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A Modified Delphi Consensus Study to Quantify Surgical Burden of Degenerative Lumbar Spinal Procedures: The Minimally Invasive Spine Surgery Invasiveness Classification "MISS-INC (L)"

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Abstract

Study Design: Consensus-based classification development utilizing a modified Delphi process. **Objectives:** To develop a practical, standardized classification system to quantify surgical invasiveness in minimally invasive degenerative lumbar spine procedures. **Methods:** An international panel of 45 spine surgeons from the AO Spine Knowledge Forum – Degenerative participated in a three-stage, modified Delphi consensus process. First, candidate determinants of invasiveness were

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identified through evaluation of existing indices and literature review, then refined through iterative expert rounds. The scale was applied to standardized case scenarios, with internal review by the AO Spine Knowledge Forum – Degenerative and external review by the AO Spine MISS Task Force. Finally, a consensus survey reached ≥75% agreement on all final factors for inclusion in the grading scale. **Results:** The final classification system included nine factors: operative time, number of approaches, blood loss, instrumentation, muscle dissection/access, anesthesia, number of levels, fusion technique, and revision status. Consensus was achieved on all components of the scale following iterative refinement. Each factor was scored from 0 (least invasive) to 2 (most invasive), generating a cumulative invasiveness score. Application of the scale across representative procedures demonstrated a spectrum ranging from least invasive (endoscopic 1-level discectomy) to most invasive (thoracic-to-pelvis fixation). Procedures were stratified into minimally invasive, less invasive, and more invasive categories. **Conclusions:** MISS-INC (L) is a proposed, consensus-based classification that quantifies surgical invasiveness among minimally invasive lumbar spine procedures. It offers a user-friendly framework for communication, research, and patient counseling, with further validation against clinical outcomes representing an important next step.

Keywords
minimally invasive spine surgery, surgical invasiveness, classification, lumbar

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Introduction

Minimally invasive spine surgery (MISS) has evolved into a collection of well-established procedures, with estimates suggesting that approximately 75% of surgeries for degenerative spinal disorders can be performed partially or completely using these techniques.[1] According to the AO Spine MISS curriculum, these procedures comprise a "suite of technology-dependent methods that aim to reduce local tissue damage and systemic surgical stress, thereby enabling earlier return to function and improved outcomes compared to traditional techniques."[2] A diverse array of these procedures is detailed in the AO Spine MISS curriculum.[3-6]

MISS techniques offer several documented benefits, including reduced blood loss, minimal muscle dissection, less postoperative pain, and earlier mobilization, all contributing to enhanced recovery compared to open surgery.[3-5] However, there remains uncertainty regarding which specific factors best define invasiveness and reliably reduce tissue damage and surgical stress. No universally accepted or standardized definition of MISS exists, and the concept of "invasiveness" is interpreted differently within the surgical community, the device industry, and from the patient's perspective.[7]

Generally, MISS is characterized by smaller incisions, specialized soft tissue retractors, reduced muscle damage (as assessed by biochemical markers), and the utilization of advanced technology such as microscopes, endoscopes, stereotactic navigation, and robotics.[8-10] While the device industry has worked closely with surgeons and engineers to develop MISS tools, there is no standard method to compare the invasiveness of these technologies. Additionally, patients may find it challenging to understand the differences in invasiveness, clinical outcomes, and risks among various MISS procedures. As MISS becomes more widely adopted, a clearer understanding and standardized classification of these procedures is needed—one that acknowledges the gradations and grey zones inherent to invasiveness.

While the focus of this study is on invasiveness, it is important to distinguish three related but non-identical constructs. Here, invasiveness refers to the degree of tissue disruption and physiologic surgical stress imposed by an approach. Surgical complexity refers to the technical and cognitive demand of a procedure. Surgical risk refers to the probability of an adverse event. These do not always correlate: an endoscopic procedure may be technically complex yet impose minimal tissue disruption, whereas a comparatively simple open procedure may be more invasive.

Several surgical-invasiveness indices already exist, but none is well-suited to the present knowledge gap. The Spine Surgical Invasiveness Index (SSII) quantifies operative disruption from decompression, arthrodesis, and instrumentation. Adult spinal deformity scores, for example the Adult Spinal Deformity Surgical and Radiographical (ASD-SR) score and the Cervical Deformity Invasiveness Index (CDII), extend this approach to specific populations.[11-14] Other examples include the thoracic invasiveness index (TII) and the spinal metastasis invasiveness index (SMII).[15,16] None, however, is tailored to MISS. These tools share three limitations: (1) they are not specific to minimally invasive techniques and therefore do not capture the access- and muscle-related dimensions that most distinguish MIS approaches; (2) they are not exclusively focused on the degenerative lumbar spine, the most common anatomic region where MIS procedures are performed and where the clinically meaningful granularity lies; and (3) they are not designed for practical, point-of-care communication among surgeons, industry, and patients.

Improved classification could help healthcare providers, manufacturers, and patients communicate more accurately about surgical options and expectations. Our goal is to identify the essential factors that determine invasiveness and integrate them

into a practical classification system usable for comparing different spinal procedures. MISS-INC (L) was developed to address these gaps simultaneously. Influential elements may differ depending on the surgeon, institution, technology access, and region, but most research highlights muscle disruption, blood loss, and operative time as among the most representative determinants of invasiveness.[12,17,18]

The purpose of this study is to develop a practical and user-friendly, lumbar degenerative-specific MISS invasiveness classification system to describe each surgical approach's potential to reduce tissue damage and surgical stress, facilitating earlier return to function. We aim to provide a standardized communication tool for clinicians, researchers, and patients, to improve clarity, research reproducibility, and patient education, and to reduce ambiguity and misuse of the term "minimally invasive" within the spine care community.

Methods

The study consisted of three stages (Figure 1): Stage 1, defining the factors that influence the invasiveness of MISS and developing a grading scale to rank the invasiveness of each factor; Stage 2, employing a modified Delphi process to test the preliminary grading scale against case scenarios with internal and external consensus refinement; and Stage 3, agreement scoring and the final proposal. A panel of international surgeons was enlisted from the AO Spine Knowledge Forum – Degenerative, an expert group within the AO Spine organization. All participants were fellowship-trained orthopaedic or neurosurgical spine surgeons and active members of the Knowledge Forum – Degenerative, admitted based on a demonstrated track record in degenerative spine surgery and clinical research. Panelists practice across a range of academic and clinical settings and career stages. A total of 45 panelists participated across the three stages of this study. Regional representation spanned five AO Spine regions: Asia Pacific (n = 8), North America (n = 24), Europe/South Africa (n = 11), Middle East and Northern Africa (n = 1), and Latin America (n = 1) (Table 1).

Stage 1

Factor determination followed a two-step process of identification and selection. First, a structured literature review identified published determinants of surgical invasiveness, drawing on established invasiveness indices and peer-reviewed operative surrogate studies. This yielded an initial candidate list of 16 factors (Table 2). The list of candidate factors was then refined by the panel using a modified Delphi approach, in which feedback on each factor was collected, compiled by a project manager, and presented to the group before the next round of feedback. Each factor was evaluated for: (i) relevance to procedural invasiveness; (ii) feasibility of consistent assessment across institutions; and (iii) supporting evidence for proposed scoring thresholds. Factors were removed if they introduced confounding variables, were captured by another factor, or lacked discriminatory value. Cut-offs for quantitative factors such as operative time ("OR time") and blood loss were expert consensus-derived given inconsistency in the literature. Expected variation in technique, experience, and resources served as the rationale for the standardized assumptions.

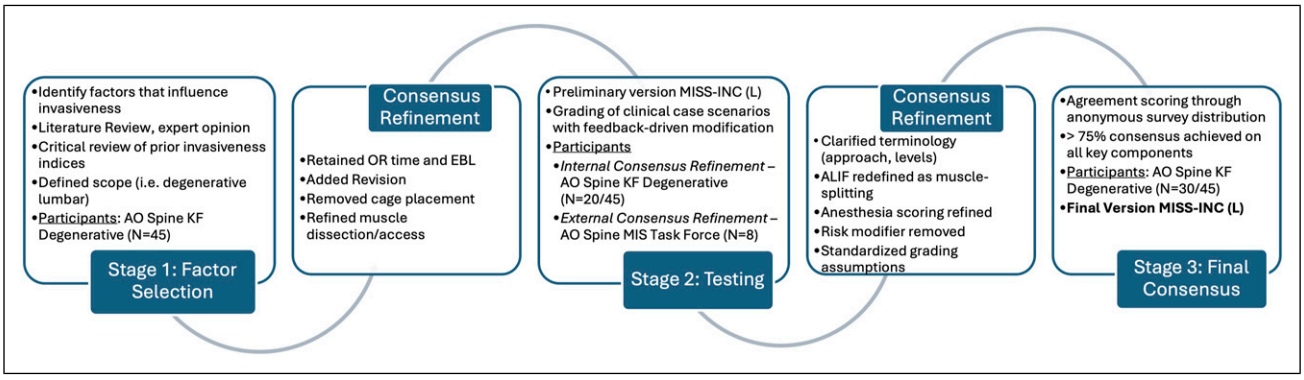


Figure 1. Illustrating study methodology and modified Delphi process. The flowchart outlines the expert iterative rounds used to achieve panel consensus across successive evaluation stages

Table 1. Geographic Distribution of Panelists for Modified Delphi Process

	Number
Europe & South Africa	11
Asia Pacific	8
Latin America	1
Middle East & Northern Africa	1
North America	24

Stage 2

A preliminary version of the grading scale was initially distributed to 20 surgeons from the panel, who were provided a selection of 11 common degenerative lumbar spine surgeries and asked to grade their invasiveness using the scale. Scoring results and qualitative feedback were then compiled and used to refine the grading scale further and gain consensus at subsequent meetings. An illustrative preliminary example of this is shown in Figure 2. All procedures were graded based on the assumption that they are performed in a well-equipped facility by a surgeon with appropriate training and experience in the specific procedure. The grading scale and list of selected procedures were then distributed to an independent cohort of

Table 2. Evaluation and Selection of Candidate Factors During Stage 1

Candidate Factor	Origin	Disposition	Rationale
OR Time	McAfee et al (2010)	**Retained**	Point values refined to <1h/1–3 h/>3h based on expert opinion
Number of Approaches	Mirza et al (2008)	**Retained**	Previously validated factor; increased number of approaches associated with higher blood loss and operative time
Blood Loss	McAfee et al (2010)	**Retained**	Point values set at <50/<200/>200 mL based on expert opinion with >200mL recognized as generally open
Anesthesia	Expert opinion	**Retained (modified)**	Local/Sedation = 1 Pt and General = 2 Pt to better discriminate endoscopic cases (Stage II, Dec 2024)
Number of Levels	Mirza et al (2008)	**Retained**	Previously validated factor with increased operative levels associated with higher blood loss and operative time
Fusion Technique	Mirza et al (2008)	**Retained**	Made additive (Interbody 1 Pt + Posterolateral Fusion 2 Pt = 3 Points Total); facet-only grafting discussed but not adopted as a separate subcategory
Muscle Dissection	Buis et al (2022)	**Retained**	Merged with Access Technology into one Muscle Dissection/Access factor; ALIF reclassified from minimal to muscle-splitting (Stage II)
Screw Placement	Mirza et al (2008)	**Retained (modified)**	Re-anchored from screw count (0/2–4/>4) to levels instrumented (0/1/>1); interspinous spacer folded in at a 1-point minimum (Stage II, Jan 2025)
Revision Status	Expert opinion	**Added following discussion**	Added in Stage I to capture revision decompression/microdiscectomy (1 Point) and hardware removal/insertion (2 Point)
Access Technology	McAfee et al (2010)	Merged	Folded into Muscle Dissection/Access (Stage I)
Cage Placement	Mirza et al (2008)	Not adopted	Considered captured within Fusion Technique (Stage I)
Hospital Stay/LOS	McAfee et al (2010)	Not adopted	Confounded by patient factors, ASC vs inpatient setting, and regional/surgeon preference (Stage I)
Surgical-Risk Modifier ("R")	Expert Opinion	Not adopted	Considered in early iterations; excluded to keep the index focused on invasiveness and deferred to future work
Radiation/Imaging Exposure	Buis et al (2022)	Not adopted	Discussed (fluoroscopy vs O-arm vs navigation); not incorporated to retain procedure focus
Patient Factors (BMI, Comorbidities)	Mirza et al (2008)	Not adopted	Excluded to maintain procedure-focus versus patient risk factors
Biochemical Factors (IL-1β, IL-6)	Buis et al (2022)	Not adopted	Excluded as factors are not widely available across cases

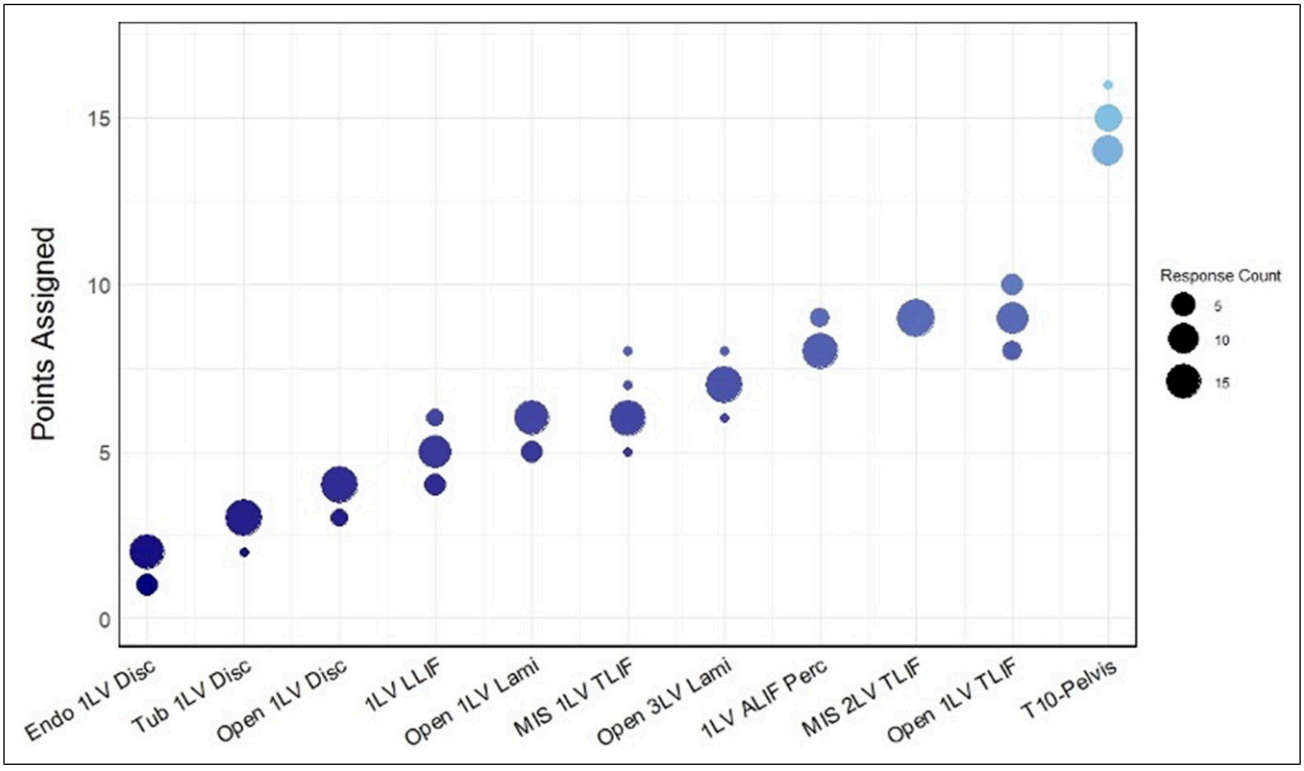


Figure 2. Preliminary MISS-INC (L) internal consensus refinement scoring. An illustrative example of grading results using the Minimally Invasive Spine Surgery Invasiveness Classification "MISS-INC (L)" evaluating 11 common degenerative lumbar spine surgeries during Stage 2

eight surgeons, members of the AO Spine MISS Task Force, deliberately extrinsic to the core panel. Cases were again graded, with qualitative feedback collected and used to further refine the grading scale. Both internal and external refinement of the scale served to optimize the scale's usability and reproducibility.

Stage 3

The objective of this stage was to achieve consensus on all items and point cut-offs included in the final version of MISS-INC (L). Consensus was assumed to be achieved when >75% of panelists agreed. An anonymous online survey was distributed to 45 members, with 30 responses received (Table 3). Survey completion occurred over the course of one month, with one follow-up meeting to review the results as a group and any relevant feedback. The final version of MISS-INC (L) was then created (Table 4).

Results

Stage 1 involved a panel of 45 surgeons and occurred over 8 months and 7 meetings. Initially, 16 factors were considered at the inception of the study based on existing classification systems and definitions of minimally invasive surgery, as shown in Table 2. Through multiple meetings and rounds of discussion and refinement, seven factors were ultimately excluded. Hospital stay was one of these, excluded due to confounding variables such as patient-specific medical factors, procedures being performed in the hospital versus ambulatory surgery center, and surgeon preference, which may vary based on training or geographic region. Interbody cage placement was excluded as a factor, as it was felt to be accounted for in the "Fusion Technique" category. The categories of Muscle Dissection and Access Technology were also ultimately combined. One additional factor, revision status, was added after further refinement of the scale to reflect the invasiveness associated with revision decompression and/or microdiscectomy and removal/reinsertion of instrumentation. Additional factors—including a surgical-risk modifier, radiation exposure, patient-specific factors, and biochemical markers—were considered but not incorporated, to keep the index focused on the procedure itself and to preserve simplicity. A summary of all candidate factors, their rationale, and final disposition is provided in Table 2.

Table 3. Final Candidate Factor List With Respective Agreement Percentages at the End of Stage 3

Candidate factor	Point value	Agree (n)	Disagree (n)	Agreement (%)
OR time ("skin to skin")				
OR time < 60 min	0	28	2	93.33
OR time 1–3 hours	1	27	3	90.00
OR time > 3 hours	2	26	4	86.67
Number of Approaches				
1 approach	0	26	4	86.67
2 approaches	1	26	4	86.67
3 or more approaches	2	24	6	80.00
Blood Loss				
< 50 mL	0	29	1	96.67
50 to 200 mL	1	30	0	100.00
> 200 mL	2	28	2	93.33
Pedicle Screw Placement/Interspinous Spacer				
0 levels	0	27	3	90.00
1 level	1	27	3	90.00
> 1 level	2	26	4	86.67
Muscle Dissection				
Minimal (endoscopic)	0	28	2	93.33
Muscle Splitting (Tubular/Specular, ALIF, LLIF)	1	28	2	93.33
Muscle Detachment (Open)	2	26	4	86.67
Anesthesia				
N/A*	0			
Local/Sedation	1	25	5	83.33
General	2	25	5	83.33
Number of Levels				
1 level	0	29	1	96.67
2 to 3 levels	1	28	2	93.33
> 3 or Pelvic Fixation	2	27	3	90.00
Fusion Technique				
Decompression Only	0	27	3	90.00
Interbody	1	24	6	80.00
Posterolateral	2	24	6	80.00
Revision				
None	0	27	3	90.00
Decompression Only	1	25	5	83.33
Instrumentation Removal/Reinsertion	2	25	5	83.33

*Any type of anesthetic is considered an intervention.

In Stage 1, points were assigned to each factor at values of 0, 1, and 2 based on the increasing relative invasiveness of that factor category. For blood loss, for example, 0 points were assigned to minimal (<50 mL) blood loss, whereas 2 points were assigned to blood loss >200 mL, considered high for the purposes of this scale. The increase in points is intended to reflect a perceived increase in invasiveness for each factor. Factor weighting (i.e., providing different point values to each factor) was also discussed but deliberately not adopted, due to complexity and reduced point-of-care usability. The cut-offs chosen for

Table 4. Minimally Invasive Spine Surgery Invasiveness Classification - "MISS-INC (L)"

	0	1	2
OR Time	< 1 h	1-3 h	> 3 h
# of Approaches	1	2	3 or more
Blood Loss	< 50 mL	50 - 200 mL	> 200 mL
Pedicle Screw/Interspinous Spacer	0	1 Level	>1 Level or Pelvic
Muscle Dissection	Minimal	Muscle-Splitting	Detachment
Anesthesia	-	Local/Sedation	General
# of Levels	1	2-3	>3 or Pelvic Fixation
Fusion Technique	-	Interbody	Posterolateral
Revision	-	Decompression Only	Instrumentation

each point value were proposed by the authors and expert-consensus derived given inconsistency in the literature. Early iterations of our invasiveness index included a surgical-risk modifier ("R") to account for procedures with greater inherent approach-related risk (i.e., increased risk of bleeding or neurologic injury). It was ultimately decided to exclude this from the finalized index to maintain focus on measuring the relative invasiveness of various MIS procedures.

The final proposed factors included procedure time, number of approaches, blood loss, pedicle screw placement, muscle dissection, anesthesia, number of levels, fusion technique, and status as a revision procedure. Each factor was graded on a scale of 0 to 2, with 0 being the least invasive and 2 being the most invasive. A deliberate decision was made to weight all factors equally rather than applying factor-specific weights.

In Stage 2, which occurred over 11 months and 5 meetings, a preliminary version of the grading scale was distributed to 20 surgeons within the AO Spine Knowledge Forum – Degenerative who had demonstrated consistent engagement in project meetings and expressed interest in participation. They were provided 11 common degenerative lumbar spine surgeries and asked to grade their invasiveness. The procedures consisted of endoscopic 1-level discectomy, tubular 1-level discectomy, open 1-level discectomy, 1-level lateral lumbar interbody fusion, 1-level laminectomy, MISS 1-level transforaminal interbody fusion (TLIF), open 3-level laminectomy, 1-level anterior lumbar interbody fusion with percutaneous pedicle screw fixation, MISS 2-level TLIF, open 1-level TLIF, and thoracic-to-pelvis fixation with a 1-level TLIF. Operative time, blood loss, and other pertinent information were provided to the scoring surgeons. Scoring results and qualitative feedback were then compiled and used to refine the grading scale further, and were discussed at subsequent meetings to assess the feasibility and appropriateness of the scale. An illustrative example of the results of one of these internal consensus refinements is shown in Figure 2.

Across the 11 representative procedures graded during the Stage 2 scoring exercise, mean invasiveness scores increased consistently from 0.79 for endoscopic single-level discectomy to 13.58 for thoracic-to-pelvis fixation (Figure 2), spanning the full minimally invasive to more invasive range. This aligned with clinical expectations—open procedures scored higher than their minimally invasive counterparts at the same level (open 1-level discectomy 2.89 vs. tubular 1.95 vs. endoscopic 0.79)—supporting the scale's ability to discriminate between approaches of differing invasiveness. Based on those results and subsequent group discussions, further adjustments were made over several meetings to optimize the grading scale. External consensus refinement was then carried out, distributing the grading scale and the same list of selected procedures to an independent cohort of eight surgeons, members of the AO Spine MISS Task Force, deliberately extrinsic to the core panel. Cases were again graded, and qualitative feedback was compiled and used to further refine the grading scale.

In Stage 3, an anonymous online survey was distributed, seeking agreement on all final items in the proposed scale. Of the 45 panelists invited to the final consensus survey, 30 completed it (67% response rate). Every scored factor exceeded the predefined 75% agreement threshold, with agreement ranging from 80.0% to 100% (median 90.0%; mean 88.7%) (Table 3). Consensus was highest for the blood-loss and number-of-levels factors—agreement reached 100% for a blood loss of 50–200 mL and 96.7% for both <50 mL blood loss and single-level surgery. The lowest agreement, though still above threshold at 80.0%, occurred for the interbody and posterolateral categories of the fusion-technique factor and for the "three or more approaches" selection. Survey completion occurred over the course of one month, with one follow-up meeting to review the results as a group, after which the final version of MISS-INC (L) was created.

Table 4 presents the final version of the Minimally Invasive Spine Surgery Invasiveness Classification "MISS-INC (L)," and Figure 3 provides general guidelines and factor-specific guidance for the user. These guidelines were developed to avoid misconceptions and misunderstandings; they are intended to accompany the grading scale and maximize its utility and ease of use. The factors ultimately included are described in detail below.

It was felt to be helpful to grade a set of representative cases based on the final scoring system and the intended use of MISS-INC (L), illustrated in Table 5. A proposed invasiveness spectrum based on ideal scoring was then created as a visual tool (Figure 4), stratifying and grouping procedures by their relative scores into categories of minimally invasive (<5 points, green), less invasive (5–10 points, yellow), and more invasive (>10 points, red).

OR Time

For the purposes of this study, OR time was "skin-to-skin" time, or the amount of time it takes for the surgeon to perform the given surgical procedure. The assumption was made that the procedure was being performed by an experienced, well-trained surgeon in a well-equipped facility. Other common measures, including "door-to-door" time or "total anesthesia time," were not included, due to the potential for additional confounding variables that may influence the duration of surgery, including medical factors or delays related to equipment and staffing. Presumably, the invasiveness of the procedure increases with increasing OR time.



Figure 3. Guidelines for use of MISS-INC (L). A comprehensive overview detailing factor-specific parameters and general criteria to optimize use of the Minimally Invasive Spine Surgery Invasiveness Classification "MISS-INC (L)"

Number of Approaches

The number of surgical approaches was based on the number of separate surgical sites involved. This is true regardless of special circumstances such as single-position surgery or staging of surgical procedures. For example, a posterior lumbar approach is one approach regardless of how many incisions. Lateral lumbar transpsoas (LLIF) and anterior lumbar (ALIF) are each considered separate approaches. Oblique lateral (OLIF) is considered one approach, also if it includes L5–S1. The invasiveness of the procedure increases with an increase in the number of surgical approaches.

Blood Loss

Estimated blood loss is a well-established and validated factor in other surgical invasiveness indices within and outside of the spine subspecialty. Here, blood loss <50 mL was considered minimal. A threshold of 200 mL was agreed upon among our

Table 5. MISS-INC (L) Ideal Scoring for Common Degenerative Lumbar Spine Surgeries

Case	Factor	Points	Total
Endoscopic 1-Level Discectomy (Local Anesthesia/Sedation)	Anesthesia	1	**1**
Endoscopic 1-Level Discectomy (General Anesthesia)	Anesthesia	2	**2**
Tubular 1-Level Discectomy	Muscle Dissection	1	**3**
	Anesthesia	2	
Tubular 1-Level ULBD	OR Time	1	**4**
	Muscle Dissection	1	
	Anesthesia	2	
Open 1-Level Discectomy	Muscle Dissection	2	**4**
	Anesthesia	2	
1-Level Standalone Lateral Lumbar Interbody Fusion (LLIF)	OR Time	1	**5**
	Muscle Dissection	1	
	Anesthesia	2	
	Fusion	1	
Open 1-Level Laminectomy	OR Time	1	**6**
	EBL	1	
	Muscle Dissection	2	
	Anesthesia	2	
MIS 1-Level Transforaminal Lumbar Interbody Fusion (TLIF)	OR Time	1	**6**
	Pedicle Screw/ Spacer	1	
	Muscle Dissection	1	
	Anesthesia	2	
	Fusion	1	
Open 3-Level Laminectomy	OR Time	1	**7**
	EBL	1	
	Muscle Dissection	2	
	Anesthesia	2	
	# Levels	1	
MIS 1-Level Transforaminal Lumbar Interbody Fusion (TLIF) and Adjacent ULBD (1 ½ TLIF)	OR Time	2	**8**
	Pedicle Screw/ Spacer	1	
	Muscle Dissection	1	
	Anesthesia	2	
	Fusion	1	
	Levels	1	
1 Level Anterior Lumbar Interbody Fusion (ALIF) + Percutaneous Pedicle Screw Fixation	OR Time	1	**8**
	# Approach	1	
	EBL	1	
	Pedicle Screw/ Spacer	1	
	Muscle Dissection	1	
	Anesthesia	2	
	Fusion	1	
MIS 2-Level Transforaminal Lumbar Interbody Fusion (TLIF)	OR Time	2	**10**
	EBL	1	
	Pedicle Screw/ Spacer	2	
	Muscle Dissection	1	
	Anesthesia	2	
	# Levels	1	
	Fusion	1	

(continued)

Table 5. (continued)

Case	Factor	Points	Total
Open 1-Level Transforaminal Lumbar Interbody Fusion (TLIF)	OR Time	1	**10**
	EBL	1	
	Pedicle Screw/ Spacer	1	
	Muscle Dissection	2	
	Anesthesia	2	
	Fusion	(1+2) =3	
MIS L3-L4 TLIF/Extension of Prior L4-S1 Fusion	OR Time	2	**10**
	EBL	1	
	Pedicle Screw/ Spacer	1	
	Muscle Dissection	1	
	Anesthesia	2	
	# Levels	0	
	Fusion	1	
	Revision	2	
Open 2-Level Transforaminal Lumbar Interbody Fusion (TLIF)	OR Time	2	**14**
	EBL	2	
	Pedicle Screw/ Spacer	2	
	Muscle Dissection	2	
	Anesthesia	2	
	# Levels	1	
	Fusion	(1+2) =3	
Open L3-L4 TLIF/Extension of Prior L4-S1 Fusion	OR Time	2	**14**
	EBL	2	
	Pedicle Screw/ Spacer	1	
	Muscle Dissection	2	
	Anesthesia	2	
	# Levels	0	
	Fusion	(1+2) =3	
	Revision	2	
Thoracic to Pelvis Fixation with 1-Level TLIF	OR Time	2	**15**
	EBL	2	
	Pedicle Screw/ Spacer	2	
	Muscle Dissection	2	
	Anesthesia	2	
	# Levels	2	
	Fusion	(1+2) =3	

group, as any values above this would likely indicate that a multilevel and/or open procedure was being performed. The invasiveness of the procedure increases with an increase in blood loss.

Pedicle Screw Placement/Interspinous Spacer

We consider the use of a spinal implant inherently invasive. Pedicle screw placement was determined to be a factor independent of the number of surgical approaches. The invasiveness of the procedure increases with an increase in the number of levels instrumented. The placement of an interspinous spacer was also considered in this category. Whether pedicle screws or an interspinous spacer, one level was assigned 1 point and more than one level at which implants were placed was assigned 2 points. A surgery involving pelvic fixation was automatically assigned 2 points. The instrumentation

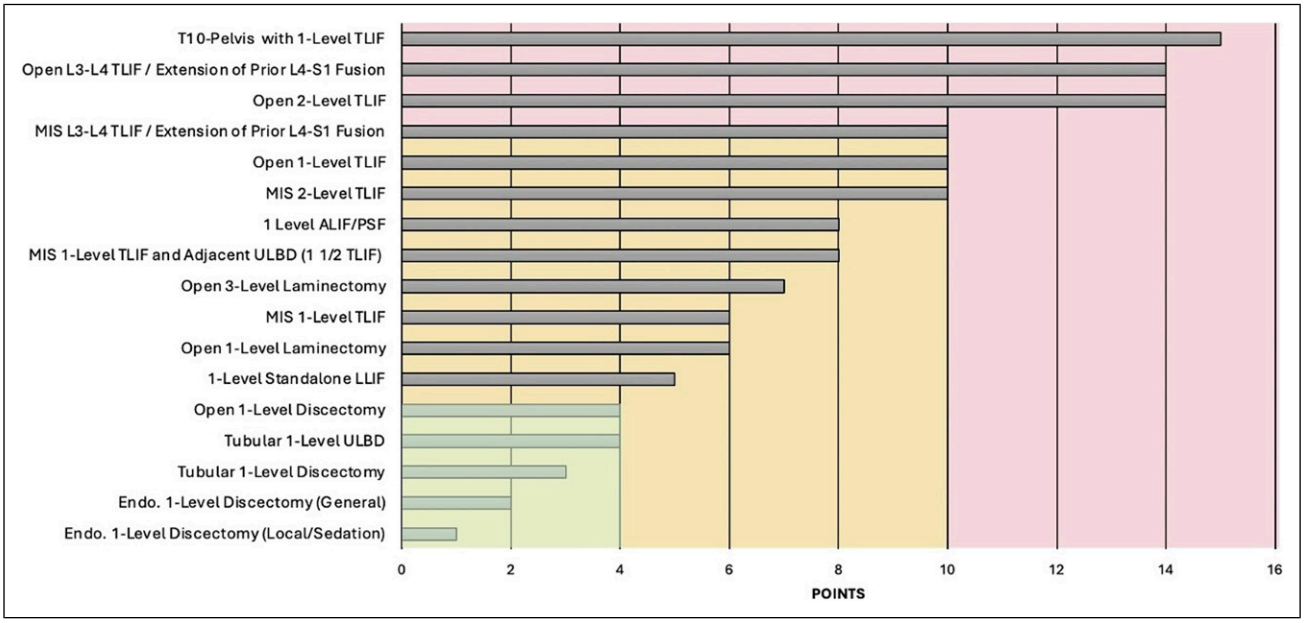


Figure 4. MISS-INC (L) spectrum for common degenerative lumbar spine surgeries based on ideal scoring. A proposed invasiveness spectrum based on intended use of the Minimally Invasive Spine Surgery Invasiveness Classification "MISS-INC (L)" stratifying common degenerative lumbar spine surgeries according to their ideal scores into minimally invasive (<5 points, green), less invasive (5–10 points, yellow), and more invasive (>10 points, red) categories

factor was framed around the implant types prevalent in degenerative lumbar MISS at the time of development (pedicle screws and interspinous spacers). Motion-preserving and joint-replacing technologies—such as lumbar total disc arthroplasty, the TOPS system, and total lumbar joint arthroplasty—were not separately scored; these can be accommodated within the instrumentation factor and represent a possible extension for future versions of the scale.

Muscle Dissection/Access

This factor was considered based on the perceived amount of muscle or soft tissue disruption required to perform the surgery. Minimal muscle violation was considered endoscopic access. Muscle splitting refers to tubular approaches, including expandable tubes, specular retractors, lateral and oblique approaches, and anterior lumbar approaches. Beyond this, the muscle detachment required in open surgery was considered a more invasive form of access.

Anesthesia

No anesthesia type was assigned 0 points, as any type of anesthesia was considered an intervention. Both local anesthetic and sedation were assigned 1 point; general anesthesia was assigned 2 points and considered more invasive, primarily due to the physiologic changes that occur during induction, maintenance, emergence, and recovery.

Number of Levels

Every surgical procedure was considered at least one level and therefore assigned 0 points. A surgery involving 2–3 levels was assigned 1 point. A surgery involving >3 levels or pelvic fixation was assigned 2 points. For example, an L4–5 discectomy was considered one level and an L4–S1 discectomy two levels. The invasiveness of the procedure increases with an increase in the number of levels of surgery performed.

Fusion Technique

A procedure in which a decompression only was performed was assigned 0 points. Interbody refers to a discectomy and placement of bone graft material with the intention to achieve fusion, with or without placement of an interbody cage; this was assigned 1 point. A posterolateral fusion technique, with presumed placement of bone graft material between the transverse

processes, was assigned 2 points. This implies an open dissection of the muscle off the facet joints and transverse processes, and not solely placement of bone graft in the posterolateral gutters. This technical point highlights the difference between decorticating the facet joints alone in minimally invasive procedures, which would not be considered a posterolateral fusion by this definition; while commonly performed, points are not assigned for decortication of the facet joints alone. If a combined technique is used, each individual element is added when scoring. For example, interbody (1 point) + posterolateral (2 points) = total (3 points).

Revision

A revision decompression and/or microdiscectomy was assigned 1 point. A revision surgery that entails removal and/or insertion of new implants was assigned 2 points. In a revision case, the number of levels is based on the additional surgery being performed; for example, a one-level TLIF adjacent to a prior two-level fusion counts as a one-level case. Revision instrumentation includes possible decompression; therefore, the points are not additive.

For the purposes of this study, degenerative lumbar cases only were used, as these encompass the majority of minimally invasive spine cases performed. Using the developed grading scale, an endoscopic 1-level discectomy was the least invasive procedure graded, and thoracic-to-pelvis fixation the most invasive.

Discussion

This study proposes a novel invasiveness classification grading scale for degenerative lumbar spine surgical procedures, derived from nine factors selected through a consensus-driven, modified Delphi process with the AO Spine Knowledge Forum – Degenerative. Our aim is to clarify subtle gradations in invasiveness among common lumbar spine surgeries by developing a standardized assessment method. Notably, several predecessor indices have been associated with clinically meaningful endpoints—for example, the Spine Surgical Invasiveness Index with surgical-site infection risk and adult spinal deformity invasiveness with major perioperative complications.[19,20] MISS-INC (L) has not yet established such associations, which represent a priority for subsequent validation.

The nine-factor structure retains ease of use while still addressing the variety in lumbar degenerative procedures. Development of this scale involved a comprehensive literature review of existing invasiveness indices, followed by multiple meetings, rounds of discussion among international spine surgeons, and iterative refinement before a consensus survey. Internal consensus refinement occurred within the AO Spine Knowledge Forum – Degenerative, while external consensus refinement was supported by an independent cohort of surgeons, specifically members of the AO Spine MISS Task Force, who graded a spectrum of common procedures with the new scale and provided iterative feedback for refinement.

To support clinical usability, we deliberately kept the grading system straightforward and focused on degenerative lumbar pathology, with plans to expand to cervical and thoracic conditions in the future. The focus was also maintained on the less invasive spectrum of lumbar spine surgeries to highlight the nuances in invasiveness among these procedures. The nine included factors—operative time, number of approaches, estimated blood loss, instrumentation, muscle dissection, anesthesia, surgical levels, fusion technique, and revision—were selected for their practicality, relevance, and ease of evaluation. Each factor was defined with clear, simple rules. For example, operative time was measured from skin incision to closure, assuming an experienced surgeon in an optimal facility, while the number of surgical approaches reflected distinct anatomical access points, regardless of the total number of incisions. While there may be institutional variability in anesthesia choice, operative time, and estimated blood loss, the assumption of an experienced surgeon in a well-equipped facility should reduce but not eliminate this variability. For this reason, inter-institutional reproducibility should be examined closely in future studies.

In the present study we excluded biochemical markers of tissue injury, which, while previously investigated, are not widely available across all cases.[21-23] Alternate novel methods to assess invasiveness have been described, including direct volumetric measurement of surgical exposure. Regev et al used this technique by measuring the amount of saline needed to fill the exposed cavity in various minimally invasive and open spinal surgical approaches, quantifying the volume of muscle tissue dissected and retracted.[24] While we acknowledge the utility of these surrogates for surgical invasiveness, it was not possible to uniformly obtain this information for all surgical cases considered, and it may represent a future area of study. The grading system was piloted across a series of hypothetical, common procedures, ranging from a simple endoscopic one-level discectomy (least invasive) to extensive thoracic–pelvic fixation (most invasive). This granularity was designed to highlight subtle differences between less invasive procedures rather than focusing only on the extremes.

Looking ahead, we envision many opportunities for future inquiry: MISS-INC (L) values can be studied in relationship with patient outcomes, complication rates, or biochemical invasiveness factors, and cost-effectiveness studies could also be considered. With this input, the classification system could be further refined and modified as necessary to maximize its

utility. The scale can also be used by individual surgeons to track their "invasiveness profile" and learning curve over time or across procedure types.

Limitations

While offering promise as a research and communication tool, some limitations should be acknowledged:

Grading introduces some subjectivity, which may be influenced by individual surgeon experience, varying surgical techniques, and regional practice patterns. Parameters such as OR time and blood loss may be difficult to assess in individual cases. Future research may address the relevance of these factors for MISS-INC (L) grading.

In its current additive, equally weighted form, the scale can exhibit ceiling effects at the more invasive end of the spectrum, where procedures of differing magnitude may share a near-maximal score. Refinement of scoring boundaries and factor weighting is anticipated as outcome data become available.

Concurrent or predictive validity for MISS-INC (L) has not yet been established (i.e., whether a higher score is predictive of a longer hospital stay), but we consider this a valuable component of future studies. Specifically, larger validation trials could integrate MISS-INC (L) with structured, measurement-based outcome-tracking systems—such as those used by Cizik et al (2012)—to precisely quantify its predictive power.[19]

Methodological guidance for consensus studies, such as CREDES (Guidance on Conducting and REporting DElphi Studies), emphasizes minimizing the influence of dominant participants and carefully managing controlled feedback between rounds.[25] Because our modified process incorporated facilitated group discussion to resolve terminological ambiguity, complete anonymity was not maintained during the refinement stages, which may introduce social-influence bias. We mitigated this by collecting independent scores before group discussion and by conducting the final agreement vote (Stage 3) anonymously. Nonetheless, residual bias cannot be excluded, and fully anonymized iterative voting would further strengthen future iterations.

MISS-INC (L) currently addresses lumbar pathology; further studies are needed to validate its utility for cervical and thoracic pathology.

Conclusion

In summary, MISS-INC (L) is a proposed, preliminary, consensus-based classification for quantifying invasiveness among minimally invasive degenerative lumbar spine procedures. It offers a practical, user-friendly framework for communication, research standardization, surgical profiling and patient counseling. It is not yet validated against clinical data or established for widespread adoption; prospective studies correlating scores with outcomes, complications, cost, and revision rates—and assessing inter-rater reliability and cross-setting reproducibility—are required before broader clinical applications can be recommended. Until such validation is established, MISS-INC (L) should primarily be used as a descriptive tool for research standardization and surgical profiling rather than as a point-of-care instrument for clinical decision-making or for reimbursement and coverage determinations.

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Ethical Considerations

Ethical approval was not required.

Author Contributions

RH, RB, YW contributed to the study's conceptualization and methodology. YW performed the data analysis by compiling the survey data at each phase. Investigation and data collection through the modified Delphi rounds and consensus meetings were performed by all authors. RH, RB, and NW drafted the original manuscript. All authors reviewed, edited, and approved the final version. RH supervised the project.

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Not applicable based on study design.

Supplemental Material

Supplemental material for this article is available online

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