AOSpine Classification Systems (Subaxial, Thoracolumbar)

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Summary: Numerous classification systems for subaxial and thoracolumbar spine injuries were proposed in the past with the attempt to facilitate communication between physicians. The AO-Magerl, thoracolumbar system, and Subaxial Cervical Spine Injury Classification systems are all well known, but did not achieve universal international adoption. A group of international experienced spine trauma surgeons were brought together by AOSpine with the goal to develop a comprehensive yet simple classification system for spinal trauma. This article is a synopsis of the proposed subaxial and thoracolumbar classification systems. In several studies, this classification system was developed using an iterative consensus process among the clinical experts in sufficient number and quality of DICOM images of real cases searching for meaningful and reproducible patterns. Both systems are based on 3 injury morphology types: compression injuries (A), tension band injuries (B), and translational injuries (C) with a total of 9 subgroups. In the subaxial cervical spine 4 additional subtypes for facet injuries exist. Patient-specific modifiers and neurologic status were also included to aid surgeons in therapeutic decision making. The proposed classification systems for subaxial and thoracolumbar injuries showed substantial intraobserver and interobserver reliability ($\kappa = 0.64–0.85$) for grading fracture type. Grading for the subtypes varied considerably due to the low frequency of certain injury subtypes among other reasons. In summary, the AOSpine thoracolumbar and subaxial cervical spine injury systems show substantial reliability, thus being valuable tools for clinical and research purposes.

Key Words: classification, thoracolumbar spine, subaxial spine, injury, spinal fracture, reliability

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INTRODUCTION

Classification systems attempt to facilitate communication between physicians. The ideal classification should be simple to use, reproducible, and focus on characteristics that are relevant to the prognosis and for therapeutic decision making. Numerous classification systems for the thoracolumbar and subaxial spine injuries have been proposed but none has achieved universal acceptance. Common reasons are lack of reliability, accuracy, and clinical relevance.[1] The Spine Trauma Study Group proposed a thoracolumbar system (TLICS) and a cervical subaxial fracture system (SLIC).[2,3] Both systems are based on the categories of injury morphology, integrity of the posterior ligamentous complex, and neurologic status in order to suggest a treatment based on a point system. Despite rather favorable reliability of treatment recommendations, many users had problems agreeing on the precise definition of injury morphology and PLC injury. In 2008, the AO established a Spine Classification Group aiming to revise the AO-Magerl classification.[4] Based on the work of this group the later founded AOSpine Knowledge Forum Trauma, a group of international academic surgeons with special interest in trauma, further developed and validated the classification systems. The AOSpine Knowledge Forum Trauma aims to develop a comprehensive and user-friendly classification system for the entire spine based on recognition of meaningful and reproducible injury patterns. The classification system's main goal is to strive for international acceptance and to be applicable for both clinical and research purposes. Furthermore, it should incorporate fracture morphology, neurological status, and clinical factors relevant for the prognosis and theurapeutic decision making. So far, the AOSpine Knowledge Forum Trauma has developed injury classifications for the subaxial and thoracolumbar spine and for the sacrum. This article is a synopsis of the cervical subaxial and thoracolumbar spine classification systems.[5,6]

METHODS

Both classifications were developed according to scientific guidelines.[7] The AOSpine Classification Group reviewed several drafts of the classifications in multiple face-to-face meetings, whereby the group members analyzed more than 200 thoracolumbar and subaxial trauma cases with CT scans saved as Digital Imaging and Communications in Medicine (DICOM) images. In an iterative process, the results were evaluated to assess the classification's reliability and accuracy and to identify disagreement. The systems were complete when group members reached unanimous consensus on the proposed system and was supported by the evaluation results. During the final sessions, led by the AOSpine Knowledge Forum Trauma, the concepts of neurological and patient-specific modifiers were incorporated. Besides describing morphology, the goal was also to predict prognosis and to develop treatment strategies.

For the final assessment of the thoracolumbar classification, 40 selected cases representing all grades of fracture types were evaluated by 9 spine surgeons. A second round of grading was performed 1 month later.

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For the final assessment of the cervical subaxial classification, 40 selected cases were sent to the reviewers for evaluation on 2 separate occasions, 1 month apart. Cases represented a selection of subaxial injuries across all grades of morphology, facet injury, neurology, and patient-specific modifiers. Each case was provided with sufficient CT-images and on demand with MRI-images.

Statistical Analysis

Kappa coefficient (κ) was utilized to assess the reliability of the classification systems among different observers (interobserver agreement) and the reproducibility for the same observer on separate occasions (intraobserver reproducibility). The coefficients were interpreted using the Landis and Koch grading system.[8]

CLASSFICATION SYSTEMS

The classifications were based on the evaluation of the following parameters:

1. Morphology of the fracture
2. Neurological status
3. Clinical modifiers
4. Facet joint injury (only valid for cervical subaxial classification)

Injuries are described by their level, followed by the morphologic type of the primary injury. The secondary injuries and modifiers are placed in parentheses (facet injury, neurologic status, and modifiers). The classical AO-Magerl[9] system's basic A, B, C division is redefined and clarified and is used as the principle indicator of the ascending severity. These types describe the observed mode of failure of the spinal column as a mechanical construct.

Type A: Compression injuries with intact tension band.

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.

Coding

Type A injuries affect either a single vertebra or occur in combination with type B or type C injuries. B1 injuries affect a single vertebral body, too. Type A and B1 injuries are coded by the single vertebral levels they affect (eg, L1). B2, B3, and type C injuries affect at least 1 motion segment. These injuries are coded according to the affected segment (eg, T12–L1). Multilevel injuries should be classified separately and listed according to declining severity. When injuries of the same subtype are present, the injuries will be described in order of cranial to caudal location.

Grading

Type A Injuries: Compression Injuries of the Vertebral Body

Type A describes the injuries of the vertebral body. There are 5 subclassifications. These subclassifications are also used to describe the vertebral body in combination with type B or C injuries.

A0—mechanically insignificant fractures of the spinous or transverse processes. In the subaxial spine it is also used when a patient presents with an isolated fracture of the lamina or with central cord syndrome without any associated fracture (Figs. 1, 2).

A1—compression or impaction fractures a single endplate (cranial or caudal) without any involvement of the posterior wall of the vertebral body (Figs. 3, 4).

A2—are coronal split of pincer-type fractures involving both endplates but do not involve the posterior vertebral wall (Figs. 5, 6).

A3—incomplete burst fractures affecting a single endplate with any involvement of the posterior vertebral wall (Figs. 7, 8).

A4—complete burst fractures affecting both endplates with any involvement of the posterior vertebral wall. Split

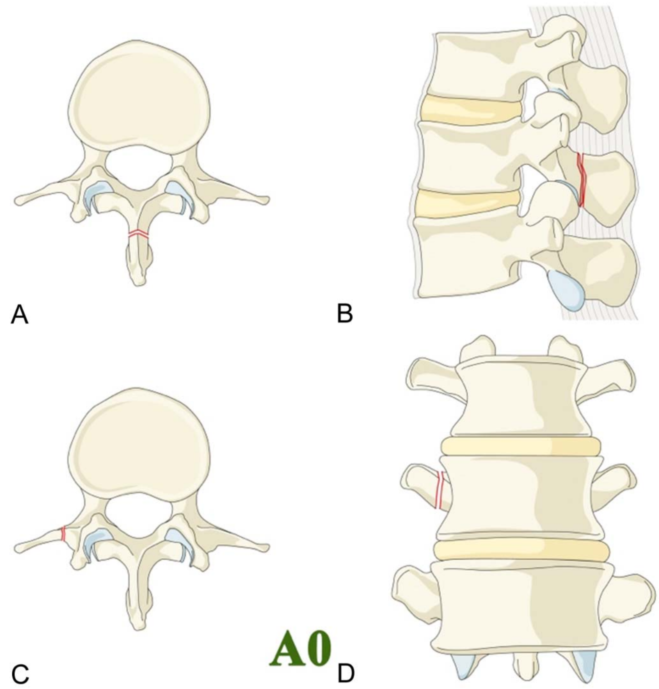

FIGURE 1. A–D, Images of a thoracolumbar A0 fracture.[5] Reproduced with permission copyright Wolters Kluwer Health.

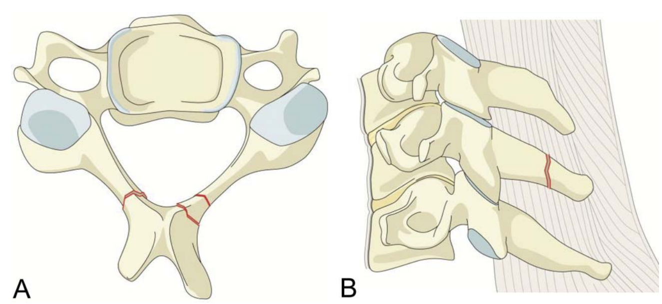

FIGURE 2. A and B, Images of a subaxial A0 fracture.[6] Reproduced with permission copyright Springer.

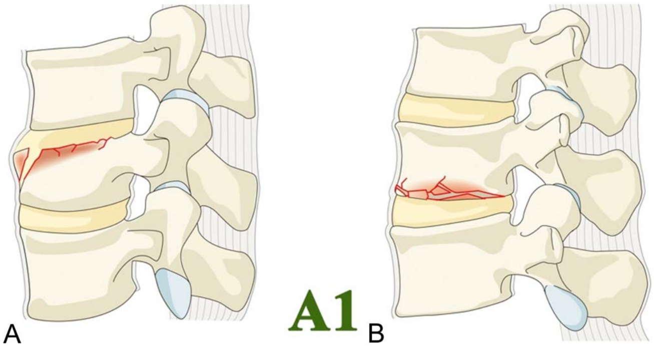

FIGURE 3. A and B, Images of a thoracolumbar A1 fracture.[5] Reproduced with permission copyright Wolters Kluwer Health.

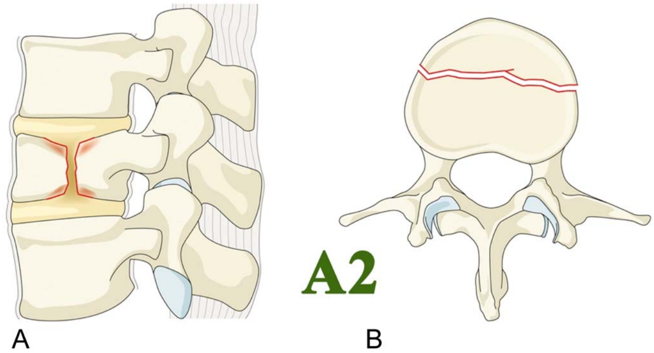

FIGURE 5. A and B, Images of a thoracolumbar A2 fracture.[5] Reproduced with permission copyright Wolters Kluwer Health.

fractures of the vertebral body involving the posterior vertebral wall are also included in this group. These fractures may be associated with vertical fracture lines of the lamina but without disruption of the posterior tension band (Figs. 9, 10).

Type B Injuries: Tension Band Injury

Type B describes injuries affecting either the anterior or posterior tension band. B2 and B3 injuries may be seen in combination with type A fractures of the vertebral body. The latter are then coded separately. From B2 on all injuries affect a motion segment containing 2 vertebral bodies and the associated disc.

B1—monosegmental osseous failure of the posterior tension band extending into the vertebral body. In the thoracolumbar spine they are known as “Chance” fractures. The B1 subtype is a fracture pattern going through a single vertebra (Figs. 11, 12).

B2—disruption of the posterior tension band with or without osseous involvement. The injury of the posterior tension band may be bony, capsuloligamentous, ligamentous, or any combination of these structures (Figs. 13, 14).

B3—anterior tension band injury with disruption or separation of the anterior structures (bone/disc) with tethering of the posterior elements. These injuries may pass through either the intervertebral disc or through the vertebral body itself (as in the ankylosed spine). An intact posterior hinge prevents gross displacement (Figs. 15, 16).

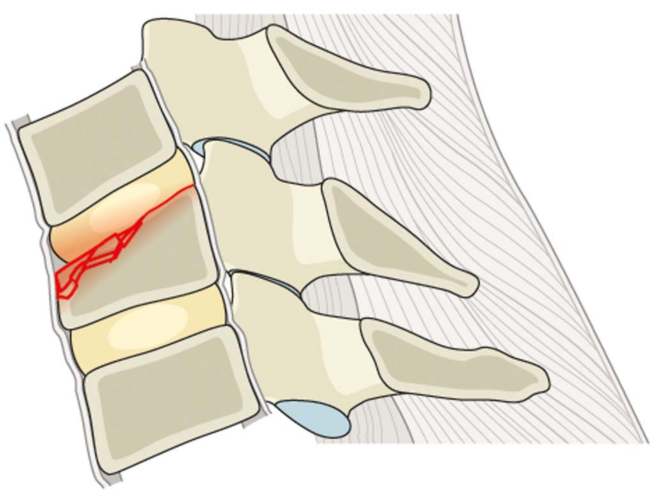

FIGURE 4. Image of a subaxial A1 fracture.[6] Reproduced with permission copyright Springer.

Type C Injuries: Displacement/Translational Injury

Type C injuries are translational injuries in any axis. No further subdivision is necessary since all Type C injuries are highly unstable due to separation, displacement, or translation of 1 vertebral body (or elements of it) relative to another in any direction. Any associated injury (either type A or type B) may be coded separately as a subtype (Figs. 17, 18).

Facet injuries in the Subaxial Spine

In the subaxial spine there are injury patterns where the dominant injury is to the facet joints. Frequently, there is no or minor associated vertebral body fracture, and the facet injuries are the main determinant of the residual stability. This is the reason for the development of a separate facet injury classification for the subaxial spine. Four types of cervical facet injuries are described with the subaxial cervical classification. If there are multiple injuries to the same facet only the highest level of injury is classified. If both facets on the same vertebrae are injured, the right-sided facet injury is listed before the left sided injury. The “Bilateral” modifier is used if both facets have the same type of injury. If only facet injuries are identified (no A, B, or C injury), they are listed first after the level of injury.

F1—non-displaced facet fractures (either superior or inferior facet) with a fragment of less than 1 cm in size, involving less than 40% of the lateral mass (Fig. 19).

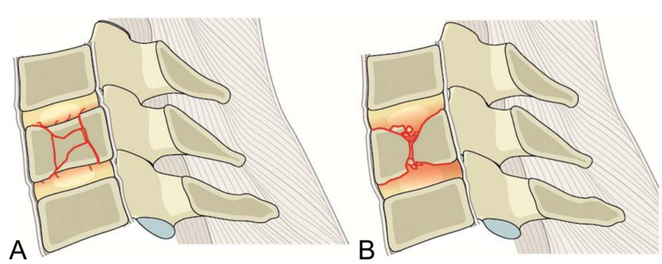

FIGURE 6. A–B, Images of a subaxial A2 fracture.[6] Reproduced with permission copyright Springer.

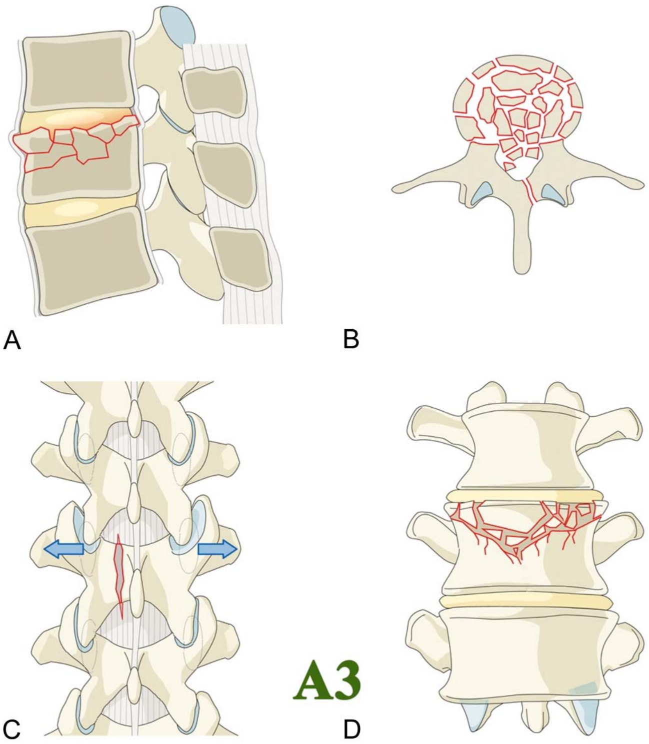

FIGURE 7. A–D, Images of a thoracolumbar A3 fracture.[5] Reproduced with permission copyright Wolters Kluwer Health.

F2—facet fractures with potential for instability (either superior or inferior facet) with a fragment of more than 1 cm in size, involving more than 40% of the lateral mass, or any displaced fragments (Fig. 20).

F3—floating lateral mass with disruption of pedicle and lamina resulting in disconnection of both superior and inferior articular processes from the vertebral body (Fig. 21).

F4—subluxation-perched or dislocated facet (Fig. 22).

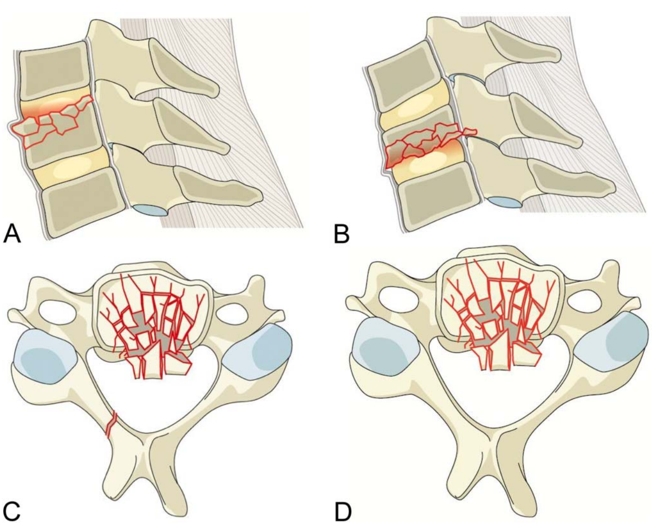

FIGURE 8. A–D, Images of a subaxial A3 fracture.[6] Reproduced with permission copyright Springer.

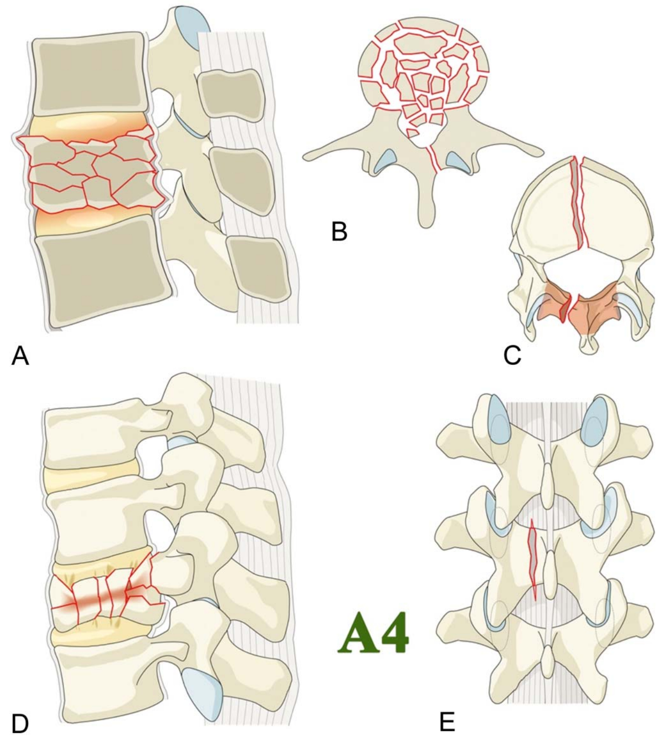

FIGURE 9. A–E, Images of a thoracolumbar A4 fracture.[5] Reproduced with permission copyright Wolters Kluwer Health.

Neurological Deficits

Neurological status at the initial admission is graded as follows:

N0—neurologically intact.

N1—transient neurological deficit, which is no longer present by the time of clinical examination.

N2—symptoms or signs of radiculopathy.

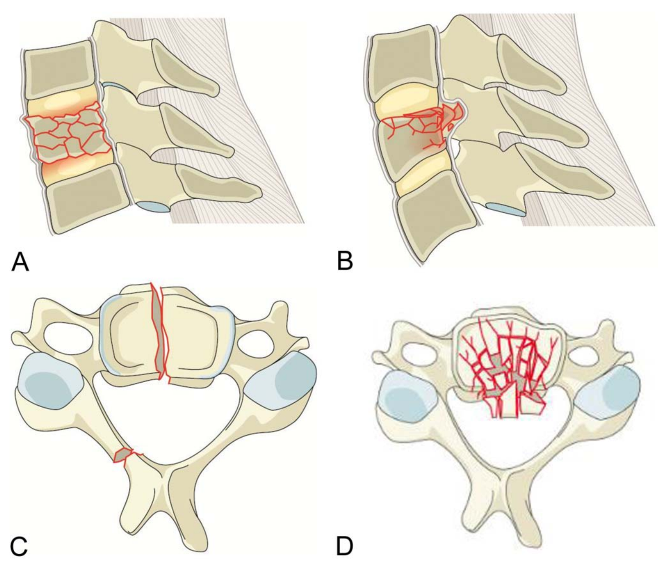

FIGURE 10. A–D, Images of a subaxial A4 fracture.[6] Reproduced with permission copyright Springer.

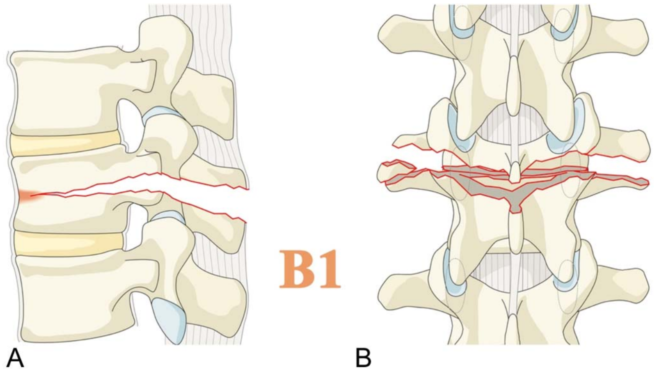

FIGURE 11. A–B, Images of a thoracolumbar B1 injury.[5] Reproduced with permission copyright Wolters Kluwer Health.

N3—incomplete spinal cord or (in the thoracolumbar spine) cauda equina injury.

N4—complete spinal cord injury.

NX—neurology undetermined (due to intubation, sedation, intoxication, cerebral trauma etc).

In the subaxial cervical system, the adjunct "+" is given in case of ongoing cord compression in the setting of an incomplete neurological defict (N3).

Case-Specific Modifiers

Case-specific modifiers describe unique conditions relevant to clinical decision making. They are not relevant to every case and are used on an as-needed basis to assist the physician in deciding treatment. In the thoracolumbar spine system, 2 modifiers are defined, whereas in the subaxial cervical system, 4 modifiers exist.

Thoracolumbar Modifiers

M1—is used to designate fractures with an indeterminate injury to the tension band based on spinal imaging such as MRI or clinical examination.

M2—is used to designate a patient-specific comorbidity, which might argue either for or against surgery for those patients with relative indications for surgery. Examples are: ankylosing spondylitis, rheumatologic conditions, diffuse idiopathic skeletal hyperostosis, osteopenis/porosis, or burns affecting the skin overlying the injured spine.

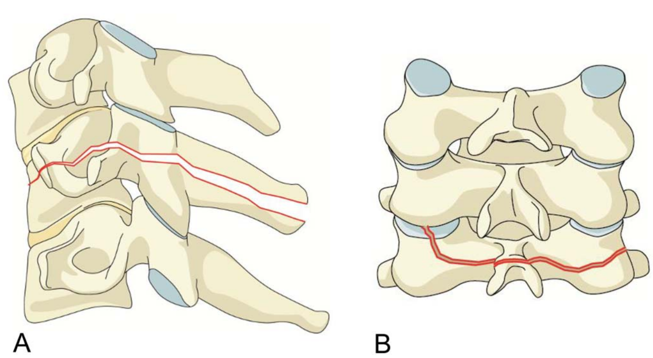

FIGURE 12. A and B, Images of a subaxial B1 injury.[6] Reproduced with permission copyright Springer.

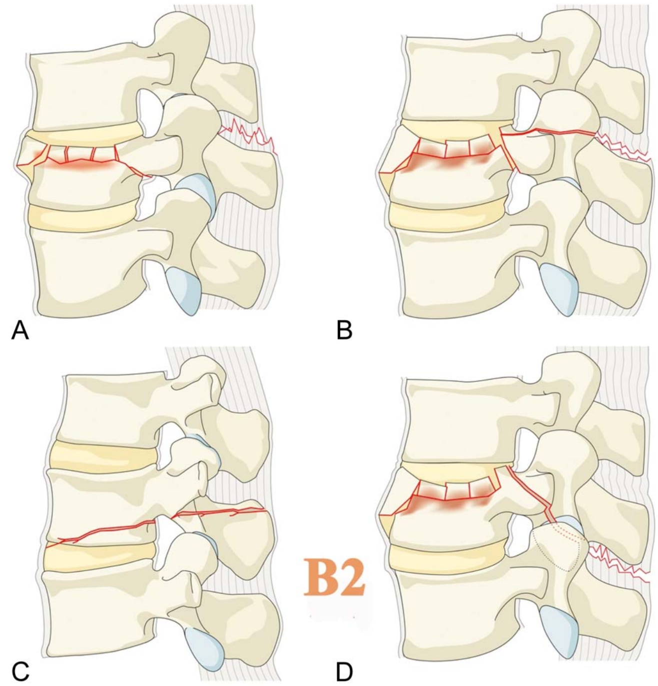

FIGURE 13. A–D, Images of a thoracolumbar B2 injury.[5] Reproduced with permission copyright Wolters Kluwer Health.

Subaxial Modifiers

M1—defines posterior capsuloligamentous complex injury without complete disruption. This modifier designates injuries with some evidence of injury to the posterior ligamentous structures without complete disruption similar to the thoracolumbar M1 modifier.

M2—defines a critical disc herniation caused by tissue signal intensity that is consistent with nucleus pulposus

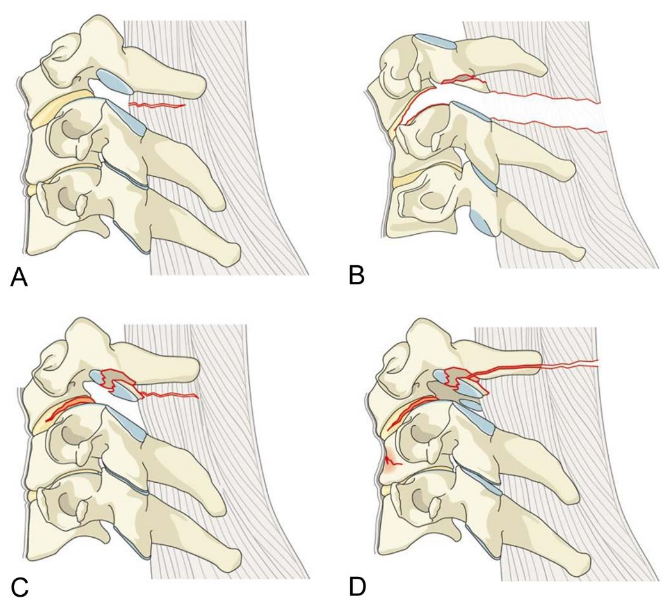

FIGURE 14. A–D, Images of a subaxial B2 injury.[6] Reproduced with permission copyright Springer.

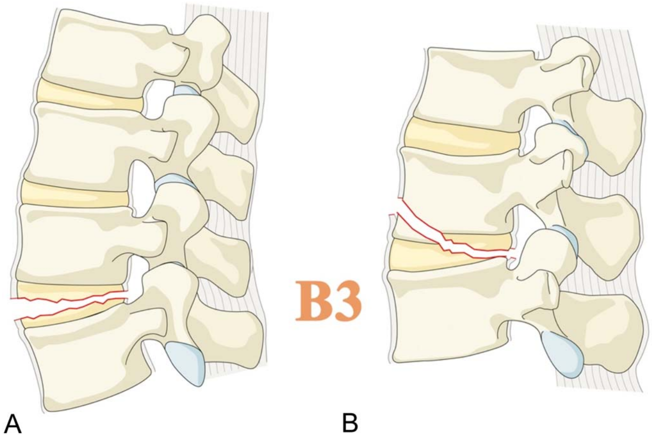

FIGURE 15. A and B, Images of a thoracolumbar B3 injury.[5] Reproduced with permission copyright Wolters Kluwer Health.

protruding posteriorly to a vertical line drawn along the posterior border of the inferior vertebral body at the injured level.

M3—defines stiffening/metabolic bone diseases, which might argue either for or against surgery for those patients with relative indications for surgery. Examples are: Diffuse Idiopathic Skeletal Hyperostosis, Ankylosing Spondylitis, Ossification of the Posterior Longitudinal Ligament, or Ossification of the Ligamentum Flavum. The modifier is similar to the thoracolumbar M2 modifier.

M4—Signs of vertebral artery injury.

RESULTS OF THE FINAL EVALUATION SESSIONS

Interobserver Reliability

In the thoracolumbar random sample series, the Kappa (κ) statistic for overall agreement on grading by fracture type without regard to subtype was 0.72. The κ values were 0.72 for type A injuries, 0.58 for type B injuries, and 0.7 for type C injuries. The highest level of agreement for specific subtypes was for fracture type A0 (κ = 1.0) and B1 (κ = 0.64), the lowest level of agreement was for fracture type B2 (κ = 0.34) and B3 (κ = 0.41).

In the subaxial cervical classification series, the interobserver reliability including individual subtypes of injuries was substantial (κ = 0.64). When comparing levels of fracture severity (A/B/C/F), the overall agreement on severity rating was again substantial (κ = 0.65). Regarding the subtypes, the κ values showed a broad range with the lowest values for F1, F4, B2, and A3. The highest values were seen for A2, A0, A1, and B3.

Intraobserver Reliability

The reproducibility results for thoraoclumbar fracture type were excellent with an average κ value of 0.85 (range, 0.75–0.96). The reproducibility of fractures subtypes were κ = 0.43 for B type and κ = 0.72 for A type.

The average κ values for all subaxial subtypes was 0.75 showing a substantial reproducibility. Regarding the subtypes the κ values were 0.66 for A type, 0.54 for B type, 0.73 for C type, and 0.66 for F type injuries.

DISCUSSION

To date, no classification system has been able to simultaneously describe pathomorphology and estimate injury severity while considering all clinical, neurological, and radiological characteristics relevant to clinical decision making. Almost all past efforts have used only expert opinions.[1,10] Reliable and reproducible morphological characteristics, which are also known to be relevant for the prognosis are the basic foundation of a meaningful and practical fracture classification system. The presented AOSpine injury classification system provides a short and systematic description based on observed patterns of injury, which are deemed to be relevant for the prognosis according to the available evidence. The classifications were designed to be primarily based around features identifiable using CT scan, which is the most available modality at most trauma centers.[11,12] However, MRI can aid in the diagnosis of subtle injuries to the posterior (capsulo) ligamentous complex (PLC) when disruption of the bony structures, such as widening of the spinous processes, is not obvious.[13] Despite the fact that the integrity of the PLC plays an important role for treatment decision, evaluation of the integrity of the PLC should not be based on MRI alone.[14,15] It has been shown that MRI provides only a slightly better reliability in determining the integrity of the PLC in type A fractures in comparison with CT in thoracolumbar spine.[16]

The subaxial cervical and the thoracolumbar systems also include a modifier (M1) to acknowledge cases in which injury to the PLC is indeterminate or shows signs of injury without complete disruption. Reflecting the contributions of TLICS and SLIC, the proposed schemes acknowledge the relevance of patient comorbidities and neurological status for treatment decisions.[2,3] Stiffening and metabolic diseases of

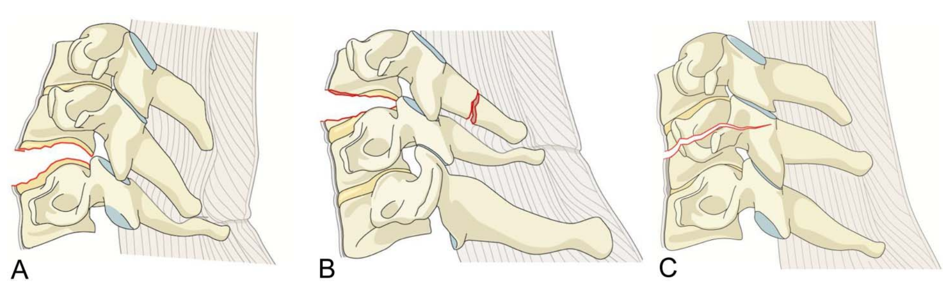

FIGURE 16. A–C, Images of a subaxial B3 injury.[6] Reproduced with permission copyright Springer.

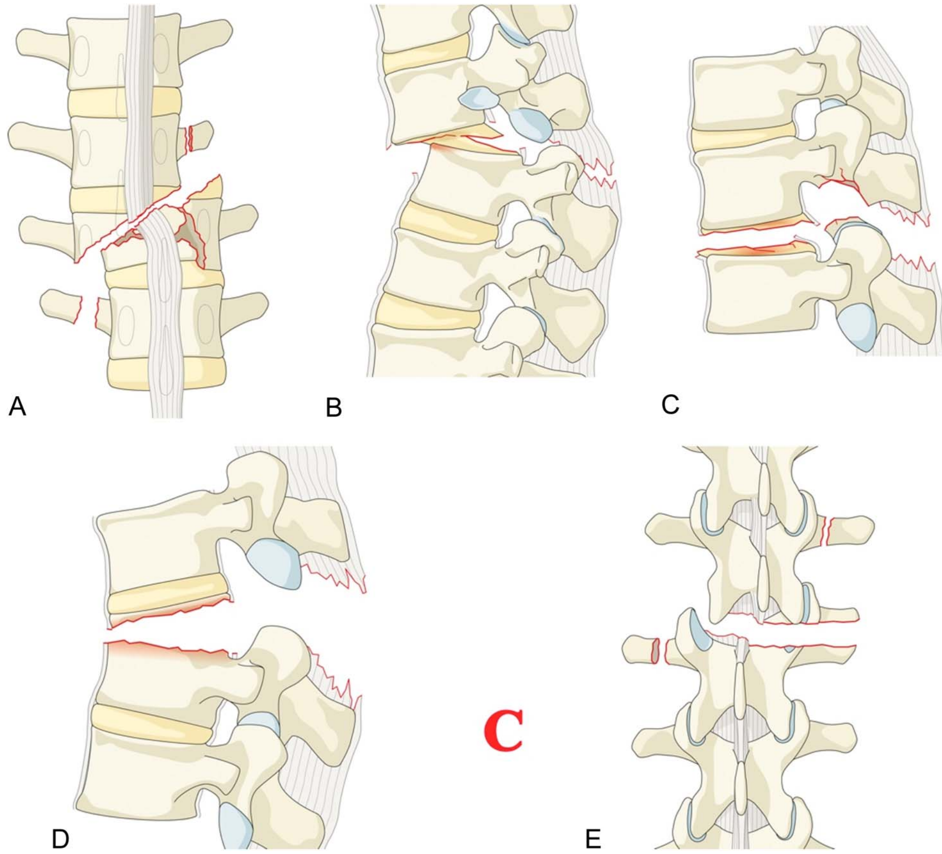

FIGURE 17. A–E, Images of a thoracolumbar C-type injury.[5] Reproduced with permission copyright Wolters Kluwer Health.

the spine might argue either for or against surgery for those patients with relative indications for surgery. Especially in the throracolumbar spine, osteoporosis, either as a comorbidity or as the origin of fractures, determines treatment strategies and especially specific surgical procedures. The Modifiers M2 (thoracolumbar) and M3 (subaxial) acknowledge the above mentioned patient-specific situations. In the subaxial spine, the modifiers M2 (critical disc herniation) and M4 (vertebral artery injury) may further emphasize specific situations in which surgery is indicated or certain measures have to be taken.

The importance of the neurological status on treatment decisions is undisputed and is part of the spine injury score.[17] Although ASIA (American Spinal Injury Association) scoring system is universally accepted, this is only a categorization based on the functional state of the patient in the long term. The ASIA level is, per definition, only determined after 3 separate evaluations within 72 hours. This makes it impractical for decision making at the initial admission. That is the main reason that the AOSpine Knowledge Forum Trauma decided to devise a system to describe the patterns of neurologic state encountered by the surgeons during the initial assessment at the emergency setting. Neurological states are graded from NX to N4 with emphasis on the acute clinical situation. In contrast to other grading systems, the N1 as a new subgroup has been defined. This transient neurologic deficit is usually completely resolved by the time of clinical examination (usually within 24 hours from the time of injury). It can occur even in fractures without involvement of the posterior vertebral wall. Also important is the category NX for cases where neurological examination is not possible or not reliable due to changed states of consciousness.

Unique to the subaxial cervical classification system is the assessment of the facet injuries as a separate descriptor. Facet injuries vary from stable nondisplaced fractures to highly unstable, perched, or dislocated facets. Together with the PLC, the facets are extremely important stabilizers for axial rotation and flexion/rotation.[18] The presence of facet dislocation not only suggests an injury of significant energy, but also a mechanism of flexion distraction.[19]

Overall, the interobserver and intraobserver reliabilities for the subaxial cervical system were substantial (κ = 0.64 and 0.75, respectively). In the first evaluation with 30 cases only, low Kappa values occurred due to the low frequency of certain injury subtypes (A3, B1, F1, and F4). In a recently published independent validation with images of 51 patients, the principal agreement for main groups ranged from 0.61 to 0.93, and the intraobserver agreement for groups ranged from 0.66 to 0.95, both meaning substantial to almost perfect reliability. The authors concluded that the general reliability of the subaxial classification was acceptable for group classification, but still to improve in the subgroups and facet

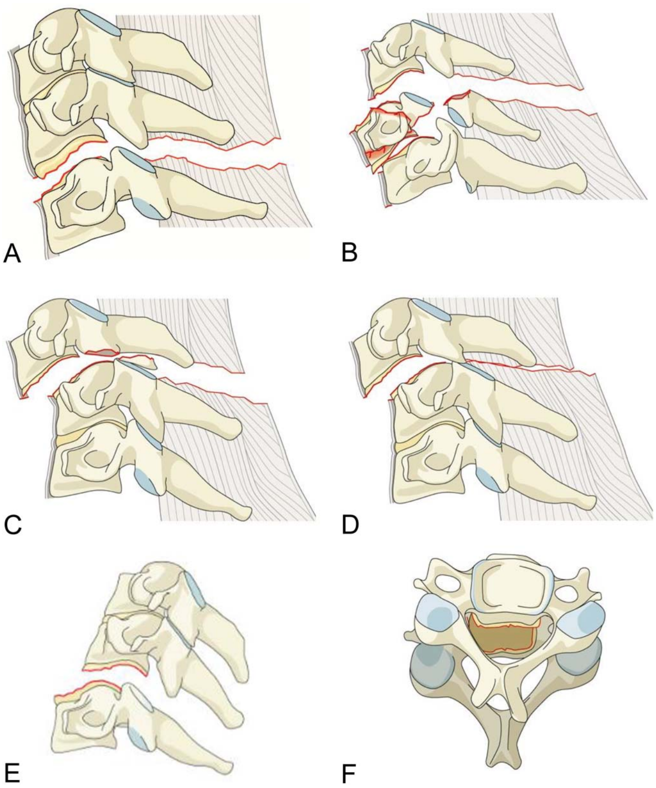

FIGURE 18. A–F, Images of a subaxial C-type injury.[6] Reproduced with permission copyright Springer.

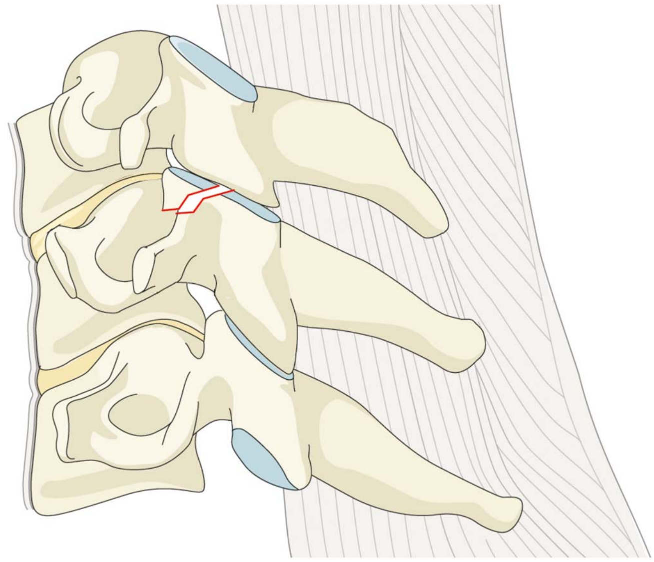

FIGURE 20. Image of a F2 facet injury.[6] Reproduced with permission copyright Springer.

classification.[20] Similar results with substantial interobserver and intraobserver agreement for fracture types and subtypes were found by another independent group.[21] Furthermore, this group compared the AOSpine classification with the Allen and Ferguson scheme and found significantly better agreement in the AOSpine proposal for the 4 main injury types and the subtypes.[22]

For the thoracolumbar spine, the interobserver reliability showed a Kappa of 0.64 for all fracture types and subtypes after evaluating 40 cases. While type A and type C injuries showed Kappa values of 0.72 and 0.7, respectively, the reliability of tension band injuries (type B) was much lower (κ = 0.58). Subsequently, an international reliability study with 100 worldwide spinal surgeons without previous exposure to the AOSpine Thoracolumbar Spine Injury Classification System was conducted.[23] While the overall reliability for all cases was only moderate (κ = 0.56), the interobserver agreements were 0.80 for type A injuries, 0.68 for type B injuries, and 0.72 for type C injuries, all representing substantial reliability. The lowest level of agreement for specific subtypes was for fracture subtype A4 (κ = 0.19). In a further international validation study it could be demonstrated that the spine surgeons' level of experience does not substantially influence the classification and intraobserver reliability.[24] Several external and independent groups have evaluated the thoracolumbar classification. Urrutia et al performed an agreement study with images of 70 patients and found the interobserver reliability to be substantial when considering the fracture type (A, B, or C), with a Kappa of 0.62 (0.57–0.66). Similar to our own results the reliability of the subtypes was moderate with a Kappa of 0.55 (0.52–0.57). The intraobserver reproducibility of fractures and subtypes was substantial with Kappa values of 0.77 and 0.71, respectively. No significant differences were observed between spinal attending surgeons and orthopedic residents.[25] Azimi et al[26] evaluated images of

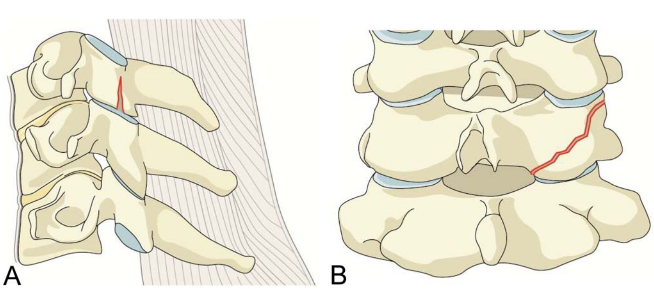

FIGURE 19. A and B, Images of a F1 facet injury.[6] Reproduced with permission copyright Springer.

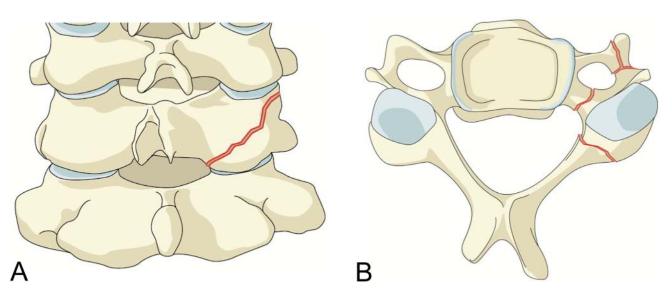

FIGURE 21. A and B, Images of a F3 facet injury.[6] Reproduced with permission copyright Springer.

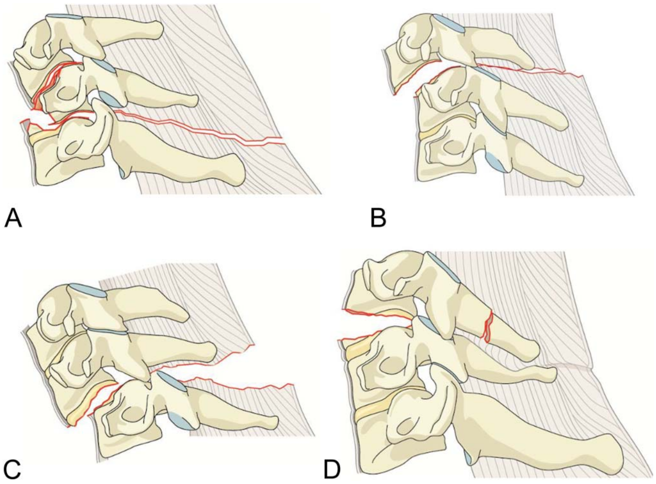

FIGURE 22. A–D, Images of a F4 facet injury.[6] Reproduced with permission copyright Springer.

56 patients with 74 levels of thoracolumbar trauma and found Kappa values for intraobserver and interobserver reliability ranging from 0.83 to 0.89, indicating nearly perfect agreement. In contrast, in a group of Chinese surgeons, only moderate reproducibility for all injury types were found.[27] Whether TLICS or AOSpine classification is more useful in daily clinical practice remains unclear. Recently, a multicenter study with direct comparison of both classifcations was performed showing better reliability for identifying fracture morphology with the AOSpine classification.[28]

CONCLUSIONS

The AOSpine subaxial and thoracolumbar spine injury classification systems represent carefully developed, simple but comprehensive schemes. By combining the key benefits of TLICS, SLIC, and AO-Magerl classification, the subaxial and thoracolumbar AOSpine injury classifications simultaneously consider the morphological description of spinal column injuries, all major modes of failure and clinical features such as neurological status and treatment modifiers. Several agreement studies demonstrated substantial interobserver and intraobserver reliability for both classifications. We think that AOSpine has developed valuable tools for communication, patient care, and for research purposes.

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