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The Spinal Instability Neoplastic Score (SINS) as a Surgical Decision-Making Tool for the Treatment of Spine Metastasis

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Study Design: Retrospective cohort study.
Objectives: To investigate the potential clinical use of the spinal instability neoplastic score (SINS) for determining the surgical strategy, especially regarding the need for anterior support.
Summary of Literature Review: The SINS seems to enable an improved qualitative and quantitative assessment of spinal instability in patients with spinal metastasis.
Materials and Methods: We retrospectively reviewed 69 consecutive patients who underwent surgical treatment for spinal metastasis. We assessed the patients' preoperative status with respect to each component of the SINS. Multiple logistic regression was performed to calculate odds ratios (ORs) representing the associations among SINS, age, Eastern Cooperative Oncology Group performance status, modified Tokuhashi score, as well as the preoperative Nurick grade variables and reconstruction of the anterior spinal column.
Results: Among the 6 items in the SINS, those indicating the degree of collapse and alignment had significantly higher scores in those who underwent corpectomy and anterior support ($p<0.001$). Multiple logistic regression revealed that the total SINS was the only factor significantly associated with predicting whether anterior support should be performed (adjusted OR=1.595). Receiver operating characteristic (ROC) curve analysis suggested that a cut-off value of 10 points on the SINS scale could be used to decide whether anterior support following corpectomy should be performed (AUC=0.706).
Conclusions: The SINS, insofar as it assesses the degree of collapse and alignment, is a potentially useful tool for determining the surgical strategy in patients with spinal metastasis, especially for deciding upon the necessity of additional anterior support procedures.

Key words: Anterior support procedure, Spinal Instability Neoplastic Score, spinal metastasis, spinal stability

Introduction

Restoration or preservation of spinal stability is one of the critical goals of surgical treatment for spinal metastasis along with reversal of neural deficit and alleviation of pain.[1] However, application of the concept of "spinal stability" into clinical practice relies on each clinician's subjective judgment, although it has been more than 30 years after introduction of the concept by White and Panjabi et al.[2] It is even more elusive to be defined in patients with spinal metastases and most recent systematic reviews failed to define "spinal instability" in oncologic patients.[3]

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The recently proposed spinal instability neoplastic score (SINS) system is expected to provide a quantitative and reliable basis for judgment of spinal instability in oncologic conditions and offer a more concrete shape to the concept.[4] It is composed of 6 individual components used to analyze vertebral instability, and is scored according to the location of the lesion, mechanical pain, bone lesion quality, change in spinal alignment, vertebral body collapse, and posterolateral involvement. The total score (ranging from 0 to 18) is categorized into 3 groups: stable (0–6 points), potentially unstable (7–12 points), and unstable (13–18 points). Surgical indication is recommended for metastatic spinal tumors exceeding 7 points (Table 1). The SINS system has demonstrated high reliability and validity in the categorization of stable, potentially unstable, and unstable spinal metastasis.[5,6] Another difficulty in practice lies in the selection of optimal surgical strategy to provide stability for the affected vertebral column. Findlay et al.[7] reported poor clinical results in patients treated by laminectomy alone without anterior support or instrumentation, and emphasized the need to provide sufficient stability via thorough vertebral column reconstruction during surgical treatment of metastatic spinal disease. Deciding upon the need for anterior column support is often difficult, as there are currently no established indications for performing additional vertebral column reconstruction in spinal metastases.

Authors have postulated that if the SINS system is successful in assessing spinal instability in a quantitative manner, it may also be helpful in deciding the surgical approach, degree of corpectomy (or tumor resection), and reconstruction method, especially the necessity of anterior support, which is related with restoration of spinal stability. In the present study, we aimed to determine this additional clinical usefulness of the SINS system, and clarify its significance on surgical decision making for the treatment of spinal metastasis, particularly in deciding the need for anterior support.

Materials and methods

This retrospective study was approved by our hospital's Institutional Review Board (H-1408-133-607), and patient informed consent was waived.

Table 1. The SINS classification according to Fisher et al.[4]

	Score
Location	
Junctional (occiput-C2, C7-T2, T11-L1, L5-S1)	3
Mobile spine (C3-C6, L2-L4)	2
Semirigid (T3-T10)	1
Rigid (S2-S5)	0
Pain*	
Yes	3
Occasional pain but not mechanical	1
Pain-free lesion	0
Bone lesion	
Lytic	2
Mixed (lytic/blastic)	1
Blastic	0
Radiographic spinal alignment	
Subluxation/translation present	4
De novo deformity (kyphosis/scoliosis)	2
Normal alignment	0
Vertebral body collapse	
> 50% collapse	3
< 50% collapse	2
No collapse with > 50% body involved	1
None of the above	0
Posterolateral involvement of spinal elements†	
Bilateral	3
Unilateral	1
None of the above	0

*Pain improvement with recumbency and/or pain with movement/loading of spine.
†Facet, pedicle, or costovertebral joint fracture or replacement with tumor.

I. Patient selection

We constructed a retrospective cohort with a series of patients who were diagnosed with metastatic spinal lesions in our hospital between 2000 and 2010. The inclusion criteria are as follow: (1) patients with single spinal metastatic fracture, (2) patients in whom data were available for preoperative SINS assessment, and (3) patients who underwent surgical treatment for metastatic spinal lesions.

II. Data collection and analysis

Basic clinical characteristics of the study patients (demographic data, oncologic variables, surgical variables) were retrieved using electronic medical records. Demographic data included age, sex, and body mass index (BMI). Oncologic variables included primary tumor type, location of metastasis, SINS scale (preoperative score of mechanical pain, the only clinical component of the SINS), Eastern Cooperative Oncology Group performance status (ECOG-PS) score,[8] modified Tokuhashi score,[9] neurologic status by the Nurick grade,[10] and mean survival periods. ECOG performance scale is widely used tool for assessing the functional status of oncologic patients. It was classified from grade 0 (fully active, able to carry on all pre-disease performance) to grade 5 (dead). The modified Tokuhashi score is a scoring system for prediction of patient's prognosis with a metastatic spine tumor; it consists of 6 items considered to affect survival outcome. A score of 0-8 predicts a survival period of <6 months, while a score of ≥12 predicts a survival period of ≥ 1 year. Surgical variables included type of approach, grade of excision of vertebral body, vertebral column reconstruction, and number of instrumentation. The surgical approach employed was classified into anterior, posterior, and combined anterior and posterior procedures. The grade of excision of vertebral body tumor was assessed as grades 0 to 3: grade 0, when corpectomy was not performed and only laminectomy was conducted for posterior decompression; grade 1, when corpectomy was performed partially with less than 50% of vertebral body resection; grade 2, with 50% or more resection; and grade 3, when total resection was performed. The other five radiographic parameters including the location, alignment, collapse, bone lesion quality, and posterior involvement was assessed via computed tomography and magnetic resonance imaging by a single spine surgeon with a 7-year experience.

III. Statistical analysis

The basic clinical characteristics of demographic and oncologic variables as well as the SINS scores were compared between two groups of patients: those who underwent reconstruction with anterior support and those without. To compare continuous variables, Student's t-test was used in variables with normal distribution, and Mann-Whitney test was used in the others. Chi-square test was used for categorical variables. Multiple logistic regression was performed to calculate the odds radios (ORs) which represent the association between variables and reconstruction of anterior spinal column. ROC (receiver operating characteristic) curve analysis[11] was performed to assess the usefulness of the SINS system in surgical decision making, especially regarding the need for anterior support, and if applicable, to find a suitable cutoff value. Statistical analysis was performed using IBM SPSS software (version 20.0; IBM Corp., Armonk, NY, USA). Differences were considered statistically significant at a p-value of <0.05.

Results

The clinical characteristics of the study population are showed in Table 2 according to anterior support. Of the 311 patients, 69 patients were enrolled for this study. The mean age was 54.7 years; 26 patients were female and 43 were male. The type of primary tumor is as follows: hepatocellular carcinoma (n=15), urogenital (n=13), lung cancer (n=10), sarcoma (n=8), colorectal cancer (n=5), thyroid cancer (n=5), hematologic malignancy (n=7), breast cancer (n=2), and pancreatic cancer (n=1). Three cases were metastases from unknown origin. Of the 69 patients, 21 underwent posterior decompression and instrumentation without anterior support, while 48 underwent anterior support after corpectomy via the posterior or anterior approach.

Among the 6 items in the SINS system, the 2 indicating degree of collapse and alignment were significantly higher in those who underwent corpectomy and anterior support ($p<0.001$). The degree of corpectomy performed was significantly associated with additional anterior support procedures ($p<0.001$). Scores regarding bone lesion quality, location, and pain showed no significant difference.

With the aforementioned demographic and oncologic variables and total SINS as independent variables, multiple logistic regression revealed that total SINS was the only significant factor (adjusted OR=1.595, p=0.007) associated with predicting whether anterior support should be performed or not (Table 3).

ROC curve analysis suggested that a cutoff value of 10 points in SINS can be used to decide whether or not anterior support should be conducted following corpectomy. The AUC

Table 2. Basic clinical characteristics of patients with and without anterior support

Characteristics	Total (n=69)	Without anterior support (n=21)	With anterior support (n=48)	p-value*
Age (yr)	54.7±13.8	53.5±14.2	55.2±13.8	0.653
Sex (n)				0.493
Male	43	16	27	
Female	26	7	19	
Body weight (kg)	62.2±8.5	64.3±7.3	61.3±8.9	0.201
BMI (kg/m^2)	23.3±2.9	23.4±3.0	23.2±2.9	0.792
Primary tumors (n)				0.346
Hepatocellular carcinoma	15	6	9	
Urogenital	13	1	10	
Lung	10	2	8	
Sarcomas	8	3	5	
Colorectal cancer	5	1	4	
Thyroid cancer	5	1	4	
Hematologic malignancy	7	4	3	
Breast cancer	2	1	1	
Pancreas	1	1	0	
Unknown origin metastasis	3	1	2	
Spinal Instability Neoplastic Score	10.20±2.4	8.95±1.5	10.75±2.5	0.039
Pain	3.00±0.0	3.00±0.0	3.00±0.0	1.000
Location	1.89±0.8	1.86±0.9	1.90±0.9	0.746
Bone lesion quality	1.55±1.6	1.33±0.8	1.65±0.5	0.317
Collapse	1.55±1.0	0.76±0.7	1.90±0.9	<0.001
Alignment	0.77±1.0	0.10±0.4	1.06±1.0	<0.001
Posterolateral involvement	1.48±1.2	1.95±1.1	1.27±1.2	0.099
ECOG performance status (n)				0.627
Grade 0	24	8	16	
Grade 1	22	6	16	
Grade 2	7	3	4	
Grade 3	11	4	7	
Grade 4	5	0	5	
Modified Tokuhashi score (n)				0.778
0-8 points	26	10	16	
9-11 points	25	4	21	
12-15 points	18	7	11	

(Continued to the next page)

Table 2. Continued

Characteristics	Total (n=69)	Without anterior support (n=21)	With anterior support (n=48)	p-value*
Survival after spinal surgery (days)	653	603	675	0.408
Preoperative Nurick grade				0.294
Grade 0	24	6	18	
Grade 1	18	5	13	
Grade 2	5	1	4	
Grade 3	5	2	3	
Grade 4	2	1	1	
Grade 5	15	6	9	
Postoperative Nurick grade	1.59	1.8	1.5	0.690
Grade 0	25	7	18	
Grade 1	20	5	15	
Grade 2	8	3	5	
Grade 3	1	1	0	
Grade 4	4	1	3	
Grade 5	11	4	7	
Neurologic recovery rate (%)	30.8	43.9	25.0	0.928
Grade of Excision of Body (n)				<0.001
0: no corpectomy	15	15	0	
1: corpectomy<50%	7	7	0	
2: corpectomy>50%	38	0	38	
3: spondylectomy	9	0	9	

Numeric parameters are expressed as mean±standard deviation in parentheses.
Categorical parameters are expressed as counts.
BMI: body mass index, ECOG: Eastern Cooperative Oncology Group
*p-value as two-tailed probability from comparison of groups with and without anterior support by t-test for variables with normal distribution (age, body weight, BMI); primary tumor & pre- & post-operative neurologic status (Nurick grade) by Chi-square test; other variables by Mann-Whitney test

Table 3. Association between spinal instability neoplastic score (SINS) and reconstruction with anterior support using multiple logistic regression

	Unadjusted OR (95% CI)	p-value	Adjusted OR* (95% CI)	p-value
Without anterior support	1.0	0.004	1.0	0.004
With anterior support	1.527 (1.144 - 2.039)		1.677 (1.179 - 2.387)	

OR: Odds radio, 95% CI: 95% confidence interval
*Adjusted by age, body mass index, Eastern Cooperative Oncology Group performance score, modified Tokuhashi score, preoperative Nurick grade.

(area under the ROC curve) was 0.706, with a p−value (when AUC=0.5) of less than 0.001. When the SINS criteria exceed 10 points, the necessity for vertebral column reconstruction with anterior support can be assumed with 90.5% of specificity and 50.0% of sensitivity within our series of patients (Fig. 1).

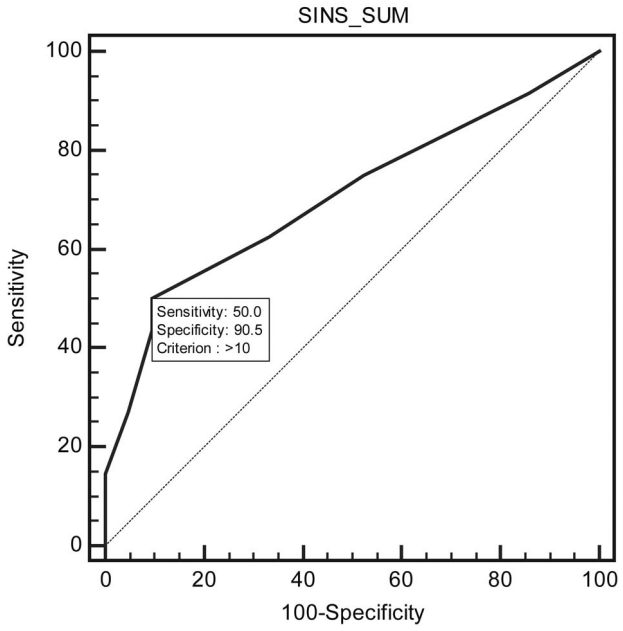

Fig. 1. Receiver operating characteristic (ROC) curve analysis. Spinal instability neoplastic score (SINS) and the need for vertebral column reconstruction by anterior support.

Discussion

Anterior support by replacement of the affected vertebra provides much better stability; it is also essential in some cases when posterior instrumentation alone may result in loosening, breakage, and/or kyphosis. However, additional procedures for anterior support require additional surgical effort, which may be accompanied by longer surgical time and potential increased risk of intraoperative bleeding and complications. There is currently no clear consensus as to when an anterior support procedure is warranted in patients with metastatic spinal lesions. The results of this study provide relevant information on the surgical decision-making for metastatic spinal tumors.

The patients in this study underwent surgery before the introduction of the SINS system, when surgical decision was mostly subjective, i.e., based on a surgeon's experience, rather than on a systemic evidence-based approach, given the scarcity of evidence and systemic guidelines available then. However, when we applied the SINS system retrospectively on these patients, we found that total SINS and several individual component scores were significantly higher in the group of patients who underwent anterior support, compared to those who did not. Moreover, ROC curve analysis with a threshold value of 10 points utilizing the SINS system exhibited relatively high specificity (90.5%) and AUC value (0.706), with regards to the decision of whether additional anterior support should be conducted or not. This means that, at least within the authors' series of patients, the SINS system may serve as a useful tool in surgical decision making. Total SINS and individual component scores, which indicate collapse of the vertebral body and spinal alignment, was significantly related with whether anterior support procedures were performed. This is in accordance with findings that laminectomy alone, without spinal column reconstruction, in the presence of a vertebral body collapse is associated with poor results.[7] Given that the SINS system provides quantitative assessment of stability in a more deliberate way, it may be used as an indicator in deciding on stabilization techniques.

Considering that the SINS system was formulated based on the Delphi technique, a method in which a consensus opinion on a specific subject is reached through multiple anonymous questionnaire rounds by a panel of experts, one criticism is that it is not based on factual data of a real patient population, but merely a sum of experience-based concepts of the panel.[4,12] However, it appears promising, with recent reports of high intra- and inter-observer reliability, and demonstration of clinical usefulness, such as in predicting vertebral body collapse following radiotherapy.[5,13,14] Authors have found that the SINS system can be utilized in surgical decision-making with regards to the degree of corpectomy and additional anterior support. The results suggest additional potential application of the SINS system, in terms of surgical planning and selection of options to provide spinal stability. It is worth nothing that the patients in the present study were operated on before the introduction of the SINS system, and our results showed that to some degree, the SINS system has incorporated the previously vague concept of spinal stability, and may be useful as a surgical decision-making tool. Our study could promote future modification and application of the SINS system as a more practical tool in contemplating surgical strategy. With further refinement in future studies, it can be expected to serve as the "Mirel's criteria" for the treatment of metastatic spinal lesions.[15-17]

The SINS system was originally designed to enhance multidisciplinary communication in the assessment of spinal stability; it cannot be used as a single deciding factor in treating metastatic spinal disease. Several authors proposed that the

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SINS system could be incorporated into a decision framework of optimal treatment strategy for spinal metastasis, with additional considerations including patient factors, oncological factors, and neurologic status.[18] More comprehensive considerations in terms of assessment of neurologic status, oncologic status, prognosis, general medical conditions, and functional status are required in order to provide optimal treatment for patients with spinal metastasis.[1,18,19]

There are several limitations to this study. First, because of its retrospective nature, it cannot be used to validate the clinical application of the SINS system. Perhaps future studies – preferably prospective in design – with another patient group treated by other clinicians will provide additional findings to refine this tool. Second, we excluded several factors such as tumor stage, radio-sensitivity, and medical co-morbidities, in obtaining ORs using multiple logistic regression. However, these factors were reflected in the ECOG and modified Tokuhashi score, and were more likely to affect the prognosis rather than the decision of the surgical approach and reconstruction method.

Conclusion

The results of this study are encouraging in that within the authors' series of patient population, the SINS system adequately incorporated previously vague concepts regarding surgical decision making, in terms of the extent of vertebral body resection and reconstruction. Furthermore, in deciding the need for anterior support, we were able to identify a distinct cutoff value with high specificity and acceptable AUC value.

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척추 전이 종양 환자의 수술 방법 결정에 있어 Spinal Instability Neoplastic Score (SINS)의 의의

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연구 계획: 후향적 코호트 연구

목적: Spinal Instability Neoplastic Score (SINS)이 기존에 알려져 있는 척추 전이 종양 환자들의 수술 방법의 결정에 어떤 역할을 하는지 평가하고자 한다.

선행 연구문헌의 요약: SINS는 척추 전이 종양에서 척추 불안정성을 평가하는 방법이다.

대상 및 방법: 척추 전이 종양으로 수술 받은 총 69명 환자들에 대해 수술 전 SINS 구성 요소를 후향적으로 평가하였다. 로지스틱 회귀분석을 이용하여 SINS 구성요소, 각종 환자 정보 및 전방 지지술 유무와의 연관성을 살펴보았다.

결과: SINS의 항목 중 추체의 함몰 정도($p<0.001$)와 척추 정렬 상태($p=0.001$)가 추체 제거 정도 및 전방지지술 유무와 유의한 관계가 있었다. 로지스틱 회귀분석에서 SINS의 총 점수가 전방 지지술 유무와 유의한 관계가 있었다(adjusted OR=1.595). ROC 곡선을 이용한 분석에서 SINS 10점을 추체 제거술 및 전방지지술을 시행하는 절단 값으로 정하였고, 값은 0.704였다.

결론: SINS 점수 중 추체 함몰 정도와 척추 정렬상태는 척추 종양 환자의 수술 결정에 대해 유용한 수술 결정 방법이며, 특히 전방지지술의 시행여부를 결정하는 중요한 요소이다.

색인 단어: 척추 전이 종양, 척추 전방 지지술, Spinal Instability Neoplastic Score, 수술 방법 결정

약칭 제목: SINS를 이용한 수술방법결정

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