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In Brief

Classification in Brief: Subaxial Cervical Spine Injury Classification and Severity Score System

Michael J. Spitnale MD, Gregory Grabowski MD

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History

Spine injuries have been described since 3000 BC in Egypt when it was illustrated in Edwin Smith's surgical papyrus [37], and many classifications for subaxial spine injuries have been developed and used in the intervening decades since Bohler [6] did so in 1929 [2-6, 9, 15, 17, 18, 25, 30, 38, 45, 47-49] (Table 1). Although most of these classifications have contributed to the understanding of spinal stability and mechanisms of injury, each classification also has at least one shortcoming that caused it to fall into disuse. The most-common shortcomings have included: lack of exclusivity to the cervical spine, use of injury mechanism, lack of consideration of neurological status, and lack of validity.

We believe that classifications used for the thoracolumbar spine are ill-suited to the subaxial spine because of the important anatomic and biomechanical differences between those anatomic locations. The different anatomic and biomechanical characteristics between the subaxial cervical spine and the thoracolumbar spine are reasons they should not be classified together. The use of injury mechanism instead of morphology is a shortcoming, as the direct reading of images requires a person to first identify a morphologic feature on imaging, then interpret this morphology into a mechanism of injury. This extra step in interpretation was thought to be overly complicated, leading to less intraobserver reliability [38, 41]. The lack of consideration with respect to the neurological status of the patient allows for a treatment decision to be made without considering the patient evaluation, which is generally an important aspect that guides intervention. Ultimately, however, the most-common shortcoming was lack of validity of the classification system, making most not generalizable or reproducible enough for practical use.

For these reasons, Vaccaro et al. [41] developed the Subaxial Injury Classification and Severity Scale (SLICS) for subaxial cervical spine injuries. This system sought to create a simpler classification system that could be used to help guide patient treatment and facilitate communication among treating physicians. SLICS includes three separate categories: the morphology, the neurologic status of the patient, and integrity of the discoligamentous complex (DLC). Each of these categories is summed for a total score that is meant to guide surgical versus nonsurgical management of the injury.

Purpose

Subaxial cervical spine injuries account for more than two-thirds of all cervical spine trauma, and these patients are considerably more likely to have neurologic symptoms compared with patients who have atlantoaxial injuries [1, 14]. Subaxial cervical spine injuries, like all injuries to the cervical spine, require emergent evaluation and

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M. J. Spitnale, G. Grabowski, University of South Carolina School of Medicine, Prisma Health Midlands – USC Orthopaedics Center, Columbia, SC, USA

M. J. Spitnale (✉), University of South Carolina School of Medicine, Prisma Health Midlands , USC Orthopaedics Center, 2 Medical Park, Suite 404, Columbia, SC, 29203 USA , Email: Michael.spitnale@gmail.com

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Table 1. Previous classification systems involving either the subaxial cervical spine, or morphologic characteristics of thoracolumbar injuries that are also used to describe similar morphologic injury characteristics of the subaxial cervical spine

Author	Notable contributions	Disadvantages
Bohler [6]	Vertebra versus neural arch injuries	Primarily thoracolumbar
Watson-Jones [45]	Wedge, comminuted, fracture dislocation identified. Importance of posterior longitudinal ligament	
Nicoll et al. [30]	Different wedge fracture types	
Kelly and Whitesides [25]	Two-column concept (anterior and posterior column)	
Holdsworth [17]	First classification based on injury mechanism; importance of posterior ligamentous complex	
Denis [9]	Three-column theory (middle column)	
Whitley and Forsyth [49]	Promoted mechanism-based classification for subaxial cervical trauma	Retrospective interpretation of an injury mechanism based on observed morphology
White and Punjabi [47, 48]	Defined spinal stability in the cervical spine based on biomechanical study	Iatrogenic injuries to cadaveric specimens, not real patient injuries.
Jacobs [18] Babcock [5]	Promoted mechanism-based classification	Not comprehensive
Allen et al. [3]	Mechanism based classification, comprehensive categories	Challenging for beginners; retrospective interpretation of an injury mechanism based on observed morphology
Harris [15]	Similar to Allen-Ferguson, but included rotational vectors and categories based on causative force vectors	Lack of gradation for compression injuries; challenging for beginners
Aebi and Nazarian [2]	Upper and lower cervical spine in same system; bony or ligamentous involvement or both	Lack of clinical relevance
Argenson et al. [4]	Rotational injuries; high interobserver reliability	Oversimplification of some flexion-distraction and extension-distraction types

communication among physicians to correctly treat the patient. Vaccaro et al. [41] sought to create this classification system to help facilitate physician communication through simpler injury morphologic characteristics, and to help predict surgical versus nonsurgical management with the summation of three different categories. Although prognostic and research utility are other common reasons to use a classification system, Vaccaro et al. [41] did not specifically address those reasons during the creation of SLICS. Identification and communication between physicians about these injuries is critical in treating patients promptly and appropriately.

Unfortunately, as will be discussed further, the SLICS system is not well validated. This lack of validation renders the primary goals of guiding treatment and facilitating physician communication for subaxial cervical spine injuries inadequate, or even potentially harmful, in the clinical setting. Where research is concerned, using an inadequately validated classification system is problematic, as it undermines the robustness of research based on it.

Description

The SLICS scale has an incorporated scoring system that helps to guide the transition from nonsurgical to surgical management based on three categories: morphologic features, integrity of the DLC, and neurologic status of the patient [41] (Table 2). This is similar to another classification system created by Vaccaro for thoracolumbar injuries, called the Thoracolumbar Injury Classification and Injury Severity Score System (TLICS) [19, 43], except that the DLC integrity in SLICS is replaced with the posterior ligamentous complex (PLC) in the TLICS system, along with some subtle differences in the individual scoring categories. The scores in SLICS are determined by an interpretation of radiographs, CT images, and MRI. Each category has a point value based on increasing severity, from 0 (least severe) to 4 (most severe). If the summative score of the three categories is less than or equal to 3, then nonsurgical treatment is recommended in SLICS [41]. If the score is 5 or greater,

Table 2. Subaxial Injury Classification and Severity Scale (SLICS) for subaxial cervical spine injuries

Injury	Score
Morphologic features	
No morphologic abnormality	0
Compression	1
Burst	2
Distraction	3
Rotational and/or translational	4
Integrity of the discoligamentous complex	
Intact	0
Indeterminate	1
Disrupted	2
Patient's neurologic status	
Intact	0
Nerve root injury	1
Complete	2
Incomplete	3
Persistent cord compression (in the setting of a neurologic deficit)	+1
Total SLICS score	0 - 10

Author recommendations based on total score: nonoperative treatment for a total score ≤ 3; operative treatment for a total score ≥ 5; for a total score of 4, a recommendation is indeterminate requiring discretion of the treating surgeon.

surgical management is recommended by the creators of SLICS. A score of 4 is indeterminate in terms of recommending for or against surgical management by the creators of SLICS. The purpose of this overall score is to maximize the likelihood of neurologic recovery if a deficit exists and/or to prevent neurologic decline if instability is present [41].

Morphologic Features

The injury morphology category is based on the injury pattern. It is scored as a 0 for no abnormality. A score of 1 is given for compression injuries and 2 for burst injuries (Fig. 1). A score of 3 is given for distraction injuries (Fig. 2). A score of 4 is given for rotational or translation injuries (Fig. 3) [41]. With distraction injuries, either the anterior or posterior columns may have remained intact. This contrasts with a rotation or translation injury, in which both the anterior and posterior structures are more likely to be compromised, according to MRI studies [41]. Therefore, rotation or translation injuries are associated with a greater degree of instability, and this is accounted for in this scoring system. An example injury that would be categorized as translational shows the disruption of both the anterior and posterior structures (Fig. 4).

Integrity of the Discoligamentous Complex (DLC)

The DLC includes the following anatomic structures: vertebral disc, anterior longitudinal ligament, posterior longitudinal ligament, ligamentum flavum, facet capsules, interspinalis muscle, and supraspinous ligaments. When there is no injury to any of these structures, a score of 0 is given, an indeterminate condition of these structures is assigned a score of 1, and injury to any of these structures is given a score of 2, which is associated with a greater degree of instability. Injury to the DLC is considered separately in the assessment of spinal stability because the healing capacity of these soft tissues is less predictable than that of bone healing, and if injury to the DLC is misjudged, it may lead to instability, deformity, and neurologic decline [41]. With the use of MR imaging, subtle signal changes on different sequences can help verify if the DLC is intact (Fig. 5). When there is a high suspicion for disruption of the DLC, but there is either poor or nonexistent imaging studies, this makes the determination of disrupted or intact DLC difficult giving this category an indeterminate score. In the setting of suspected DLC disruption based on CT images alone, additional MR imaging with obvious signal change and evidence of DLC disruption supports the presence of instability (Fig. 6).

Neurologic Status

A clinical evaluation of the patient and determination of his or her neurologic status is important, along with correlating the imaging studies to the observed clinical presentation [41, 47]. Neurologic status is scored as a 0 for a patient without neurologic impairment, 1 for a nerve root injury, 2 for a complete spinal cord injury, and 3 for an incomplete spinal cord injury; an additional point can be added to any of these scores if continuous cord compression is observed in the setting of a neurologic deficit.

With three categories, and up to five grades in each category, this classification system can be difficult to use in practice because of the wide variations in score tallying. The studies discussed below have sought to validate this classification system, but they have not found it to have a high level of interobserver reliability, meaning that the scoring system is not consistent enough between observers to effectively and accurately communicate a given subaxial spine injury. Because of this lack of reliability, it should not be used clinically and means that research based on the classification system may be misleading.

Validation

To justify widespread use of the SLICS, a high degree of interobserver and intraobserver reliability would be

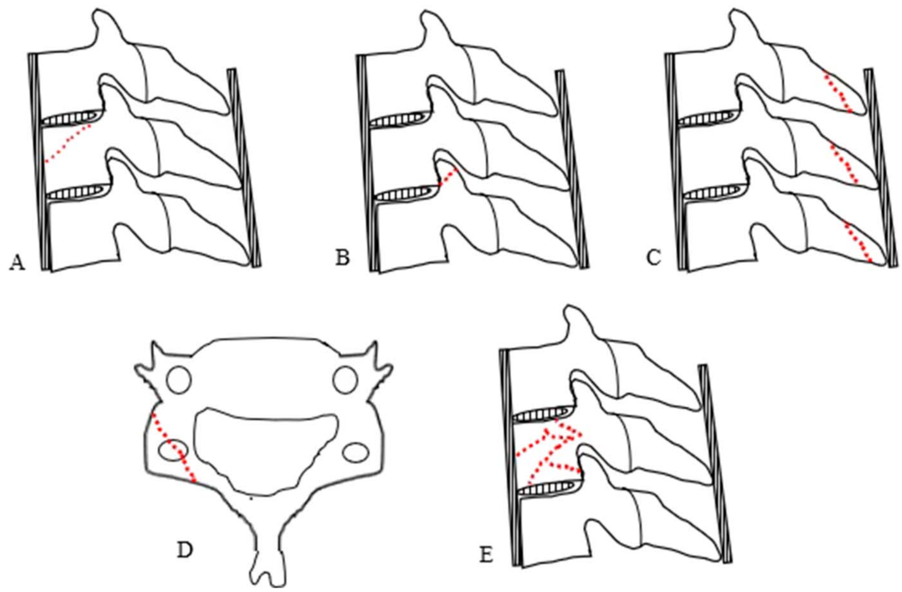

Fig. 1 A-E Illustrations of example injuries that would fall into the compression morphologic category of the Subaxial Injury Classification and Severity Scale. (**A**) Simple compression fracture, (**B**) simple nondisplaced superior articulating process fracture, (**C**) spinous process fractures, (**D**) lateral mass fracture. (**E**) An example burst fracture with or without retropulsion would be placed into the burst morphologic category. Dotted lines represent fracture lines.

critical; unfortunately, this has not been demonstrated. Five studies have looked at the interobserver and/or intraobserver reliability of SLICS as a whole and its three categories separately [24, 28, 39, 41, 44] (Table 3). To our knowledge, only the developers [39, 41] of the system and a single institution study in South Korea [28] have written supportively in terms of its interobserver reliability, while others found inconsistent intra- and interobserver reliability across the three domains of the classification (morphology, DLC, and neurologic status) and the overall SLICS score [24, 44].

At the time the SLICS classification was created, Vaccaro et al. [41] demonstrated the following interobserver reliability ratings for the these SLICS categories: Moderate for injury morphology, fair for the DLC category, substantial for neurologic status, slight to fair for

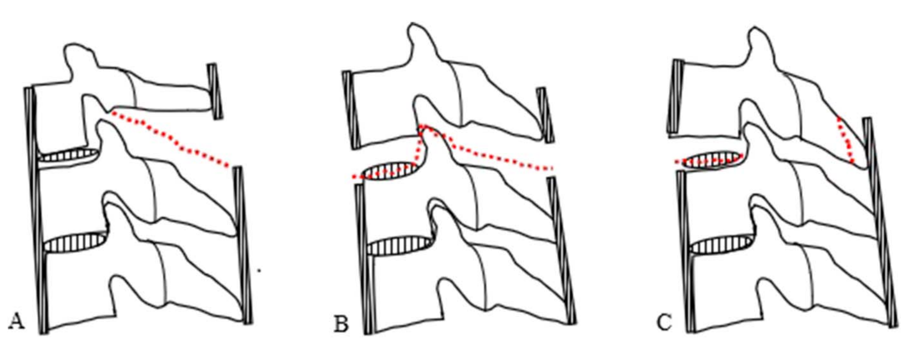

Fig. 2 A-C Illustrations of three different types of injuries that would fit into the distraction category of morphologic features. (**A**) Injury to the posterior elements causing distraction of the two adjacent spinous processes. (**B**) Injury to the discoligamentous complex, anterior, and posterior ligaments with distraction between the two vertebra. (**C**) Spinous process fracture with superior distraction of the anterior vertebral body. Dotted lines represent ligamentous disruption or fracture lines.

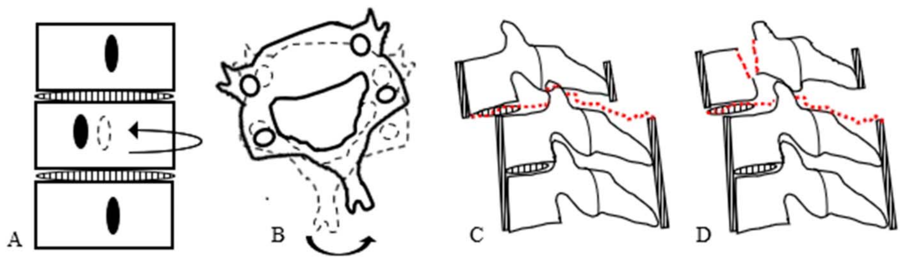

Fig. 3 A-D Illustrations of four different types of injury patterns that would fit into the rotational/translational category of morphologic features. (**A**) Coronal plane view of a vertebral body segment with rotational malalignment of the middle segment relative to the superior and inferior vertebrae based on the change in orientation of the spinous process. (**B**) Axial plane view of an inferior vertebra, solid line, with rotational deformity relative to the inferior vertebra, dashed line. (**C**) Translational injury showing facet dislocation, a superior articular process fracture, and disruption of both the anterior and posterior ligamentous. (**D**) Fracture of the pedicle with translation of the anterior fragment and disruption of both the anterior and posterior ligamentous structures. Dotted lines represent ligamentous disruption or fracture lines.

the overall score, and moderate for the SLICS management recommendation (intraclass correlation coefficient (ICC) = 0.58; κ = 0.44). Although the authors suggested there was a high construct validity because interrater agreement for treatment recommendations based on the SLICS algorithm was 93.3%, low ICC and kappa values suggest that a substantial portion of patient injuries were mischaracterized, which is also evident by the contradictory ICC and kappa values of the overall score category that suggests fair (ICC = 0.71) and slight (κ = 0.2) agreement, respectively. Ideally, each category (and not just the overall score) should have good reliability, and if this is not the case, it means that there may be elements of each injury pattern that are missed. As such, this system is not suitable for clinical care or research.

In an external validation study, Kanagaraju et al. [24] compared SLICS with the Allen-Ferguson classification. They found only slight-to-fair interobserver reliability and poor-to-fair intraobserver reliability for the overall SLICS score; the highest level of agreement for the individual categories was the neurological status, which was only rated as fair (ICC = 0.46; κ = 0.28). This study appears to be more comprehensive than the other four studies because of the number of patients involved, the number and types of observers, the results for both interobserver and intraobserver reliability, the reporting of both ICC and kappa values, the geographical variability, and the lack of original SLICS authors involved in the study (Table 4). Another external validation study by Van Middendorp et al. [44], which also did not have any contributing developer of SLICS in the study byline, also demonstrated only fair-to-moderate interobserver reliability within the morphology and DLC integrity categories. However, we note that it did show substantial agreement for the overall SLICS score comparable to Vaccaro's results [41, 44]. Van Middendorp et al. [44] only reported ICC values for interobserver data, and they had no data regarding intraobserver reliability.

Stone et al. [39] and Lee et al. [28] also sought to validate the SLICS classification. Stone et al. [39] demonstrated excellent agreement in every category and overall SLICS score for both interobserver and intraobserver reliability, but that study included developers of the SLICS system. In addition, Stone et al. [39] had the smallest number of observers, and its geographical diversity was second only to Lee et al. [28]. Lee et al. [28] showed

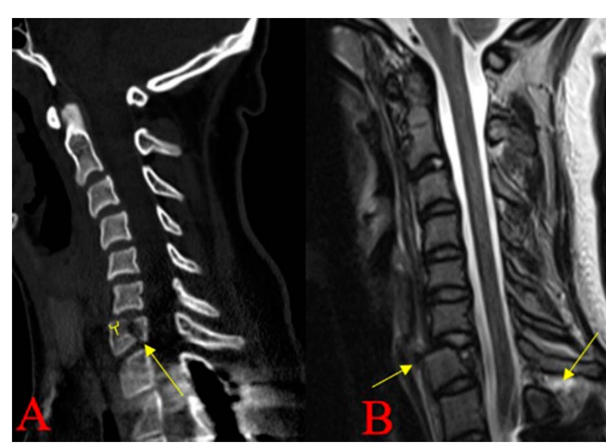

Fig. 4 A-B (**A**) Sagittal CT imaging example of a translational injury demonstrating by a C7 vertebral body fracture with retrolisthesis of the C6 vertebra relative to the C7 vertebra and (**B**) Sagittal MR images showing disruption of the anterior and posterior ligamentous structures.

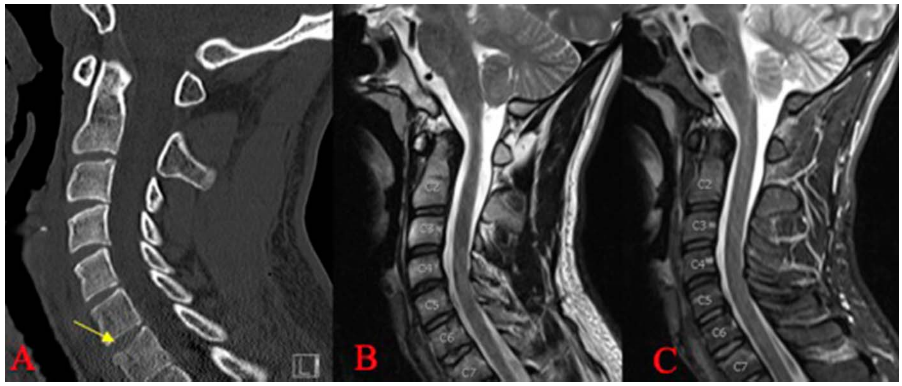

Fig. 5 A-C (**A**) Sagittal CT imaging example of a compression fracture of C7, with sagittal (**B**) MR-STIR sequence and (**C**) MR-T2-weighted sequence showing no disruption of the discoligamentous complex.

substantial-to-excellent agreement in every category of the interobserver and intraobserver reliability, except for the moderate agreement in the DLC integrity category for interobserver data. However, a shortcoming of Lee's study, which might contribute to the high reliability they observed, was that the patients who were selected were only those who were treated nonoperatively [28].

Several other studies have also been done to look at the correlation of the SLICS score with surgical versus nonsurgical treatment of patients, with varying results [7, 8, 11, 16, 20-23, 33-35, 44, 46]. Although some of these are high-quality studies, they fail to address the lack of reliability inherent within the SLICS system that the abovementioned studies have reported.

The biggest limitation of the SLICS system is the lack of supportive data from a higher quality, more generalizable external validation study. For these reasons, along with the low intra- and interobserver reliability observed in the higher-quality validation studies of the SLICS system [24, 44], we recommend that this classification system not be used for communication among physicians or to guide treatment.

Limitations

As with any classification system, and especially given the evolving history of previous classification systems for traumatic subaxial cervical spine injuries, there are limitations to SLICS. The most obvious limitation is the poor interobserver reliability of morphologic characteristics. Vaccaro et al. [41] theorized that this would increase with time and increased familiarity with the classification system, but ultimately the opposite has been true in the validation studies that followed [24, 44]. The morphologic characteristic category was created because other classifications focusing on the mechanism were complex, indirect evaluations of the injury and had numerous categories to

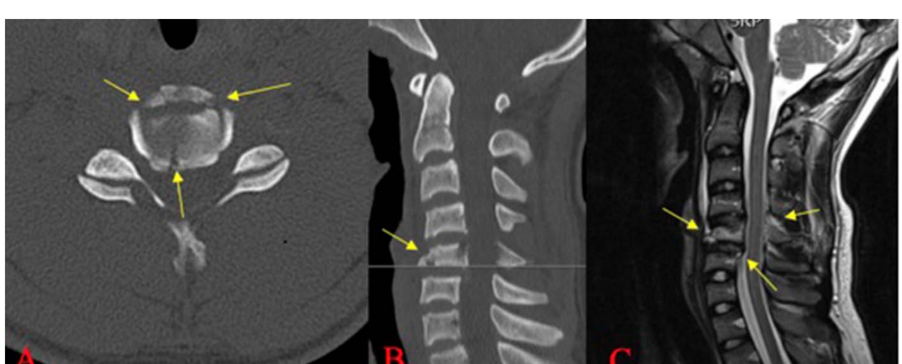

Fig. 6 A-C CT imaging example of a C5 burst fracture in the (**A**) axial and (**B**) sagittal plane with (**C**) sagittal MR imaging showing disruption of the discoligamentous complex.

Table 3. Interobserver and Intraobserver ICC and kappa values for different validation studies of SLICS

Study	Interobserver or intraobserver data	Morphology		Integrity of DLC		Neurologic status		Total SLICS score	
		ICC	Kappa	ICC	Kappa	ICC	Kappa	ICC	Kappa
Vaccaro et al. [41]	Interobserver	0.57	0.51	0.49	0.33	0.87	0.62	0.71	0.20
	Intraobserver	0.75	0.65	0.66	0.50	0.90	0.72	0.83	0.39
Stone et al. [39]	Interobserver	0.86		0.90		0.98		0.79	
	Intraobserver	0.94		0.94		0.99		0.98	
Lee et al. [28]	Interobserver	0.60		0.30		1.0		0.78	
	Intraobserver		0.92		0.88		1.0		0.96
Van Middendorp et al. [44]	Interobserver		0.29		0.46		0.70	0.78	
	Intraobserver								
Kanagaraju et al. [24]	Interobserver	0.32	0.21	0.32	0.21	0.46	0.28	0.41	0.15
	Intraobserver	0.33	0.41	0.59	0.39	0.78	0.65	0.16	0.23

ICC = intraclass correlation coefficient; SLICS = Subaxial Injury Classification and Severity Scale; DLC = discoligamentous complex.

apply when classifying a patient's injuries. The morphology section of this classification was intended to lead to a simpler, more-direct interpretation based on imaging [41], and so it might be easier to remember. Unfortunately, it appears that this difference did not improve the performance of the new classification. Its poor reliability may be explained by the fact that the injury's morphology was oversimplified, leading to mischaracterizations of injury patterns, which also led to the poor reliability of the overall score that integrated this morphology category.

Another limitation regarding the validation of the SLICS classification is the imaging. A study to determine the utility of CT alone versus CT and MRI in calculating the SLICS score showed higher interobserver reliability with the CT and MRI analysis [29]. Some validation studies did not state whether full CT and MR images were available for all patients [24, 28, 39, 41, 44], which could have influenced the findings in important ways.

When specific injuries patterns are encountered using the SLICS algorithm that result in a treatment recommendation for nonoperative care or when the injury falls into the indeterminate category, this presents yet another limitation to the classification system (Table 5). Although the list provided in the table shows some common scenarios

Table 4. Summary of the different validation studies done for the SLICS classification and their notable study characteristics

Study	Patient cases	Number and type of observers	Geographical diversity of where observers work	CT/MRI availability for each patient case	Case selection method	Original SLICS authors involved?
Vaccaro et al. [41]	11	20 (five neurosurgeons, 15 orthopaedic spine surgeons)	Five countries	Not reported	Self-selected	Original article
Stone et al. [39]	50	Five fellowship-trained spine surgeons	Two countries	100% for CT, 70% for MRI	Consecutive case series	Yes
Lee et al. [28]	75	Three (one spine surgeon, one resident, one radiologist)	South Korea only, single institution	100% for both CT and MRI	Cases selected for clarity, only operative cases	No
Van Middendorp et al. [44]	51	12 (five fellowship-trained spine surgeons, seven spine fellows)	Nine countries	100% CT, 41% MRI	Consecutive case series	No
Kanagaraju et al. [24]	34	13 spine surgeons from STSG ISCS	Four countries	Not reported	Consecutive case series	No

SLICS = Subaxial Injury Classification and Severity Scale; STSG ISCS = Spine Trauma Group of the International Spinal Cord Society.

Table 5. A list of specific injuries that would carry a nonoperative or indeterminate recommendation from the SLICS algorithm, which would otherwise be treated surgically based on commonly accepted surgical indications in the available evidence [10, 12, 13, 26, 27, 31, 32, 36, 40]

Example injury	Total SLIC Score
Burst fracture (2), with a nerve root injury (1), with or without continuous cord compression (+1)	3-4
Complete (2) or incomplete (3) spinal cord injury with indeterminate DLC injury (1)	3-4
Compression fracture (1) with a complete (2) or incomplete (3) spinal cord injury	3-4
DLC injury (2) with severe kyphosis	2
DLC injury (2) with nerve root (1) or complete spinal cord injury (2)	3-4
Floating lateral mass (compression = 1, DLC injury = 2), with or without a nerve root injury	3-4
Other facet fractures without observed distraction/translation/rotation components, and with varying degrees of neurological deficit	1-4

SLICS = Subaxial Injury Classification and Severity Scale; DLC = discoligamentous complex.

where SLICS is limited, it is not comprehensive and does not address injuries to other surrounding structures in the cervical spine, such as the vertebral artery. Some evidence supports the decision to pursue operative treatment in the specific examples given, along with the commonly supported surgical indications including decompression of the spinal cord, stabilization to keep injuries from progressing, and deformity correction [10, 12, 13, 26, 27, 31, 32, 36, 40]. When looking at these specific injury patterns and supportive evidence for operative treatment, it is easy to see how the use of SLICS could lead to poor treatment choices when treating physicians try to communicate using an imperfectly validated classification. The limitations of this classification system ultimately led Vaccaro to create the AO Spine Subaxial Cervical Spine Classification system, which remains under investigation [42].

Conclusions

The SLICS scale is the first subaxial cervical spine injury classification that includes the morphologic characteristics of the injury and a neurologic evaluation of the patient. It incorporates an evaluation of stability, the patient, and the injury's morphology. Although a few studies showed good interobserver reliability with this classification [26, 28, 39], those studies are of lower quality than some more-recent studies that have questioned the intra- and interobserver reliability of this system [39, 44]. Because of this, we cannot recommend its use in clinical practice or research until high-quality studies demonstrate it to be reproducible across a range of users' experience levels and clinical settings.

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