MM, with a rapid growth in incidence, will become one of the more significant diseases that affect people's health in the country. In the treatment of MM, spinal stability problems due to the lesion are increasing<sup>[5-8]</sup>. Currently, there is no method of evaluating the spinal stability of individuals with multiple myeloma. According to the 2010 The Spine Oncology Study Group (SOSG), spinal instability is defined as the loss of spinal integrity due to tumor growth, which is associated with motor-related pain and symptoms, progressive deformities and/or impairments in neurological function under physiological loads<sup>[9]</sup>. Many studies have validated this scoring system and applied it in clinical practice for diseases including primary spinal tumors, metastatic spinal tumors, and MM. People found that SINS demonstrated near-perfect inter- and intraobserver reliability in determining

three clinically relevant categories of stability. Therefore, SINS has become the most widely used scoring system for evaluating tumor-related spinal instability in the world.

However, MM is different from other primary and metastatic malignant tumors of the spine. Osteolytic destruction is the most common type of bone destruction in most MM patients; it commonly involves bone metastasis in multiple vertebral bodies, which are often accompanied by peripheral soft tissue masses and nerve compression symptoms. To some extent, SINS is not applicable to MM patients.

Based on the disease characteristics of multiple myeloma, a simple and practical new method for evaluating spinal stability in individuals with multiple myeloma is proposed, which can be used for the clinical evaluation and intervention of multiple myeloma patients.

## Materials And Methods

### Systematic review

The current literature on multiple myeloma and spinal stability was systematically reviewed before the study began to determine the best clinical and imaging evidence of spinal stability and to establish a framework for MM spine stability assessments<sup>[9-12]</sup>.

### Delphi method

The Delphi method is a method of communication among groups of experts from all over the world aiming to enable a team to deal with complex problems or tasks systematically (how to define spinal instability with MM in the study). By using this method, information was collected and extracted through a series of questionnaires and improved via feedback. This process included the following 5 steps:

1. The initial group meeting included a seminar hosted by the designated 'chairperson' who determined the criteria for evaluating spine stability. From the field of spine surgery and multiple myeloma, a total of 15 orthopedic and hematologists were asked to list factors associated with spinal instability in the context of the tumor. The first round of evaluations was then organized, and different scores were assigned based on the importance of the indicators to form a framework for the spinal stability scoring system of multiple myeloma.
2. The second round of surveys was conducted via questionnaires and a questionnaire was formulated to determine the relative importance of each factor. A five-item Likert scale was adopted as the evaluation index for the spinal stability scoring system for spinal cord tumors in multiple myeloma patients, and the degree of importance was divided into five grades: 'very important', 'important', 'moderate', 'less important', and 'not important'. The indicators were evaluated in combination with the experience of the experts. The five grades of 'very important', 'important', 'moderate', 'less important' and 'not important' were assigned point values of '5', '4', '3', '2', and '1', respectively, to facilitate statistical processing. The indicators added by experts were filled in the 'supplementary

indicators' column, and the evaluations, comments and suggestions for each indicator were filled in the "remarks" column.

3. After the second round of questionnaires, additional feedback from expert members was collected to improve the scoring system until the expert opinions tended to be consistent.
4. The multiple myeloma spine stability scoring system was established.
5. A surgeon applied the multiple myeloma spine stability scoring system to a series of representative cases to assess the feasibility and trialability of the new system.

## **Patient Case Selection and Evaluation**

A total of 72 cases were reviewed and scored using SINS and MM spinal stability scoring system by the authors. Cases with insufficient history or inadequate imaging were excluded. Images provided included select slices from either computed tomography (CT) scan or magnetic resonance imaging (MRI) combined with X-rays.

## **Statistical methods**

Patients' clinical data were analyzed by chi-square test. All data were analyzed by SPSS 23.0 statistical software. The measurement data were expressed as mean  $\pm$  standard deviation, and  $P < 0.05$  was considered as significant difference.

# **Results**

Subsequently, fifteen clinicians completed a second round of questionnaires (Table 1) and compared their answers with those of the first round of questionnaires to identify significant comments or changes that required group discussions. As a result, no further feedback was used to improve the scoring system. Expert opinions tended to be consistent (Table 2). After integrating the information from the expert consultation questionnaire, we established the initial scoring system for MM spine stability and used the scoring system to assess a series of representative clinical cases. The scoring system consisted of the following six components.

## **First-level Index**

### **Location**

This section refers to the SINS evaluation method. Different parts of the spine have different effects on stability after lesions (mainly vertebral compression fractures). Multiple myeloma is a diffuse lesion in which vertebral bodies and appendages can all be involved and the three-column structure of the spine is affected. This behavior is different from the behavior of metastatic and primary tumors of the spine; therefore, it is chosen as the first-grade index. Junctional involvement, such as occipitocervical (C1-C2), cervicothoracic (C7-T2), thoracolumbar (T11-L1) and lumbosacral (L5-S1) involvement, scored a '4'. Mobile spines, such as those with cervical vertebrae (C3-7) and lumbar vertebrae (L2-4) involvement,

scored a '3'. Semirigid spines (T3-T10) scored a '2'. Rigid spines (S2-S5) scored a '1'. Cases without spinal involvement scored '0' (Table 3).

## **Pain**

Back pain is the most common symptom of multiple myeloma. The causes of pain include tumor pain and mechanical pain caused by spinal stability changes. The pain caused by tumors can be quickly relieved after chemotherapy, while mechanical pain is difficult to relieve. Thus, we regarded pain as a primary index and further classified it with a specific score. Intractable pain (not alleviated by bed rest/chemotherapy, VAS $\geq$ 7) scored a '4'. Moderate pain (not alleviated by bed rest/chemotherapy, VAS 4-7) scored a '3'. Mild pain (after bed rest/chemotherapy, VAS=3) scored a '2'. Slight pain after activity (VAS $\leq$ 2) scored a '1'. No pain during activity after chemotherapy scored a '0' (Table 4).

## **Number of segments**

The lesion sites and the number of involved segments are important factors affecting the instability of the spine. Pathological compression fractures of two or more spinal segments often occur in patients with multiple myeloma. This behavior is significantly different from the behavior of spinal metastases or primary tumors. We further divided the index and assigned scores to the different types of fractures: compression fractures involving more than three segments scored a '4'; those involving three segments scored a '3'; those involving two segments scored a '2'; those involving a single segment scored a '1'; and an uncompressed fracture morphology/vertebral morphology that presented no change scored a '0' (Table 5). The lateral radiograph of the spine or the MRI is the best way to observe the characteristics of this pathological issue.

## **Physiological curvature**

Changes in the physiological curvature of the spine in the sagittal or coronal plane due to compression fractures of the spine are an important basis for spinal stability, which can be assessed by imaging. Although lateral radiographs of overextension and flexion of the spine are often used in the diagnosis of degenerative spinal instability, overextension and flexion of the spine may induce or cause compression fractures or aggravate the original fracture in patients with multiple myeloma, which is not recommended. Although the stability of the spine can also be evaluated by comparing images taken in the supine or erect positions, the supine position is safer for patients with multiple myeloma who are suspected of having spinal instability. In view of this clinical condition, the indicator was further divided: 1. according to the lateral X-ray, abnormal physical curvature of the lesion site scored a '2' and normal physical curvature of the lesion site scored a '0' and 2. according to the anteroposterior X-ray, spines with scoliosis/rotation scored a '2' and those without scoliosis/rotation scored a '0' (Table 6). The lateral radiograph of the spine is simple and practical and can be compared and followed up at different times. It should be the first choice for evaluation.

## **Comorbidities**

MM tends to occur more frequently in elderly people than do primary spine tumors. These patients may have degenerative changes, such as disc herniation, epiphysis, spondylolisthesis, and bony fusion, which may increase the instability of the spine before they are diagnosed with MM. According to the characteristics of the spine, we divided this index into four scores: spines with slippage (>1 degree) scored a '4'; those with displacement/dislocation (0-1 degrees) scored a '3'; those with disc herniation scored a '2'; those with a traction spur scored a '1'; and those with bone fusion and normal spines scored a '0' (Table 7).

### **Neurological function (according to Frankel classification)**

Spinal instability can lead to changes in neurological function, and it is often found in individuals with both multiple myeloma and intraspinal tumor infiltration, which causes compression of the spinal cord and nerve roots, resulting in severe complications such as paraplegia and incontinence. For the purpose of identification, this scoring system first excludes MM patients with tumor lesions in the spinal canal. The Frankel scoring system is commonly used in clinical practice and is easy to understand. This indicator was based on Frankel's assessment of neurological function: Frankel A (complete loss of sensory and motor function below the injury plane) scored a '4'; Frankel B (no motor function with some sensory function below the injury plane)) scored a '3'; Frankel C (some useless motor function below the injury plane) scored a '2'; Frankel D (useful motor function below the injury plane, but not fully normal) scored a '1'; and Frankel E (normal sensorimotor and sphincter function) scored a '0'(Table 8).

The MM spinal stability scoring system was created by calculating the scores of the six separate components. The minimum value was '0', and the maximum value was '24'. A score of '0-10' indicated 'spine stability', a score of '11-17' indicated 'potential instability', and a score of '18-24' indicated 'spine instability'. Patients with a score of '11-24' need an intervention such as surgery.

The following three cases illustrate the clinical application of the MM spinal stability score:

**Case 1:** A 52-year-old male with MM had a vertebral compression fracture at T11 and L1-2 and the following scores: VAS = 3; number of segments = 3; physiological curvature: positive and lateral according to X-ray and MRI; complications: none; and Frankel score of neurological function: D. The MM spine stability score of this patient was as follows: 3 points for location + 2 points for pain + 3 points for the segments + 0 points for the physiological curvature + 0 points for complications + 1 point for neurological function = 9 points. The score indicated 'spinal stability' (Figure 1).

**Case 2:** A 58-year-old male with MM had lumbar disc herniation. The spinal stability score was as follows: 4 points for location + 3 points for pain + 4 points for the segments + 0 points for the physiological curvature + 2 points for complications + 0 points for neurological function = 13 points. The score indicated 'potential instability' (Figure 2).

**Case 3:** A 58-year-old male with MM had spondylolisthesis and lumbar spondylolysis (2 degrees). The spinal stability score was as follows: 4 points for location + 4 points for pain + 2 points for the segments

+ 2 points for the physiological curvature + 4 points for complications + 2 points for neurological function = 18 points. The score indicted 'spinal instability' (Figure 3).

A comparison of the MM scoring system results with those of the SINS scoring system showed that the results of MM scoring system were inconsistent with those of the SINS (McNemar-Bowker 38.105;  $P=0.000$ ) (Table 9). The main difference was in the evaluation of potential instability of the spine.

## Discussion

### Evaluation of MM spinal stability scoring system

MM is characterized by the accumulation of clonal plasma cells in bone marrow (BM), the secretion of monoclonal immunoglobulins, and the presence of osteolytic bone lesions, which involve multifactorial problems. How to protect the spine and improve the quality of life of patients with routine chemotherapy in the hematology department is an important issue. It is necessary to evaluate the stability of the spine to develop interventions and determine prescriptions. At present, methods for evaluating the stability of the spine in individuals with primary tumors and metastatic cancer already exist, but no methods have been reported for the evaluation of spinal stability in individuals with multiple myeloma. Based on the clinical features of multiple myeloma, this study established a method for assessing the stability of a MM spine. It should be emphasized that the evaluation of spinal stability is one of the assessments in the course of diagnosis and treatment of MM patients. It may be the most difficult assessment for physicians who are not spinal surgeons. Therefore, constructing a simple and easy to learn scoring system is our main research topic.

The spine requires stability to ensure its degree of movements without pain and prevent neurological dysfunction and abnormal angulation<sup>[13]</sup>. Spinal stability depends on the integrity of the static structure and function of its components (bones, ligaments, intervertebral discs, facet joints, etc.), the dynamic structures of the muscles, the structure of the nervous system and the functional integrity. Spinal instability caused by tumors is mainly due to the destruction of the bone structure, and other structures are for the most part normal; this condition is quite distinct from those of spinal degenerative instability (with mainly affects ligaments and intervertebral discs a causes changes in facet joints) and traumatic spinal instability (which leads to bone, ligament, and muscle damage or fractures). Similarly, it is not the same as spinal instability caused by neuromuscular disease. Because multiple myeloma is predominantly characterized by osteolytic lesions, osteogenesis and mixed bone changes do not occur. Therefore, it is not appropriate to evaluate the stability of the spine in individuals with multiple myeloma by using methods for assessing the spinal stability of individuals with primary tumors and spinal metastases.

SOSG defines spinal instability as a loss of functional integrity of the spine. Potential instability of the spine is an intermediate state between stability and instability, which is also a significant factor affecting the clinical decision-making process of treatment for individuals with a spinal disease and tumors. There

is no consensus on the definition of potential instability<sup>[9]</sup>, but the importance of the underlying spinal instability with multiple myeloma is noticeable. A surgical intervention can be performed for the spinal nerve compression caused by multiple myeloma spinal lesions<sup>[5-8, 14-16]</sup>. For MM patients without neurological deficits, it is of great clinical significance to evaluate the stability of the spine, detect spinal instability, determine whether it is accompanied by spinal cord and neurological dysfunction, and prevent spinal instability caused by pathological fractures and the deterioration of neurological symptoms.

### **Clinical significance of MM spine stability evaluation**

The purpose of the MM spine stability assessment is to guide clinical decision making and should be characterized by effectiveness, repeatability, reliability, and maneuverability. Most importantly, it should promote multidisciplinary cooperation and communication between spine surgeons and hematologists. Currently, the SINS score is an internationally accepted method for assessing tumor-related spinal stability. The scoring system was established on the basis of six aspects, including tumor location, degree of pain, type of bone destruction, imaging changes in the spinal line, degree of vertebral collapse and posterior lateral involvement as determined by the SOSG in 2010. Daryl R et al. analyzed the reliability and effectiveness of the SINS scoring system, which is considered to have good prediction accuracy<sup>[17]</sup>. The specificity and sensitivity of the SINS scoring system in predicting spinal instability were 79.5% and 95.7%, respectively. Fisher et al. have shown that the SINS scoring system is highly reliable; of 629 patients with spinal instability or potential instability, 621 had SINS scores >7<sup>[18]</sup>, and most of them were potentially unstable. Mauricio Campos et al. also obtained similar results for the study of the repeatability and reliability of the SINS scoring system<sup>[19]</sup>.

Despite the recognition of the specificity and sensitivity of the SINS scoring system, there is still a lack of relevant large-scale prospective studies. Moreover, the scoring system only evaluates the stability of local lesions without considering the general status of the patient. In previous literature, some scholars used the SINS scoring system to evaluate the spinal stability of patients with multiple myeloma, but the sensitivity of multiple myeloma to chemotherapy and radiotherapy and its clinical features were not considered. Therefore, the SINS scoring system still has some limitations when used in the MM population. Our group reviewed the clinical data of 72 patients with MM spinal involvement and evaluated them with the SINS scoring system and MM spinal stability scoring system and found that the two scoring systems differed greatly in assessing 'potential instability'. Subsequently, for a number of patients, the SINS scoring system showed 'stability', while the MM scoring results showed 'stability' and 'potential instability'. MM tends to occur in the elderly population, and some patients have spinal degeneration, ankylosing spondylitis and other diseases. Different from other primary/secondary malignant tumors of the spine, the number of tumor infiltrating segments by MM was large, and almost all cases involved osteolytic destruction. MM directly destroys the bone, causing the rigidity of the spine to decrease. In addition, multiple segments are involved in the course of MM, so MM is more likely to cause spinal instability or increase the tumor-related instability on the basis of the original degenerative instability of the spine. These factors are closely related to the evaluation of MM spine stability; however,



the SINS scoring system does not take these factors into consideration. Therefore, the actual stability and potential risk of instability of patients with MM spinal involvement are higher than the results obtained by the SINS scoring system.

The lesion location of the tumor affects the stability of the spine. The risk of instability is the largest in the transitional sites of the spine, with the highest score weighting in these areas; the next largest risk of instability is in the active areas, while the weightings of the semiactive region composed of T3-T10 and the fixed region composed of S2-S5 were low.

Although pain is not the only symptom of spinal instability that is caused by tumors, it plays an important role in assessing the instability of the spine. Pain caused by spinal instability can be aggravated by exercise and relieved by bed rest, which is related to the destruction of the spinal structure. As the disease progresses, most patients with MM may feel pain in the chest and lower back, which are caused by local tumor infiltration and spinal instability. Pain associated with tumor invasion can be effectively controlled by chemotherapy, while pain caused by instability cannot be relieved after chemotherapy. Therefore, we rated the pain according to the location and severity of the pain. We evaluated postchemotherapy pain caused by spinal instability, which was different from the pain assessed in the SINS scoring system.

Many studies have indicated that skeletal system-related destruction includes osteolytic lesions and bone pain in patients with MM. Moreover, osteolytic lesions are important factors causing structural instability, and the risk of vertebral collapse caused by osteolytic lesions is higher than that caused by osteoblastic lesions<sup>[25]</sup>.

Unlike spinal metastatic and primary tumors, which may occur with osteogenesis or osteolytic lesions, this indicator showed no significant differences in the MM spinal stability assessment, which is different from the results of the SINS scoring system.

In general, changes in the physiological curvature or abnormalities often lead to instability of the spine<sup>[26]</sup>. Malformations may occur gradually, which may be the cumulative effect of multiple lesions. Since vertebral compression fractures caused by multiple myeloma are mostly accompanied by multiple fractures, kyphosis, and spinal degeneration due to advanced age, the scoring system includes the patient's spinal curvature as an indicator. In addition, degenerative changes in the spine (spondylolisthesis/displacement greater than 1 degree, disc herniation less than 1 degree, bone spurs, bony fusion or no lesion) were also assessed separately as first-level indicators; this method of assessment was different from that of the SINS scoring system.

### **Number of involved segments**

More than one segment of the spine was involved in MM. Moreover, a greater number of segments involved in the vertebral compression fracture corresponded to a greater probability of spinal instability, so we considered the number of affected segments as a primary indicator. It should be noted that spinal

compression fractures may not be continuous in many situations, and the doctor may evaluate the stability of the corresponding site based on the fracture, which was not mentioned in the previous SINS scoring system.

## **Neurological function**

Sudden neurological dysfunction may occur in patients with MM during treatment, including compression of the spinal cord caused by direct tumor infiltration of the spinal canal and neurological changes due to vertebral instability, which can be distinguished by imaging examinations. In contrast to the SINS scoring system, this scoring system excluded neurological dysfunction caused by intraspinal lesions and assessed neurological changes due to spinal instability based on the Frankel score.

## **Applicability of the spinal stability assessment for multiple myeloma patients**

This scoring system was based on the above indicators and was used to guide the clinical treatment of individuals with MM. The most important clinical contributions of the system are its ability to evaluate patients with MM and provide specific interventions according to the scores to minimize the serious consequences of spinal instability for improving the quality of life of patients. Notably, the spine stability score is a part of the assessment of the stability of a patient's spine. BMI, daily activity, bone quality, and history of previous spinal surgery may also affect the stability of the spine. Special considerations are needed in an overall evaluation of a patient. In guiding treatment, the timing of interventions may change as the disease becomes less invasive. Stability is a part of the assessment when making a surgical treatment decision. The general health, prognosis, neurological function, and decisions of patients must also be taken into consideration.

## **Conclusion**

Multiple myeloma with special characteristics is different from primary bone tumors and bone metastases. The initial establishment of the MM spine stability scoring system provides a vital theoretical basis for the evaluation of spine stability in individuals with MM. After further verification and reliability testing of the MM scoring system, we believe that the establishment of the MM spinal stability scoring system is reasonable and that the system is of value in clinical applications and guiding clinical decisions.

## **Abbreviations**

**MM** Multiple myeloma

**SINS** Spinal Instability Neoplastic Score

**SOSG** Spine Oncology Study Group

**CT** Computed tomography

**MRI** Magnetic resonance imaging

**BM** Bone marrow

## Declarations

### Ethical approval and consent to participate

The conducted study contains a retrospective analysis of medical records of our hospital database. Beijing Chao-yang Hospital Human Research Ethics Committee

classifies this as a retrospective audit. The ethics approval and consent was given for the conducted retrospective data analysis.

### Consent for publication

This study was approved by the Ethics Committee of Beijing Chao-yang Hospital. Since the study was conducted anonymously, no consent to publication by the patient was required.

### Availability of data and materials

The datasets collected during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

### Competing interests

The authors declare that they have no competing interests.

### Funding

This study was funded by Natural Science Foundation of Beijing Municipality(no. 7192071).

### Authors' contributions

XCY is the primary author and contributed to the drafting and revising of the manuscript. ZYX/XJS contributed to the data collections and drafting of the manuscript. JT/YZW/ZHZ/LQ contributed to the data analysis and interpretation of the data. XRD/LHL contributed to the conception of the article and revising of the manuscript. All authors read and approved the final manuscript.

**Acknowledgments** We wish to thank Dr. Aijun-Liu and Dr. Wenming-Chen of the Beijing Chao-Yang Hospital Hematology Dept for their help in the statistical analysis and data processing.

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## Tables

Table 1. Basic characteristics of the experts

Content	Number (%)
Gender	
Males	11(73)
Females	4(27)
Age (years)	
31-40	6(40)
41-50	3(20)
≥50	6(40)
Engaged in medical care time (years)	
≤10	3(20)
11-20	5(33)
≥20	7(47)
Educational background	
Bachelor's degree	4(27)
Master's degree	4(27)
doctorate	7(46)
Professional titles	
attending	5(33)
associate chief of doctor	4(27)
chief of doctor	6(40)

Table 2. The expert scores from the second round of the consultations

First-level indices	Second-level indices	Mean±SD	CV%
Location	Junctional	4.87±0.34	0.07
	Mobile	4.47±0.50	0.11
	Semirigid	3.53±0.62	0.17
	Rigid	3.07±0.44	0.14
	Lesion-free	2.47±0.81	0.33
Level of pain	Recalcitrant pain in the corresponding zone (not relieved after chemotherapy) VAS=7	4.80±0.40	0.08
	Moderate pain in the corresponding zone (not relieved after chemotherapy) VAS 4-7	4.47±0.49	0.11
	Mild pain in the corresponding zone (VAS=3 after chemotherapy)	3.67±0.48	0.13
	Mild pain during activity (VAS≤2 after chemotherapy) no rest pain	3.20±0.40	0.12
	No pain during activity after chemotherapy	2.67±0.94	0.35
Number of segments	≥3	4.93±0.25	0.05
	3	4.87±0.56	0.11
	2	4.67±0.79	0.17
	1	3.80±0.99	0.26
	No change in morphology	2.73±0.10	0.36
physiological curvature			
lateral radiograph	Physiological curvature of the lesion is abnormal	4.67±0.47	0.10
	Physiological curvature of the lesion is normal	3.00±0.52	0.17
front radiograph	Scoliosis/rotation	4.80±0.40	0.08
	No scoliosis/rotation	3.00±0.52	0.17
Comorbidities	Spondylolisthesis>1degree	4.87±0.34	0.07
	Shift/dislocation0-1degree	4.53±0.62	0.14
	Herniated disk	3.93±0.44	0.11
	Bone spurs	3.13±0.50	0.16

	Bony fusion	2.80±0.54	0.19
Neurological function	Frankel A	5.00±0.00	0.00
	Frankel B	4.87±0.34	0.07
	Frankel C	4.73±0.44	0.09
	Frankel D	4.07±0.25	0.06
	Frankel E	2.87±0.34	0.12

Table 3. The location score and its secondary index score

Location	Score
Junctional	4
Occipitocervical region (C1-C2)	
Cervicothoracic region (C7-T2)	
Thoracolumbar region (T11-L1)	
Lumbosacral region (L5-S1)	
Mobile	3
Cervical vertebra (C3-C7)	
Lumbar vertebra (L2-L4)	
Semirigid (T3-T10)	2
Rigid (S2-S5)	1
Lesion-free	0

Table 4. The pain score and its secondary index score



Pain	Score
Intractable pain (not alleviated by bed rest/chemotherapy, VAS $\geq$ 7)	4
Moderate pain (not alleviated by bed rest/chemotherapy, VAS 4-7)	3
Mild pain (After bed rest/chemotherapy, VAS=3)	2
Slight pain after activity (VAS $\leq$ 2) no pain when resting	1
No pain during physical activity after chemotherapy	0

Table 5. The number of segments score and its secondary index score

Number of segments	Score
$\geq 3$	4
3	3
2	2
1	1
No change in morphology	0

Table 6. The physiological curvature score and its secondary index score

physiological curvature	Score
lateral radiograph	
Physiological curvature of the lesion is abnormal	2
Physiological curvature of the lesion is normal	0
front radiograph	
Scoliosis/rotation	2
No scoliosis/rotation	0

Table 7. The comorbidities score and its secondary index score

Comorbidities	Score
Spondylolisthesis >1 degree	4
Shift/dislocation 0-1 degree	3
Herniated disk	2
Bone spurs	1
Bony fusion	0

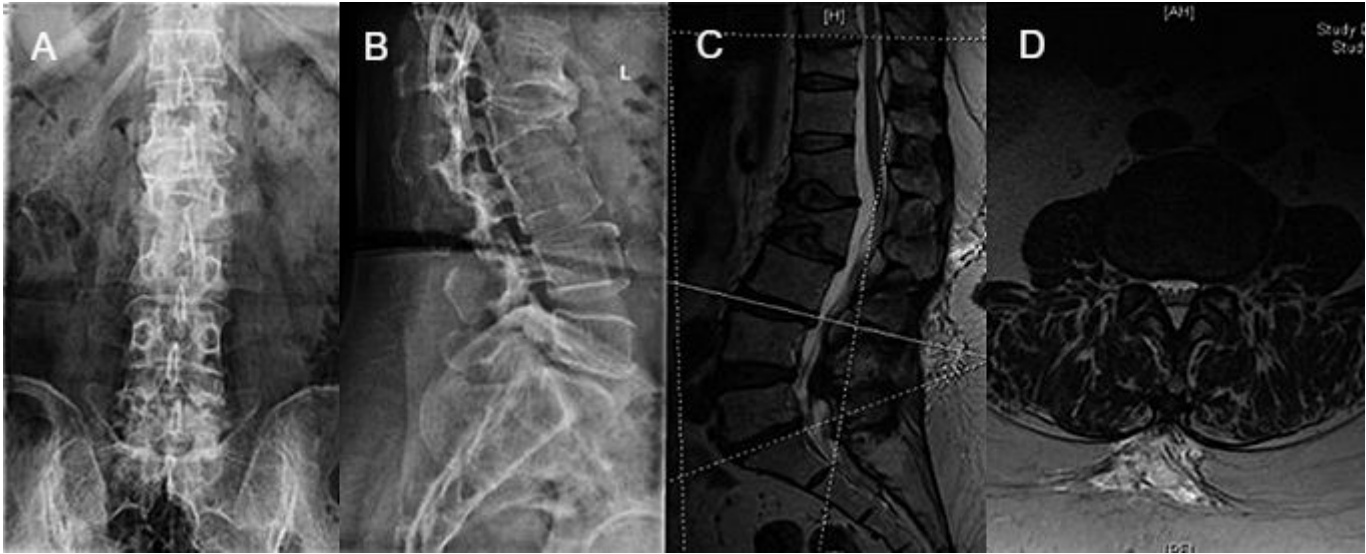
Table 8. The neurological function score and its secondary index score

Neurological function (according to the Frankel classification)	Score
Frankel A	4
Frankel B	3
Frankel C	2
Frankel D	1
Frankel E	0

Table 9. Results of the MM spinal stability scoring system and SINS by R-R paired Chi-square test

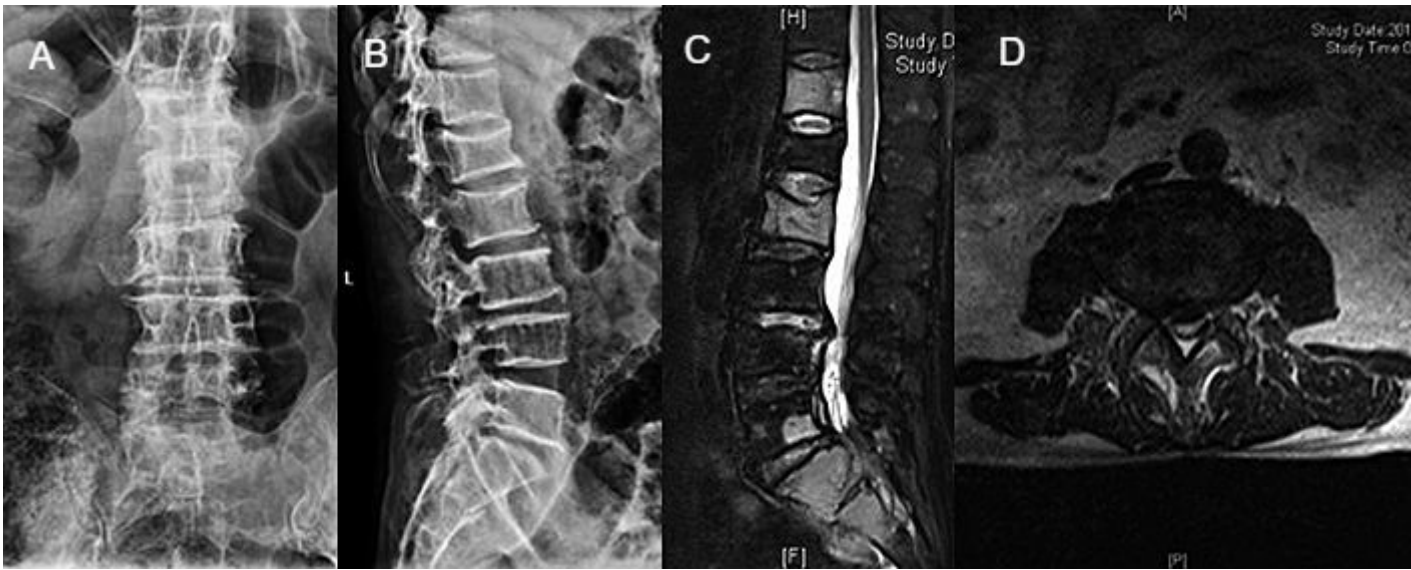
SINS					McNemar-Bowker	P-Value
MM		Stable	Potentially unstable	unstable	total	38.105 0.000
	Stable	5	37	3	45	
	Potentially unstable	1	21	3	25	
	unstable	0	1	1	2	
	total	6	59	7	72	

## Figures



**Figure 1**

Lumbar spine X-ray image, showing the presence of a physiological curvature (A-B). A sagittal plane MR image in which T11 and L1-2 lesions are visible (C). A normal MRI image (D).



**Figure 2**

Lumbar spine X-ray image showing the presence of a lumbar physiological curvature (A-B). Sagittal plane MR images in which T12, L1 and S1-2 lesions are visible (C). Lumbar disc herniation on a cross-sectional MR image (D).



**Figure 3**

Lumbar spondylolisthesis is visible from the lateral view of the patient (A-B). Lumbar CT cross-sectional image that shows an L2 lesion (C) and a T11 lesion (D). Lesion in the sagittal plane of the thoracic vertebra and a T11 lesion (E).