



# Georg schmorr prize of the German spine society (DWG) 2021: Spinal Instability Spondylodiscitis Score (SISS)—a novel classification system for spinal instability in spontaneous spondylodiscitis

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## Abstract

**Purpose** Even though spinal infections are associated with high mortality and morbidity, their therapy remains challenging due to a lack of established classification systems and widely accepted guidelines for surgical treatment. This study's aim therefore was to propose a comprehensive classification system for spinal instability based on the Spinal Instability Neoplastic Score (SINS) aiding spine surgeons in choosing optimal treatment for spontaneous spondylodiscitis.

**Methods** Patients who were treated for spontaneous spondylodiscitis and received computed tomography (CT) imaging were included retrospectively. The Spinal Instability Spondylodiscitis Score (SISS) was developed by expert consensus. SINS and SISS were scored in CT-images by four readers. Intraclass correlation coefficients (ICCs) and Fleiss' Kappa were calculated to determine interrater reliabilities. Predictive validity was analyzed by cross-tabulation analysis.

**Results** A total of 127 patients were included, 94 (74.0%) of which were treated surgically. Mean SINS was  $8.3 \pm 3.2$ , mean SISS  $8.1 \pm 2.4$ . ICCs were 0.961 (95%-CI: 0.949–0.971) for total SINS and 0.960 (95%-CI: 0.946–0.970) for total SISS. SINS yielded false positive and negative rates of 12.5% and 67.6%, SISS of 15.2% and 40.0%, respectively.

**Conclusion** We show high reliability and validity of the newly developed SISS in detecting unstable spinal lesions in spontaneous spondylodiscitis. Therefore, we recommend its use in evaluating treatment choices based on spinal biomechanics. It is, however, important to note that stability is merely one of multiple components in making surgical treatment decisions.

**Keywords** Discitis · Infections · Classification · Spine

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## Introduction

Infections of the spine account for 2–7% of all musculoskeletal infections [1, 2]. Even though they are associated with significant mortality and morbidity, there remains no established classification systems and treatment algorithms to optimize management. While first-line treatment usually is conservative via intravenous antibiotics, surgical treatment is generally warranted for source control, epidural abscess, neurological deficits, or spinal instability [3]. Thus, using a multidisciplinary team of infectious disease physicians, interventional radiologists, and spine surgeons to best employ proper treatment and timing of treatment is critical.

While most patients with spondylodiscitis should receive surgical consultation, there are no widely accepted guidelines for surgical treatment decisions. Even though instability has been identified as a common indication for surgery, there still is a lack of evidence-based criteria to define spinal instability in spondylodiscitis [4]. Spine surgeons therefore need to rely on clinical experience and various ill-defined radiographic features rather than objective criteria in their surgical decision-making process. Furthermore, there is no common language allowing for appropriate and timely referrals of spondylodiscitis patients from internists, radiologists or infectious disease specialists to spine surgeons.

In the setting of spinal metastasis, the Spine Oncology Study Group (SOSG) defined spine instability as “the loss of spinal integrity as a result of a neoplastic process that is associated with movement-related pain, symptomatic or progressive deformity, and/or neural compromise under physiological loads.” [5] Based on this definition, best available evidence, and a Delphi technique, the SOSG developed the Spinal Instability Neoplastic Score (SINS), a classification system with radiographic and patient factors for diagnosing neoplastic spinal instability. Depending on the total score, the spinal lesion is defined as stable, potentially unstable, or unstable. In case of a potentially unstable or unstable lesion, referral to a spine surgeon for evaluation of the need for surgical intervention is recommended [5, 6]. The SINS has greatly facilitated referral across surgical and oncology disciplines and heightened awareness of neoplastic spinal instability [7, 8].

Similar to metastatic spinal lesions, spinal infection causes instability over a period of time which therefore is different from instability caused by traumatic injury. Despite a recent study by Pithwa et al. that found extrapolation of the SINS toward the evaluation of instability in spinal tuberculosis to be useful, certain parameters of the SINS do not apply in spinal infection [9]. Therefore, the purpose of this study was to propose and psychometrically

evaluate a classification system based on the widely accepted SINS to aid physicians and surgeons to determine instability in patients with spondylodiscitis to not only facilitate referral between disciplines but also to aid in surgical decision-making.

## Methods

### Patients and ethical approval

The study was approved by the institutional ethics committee (EA1/019/21). Patients who were treated for spondylodiscitis at our department between January 2006 and December 2020 were included retrospectively. Exclusion criteria were previous interventions at the same or adjacent spinal levels and incomplete clinical or radiological data. Patients were identified using information from discharge letters and diagnostic and procedural codes, i.e., diagnostic related groups (DRG) codes. Clinical data were retrieved from electronic medical reports and patient charts including demographic parameters (age, gender), body mass index (BMI), pain at admission, and the performed treatment. Pain was assessed by numeric rating scale (NRS) scores. Treatment was conservative unless there was present or imminent neurological deficit and/or present or imminent spinal instability.

Spondylodiscitis was defined by a combination of characteristic radiological changes of the intervertebral disc in magnetic resonance imaging (MRI) and/or computed tomography (CT) scans and clinical findings including elevated CRP levels, elevated WBC, back and/or neck pain as well as fever. Localization of the infection was classified into three regions: cervical, thoracic, or lumbar. Spondylodiscitis of the cervicothoracic junction (C7/Th1) was counted as cervical, the thoracolumbar junction (Th12/L1) as thoracic and the lumbosacral junction (L5/S1) as lumbar spondylodiscitis.

### Image analysis

Three readers (reader 1, an orthopaedic surgeon with eleven years of experience; reader 2, an orthopaedic surgery resident with three years of experience; reader 3, an orthopaedic surgery resident with two years of experience) independently evaluated CT-images. A two-out-of-three-reader agreement approach was used for all scored parameters. Further disagreement was solved by a radiologist specializing in musculoskeletal diseases with eleven years of experience. For calculation of interrater reliability, a fourth reader (a medical student trained in musculoskeletal imaging) additionally evaluated CT-images.

**Table 1** Parameters of the Spinal Instability Neoplastic Score (SINS) as previously published by Fisher et al. [5]

Parameter	Score
<i>Location</i>	
Junctional (occiput-C2, C7-T2, T11-L1, L5-S1)	3
Mobile Spine (C3-6, L2-4)	2
Semirigid (T3-10)	1
Rigid (S2-5)	0
<i>Bone lesion</i>	
Lytic	2
Mixed (lytic/blastic)	1
Blastic	0
<i>Spinal alignment</i>	
Subluxation/Translation	4
De novo deformity (kyphosis/scoliosis)	2
Normal alignment	0
<i>Vertebral body collapse</i>	
> 50% collapse	3
< 50% collapse	2
No collapse with > 50% body involved	1
None of the above	0
<i>Posterolateral involvement of the spinal elements</i>	
Bilateral	3
Unilateral	1
None of the above	0
<i>Mechanical pain</i>	
Yes	3
Occasional pain but not mechanical	1
Pain-free lesion	0
<i>Total score</i>	
0–6	Stable lesion
7–12	Potentially unstable lesion
13–18	Unstable lesion

## Spinal Instability Neoplastic Score

SINS was scored as previously published by Fisher et al. (Table 1) [5]. Posterior column disintegration was defined as facet disruption, fractures at the junction of pedicle and vertebral body, or osteolysis of one or both pedicles. A total score of 0–6 was defined as stable, 7–12 as potentially unstable, and 13–18 as unstable.

## Spinal Instability Spondylodiscitis Score

For the Spinal Instability Spondylodiscitis Score (SISS), a new granular scoring systems was developed after a review of the existing literature by expert consensus of two orthopaedic surgeons based on the parameters of the SINS. This new classification system includes four parameters which are presented in Table 2. A total score of 0–4 was defined as stable, 5–9 as potentially unstable, and 10–14 as unstable spondylodiscitis.

## Statistical analysis

For determination of interrater reliability between the four readers, two-way random single-measure intraclass correlation coefficients (ICCs) were calculated to measure interrater agreement for total SINS and SISS scores and Fleiss' Kappa for multiple readers was calculated for each of the components of the SINS and SISS. Kappa values of < 0.00 were rated as poor, 0.00–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement [10]. Predictive validity was analyzed by cross-tabulation analysis. The statistical significance level for all tests performed was  $p < 0.05$ . Statistical analysis was performed using SPSS version 27 (SPSS Inc., Chicago, Illinois).

**Table 2** Parameters of the Spinal Instability Spondylodiscitis Score (SISS)

Parameter	Score
<i>Location</i>	
Junctional (occiput-C2, C7-T2, T11-L1, L5-S1)	3
Mobile Spine (C3-6, L2-4)	2
Semirigid (T3-10)	1
Rigid (S2-5)	0
<i>Bone lesion</i>	
>50% vertebral body involvement	4
<50% vertebral body involvement	2
Endplate involvement	1
Intact endplates	0
<i>Spinal alignment</i>	
Subluxation/Translation	4
De novo deformity (kyphosis/scoliosis)	2
Normal alignment	0
<i>Mechanical pain</i>	
Yes	3
Occasional pain but not mechanical	1
Pain-free lesion	0
<i>Total Score</i>	
0–4	Stable lesion
5–9	Potentially unstable lesion
10–14	Unstable lesion

## Results

### Patients

A total of 247 patients with spondylodiscitis were identified. Fifty-four patients were excluded due to previous interventions at the same or adjacent spinal segments. Eight patients were excluded due to missing clinical data. In 127 of the remaining 185 patients, CT imaging was performed. Fifty-nine (46.5%) females were included. Mean age was  $66.2 \pm 13.2$  years. Nine (7.1%) patients had spondylodiscitis of the cervical spine, 47 (36.4%) of the thoracic spine, and 71 (56.6%) of the lumbar spine. Demographic and clinical data of included patients are presented in Table 3.

### Interobserver Reliability

For SINS, Fleiss' Kappa was 0.413 ( $p < 0.001$ ) for bone lesion, 0.588 ( $p < 0.001$ ) for spinal alignment, 0.514 ( $p < 0.001$ ) for vertebral body collapse, and 0.520 ( $p < 0.001$ ) for posterolateral involvement. ICC for total SINS was 0.961 (95% CI: 0.949–0.971).

**Table 3** Demographic parameters of included patients presenting with spontaneous spondylodiscitis. Mean values are given with standard deviation

	Patients ( $n = 127$ )
<b>Age (years)</b>	$66.1 \pm 13.4$
<b>Sex (f:m)</b>	59:68
<b>BMI (kg/m<sup>2</sup>)</b>	$26.9 \pm 6.0$
<i>Symptoms</i>	
<b>Low back pain resting (VAS)</b>	$3.9 \pm 2.6$
<b>Low back pain moving (VAS)</b>	$5.6 \pm 2.8$
<i>Localization</i>	
<b>Cervical</b>	9 (7.1%)
<b>Thoracic</b>	47 (37.0%)
<b>Lumbar</b>	71 (55.9%)
<i>Treatment</i>	
<b>Conservative</b>	33 (26.0%)
<b>Surgical</b>	94 (74.0%)

For SISS, Fleiss' Kappa was 0.598 ( $p < 0.001$ ) for bone lesion and 0.588 ( $p < 0.001$ ) for spinal alignment. ICC for total SISS was 0.960 (95% CI: 0.946–0.970).

### Validity

Imaging examples of two patients are given in Fig. 1.

Mean SINS was  $8.3 \pm 3.2$ . Table 4 shows scores determined by consensus and the performed treatment. By consensus, 37 (29.1%) cases were defined as stable, 74 (5.8%) as potentially unstable, and 16 (12.6%) as unstable lesions. Twenty-five patients were treated surgically despite being classified as stable. Two patients were treated conservatively despite being classified as unstable. This yields a false positive rate (unstable lesion with conservative treatment) of 12.5% and false negative rate of 67.6% (stable lesion with surgical treatment).

Mean SISS was  $8.1 \pm 2.4$ . Table 5 shows scores determined by consensus and the performed treatment. By consensus, 10 (7.9%) cases were defined as stable, 84 (66.1%) as potentially unstable, and 33 (26.0%) as unstable spondylodiscitis. Four patients were treated surgically despite being classified as stable due to progressive neurological symptoms caused by epidural abscess formation. Five patients were treated conservatively despite being classified as unstable. In two of these cases, patient factors such as multiple concomitant diseases or patient refusal led to this decision. In three cases, spinal deformity was found to be caused by degeneration or inflammatory diseases rather than infection. This yields a false positive rate of 15.2% (unstable lesion with conservative treatment) and a false negative rate of 40.0% (stable lesion with surgical treatment).

**Fig. 1** **a** Sagittal and coronal CT-scans of a 71-year-old male patient with spondylo-discitis Th7-9. Both SINS and SISS consensus scorings were consistent with an unstable lesion. The patient was treated surgically by posterior fusion Th5/7–10/11. **b** Sagittal and coronal CT-scans of a 63-year-old male patient with spondylo-discitis Th9/10. While SINS consensus scoring yielded a stable lesion, SISS consensus scoring was consistent with an unstable lesion. The patient was treated surgically by posterior fusion Th8-11



**Table 4** Cross-tabulation of total Spinal Instability Neoplastic Score (SINS) and performed treatment

SINS	Surgical treatment	Conservative treatment	Total
2	1	0	1
3	2	2	4
4	5	5	10
5	9	2	11
6	8	3	11
7	11	6	17
8	15	3	18
9	10	7	17
10	12	1	13
11	3	2	5
12	4	0	4
13	6	0	6
14	3	0	3
15	1	2	3
16	4	0	4
<b>Total</b>	<b>94</b>	<b>33</b>	<b>127</b>

**Table 5** Cross-tabulation of total Spinal Instability Spondylodiscitis Score (SISS) and performed treatment

SISS	Surgical treatment	Conservative treatment	Total
2	1	0	1
3	1	0	1
4	2	6	8
5	8	3	11
6	8	4	12
7	15	3	18
8	19	4	23
9	12	8	20
10	11	0	11
11	10	3	13
12	3	0	3
13	4	1	5
14	0	1	1
<b>Total</b>	<b>94</b>	<b>33</b>	<b>127</b>

## Discussion

This study proposes a new classification system providing objective criteria for evaluating spinal stability in spontaneous spondylodiscitis. While instability is only one criterion for the determination of treatment in patients with spinal infections, our results show that it plays a crucial role in the clinical decision-making process as it accurately predicts the chosen treatment. Thus, the proposed classification system is the first to aid physicians in determining whether surgical referral is necessary and spine surgeons in deciding whether surgical treatment is indicated in spinal infections based on biomechanics.

Spinal instability is defined as the ability of the spine to maintain its functionality while preventing neurologic deficit, pain, and abnormal angulation [11]. Similar to spinal instability caused by neoplastic lesions, instability associated with spinal infection appears to be a clinical entity based on symptoms and imaging that is different from instability caused by traumatic injuries as it develops over a period of time rather than acutely [5]. Thus, we adapted the scoring system developed by the SOSG for metastatic spinal lesions to better represent typical findings in spondylodiscitis. According to this new classification system, instability caused by spondylodiscitis is associated with localization, mechanical pain, spinal deformity, and vertebral body affection. Localization, mechanical pain, and spinal deformity were adopted from the SINS as we found them to be well-suited to describe instability caused by infection: Junctional regions of the spine are at higher risk for instability causing deformity, which is why as in oncologic lesions, they received the highest score in the newly developed SISS. Rigid segments, in contrast, are biomechanically protected and therefore received the lowest score. As reported for oncologic instability, mechanical neck or back pain is a typical symptom of infectious spinal diseases [12]. This type of pain is associated with structural abnormality of the spine, which is why we included it in the SISS as well [5]. Spinal deformity has previously been described as indicating instability by several authors [13–15]. As kyphosis or scoliosis may be compensated and therefore remain stable, they receive less points than subluxations or dislocations. The differentiation of lesions into blastic or lytic lesions does not apply for infectious lesions which is why this parameter was not included in the SISS. Infectious lesions are more comparable to lytic lesions, which as previously described, inherit a greater risk of vertebral body collapse. Thus, a new parameter describing the extent of infectious bone lesions and the accompanying vertebral destruction was developed as it has been shown that higher cross-sectional defect area and bone mineral density correlate with vertebral body failure

and pathologic fracture risk [16–18]. This new parameter “vertebral body involvement” therefore receives more weighted points in the SISS than vertebral body collapse does in the SINS. As in the SINS, in case of multiple lesions, scores are not summed, but each lesion needs to be considered separately.

Overall, our results show that grading instability caused by spondylodiscitis according to the newly developed SISS leads to high correlation to the chosen type of treatment with fewer falsely considered stable lesions compared with the SINS. Therefore, SISS is more appropriate in detecting unstable lesions which require surgical treatment. In four cases, surgical treatment was performed even though according to the SISS, conservative management was proposed. All four of these cases did, however, show progressive neurological symptoms due to epidural abscess formation, which is an absolute indication for surgical treatment. In five cases, surgical treatment was not performed even though suggested by the SISS. In two of these cases, patient factors such as multiple concomitant diseases or patient refusal led to this decision. In three cases, spinal deformity was found to be caused by degeneration or inflammation rather than infection, which is why the affected segment was in fact thought to be stable. These cases show that spinal stability is not the only factor that needs to be accounted for in choosing optimal treatment of spondylodiscitis but factors including patient overall health, neurological status, and patient choice need to be considered as well.

Important factors in developing a new classification system are its reproducibility and reliability, but most importantly its ability to comprehensively guide clinical decision-making and at the same time being easy to use. Our study shows moderate interrater reliability for all of the SISS parameters and excellent interrater reliability for overall SISS score. This is in concordance with our and previous findings of interrater reliability of the SINS parameters and total SINS scores [6].

Some limitations need to be discussed. While the SISS was developed in an expert consensus process based on the SINS, in contrast to SINS development, only two surgeons were involved in the process and the Delphi technique was not used, which may have caused bias. Furthermore, due to the retrospective design of our study, inherent limitations and bias were present. Even though treatment was performed according to current standards, there was no predefined treatment algorithm, leaving the decision up to the surgeon. Thus, our results need to be validated in a prospective setting. Furthermore, eight cases had to be excluded due to missing imaging or clinical data, which may have caused unknown bias.

In conclusion, we propose a new comprehensive classification system to aid physicians and spine surgeons define spinal instability in spontaneous spondylodiscitis. We show

similar reliability of this new SISS compared with the widely accepted SINS and high validity especially in detecting unstable lesions which require surgical treatment. We therefore recommend its use in determining whether surgical consultation is necessary and in evaluating treatment choices based on spinal biomechanics. However, it is important to note that stability is merely one of multiple components in making surgical treatment decisions. Patient overall health, neurological status, and patient choice need to be considered as well.

**Authors' contributions** Study conception and design were developed by Friederike Schömig and Matthias Pumberger. Data collection and analysis were performed by Friederike Schömig, Zhao Li, Lena Perka, Tu-Lan Vu-Han, Torsten Diekhoff, Charles Fisher, and Matthias Pumberger. The first draft of the manuscript was written by Friederike Schömig and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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**Data availability** The datasets generated during and/or analyzed during the current study are not publicly available due to patient privacy but are available from the corresponding author on reasonable request.

## Declarations

**Conflicts of interest** The authors have no relevant financial or non-financial interests to disclose.

**Ethics approval** This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The Human Investigation Committee (IRB) of Charité – Universitätsmedizin Berlin approved this study (EA1/019/21).

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