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Evaluating Instability in Degenerative Lumbar Spondylolisthesis

Objective Variables Versus Surgeon Impressions

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Background: The subjective degenerative spondylolisthesis instability classification (S-DSIC) system attempts to define preoperative instability associated with degenerative lumbar spondylolisthesis (DLS). The system guides surgical decision-making based on numerous indicators of instability that surgeons subjectively assess and incorporate. A more objective classification is warranted in order to decrease variation among surgeons. In this study, our objectives included (1) proposing an objective version of the DSIC system (O-DSIC) based on the best available clinical and biomechanical data and (2) comparing subjective surgeon perceptions (S-DSIC) with an objective measure (O-DSIC) of instability related to DLS.

Methods: In this multicenter cohort study, we prospectively enrolled 408 consecutive adult patients who received surgery for symptomatic DLS. Surgeons prospectively categorized preoperative instability using the existing S-DSIC system. Subsequently, an O-DSIC system was created. Variables selected for inclusion were assigned point values based on previously determined evidence quality. DSIC types were derived by point summation: 0 to 2 points was considered stable, Type I); 3 points, potentially unstable, Type II; and 4 to 5 points, unstable, Type III. Surgeons' subjective perceptions of instability (S-DSIC) were retrospectively compared with O-DSIC types.

Results: The O-DSIC system includes 5 variables: presence of facet effusion, disc height preservation (≥6.5 mm), translation (≥4 mm), a kyphotic or neutral disc angle in flexion, and low back pain (≥5 of 10 intensity). Type I (n = 176, 57.0%) and Type II (n = 164, 53.0%) were the most common DSIC types according to the O-DSIC and S-DSIC systems, respectively. Surgeons categorized higher degrees of instability with the S-DSIC than the O-DSIC system in 130 patients (42%) ($p < 0.001$). The assignment of DSIC types was not influenced by demographic variables with either system.

Conclusions: The O-DSIC system facilitates objective assessment of preoperative instability related to DLS. Surgeons assigned higher degrees of instability with the S-DSIC than the O-DSIC system in 42% of cases.

Level of Evidence: Diagnostic Level II. See Instructions for Authors for a complete description of levels of evidence.

Degenerative lumbar spondylolisthesis (DLS) is an acquired anterior translation of 2 adjacent vertebrae[1]. Patients with DLS may develop radiculopathy or neurogenic claudication, with or without low back pain (LBP). Current evidence supports the role of surgery, primarily for the decompression of neural elements[2]. Instability is a common indication for surgical stabilization[3]. Decompression and fusion have been suggested to improve clinical outcomes for symptomatic DLS when compared with decompression alone. Three recent randomized controlled trials found no major advantage for either laminectomy alone or laminectomy plus fusion in patients with spinal stenosis; however, none of the studies captured patients with traditional horizontal translational instability[4-6]. Notably, there has been an exponential increase in the rates of fusion surgery in the United States[7].

Instability or translation that exists between 2 (or 3) vertebrae drives the decision to perform fusion in many instances[8]. Many clinical and radiographic variables may contribute to spinal instability, adding complexity and variation to surgical decision-making[8]. Other reported structural variables include facet joint orientation, facet effusion, sagittal disc angle, and restabilization signs, including loss of disc height, osteophytes, vertebral end-plate sclerosis, and posterior ligament ossification[8]. Inconsistent and subjective consideration of numerous parameters associated with instability naturally introduces variability in the decision-making process.

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSOA/A435).

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TABLE I The S-DSIC System*

Parameter	Type I (Stable)	Type II (Potentially Unstable)	Type III (Unstable)
Low back pain	None or very mild	Primary or secondary complaint	Primary or secondary complaint
Restabilization	Restabilization signs, grossly narrowed disc height	Some restabilization signs, reduced disc height	No restabilization signs, normal to slightly reduced disc height
Disc angle	Lordotic disc angle on flexion radiographs or <3 mm of translation on dynamic radiographs	Neutral disc angle on flexion radiographs or 3-5 mm of translation on dynamic radiographs	Kyphotic disc angle on flexion radiographs or >5 mm of translation on dynamic radiographs
Joint effusion	No facet joint effusion on MRI	Facet joint effusion on MRI without joint distraction	Large facet joint effusion on MRI

*MRI = magnetic resonance imaging.

In an effort to reduce such variation, the Canadian Spine Outcomes Research Network (CSORN) systematically reviewed the literature and described the subjective degenerative spondylolisthesis instability classification (S-DSIC) system for categorizing DLS-related stability[8] (Table I). The S-DSIC includes 1 clinical (back pain) and 3 radiographic variables (evidence of segmental restabilization, disc translation or angulation, and presence of joint effusion) supported by the best available clinical and biomechanical data. Surgeons categorize stability as Type I (stable), Type II (potentially unstable), or Type III (unstable)[9]. The system suggests decompression alone, instrumented posterolateral fusion (IPLF), or IPLF with an interbody device, depending on the degree of instability. However, the S-DSIC lacks specific cutoff values for each of the clinical and radiographic variables. An objective DSIC (O-DSIC) system is warranted.

The recently validated French[10] and CARDS (clinical and radiographic degenerative spondylolisthesis)[11] classification systems for DLS incorporate a variety of pertinent radiographic indices to improve the recognition of distinct DLS subtypes. These systems, however, do not make explicit recommendations about specific surgical procedures or account for potential overutilization of fusion surgery[7].

We enrolled 408 consecutive adult patients receiving surgery for DLS with symptomatic spinal stenosis in a prospective cohort study. Our study objectives included (1) proposing an objective version of the DSIC system (O-DSIC) based on the best available clinical and biomechanical data and (2) comparing subjective surgeon perceptions (S-DSIC) with the objective measure (O-DSIC) of instability secondary to DLS. Validation of the preliminary O-DSIC system requires future work, which should be conducted prior to its use in clinical and research settings.

Materials and Methods

Study Design and Population

Consecutive adult patients scheduled for surgery for 1- or 2-level DLS-related symptomatic spinal stenosis were enrolled by 16 surgeons across 8 sites as part of an ongoing multicenter prospective CSORN study. Patients undergoing decompression or fusion surgery for lumbar disc herniation, degenerative scoliosis of >10°, or static spinal stenosis were excluded. Patients with nondegenerative spondylolisthesis (i.e., isthmic or congenital), DLS without stenosis, trauma, infection, or malignancy were also excluded.

Data Collection

Patient data collection and privacy procedures that were employed in this study have been described previously[12]. All of the participants provided written informed consent. All of the sites obtained Research Ethics Board approval prior to data collection. The use and handling of data were independent of commercial interests.

Radiographic measurements were performed preoperatively by the surgeons. Clinical variables were recorded by trained research coordinators using patient-completed assessment forms.

Creating the O-DSIC System

The CSORN group previously summarized and published levels of evidence (i.e., very low, low, medium, or high quality) supporting common DLS-related clinical and radiographic variables and their association with instability, and Simmonds et al. provided a full summary of the evidence assignment[8]. For the purpose of creating the O-DSIC system, we retained the variables that CSORN had previously determined as being supported by low-quality evidence, and assigned a value of 1 point to each; variables with "very low-quality" evidence supporting their association with instability were excluded (see Appendix A). We chose this approach for several reasons: (1) we sought to include only variables supported by the best available evidence, (2) based on the aforementioned review of the literature, there are no variables supported by medium- and high-quality evidence, (3) the best available literature is not sufficient to correlate the quality of evidence with the magnitude of impact for each variable, (4) it allowed assigning a value of a single point to each of the variables of equal evidence quality included in the (O-DSIC) scoring system, and (5) it facilitated the calculation of O-DSIC scores by means of straightforward summation.

Surgeons who assigned S-DSIC types prospectively were not involved with the retrospective derivation and application of the O-DSIC system.

TABLE II The Preliminary O-DSIC System

Clinical/Radiographic Variables	Proposed Point Value	Quality of Evidence*
Disc height on lateral radiograph		Low
Preserved, ≥6.5 mm	1	
Narrowed, <6.5 mm	0	
Degree of translation on dynamic lateral radiographs		Low
≥4 mm	1	
<4 mm	0	
Disc angle on flexion radiograph		Low
Kyphotic or neutral	1	
Lordotic	0	
Low back pain on visual analog scale		Low
≥5 of 10	1	
<5 of 10	0	
Facet effusion†		Low
Present	1	
Absent	0	

*As previously determined by Simmonds et al.[8]. †As observed on T2-weighted magnetic resonance imaging.

Calculation of DSIC Scores and Conversion to DSIC Types

For each patient, the presence of instability variables included in the O-DSIC system was summed in order to yield DSIC scores. O-DSIC scores were converted to O-DSIC Types I, II, and III using an a priori conversion method that was determined following the creation of the O-DSIC system (as described in the Results section).

Comparing S-DSIC and O-DSIC Types

S-DSIC and O-DSIC types for the overall cohort and for each patient were presented as frequencies. In our analysis of the degree of difference among DSIC types, when surgeons assigned an S-DSIC type that was lower than the corresponding O-DSIC type, it was considered an underestimate of instability. When S-DSIC and O-DSIC types were the same, it was considered a similar estimate of instability. When the S-DSIC type was higher than the corresponding O-DSIC type, it was considered an overestimate of instability.

Patient Characteristics Stratified by Differences Between the O-DSIC and S-DSIC Types

The patient demographics of age, gender, body mass index (BMI), marital status, living arrangement, education, smoking status, and employment status were compared among the DSIC types for both the S-DSIC and O-DSIC systems. Demographic data were also stratified according to the degree of difference between the S-DSIC and O-DSIC types.

Statistical Analysis

Statistical analyses were conducted using the IBM Statistical Package for the Social Sciences (SPSS version 25). Baseline and demographic variables were tabulated and presented as frequency distributions or the mean ± standard deviation for the 2 groups, stratified by either S-DSIC or O-DSIC types. Analysis was performed using Pearson chi-square or 1-way analysis of variance (ANOVA) testing, as appropriate. For example, chi-square testing was used to compare the actual surgical procedures that had been performed with the procedures proposed on the basis of the O-DSIC and S-DSIC systems, respectively. Bonferroni correction was performed for multiple comparisons as needed, and $p < 0.05$ was considered significant.

Source of Funding

No external funding was provided for this study.

TABLE III Number of Patients with Each Instability Parameter Included in the O-DSIC System (N = 309)*

	Translation	Disc Angle	Disc Height	Facet Effusion	Low Back Pain
No.	47	88	174	148	272
%	15	29	56	47	88

*In the O-DSIC system, 1 point is assigned for each of the following: translation of ≥4 mm, kyphotic or neutral disc angle on flexion radiographs, disc height of ≥6.5 mm, facet effusion present, and low back pain with intensity of ≥5 of 10 on the visual analog scale.

Results

Demographic Data

The mean patient age and BMI were 65.8 ± 9.0 years and 29.3 ± 6.0 kg/m^2, respectively. The mean DLS-related translation at the index level on supine and standing lateral radiographs was 6.1 ± 4.1 and 7.4 ± 3.8 mm, respectively; the mean dynamic translation was 2.0 ± 3.4 mm. The mean disc height was 10.0 ± 14.7 mm on lateral radiographs. The mean preoperative LBP intensity on a visual analog scale (VAS) for pain was 7.0 ± 2.1. Additional demographic data are detailed in Appendix B.

Creating the O-DSIC System

Five evidence-based variables were retained and assigned a single point value, constituting the O-DSIC system (Table II). They include the presence of facet effusion on T2-weighted magnetic resonance imaging (MRI), preservation of absolute disc height on lateral radiographs (≥6.5 mm), translation on dynamic lateral radiographs (≥4 mm), a kyphotic or neutral disc angle on flexion radiographs, and presence of LBP (≥5 of 10 intensity on the VAS). The following variables supported by very low-quality evidence were excluded from the O-DSIC system: patient-specific factors (age, gender, occupation, and BMI), select restabilization signs (osteophyte formation, vertebral end-plate sclerosis, and ligament ossification), and facet joint orientation[8].

Calculation of DSIC Scores and Conversion to DSIC Types

There were 408 consecutive adult patients who were eligible; 99 (24%) of these lacked at least 1 of the 5 variables required to calculate the O-DSIC score and therefore were excluded. Presence of LBP (≥5 of 10 intensity) was the most frequent (n = 272 patients; 88%) instability variable, and translation of ≥4 mm was the least frequent (n = 47 patients; 15%) instability variable (Table III). DSIC types were derived from the O-DSIC scores (see Appendix C): 0 to 2 points was considered stable, Type I; 3 points, potentially unstable, Type II; and 4 to 5 points, unstable, Type III (Table IV).

Comparing O-DSIC and S-DSIC Types

The frequencies of O-DSIC and S-DSIC types are presented for the overall cohort in Table V. According to the O-DSIC system, Type I was the most common (n = 176; 57%). According to the S-DSIC system, Type II was the most common.

S-DSIC and O-DSIC types differed for more than half of the patients (p < 0.001; Table VI); surgeons assigned a higher S-DSIC type than what was objectively determined using the O-DSIC system (overestimate of instability) in 130 patients (42%) (see Appendix D). Surgeons assigned a lower S-DSIC type than what was objectively determined (underestimate of instability) using the O-DSIC system in only 34 patients (11%).

TABLE IV Conversion of Summed Points to O-DSIC Type

Points	DSIC Type
0-2	I (stable)
3	II (potentially unstable)
4-5	III (unstable)

TABLE V Type Distributions in the Cohort

O-DSIC			S-DSIC		
Type	No.	%	Type	No.	%
I	176	57.0	I	92	29.8
II	106	34.3	II	164	53.0
III	27	8.7	III	53	17.2

TABLE VI Comparison of O-DSIC and S-DSIC Types*

	O-DSIC Type		
S-DSIC Type	I	II	III
I	70	*19*	*3*
II	**89**	63	*12*
III	**17**	**24**	12

*Chi-square test: p < 0.001. The numbers in italic (totaling 34, 11.0%) indicate cases where the surgeon assigned an S-DSIC type lower than determined with use of the O-DSIC system. The numbers in bold (totaling 130, 42.1%) indicate cases where the S-DSIC type was higher than the O-DSIC type.

Patient Characteristics Stratified by Differences Between the O-DSIC and S-DSIC Types

Patients categorized as DSIC Type III were younger than DSIC Type I and Type II for both the S-DSIC and O-DSIC systems (see Appendix E). Using the O-DSIC system, we found that DSIC Type III was associated with a higher BMI. S-DSIC and O-DSIC types both were independent of gender, marital status, living arrangement, education, smoking status, or employment status.

Data were stratified according to whether surgeons assigned a lower, the same, or a higher S-DSIC type compared with that based on the O-DSIC system. No differences were identified for age, BMI, gender, marital status, living arrangement, education, smoking status, or employment status across the stratified groups (Table VII).

Discussion

The S-DSIC system was developed as an attempt to assess preoperative instability related to DLS[8,13]. The system captures the heterogeneity of DLS and subjectively facilitates the selection of a surgical technique[9]. An objective classification is warranted to further reduce variation among surgeons' interpretations of instability and tailor surgical procedures based on the best available evidence. In our study, we enrolled 408 consecutive adult patients who received surgery for symptomatic spinal stenosis related to DLS. Surgeons prospectively categorized DLS-related instability using the previously reported S-DSIC system. Our group subsequently proposed a preliminary O-DSIC system with clearly defined criteria. O-DSIC scores were retrospectively calculated for the same cohort of patients. Surgeons assigned more instability with the S-DSIC system than was determined based on the O-DSIC system. The inter- and intra-rater reliability of the O-DSIC system should be determined prior to its use in future clinical or research settings.

Interpretation

Only a small percentage of patients in this study had a degree of translation consistent with substantial instability, challenging the belief that any translation plays a significant role[8]. Loss of absolute disc height (using a height cutoff of 6.5 mm) was the only restabilization sign with evidence supporting an association with instability. As such, preservation of disc height was included in the O-DSIC system[8]. Many studies report on facet effusion measured via the facet fluid index; these studies use nonstandardized measurement and calculation techniques[14-16]. The best available evidence supports the association between DLS-related instability and the presence or absence of facet effusion, which also facilitates ease of scoring[8]. Kanayama et al. demonstrated that the disc angle on flexion radiographs impacts segmental stability; only a lordotic disc angle was considered stable in flexion[17]. Distraction stiffness and sagittal alignment in flexion were similar for both kyphotic and neutral alignments. The best

TABLE VII Patient Demographics Stratified by the Degree of Difference Between O-DSIC and S-DSIC Types* (As Presented in Appendix D)

	Degree of Difference Between O-DSIC and S-DSIC Types†			
Variable	Surgeon Underestimate of Instability	Similar Estimate of Instability	Surgeon Overestimate of Instability	P Value
Age, mean ± SD *(yr)*	64.4 ± 8.7	66.7 ± 9.0	65.3 ± 9.0	0.25
BMI, mean ± SD *(kg/m²)*	30.3 ± 6.4	29.5 ± 4.8	28.8 ± 6.9	0.32
Gender				0.50
Male	17	58	51	
Female	17	87	79	
Marital status				0.62
Married	25	102	83	
Not married	9	42	42	
Living arrangement				0.77
Living with someone	27	113	95	
Living alone	7	32	32	
Education				0.11
≤High school	12	75	53	
>High school	22	70	73	
Smoking status				0.10
Smoker	1	25	22	
Nonsmoker	32	119	105	
Employment status				0.54
Not working	6	14	19	
Working	9	41	30	
Retiree	14	80	69	
Other	12	9	2	
Procedure				0.059
Decompression only‡	7	39	17	
Decompression and IPLF§	8	35	39	
Decompression with IPLF and interbody device#	12	49	57	

*SD = standard deviation, BMI = body mass index, and IPLF = instrumented posterolateral fusion. †See Methods section and/or Appendix D for a detailed explanation regarding terminology. ‡Laminectomy alone. §Laminectomy and posterior pedicle screw and rod instrumentation for the purpose of arthrodesis. #Laminectomy, unilateral facetectomy, interbody device insertion, and posterior pedicle screw and rod instrumentation for the purpose of fusion.

evidence suggests that neither disc nor facet angles in the neutral position (nor the disc angle in extension) are significantly correlated with distraction stiffness[8,17]. Regarding LBP, only its presence or absence has been associated with DLS-related instability; since the cutoff threshold for intensity as a sign of instability has not been previously defined, we defined substantial LBP as ≥5 of 10 on the VAS.

Type I in the S-DSIC system is associated with restabilization signs, while patients with Type II exhibit fewer of these signs, and patients with Type III have no signs of restabilization[8]. These vague categories provide an opportunity for inconsistency in a surgeon's interpretation and categorization. The majority of these variables (osteophyte formation, posterior ligamentous ossification, and vertebral end-plate sclerosis) are supported by "very low-quality" evidence and were excluded[14,18,19]. Moderate-quality evidence supports measurable in vivo biomechanical markers of instability in DLS, including flexion stiffness, absorption energy, and the neutral zone[8,20]. Given that measurement requires a novel intraoperative system that includes spinous process holders, a motion generator, and a personal computer, these variables were considered impractical and not included in the O-DSIC system. Most studies have failed to demonstrate a significant correlation of age, symptom duration, BMI, and multiple comorbidities with stability in patients with DLS[2,8]. Comorbidities may be considered during surgical decision-making when assessing fitness to tolerate a procedure; however, the contribution of these variables to stability is supported by very low-quality evidence[8]. These variables may have marked impacts, however, on the type of surgery performed. We found that O-DSIC Type III was associated with younger age and higher BMI. However, there was no association between 7 other demographic variables and DSIC types. Lastly, while facet joint orientation and tropism are associated with DLS, their role in the development of the disease and segmental stability is controversial based on current very low-quality evidence[8].

Surgical technique may vary based on surgeon bias toward the anticipated degree of instability and the number of clinical and radiographic variables that are considered. The O-DSIC and S-DSIC systems have been developed in an effort to decrease such bias. There may be a "regression to the mean" in which surgeons consider 1 or 2 variables and then, in the face of uncertainty, choose a more rigid construct in the belief that doing so would make early reoperation less likely.

Future Work

Historically, translation has been considered a key contributor to the definition of DLS-related instability; we believe that our study emphasizes a more heterogeneous view of DLS-related instability in the context of numerous parameters beyond translation. At one extreme, the facet joints may be virtually ankylosed and there may be 4 mm of translation between 2 vertebrae. At the other extreme, the facet joints may be distracted such that there may be no apparent slippage between the 2 vertebrae when the patient is supine, but then translation of >12 mm on standing as the disc space becomes kyphotic. Expanding the definition of instability beyond translation may facilitate the tailoring of specific surgical plans[21,22]. Assigning objective criteria to the decision-making process represents an important first step in recognizing the heterogeneity of DLS.

Although we have proposed a preliminary O-DSIC system, this was not a validation study. The validity and magnitude of each parameter's contribution to the O-DSIC system should be determined through future study. Analysis of intra- and inter-rater reliability based on the input of each participating surgeon should be assessed. Following validation, the O-DSIC system should be assessed in the context of patient-reported outcomes stratified by the surgical procedure that is performed.

Limitations

It is possible that the S-DSIC and O-DSIC systems both underestimate instability compared with surgeon judgment. Their derivation is based on the best available evidence, although the evidence quality is low. One in 4 patients was excluded from the O-DSIC analysis for missing data for at least 1 of the 5 variables required to calculate the O-DSIC score. Although the derivation of the preliminary O-DSIC system represents an exhaustive evaluation of DLS instability, there are likely other factors that influence surgical decision-making that were not considered as part of this study (coexistent foraminal stenosis, spinopelvic parameters, coronal listhesis, etc.). Future research efforts will be directed toward determining the contribution of such parameters toward DLS-related instability. Lastly, the O-DSIC is a tool for assessing preoperative DLS-related instability in order to guide surgical management—it does not account for potential iatrogenic intraoperative instability.

Conclusions

The O-DSIC system allows for the objective assessment of preoperative instability related to DLS. This system was developed by assigning clearly defined values to previously reported instability variables. Comparing the O-DSIC and S-DSIC systems revealed that the latter may overestimate instability. The validity and magnitude of the contribution of each parameter should be determined through future study. Inter- and intra-rater reliability should be determined prior to the use of the O-DSIC system in clinical and research settings.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJSOA/A436). ■

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