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Review Article

Spine Trauma Classifications: Historical, Current, and Emerging Perspectives for Radiologists

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Abstract

The spine serves as a protective, load-bearing, and stabilizing axis for the body. Trauma can cause significant damage to spinal structures, potentially resulting in severe neurological dysfunction and disabilities such as paraplegia or quadriplegia. Early and accurate diagnosis of these injuries is important, with computed tomography and magnetic resonance imaging being important for recognizing these injuries and guiding timely treatment to minimize disability. Radiologists play a critical role in assessing spine trauma to determine stability, which informs the need for nonoperative or operative management. Trauma classification systems are vital for uniform communication between radiologists and surgeons, aiding in decision-making. Various classifications exist for cervical, thoracolumbar, and sacral trauma, each with advantages and limitations. Understanding these classification systems is essential for guiding diagnosis, treatment, and prognostication. Over the years, these systems have evolved, reflecting advancements in medical knowledge, imaging technology, and clinical practices. Contemporary classification systems have addressed the limitations of previous systems. Vaccaro et al proposed the "Thoracolumbar Injury Classification and Severity Score (TLICS)" in 2005 and the "Subaxial Cervical Spine Injury Classification System" in 2007. These classifications focus on injury morphology, the integrity of the posterior ligamentous complex or discoligamentous complex, and the patient's neurologic status. The Arbeitsgemeinschaft für Osteosynthesefragen (AO) founded the "Spine Classification Group" to review the "AO-Magerl classification" and create an extensive system for the whole spine. This system focuses on fracture morphology, neurological status, clinical modifiers, and facet joint injury. The TLICS system is straightforward and easy to use in clinical practice, while the AOSpine system is more comprehensive and reliable. As classification systems evolve, collaboration among radiologists, spine surgeons, and researchers will be essential. By embracing advancements in imaging technology and incorporating new clinical data, the field of spine trauma classification can achieve greater accuracy and consistency, ultimately enhancing patient care and outcomes.

Keywords
- spine trauma
- TLICS
- AO
- CT
- MRI

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Introduction

The spine serves as a protective, load-bearing, and stabilizing axis for the body. Even in a healthy spine, the trauma inflicted can cause damage to spinal structures, potentially resulting in severe neurological dysfunction and disabilities such as paraplegia or quadriplegia. Early and accurate diagnosis of these injuries is important. Computed tomography (CT) and magnetic resonance imaging (MRI) are important for recognizing these injuries, guiding timely treatment, and minimizing disability.[1] The responsibility of a radiologist in assessing spine trauma is important for determining the balance of the injured spine, which informs whether nonoperative or operative management is required. Spinal instability can result in deformity, pain, and neurological deficits. Importantly, a normal neurological examination does not rule out spinal injury. While conscious and alert patients can be examined for neurological deficits and associated complaints, this examination becomes challenging in unconscious or obtunded patients.[2] Imaging plays a vital role by providing detailed information on both osseous and nonosseous injuries. Trauma classification systems play an important purpose in establishing a uniform dialog between radiologists and surgeons, aiding in the decision-making process. Various classifications have been developed for cervical, thoracolumbar, and sacral trauma, each with its own advantages and limitations. A thorough understanding of various classification systems is essential to guide diagnosis, treatment, and prognostication. Over the years, these classification systems have evolved, reflecting advancements in medical knowledge, imaging technology, and clinical practices.

An ideal grading system should have a consistency between being detailed and user-friendly. It should ensure consistency across different imaging modalities and observers without being overly simplistic or excessively complex for everyday use. Essentially, the system must accurately distinguish between stable and unstable injuries. This article dives into the chronological development of these classifications, evaluating their ancestral roots, current applications, and the promising new methodologies on the horizon. By evaluating the strengths and limitations of each system, this review aims to equip radiologists with the essential insights to course through the sophisticated terrain of spine trauma, ultimately improving patient care and outcomes.

Evolution of Spine Trauma Classifications and Historical Perspective

Subaxial Cervical Spine Trauma Classification

The “Arbeitsgemeinschaft für Osteosynthesefragen (AO) Spine Society” classifies the spine into four parts: upper cervical (C0-C2), subaxial (C3-C7), thoracolumbar, and sacral.[3] The majority of cervical spine injuries occur below the axis vertebra.[4] C3 to C6 vertebrae are akin in anatomy (small vertebral bodies and spinous processes with vertebral foramina housing the vertebral artery and veins), while C7 has distinct features (larger vertebral bodies, non-bifid spinous process, and its foramina only housing veins).[5] The discoligamentous complex (DLC) includes various ligaments and the intervertebral disk, which together resist compressive, distraction, and translation forces, ensuring spinal stability and spinal cord protection.[5]

The classification of subaxial cervical spine trauma has seen considerable development, with multiple systems proposed to evaluate and manage these injuries effectively. Early pioneers such as White et al, Allen et al, and Harris et al devised stability checklists grounded in biomechanical principles.[6–8] These systems, however, were primarily based on radiographic evaluations, which suffer from the inherently low sensitivity of the modality in identifying fractures. Anderson et al introduced the “Cervical Spine Injury Severity Score,” an approach based on a “20-point scale” and a unique “four-column spinal model” comprising “anterior, posterior, right lateral, and left lateral columns.” Notably, this classification system did not consider the patient’s neurological status.[9] A common theme in these early systems was the motion segment approach, where each spinal segment was evaluated independently, with anterior and posterior ligaments contributing to stability during extension and flexion movements, respectively.

Thoracolumbar Spine Trauma Classification

Being the most frequently injured segment of the spine, this segment of the spine has received extensive research and numerous classification systems over the past century, which have evolved significantly, reflecting advancements in medical understanding and imaging technologies. Bohler pioneered the categorization of “thoracolumbar spine injuries” based on “fracture morphology and the mechanism of injury,” setting the stage for future classifications.[10] Less than a decade later, Watson-Jones introduced a new scheme that stressed the intactness of the “posterior ligamentous complex” (PLC), an important determinant of stability.[11] Building on these perspectives, Kelly and Whitesides were the first to propose a two-column approach.[12] Their classification system was simple and included only a few categories. Holdsworth’s system was groundbreaking in identifying the PLC as key to spinal stability, describing five types of fracture morphologies and dislocations with corresponding posterior element injuries. However, neurological injury was not considered a modifier in Holdsworth’s system.[13]

The advent of CT marked a turning point in spinal injury classification. Denis expanded Holdsworth’s “two-column model” into a “three-column model,” dividing the spine into the “anterior column (the anterior two-thirds of the vertebral body), the middle column (the posterior one-third of the vertebral body), and the posterior column (including the posterior elements and ligament complex)” (►**Fig. 1**).[14] Denis further clarified the term PLC to include the “posterior longitudinal ligament, ligamentum flavum, and the inter- and supraspinous ligaments.” MRI emerged as the superior modality for directly visualizing and evaluating these ligament structures. Building on Denis’s work, McAfee et al simplified the three-column model and included CT as a modality of evaluation. However, their classification system

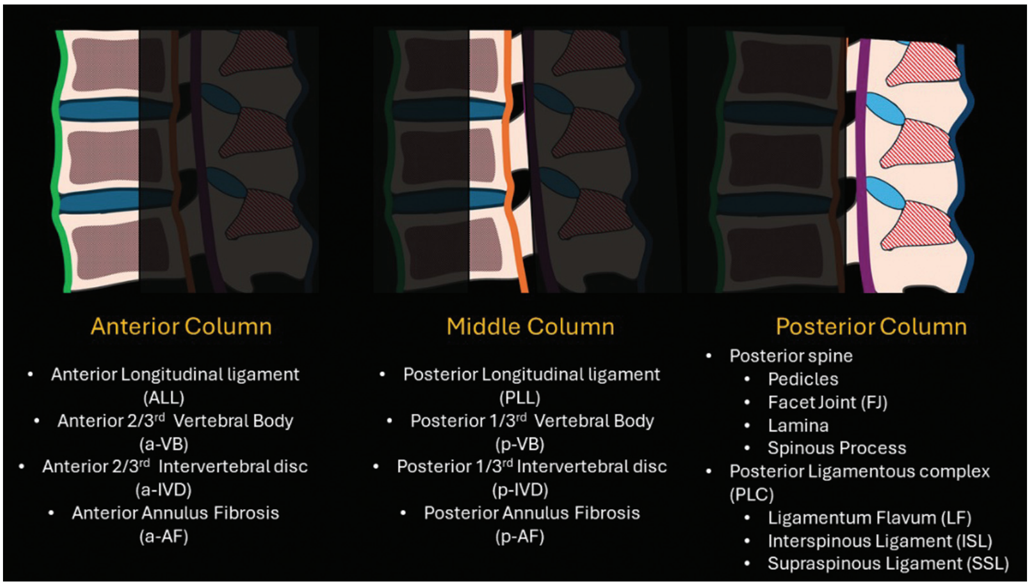

Fig. 1 A graphic illustrating the Denis classification system, highlighting the three-column model.

was not widely adopted.[15] Ferguson and Allen refined the nomenclature from "three columns" to "three elements" to more accurately describe the biokinetics of the spine, considering determinants of spinal stability and functional outcomes such as pain, deformity, and functional independence.[16]

McCormack et al analyzed treatment failures in 28 cases, developing a weighted system for preoperative use. Their system considered the degree of "vertebral body comminution, displacement and distribution of fractured fragments, and severity of kyphotic deformity" as imaging modifiers. They assigned a total of 9 points, recommending surgical fixation for scores greater than 7, though preoperative neurological status was not included as a modifier.[17] In 1994, the AO classification was established following a review of 1,445 spinal injuries across multiple centers by Magerl et al. This "pathomorphological system" evaluated morphological stability and instability using the 3-3-3 method of AO classification—"three types of injuries with three groups, each group having three subgroups, resulting in 27 individual subgroups describing various injury patterns." However, the exhaustive and extensive descriptions limited the system's utility.[18]

Contemporary Classification Systems

Subaxial Cervical Injury Classification System and Thoracolumbar Injury Classification System

Previous classification systems had several fundamental limitations. First, they were often too complex to be useful in routine clinical practice. Second, many did not include certain anatomical or physiological factors crucial for "clinical decision-making," such as PLC or the patient's neurological status. Third, most did not guide treatment based on modern diagnostic and therapeutic techniques.

To address these limitations, Vaccaro et al and the "Spine Trauma Study Group" proposed a new approach to "thoracolumbar and subaxial cervical spine injuries," which the spine surgery community has widely embraced. Vaccaro et al introduced the Thoracolumbar Injury Classification System (TLICS) in 2005 and subsequently the Subaxial Cervical Injury Classification System (SLICS) in 2007 (►**Tables 1** and **2**).[19,20] These classifications focused on three major variables, which are independent predictors of clinical outcomes: (1) the injury morphology determined by the pattern of disruption seen in

Table 1 TLICS (Thoracolumbar Injury Classification and Severity Score) classification

Morphology	"Compression"	1
	"Burst"	2
	"Rotation/translation"	3
	"Distraction"	4
PLC	"Intact"	0
	"Indeterminate"	2
	"Injured"	3
Neurologic	"Intact"	0
	"Nerve root involvement"	1
	"Complete cord injury"	2
	"Incomplete cord injury"	3
	"Cauda equina syndrome"	3
Management	"Nonsurgical"	0–3
	"Surgical or nonsurgical"	4
	"Surgical"	> 4

Abbreviation: PLC, posterior ligamentous complex.

Table 2 SLICS (Subaxial Injury Classification and Severity Score) classification

Morphology	"Compression"	1
	"Burst"	2
	"Distraction (facet perch, hyperextension)"	3
	"Rotation/translation (facet dislocation, unstable teardrop or advanced stage flexion compression injury)"	4
DLC	"Intact"	0
	"Indeterminate (isolated interspinous widening, magnetic resonance imaging signal change only)"	1
	"Injured (widening of disc space, facet perch or dislocation)"	2
Neurologic	"Intact"	0
	"Nerve root involvement"	1
	"Complete cord injury"	2
	"Incomplete cord injury"	3
	"Continuous cord compression in setting of neurological deficit (NeuroModifier)"	+1 = 1
Management	"Nonsurgical"	0–3
	"Surgical or nonsurgical"	4
	"Surgical"	> 4

Abbreviation: DLC, discoligamentous complex.

imaging studies, (2) the integrity of the PLC or DLC, and (3) the patient's neurologic status.

1. Injury/fracture morphology

Fracture patterns are described by any of the three morphologic descriptors given by "Magerl's AO thoracolumbar injury classification"[18–20]: (1) compression, (2) translation/rotation, and (3) distraction" (►**Fig. 2**).

Compression: A compressive injury occurs when axial loading affects the vertebral body. Mild cases show simple compression fractures with anterior wall buckling and increased kyphosis. Severe cases involve posterior cortex failure and retropulsion, known as burst fractures (►**Figs. 3**–**6**). Lateral angulation on an anteroposterior radiograph may indicate added instability. Modifiers like axial, flexion, or lateral further specify the injury.

Rotation/Translation: Shear or torsional forces can cause this injury and result in substantial instability as compared with compression fracture alone. These injuries lead to horizontal misalignment of spinous processes and pedicles of the involved levels, which CT or MRI can identify. Facet jumps, fractures, or dislocations are the other findings (►**Figs. 7** and **8**).

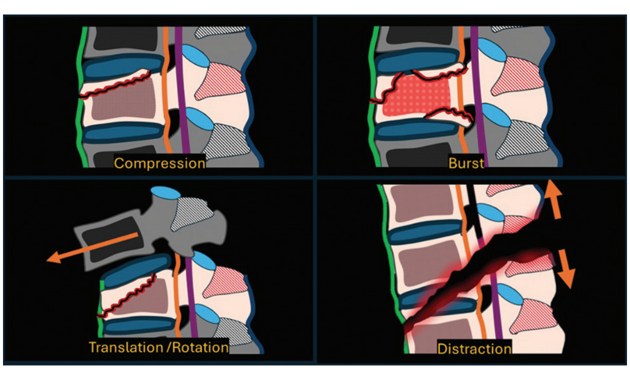

Fig. 2 A graphic depicting the three morphological descriptors of Thoracolumbar Injury Classification System (TLICS).

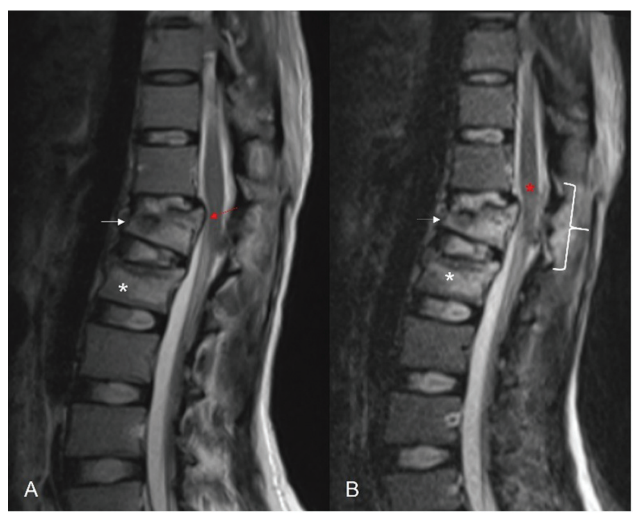

Fig. 3 Sagittal T2-weighted (T2W) (**A**) and short tau inversion recovery (STIR) (**B**) magnetic resonance (MR) images reveal a burst fracture (white arrows) of the D12 vertebral body involving the upper-end plate, accompanied by a posterior cortical fracture and a suspected posterior longitudinal ligament injury (red arrow). There is a definite injury to the ligamentum flavum and interspinous ligaments (white bracket). The posterior vertebral cortex is compressing the conus medullaris, resulting in focal edema (red asterisk). Additionally, an anterior wedge compression fracture of L1 is observed (white asterisk). Thoracolumbar Injury Classification System (TLICS): 9 points (surgical management recommended). Arbeitsgemeinschaft für Osteosynthesefragen (AO) Spine: D12 is classified as A4-N3, indicating an unstable fracture with significant neurological involvement requiring stabilization, while L1 is a stable compression injury (A1-N0) likely managed conservatively.

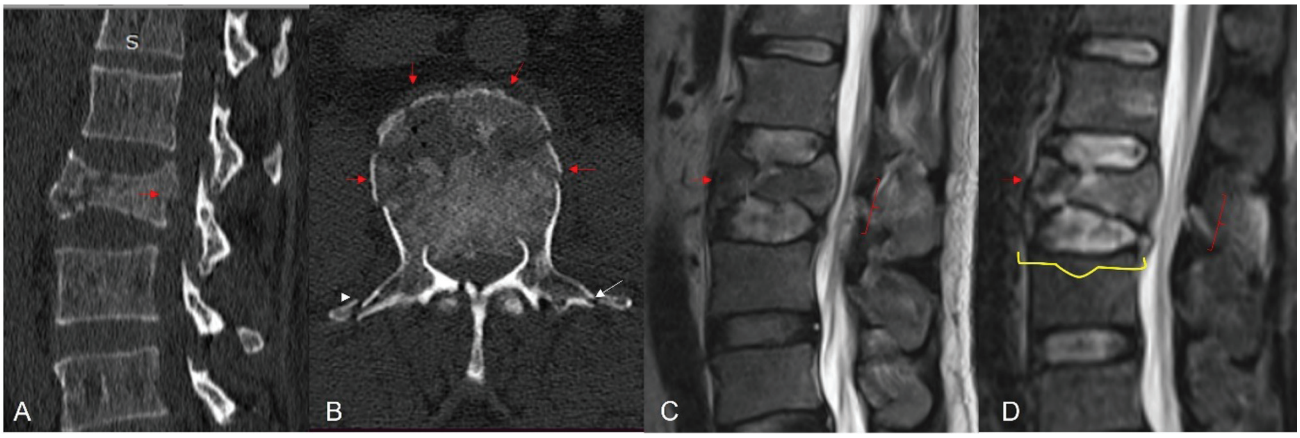

Fig. 4 Computed tomography (CT) bone window sagittal reformatted (**A**) and axial (**B**) images display a complete burst fracture (red arrows) of the L2 vertebral body and bilateral transverse process fractures (white arrows). Sagittal magnetic resonance (MR) images—T2-weighted (T2W) (**C**) and short tau inversion recovery (STIR) (**D**)—reveal a complete burst fracture with definite ligament complex injury (red and yellow brackets) involving the ligamentum flavum, interspinous ligament, anterior longitudinal ligament, and posterior longitudinal ligament. Thoracolumbar Injury Classification System (TLICS): 6 points (surgical stabilization required). Arbeitsgemeinschaft für Osteosynthesefragen (AO Spine): L2 classified as A4-N0, indicating an unstable fracture with severe ligamentous injury that necessitates operative management to restore stability and prevent further complications.

Distraction: A distraction injury is featured by the separation of one part of the spinal column from another, forming a gap. The key identifier of this morphology is the disconnection between the rostral and caudal components of the spinal column. These are typically very unstable as they involve 360-degree disruption of the spinal column, causing angulation, which can be assessed using sagittal and coronal planes on cross-sectional imaging. For descriptions of "distraction injuries," prefixes like "extension" or "flexion" may be used, and postfixes like compression or burst may be used for more detailed characterization (►**Fig. 9**).

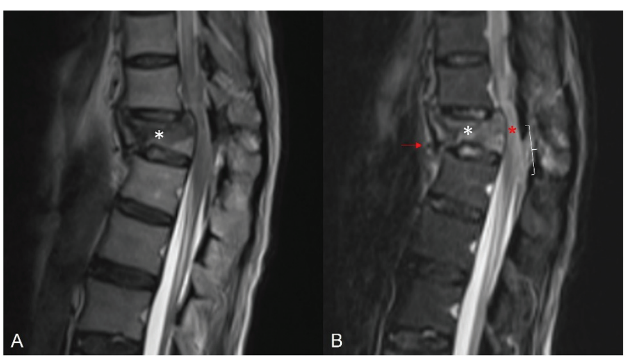

Fig. 5 Sagittal T2-weighted (T2W) (**A**) and short tau inversion recovery (STIR) (**B**) magnetic resonance (MR) images demonstrate a complete burst fracture (white asterisk) of the D11 vertebral body. There are anterior and posterior cortical fractures, along with definite injuries to the anterior longitudinal ligament and posterior longitudinal ligament (red arrow), as well as ligamentum flavum and interspinous ligaments (white bracket). The posterior vertebral cortex is compressing the conus medullaris, resulting in focal edema (red asterisk). Thoracolumbar Injury Classification System (TLICS): 9 points (surgical management required). Arbeitsgemeinschaft für Osteosynthesefragen (AO Spine): D11 classified as A4-N3, indicating a highly unstable fracture with neurological involvement and significant ligamentous injury, necessitating surgical stabilization and decompression to protect the spinal cord and restore stability.

A combination of the three morphologic descriptors is often the best approach for complex fractures. For instance, a severe distraction injury might also involve compression and translation components, called a "distraction-translation-compression" injury, or a rotational injury might include a "burst fracture (rotation burst fracture)."

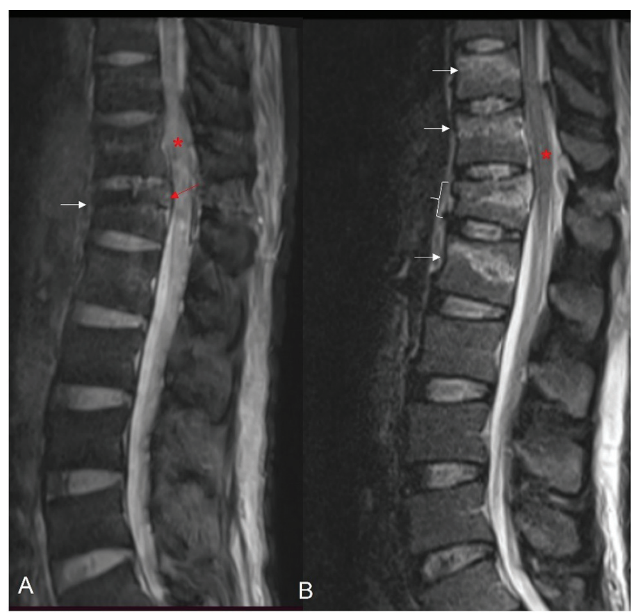

Fig. 6 Sagittal gradient echo (**A**) and short tau inversion recovery (STIR) (**B**) magnetic resonance (MR) images depict multiple wedge impaction fractures (white arrows) of dorsal vertebral bodies involving the upper-end plates. There is a posterior cortical fracture of D12 (red arrow) with anterior wedging (white bracket). The posterior vertebral cortex of D12 is compressing the conus medullaris, resulting in focal edema (red asterisk). Thoracolumbar Injury Classification System (TLICS): 5 points (indicating likely surgical management). Arbeitsgemeinschaft für Osteosynthesefragen (AO Spine): D12 classified as A3-N3 (unstable with neurological compromise), while dorsal wedge fractures are A1-N0-M0 (stable, managed conservatively).

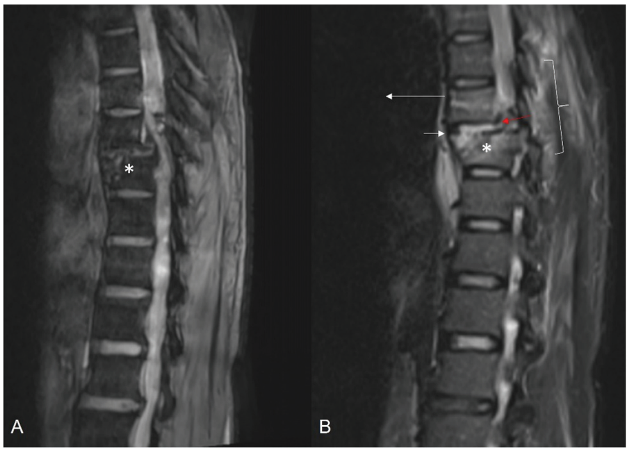

Fig. 7 Sagittal gradient echo (**A**) and short tau inversion recovery (STIR) (**B**) magnetic resonance (MR) images reveal grade 1 anterior listhesis of the T9 vertebral body over T10 (long white arrow), indicating a translational injury. The T9 vertebral body displays fractures of the upper endplate and body (white asterisk) with anteriorly displaced fragments. There is associated disruption of the anterior longitudinal ligament (white short arrow), posterior longitudinal ligament (red arrow), ligamentum flavum, interspinous ligaments, and supraspinous ligaments (white brackets), suggesting anterior and posterior osseoligamentous disruption. Thoracolumbar Injury Classification System (TLICS): 9 points (surgical management required). Arbeitsgemeinschaft für Osteosynthesefragen (AO Spine): T9-T10 classified as C-N4, indicating a highly unstable translational injury with osseoligamentous disruption.

2. PLC/DLC integrity

The PLC consists of the supraspinous ligament, interspinous ligament, ligamentum flavum, and facet joint capsules. It is crucial for preventing excessive "flexion," "rotation," "translation," and "distraction" of the spine, earning it the nickname "posterior tension band." Its significance is highlighted by the fact that once the PLC is torn, surgery is often necessary due to its less healing capability. The intactness of the PLC is classified as "intact, indeterminate, or disrupted," which can be assessed through imaging. In SLICS, the concept of DLC is used instead of PLC. The DLC is important for maintaining cervical spine stability under normal physiological loads.

3. Neurological status

Neurological status is an important measure of the intensity of spinal trauma. It has a crucial role in surgeon decision-making. The most exigent condition concerning neurologic status is "incomplete cord injury (3 points)," and this generally necessitates surgery. It is categorized in increasing order of exigency: "neurologically intact, nerve root injury, complete (both motor and sensory) spinal cord injury, and incomplete (either motor or sensory) spinal cord or cauda equina injury." In SLICS, one point is assigned extra if there is "continuous cord compression" in the setting of a neural impairment.

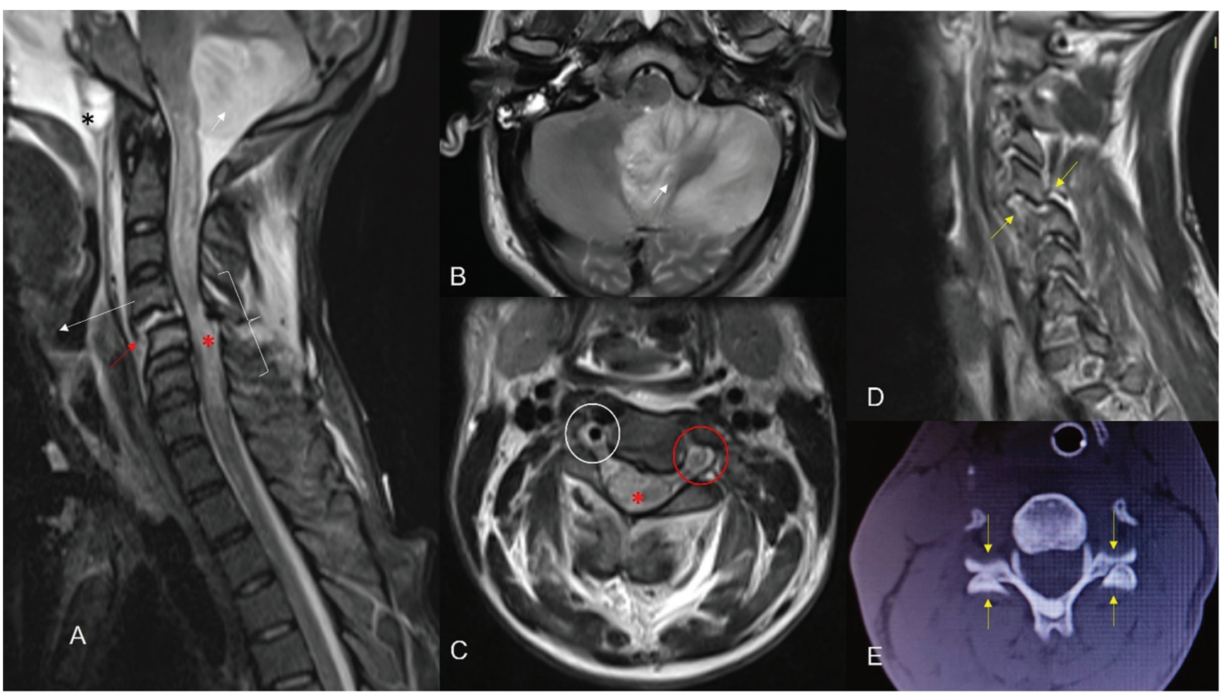

Fig. 8 The sagittal short tau inversion recovery (STIR) (**A**) magnetic resonance (MR) image reveals a grade 2 anterior listhesis of the C4 over C5 vertebral body (long white arrow), indicating a translational injury. The spinal cord is compressed and shows significant edema (red asterisk), along with a discoligamentous complex injury (red arrow and white bracket). The axial T2-weighted (T2W) MR image (**B**) at the posterior fossa level demonstrates infarcts (arrow) in the left cerebellar hemisphere, causing a mass effect. (**C**) Another axial T2W MR image at the C5 level shows a loss of flow signal in the left vertebral artery (encircled in red) compared with the right side (encircled in white), indicating thrombosis responsible for posterior circulation stroke in this patient. The sagittal para-midline MR image (**D**) and the axial bone window computed tomography (CT) image (**E**) show locked bilateral facet joints (paired yellow arrows) with CT specifically displaying a "reversed hamburger sign."

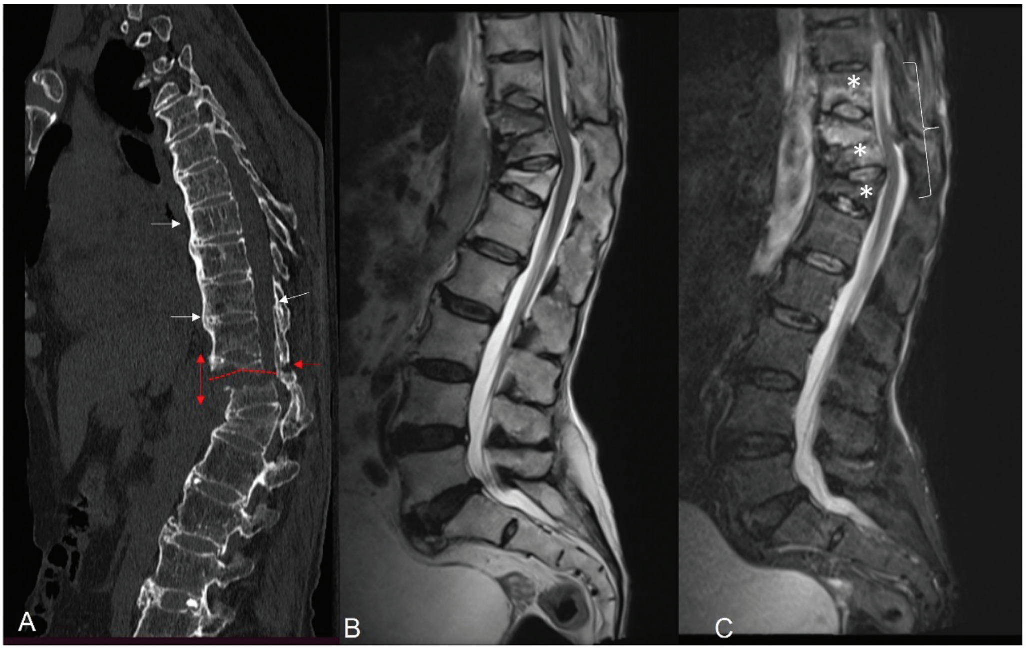

Fig. 9 The sagittal reformatted computed tomography (CT) image (**A**) reveals a D11 distraction injury in a patient with ankylosing spondylitis. A horizontal fracture line (red dotted line) traverses the vertebral body, dividing it into upper and lower halves (red double-headed arrow). The facet joint is also disrupted (short red arrow). There is an anterior translation of the proximal fracture fragment relative to the distal fragment. Additionally, anterior syndesmophytes and fused facet joints (highlighted by the white arrows) are present. The sagittal T2-weighted (T2W) (**B**) and short tau inversion recovery (STIR) (**C**) magnetic resonance (MR) images display marrow edema in multiple vertebral bodies (white asterisks) and posterior ligamentous complex (PLC) injury (white bracket).

AOSpine Classification Systems (Subaxial, Thoracolumbar)

In 2008, the "AO" formed the "Spine Classification Group" and, subsequently, "the AOSpine Knowledge Forum" to review the "AO-Magerl classification" and create a user-friendly and elaborate classification system for the whole spine by recognizing purposeful and recreatable fracture configurations. The primary goal of this system was to gain international acceptance for clinical and research purposes. These classifications focused primarily on the following variables: (1) morphology of the fracture, (2) neurological status, (3) clinical modifiers, and () facet joint injury (specific to cervical subaxial classification) (►**Table 3**).[21,22]

Fractures are characterized by their "level," followed by the "morphologic type of the primary injury." "Secondary injuries" and "modifiers" are indicated in "parentheses (facet injury, neurological status, and modifiers)." The foundational A, B, and C divisions of the classical AO-Magerl system were redefined and clarified to serve as the primary symbol of increasing gravity:

- Type A: Compression injuries with an intact tension band. This primarily involves mechanical failure of the anterior spinal column without significant compromise of the posterior tension band. The subtypes are as follows:

- A0: Spinous/transverse process fracture: Nonstructural fractures involving the posterior elements, such as the spinous or transverse processes, with minimal impact on spinal stability.
- A1: Wedge impaction fracture: A simple compression fracture resulting in a wedge-shaped deformation of the vertebral body without disruption of the posterior wall.
- A2: Split/pincer fracture: A fracture splitting the vertebral body in a sagittal or coronal plane, sometimes likened to a "pincer" deformity, typically stable if the posterior column remains intact.
- A3: Incomplete burst fracture: Compression with partial failure of the posterior vertebral wall, often involving minimal retropulsion of bony fragments into the spinal canal.
- A4: Complete burst fracture: Full collapse of the vertebral body with significant disruption of the posterior wall, frequently causing retropulsion of fragments and potential spinal canal compromise.
  - Type B: Failure of the posterior or anterior tension band through distraction. The alignment of the spinal axis is maintained without any signs of translation or dislocation.
  - Type C: Failure of all elements leading to dislocation, translation, or displacement in any plane.

A tension band injury refers to damage to the PLC, which includes structures that provide critical tensile support to the spine. These injuries occur when the PLC fails due to excessive forces, such as hyperflexion, distraction, or shear, disrupting spinal stability. In the subaxial cervical spine, sometimes the dominant injury affects the facet joints, and the vertebral body is unaffected; in such a scenario, a separate facet injury classification is used to describe the

Table 3 AOSpine thoracolumbar spine injury classification system

Injury types						Score
Injury type	**Subtype**		**Description**			
			Vertebral body involvement	**Posterior wall involvement**	**Endplates involvement**	
A Compression fractures	A0	Spinous/transverse process fracture	Absent	Absent	Absent	0
	A1	Wedge impaction	Present	Absent	Single	1
	A2	Split/pincer	Present	Absent	Both	2
	A3	Incomplete burst	Present	Present	Single	3
	A4	Complete burst	Present	Present	Both	5
B Tension band Injuries	B1	Trans osseous disruption	Posterior	Horizontal fracture line involving posterior elements—“chance fracture”		5
	B2	Osseoligamentous disruption	Posterior	Associated with vertebral body burst fractures		6
	B3	Osseoligamentous disruption	Anterior	Hyperextension injury with anterior longitudinal ligament disruption and posterior ligaments sparing		7
C Translational injuries	C	Translation injury	Displacement/dislocation present—involvement of both anterior and posterior tension bands			8
Neurological status						
Neurological Status	N0	No neurological deficit				0
	N1	Resolved temporary neurological injury				1
	N2	Single nerve root injury with radicular symptoms				2
	N3	Incomplete cord injury				4
	N4	Complete cord injury or cauda equina syndrome				4
	NX	Neurological examination is not possible				3
Patient-specific modifiers						
Patient specific modifiers	M1	Ambiguity in PLC integrity				1
	M2	Patient factors that would affect treatment—like ankylosing spondylosis, burns, diffuse idiopathic spinal hyperostosis				0
Treatment recommendations						Total score
Surgical management						> 4
Conservative management						< 4
Surgeon’s discretion						4

Abbreviations: AO, Arbeitsgemeinschaft für Osteosynthesefragen; PLC, posterior ligamentous complex.

injury. Clinical modifiers describe conditions that are not universally applicable but affect the decision-making process in particular scenarios, for example, ankylosing spondylosis and diffuse idiopathic spinal hyperostosis.

Comparison between Two Contemporary Classification Systems: SLICS/TLICS versus AOSpine

►**Table 4** describes the comparison between the two classification systems.

Fewer variables and subgroups characterize the TLICS algorithm, whereas AOSpine incorporates a more comprehensive range of fracture morphologies. TLICS is straightforward, making it easy to use in clinical practice. In TLICS, the PLC is treated as a separate, independent variable. In contrast, the AOSpine system includes PLC integrity within the tension band injury subtype. TLICS has substantial studies supporting its validity and was the first system to receive external validation. TLICS has also been validated for thoracolumbar spinal injuries in children.[23,24] Despite this, TLICS is not widely favored among spine surgeons due to its

Table 4 Comparison between two contemporary classification systems: SLICS/TLICS versus AOSpine

Feature	SLICS/TLICS	AOSpine classification system
Simplicity and clarity	High—Straightforward and easy to use	Moderate—More detailed and complex
Flexibility	Moderate—Designed for quick decision-making	High—Versatile for various clinical situations
Use in emergency settings	Quick and practical	More time-consuming and detailed
Learning curve	Easy to learn and apply	Requires more training and familiarity
Guidance for treatment	Provides direct recommendations for surgical versus nonsurgical	Does not provide direct treatment guidance
Basis	Derived from clinical data and expert consensus	Developed by a global panel of spine surgeons
Focus	Three major variables essential for clinical decision-making in spine trauma: (1) the injury morphology determined by the pattern of disruption seen in imaging studies, (2) the integrity of the PLC or DLC, and (3) the patient's neurologic status.	Based on the evaluation of the following parameters: (1) Morphology of the fracture (comprehensive injury patterns, type A, B, C); (2) neurological status; (3) clinical modifiers; (4) facet joint injury (specific to cervical subaxial classification)
Scope	Limited—May miss nuances of complex injuries	Extensive—Covers a wider range of injuries
Patient factors considered	Limited—Does not include patient comorbidities or bone quality	Includes patient comorbidities or bone quality in clinical modifiers

Abbreviations: AO, Arbeitsgemeinschaft für Osteosynthesefragen; DLC, discoligamentous complex; PLC, posterior ligamentous complex; TLICS, Thoracolumbar Injury Classification System; SLICS, Subaxial Cervical Injury Classification System.

management recommendations for vertebral burst fractures in patients without neurological deficits. While TLICS provides clear recommendations for patients with intact and disrupted PLCs, it needs clear guidance for patients with unclear PLC status, leading to deviations in management. The PLC component of TLICS is the least reliable, as diagnosing PLC injury typically requires an MRI. Additionally, PLC injury does not necessarily correlate with neurological deficits.

Pishnamaz et al aimed to evaluate and compare the "TLICS" and the "AOSpine Thoracolumbar Spine Injury Classification System." Their findings indicated that the "AOSpine fracture classification" demonstrated better reliability compared with "TLICS." Similarly, Kaul et al conducted a separate study and reported comparable findings.[25,26]

Abedi et al conducted a systematic review to assess the measurement capability of the AOSpine classification. Most studies showed that simplifying the AOSpine classification could enhance its reliability. However, drawing a definitive conclusion was challenging due to the absence of validity and reliability studies included in the review. Given that most studies were conducted by the developers of the AOSpine classification, further evaluations by independent researchers are recommended.[27]

An et al conducted a study to compare TLICS and AOSpine Injury Score in guiding treatment strategies for thoracolumbar spine injuries and concluded that the AOSpine recommendations might be more consistent especially for guiding the treatment of "complete burst fractures."[28]

Emerging Trends and Future Directions

Advanced MRI and CT imaging techniques continue to improve, providing more detailed anatomical and functional insights. High-resolution imaging helps radiologists assess subtle injuries to the PLC and other soft tissues. Functional MRI and diffusion tensor imaging (DTI) techniques offer insights into spinal cord integrity and can help predict recovery potential, adding valuable data to the classification systems. DTI studies the free movement of water molecules within tissue, providing detailed insights into structural integrity. Both the white matter tracts at the injury site and the normal-appearing proximal and distal cord experience macroscopic and microscopic changes. DTI indices such as radial diffusivity, mean diffusivity, etc. can quantify microstructural damage to the cord. Despite the cord appearing normal on conventional MRI sequences, diffusivity changes are observed proximal to the injury site. A higher apparent diffusion coefficient at the site of cord contusion is related with better postoperative outcomes.[29–31]

Artificial intelligence (AI) and machine learning algorithms are being developed to detect and classify spinal injuries automatically. These technologies can assist radiologists by providing preliminary assessments and highlighting areas of concern. Machine learning models can predict outcomes based on initial imaging, helping guide treatment decisions and improving patient management.[32,33]

Conclusion

In conclusion, the spine's critical role in protecting neural structures and maintaining stability underscores the importance of accurate and timely diagnosis of spinal trauma. This review highlights the evolution of spine trauma classification systems, tracing their development from early biomechanical models to contemporary systems like SLICS/TLICS and AOSpine, each offering distinct advantages in clinical practice. The advent of advanced imaging modalities has significantly enhanced the detection and characterization of spinal injuries, facilitating more precise classifications and treatment plans.

The SLICS and TLICS systems have simplified the approach to spine trauma by focusing on critical variables such as injury morphology, PLC/DLC integrity, and neurological status, providing clear guidelines for management. However, the comprehensive and nuanced AOSpine system, with its detailed morphological classifications and consideration of clinical modifiers, has demonstrated superior reliability and international acceptance.

Looking ahead, emerging trends such as integrating high-resolution imaging, functional MRI, and AI-driven diagnostic tools promise to further refine classification systems. The shift toward personalized medicine and incorporating genetic and molecular insights into classification frameworks will enable more tailored and effective treatment strategies. As classification systems evolve, collaboration among radiologists, spine surgeons, and researchers will be essential. By embracing advancements in imaging technology and incorporating new clinical data, the field of spine trauma classification can achieve greater accuracy and consistency, ultimately enhancing patient care and outcomes.

Authors' Contributions

K.N.: Original draft preparation.

S.S.: Conceptualization, reviewing, editing, and supervision of the work.

G.V., K.S., and K.P.I.: Resources, writing—review, and editing processes.

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Conflict of Interest

None declared.

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