Review article

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The classifications of subaxial cervical spine traumatic injuries. Part 4. AOSpine Subaxial Classification System

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Cervical spine injuries are a fairly common consequence of mechanical impact on the human body. The subaxial level of the cervical spine accounts for approximately half to 2/3 of these injuries. Despite the numerous classification systems that exist for describing these injuries, the recommendations for treatment strategy are very limited, and currently none of them is universal and generally accepted. Consequently, treatment decisions are based on the individual experience of the specialist, but not on evidence or algorithms. While the classification system based on the mechanism of trauma originally proposed by B.L. Allen et al. and subsequently modified by J.H. Harris Jr et al., was comprehensive, but lacked evidence, which to some extent limited its clinical applicability. Similarly, the Subaxial Injury Classification System proposed by the Spine Trauma Group, had no distinct and clinically significant patterns of morphological damage. This fact hindered the standardization and unification of tactical approaches.

As an attempt to solve this problem, in 2016 Alexander Vaccaro, together with AO Spine, proposed the AO Spine subaxial cervical spine injury classification system, using the principle of already existing AOSpine classification of thoracolumbar injuries. The aim of the project was to develop an effective system that provides clear, clinically relevant morphological descriptions of trauma patterns, which should contribute to the determination of treatment strategy. The proposed classification of cervical spine injuries at the subaxial level follows the same hierarchical approach as previous AO classifications, namely, it characterizes injuries based on 4 parameters: (1) injury morphology, (2) facet damage, (3) neurological status, and (4) specific modifiers. The morphology of injuries is divided into 3 subgroups of injuries: A (compression), B (flexion-distraction), and C (dislocations and displacements). Damage types A and B are divided into 5 (A0-A4) and 3 (B1-B3) subtypes, respectively. When describing damage of the facet joints, 4 subtypes are distinguished: F1 (fracture without displacement), F2 (unstable fracture), F3 (floating lateral mass) and F4 (dislocation). The system also integrates the assessment of neurological status, which is divided into 6 subtype). In addition, the classification includes 4 specific modifiers designed to better detail a number of pathological conditions. The performance evaluation of AOSpine SCICS showed a moderate to significant range of consistency and reproducibility.

Currently, a quantitative scale for assessing the severity of classification classes has been proposed, which also, to a certain extent, contributes to decision-making regarding treatment strategy.

Key words: *traumatic injury; classification; cervical spine; subaxial level; AOSpine Subaxial Classification System*

Introduction

The classification of fractures by AO Foundation / Orthopedic Trauma Association (AO / OTA) was first published in an appendix to the Journal of Orthopedic Trauma in 1996.

Using the principles of the Comprehensive Classification of Fractures of the Long Bones developed by M.E. Müller et al., the OTA committee classified and coded areas that were not included in the classification [1].

This attempt was aimed at unifying the assessment of all osteo-ligamentous injuries in order to standardize and accumulate data of the same type. Since publication, the classification has been posted on OTA and AO Foundation websites. It is used in databases of these injuries, scientific journals and textbooks. This is the official classification of OTA, AO and JOT. According to some authors, its use has significantly improved the way in which information about fractures and other injuries is transmitted, stored and used to expand the scope of competence. In some anatomical areas, classification has practically supplanted highly specialized assessment systems.

According to the authors, the classification is designed to be a flexible, evolving system that is modified based on users' feedback, criticism, and relevant clinical studies, thus meeting the needs of the medical community in both clinical practice and research. In 2007, AO and OTA committees reviewed the reliability, reproducibility and appropriateness of the classification. As a result, two different alphanumeric codes were standardized into one consistent scheme, which led to the development of an internationally recognized unified system for clinical trials [2]. It is assumed that the revision process will take place every 10 years [3].

The general scheme of construction of a classification case is given ***in Fig. 1***. According to AO / OTA, the cervical spine has the code «51», therefore, for example, the compression fracture C5 is coded as «51.5.A».

Overview of AOSpine Subaxial Classification System

In 2016, A. Vaccaro et al., based on AO / OTA classification and using the principle of AOSpine thoracolumbar spine injury classification system, proposed a new classification, which is now de facto the most common tool for describing traumatic injuries of the cervical spine at the subaxial level [4–6].

The classification describes injuries according to four criteria: traumatic injury morphology, facet joints changes, neurological status and specific modifiers. When forming the classification code, the level of damage and morphological type of primary injury are indicated. Secondary injuries and modifiers are given in parentheses (facet joint injury, neurological status and additional modifiers).

I. **The morphology** of injury takes into account three classic main types of traumatic action, which determine the specific features of bone and traumatic changes:

- compression;
- flexion and extension;
- rotation and traction,

Type A injuries are fractures that result in compression of the vertebra with an intact ligamentous apparatus. Type B are injuries with a damage to the posterior or anterior tension band with a disturbance of the relationship (usually diastasis) of the anatomical structures of the subaxial region while maintaining the axis of the spine (without signs of subluxation or dislocation). Type C includes injuries accompanied by the displacement of the body of one vertebra relative to another in any plane: forward, backward, lateral displacement or vertical separation. The general

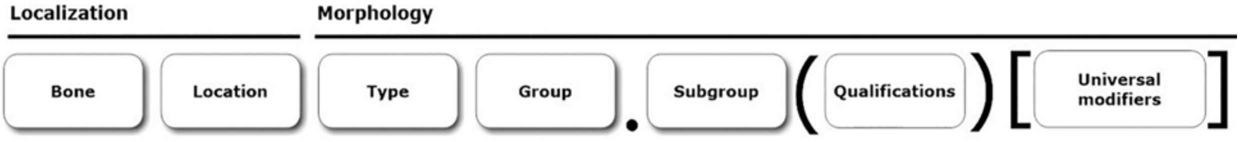

Fig. 1. General alphanumeric structure of AO / OTA classification

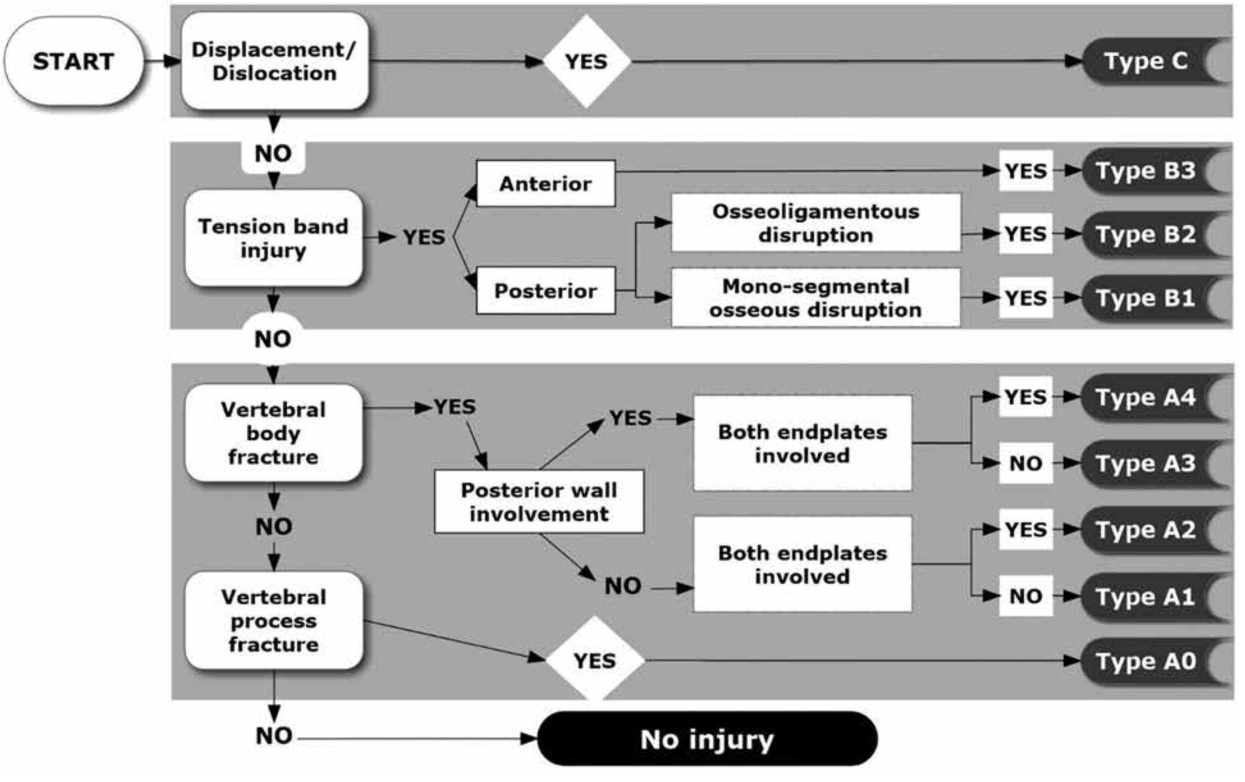

Fig. 2. Algorithm for determining the morphological type of damage according to AOSpine Subaxial Classification System

algorithm for determining the morphology of damage is shown in ***Fig. 2.***

In case of multiple injuries, traumas are classified in order of decreasing severity (C, B, A) and by the level (in the cranio-caudal direction).

1. **Type A**: compression injuries - damage to the anterior tension band under the influence of force, the vector of which corresponds to or close to the axis of the spine. This group also includes biomechanically minor fractures of the processes (for example, the spinous process or isolated lamina fracture). Type A injuries are classified into 5 subtypes in increasing order of severity:

• A0 - minor osteo-traumatic injuries, such as isolated lamina fracture or spinous process. A0 is also indicated in the absence of damage to bony structures and the presence of a clinic of traumatic nerve damage, such as SCIWORA (Spinal Cord Injury without Radiographic Abnormality) ***(Fig. 3A);***

• A1 - compression fractures involving a single endplate without damage to the posterior wall of the vertebral body ***(Fig. 3B)***;

• A2 - transverse fracture involving both endplates without involvement of the posterior wall of the vertebral body ***(Fig. 3C)***;

• A3 - incomplete burst fracture is characterized by damage to a single endplate (upper or lower) and the posterior surface of the vertebral body with a possible displacement of bone fragments dorsally ***(Fig. 3D)***;

• A4 - complete burst fracture. These injuries are similar to A3, but both endplates are involved ***(Fig. 3E)***. This subgroup also includes fractures that completely split the vertebral body in the sagittal plane - a transverse sagittal injury involving both endplates.

2. Type B: Tension band injuries. There are three subgroups:

• B1 – Posterior tension band injury with the area of damage that passes through the bony structures. The fracture line passes to the posterior parts of the vertebral body with a possible injury of the intervertebral disc ***(Fig. 4A)***;

• B2 - Posterior tension band injury with complete disruption of the posterior capsular ligament or bony capsular ligament structures. Possible damage to the vertebral body or intervertebral disc ***(Fig. 4B and 4C)***;

• B3 - Anterior tension band injury with diastasis of anatomical formations. The area of injury passes through the intervertebral disc or vertebral body (characteristic of ankylotic spondylarthritis). Undamaged facet joints usually prevent rough displacement ***(Fig. 4D)***.

In case of verification of each of the described types of damage to the osteo-ligamentous apparatus and the presence of displacement of the injury is classified as type C.

3. Type C: translation injury in any axis. This category includes injuries with displacement or translation of one vertebra relative to another in any direction ***(Fig. 4E).*** In this case, any associated injury (either A or B) is specified separately as a subtype. Injuries when the anterior and posterior vertebral elements are separated from each other (complete separation of one vertebra from another) are also classified as displaced injuries. In contrast to those described above for type C not one vertebra is indicated, but a spinal motion segment in which the damage were verified.

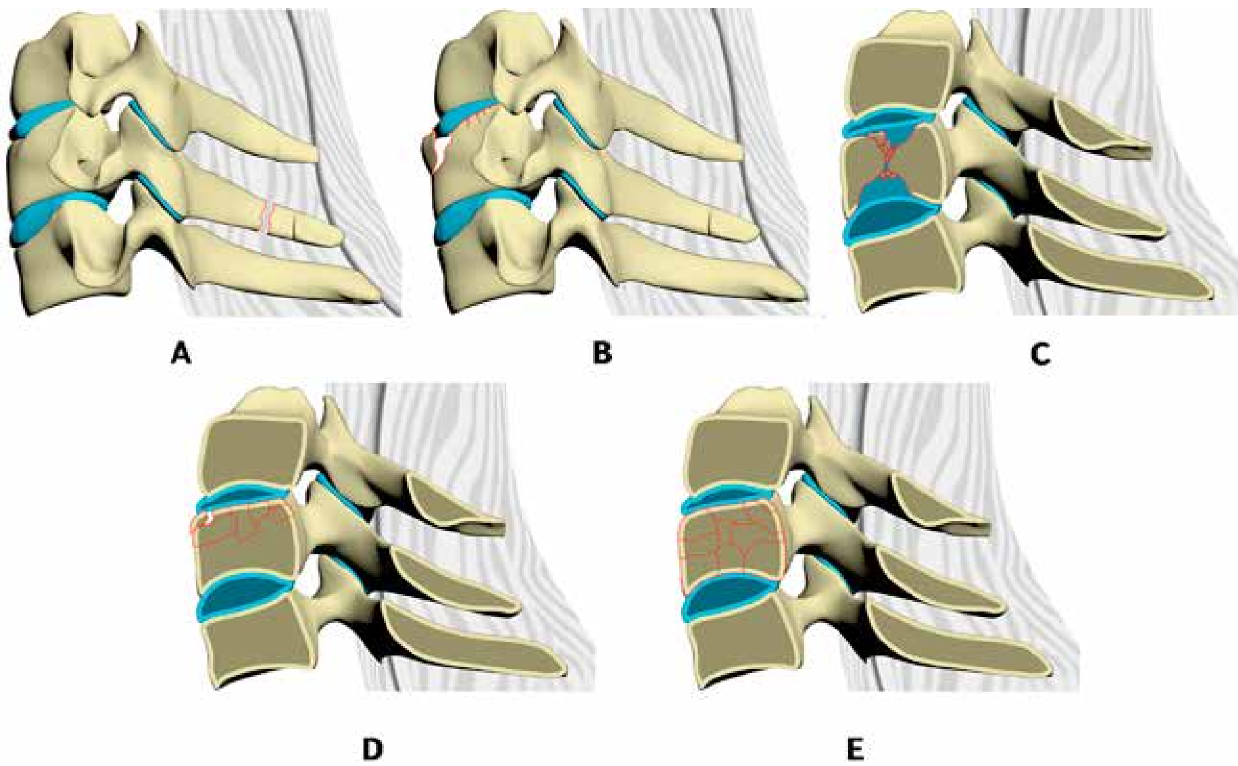

Fig. 3. Compression injuries (type A): A - A0; B - A1; C - A2; D - A3; E - A4

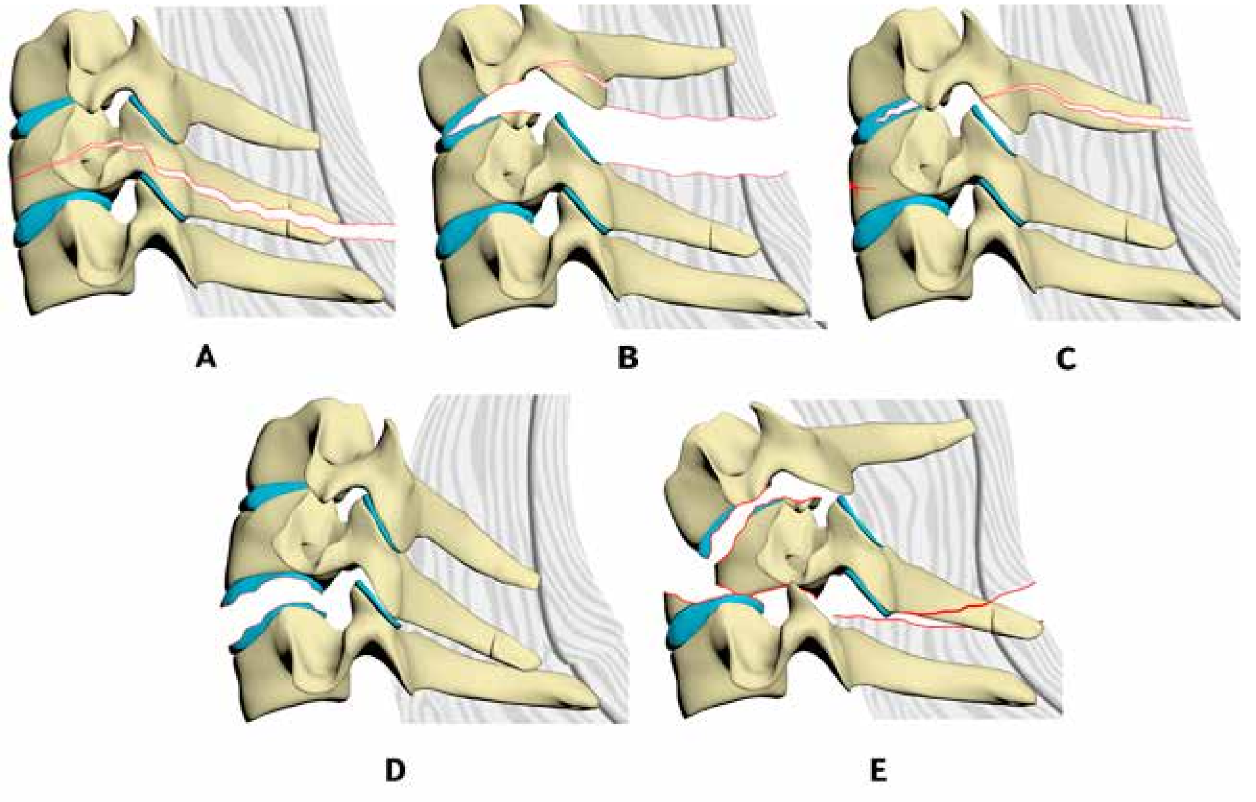

Fig. 4. Flexion-extension (type B) and rotational (type C) injuries: A - B1; B, C - B2; D - B3; E - type C

II. ***Injury of facet joints***. The classification has a series of descriptors to describe the range of possible injuries to facet joints. In the presence of several injuries of the same nature (for example, fracture and dislocation), only the most severe degree of injury is classified (dislocation). If both facets of one vertebra are damaged and assigned to different subcategories, then the right-sided facet injury is listed before the left-sided one. The "Bilateral" (BL) modifier is used if both sides have the same type of injury. If there is an isolated facet joint injury without a verified morphological type (no injuries of type A, B or C) they are listed immediately after the level:

• F1 - stable facet fracture (upper or lower surface): fragment size <1 cm, articular surface <40%;

• F2 - potentially unstable fracture of the facet joint (upper or lower surface): fragment size> 1 cm, articular surface > 40% or verified displacement of the fragment;

• F3 - floating lateral mass: fracture of the pedicle and lamina, resulting in separation of the lateral mass;

• F4 - traumatic subluxation or dislocation: an injury in which the ratio of the articular surfaces of adjacent vertebrae is disturbed by ≥50% or there is a locked facet dislocation. Such injuries are always accompanied by gross damage to the ligamentous apparatus of the posterior tension band and correspond to the morphological type C;

• BL (bilateral) - a modifier that is used for the same type of facet injury of one vertebra bilaterally.

III. **Neurological status** is assessed by six grades:

• N0 - neurologically intact;

• N1 - transient neurologic deficit, which has completely regressed within 24 hours after injury;

• N2 - radiculopathy;

• N3 - incomplete spinal cord injury (ASIA B – D);

• N4 - complete spinal cord injury (ASIA A);

• NX - neurological status was not assessed. It is used in case of impossibility to fully assess the degree of neurological disorders (multiple bony injuries, traumatic brain injury, intoxication, sedation, etc.).

In case of N2 or N3 and nerve structures compression, which continues, the modifier "+" is used.

IV. **Case specific modifiers**: created to describe additional factors relevant to clinical decision making [7]:

• M1 - injury to the posterior ligamentous complex without complete disruption. It indicates an injury that is stable in terms of the degree of damage to the bony structures, but is characterized by verified traumatic changes in the posterior ligamentous complex. Clinically, the examination reveals localized posterior tenderness of the neck. The diagnosis is confirmed by magnetic resonance imaging;

• M2 - Critical disc herniation. Magnetic resonance imaging is characterized by tissue signal intensity that is consistent with nucleus pulposus protruding posteriorly to a vertical line drawn along the posterior border of the inferior vertebral body at the injured level [15];

• M3 - metabolic changes. Diffuse idiopathic skeletal hyperostosis, ankylosing spondylitis, ossification of the posterior longitudinal ligament or ossification of the ligamentum flavum;

• M4 - signs of of vertebral artery injury.

Principles of constructing a classification code

AOSpine Subaxial Classification System, using morpho-functional classes and modifiers identical to AO / OTA classifications, for some reason has slightly different punctuation when forming the code of the case that is analyzed. Thus, firstly the vertebra is indicated (for type A or B) or spinal motion segment (for type C, sometimes for type B), which has: 1) the highest injury severity level (in descending order: C, B, A), 2) is located most cranially, and after the colon - the nature of damage.

In the case of vertebral injuries of lower severity or located more caudally, they are indicated after the primary injury in parentheses. The nature of damage to facet joints, the level of neurological disorders and additional modifiers are also given here. [8]. For example, compression fractures of bodies C4 and C5-vertebrae of subtype A2 without injury to facet joints and neurological disorders: **C4: A2 (C5: A2, N0).**

If there is damage to the facet of two types, such as fracture (**F2**) and dislocation (**F4**), the most severe, in our example - **F4** is indicated. In case of the same type of bilateral damage to facets the **BL** modifier is used. In the presence of different types of injuries to facets on both sides the right-sided facet injury is listed before the left-sided one.

In case of isolated damage to the facets without traumatic injury to the bodies, it is allowed to indicate type F before parentheses after the level of damage. For example, unilateral pedicle and lamina fracture of C5 with floating fragment, symptoms of radiculopathy in a patient with ankylotic spondylarthritis: **C5: F3 (N2, M3).**

For illustration, a clinical case is presented. Patient M., 25 years old, was injured in a road traffic accident, the level of neurological disorders corresponds to ASIA C. Computed tomography revealed: fracture-dislocation in the C4-C5- motion segment with a compression fracture of C4-vertebra, fragment fracture of C5 -vertebra. Compression fracture of C6 vertebra. Fracture of the arch of C4-C5 vertebrae on the right, C5 vertebra on the left. Dislocation of C4-C5 vertebrae on the right. Classification code: **C4-C5: C (C4: A3, C5: A4, C6: A3, F4, F2, N3 +)** ***(Fig. 5)***.

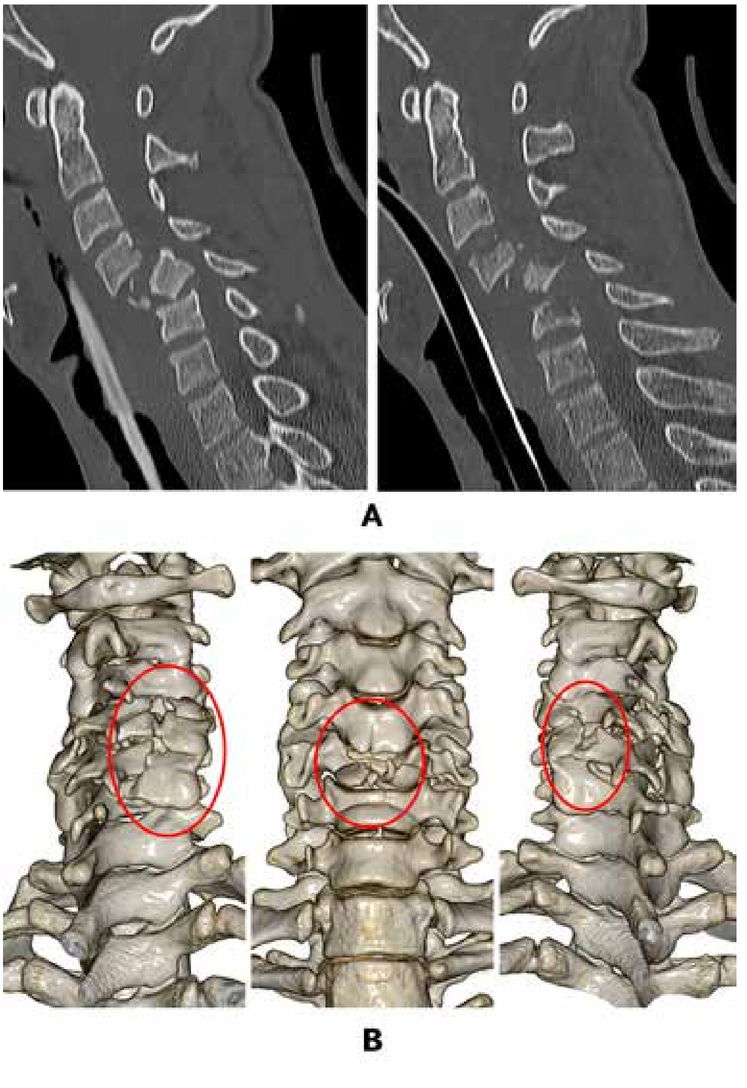

Fig. 5. Spiral computed tomography. Traumatic injury of the cervical spine: A - sagittal reconstruction; B - three-dimensional reconstruction

Principles of treatment

Despite a fairly widespread promotion and active implementation, AOSpine Subaxial Classification System does not have a full-fledged tactical focus. In contrast to previously described Subaxial Injury Classification and Severity Scale and Cervical Spine Injury Severity Score, the classification considered in the author's interpretation does not indicate any optimal treatment for a particular type of injury. The need for standardization of care for injured with traumatic injuries of cervical spine determined the advisability of developing basic principles of therapy within the proposed classification characteristics. The most detailed recommendations suggested by Spine Section of the German Society for Orthopedics and Trauma [7]. Here are the fundamental principles:

A0 - fractures are stable, subject to conservative therapy with adequate pain medication and anti-inflammatory agent. A soft collar can be used to reduce pain intensity for a short period (up to 6 weeks);

A1 - fractures are stable, in most cases, conservative therapy with early rehabilitation. In case of initial deformation or increase in kyphotic angulation by more than 15 ° (Δ-bEA), anterior monosegmental (rarely bisegmental) corporodesis is indicated in order to correct and preserve the sagittal profile of the cervical spine (CS). The Δ-bEA index is calculated as the absolute difference between the actual bisegmental endplate angle (bEA) and the value of the norm for this level ***(Table 1)*** [9,10];

A2 - fractures are stable, usually subject to conservative therapy, similar to that of A1 fractures. In A2 fractures, an increase in kyphotic angulation of more than 15 ° (Δ-bEA) is an indication for anterior corporodesis, which, unlike A1 fractures, is always performed bisegmentally;

A3 - fractures are accompanied by the risk of migration of bone fragments dorsally and the subsequent development of neurological disorders. In addition, the risk of secondary kyphotic deformity is significantly higher compared to A1 and A2, therefore depending on the degree of injury to the vertebral body, ventral mono- or bisegmental corporodesis is recommended. Patients without severe symptoms, in the absence of kyphotic deformity, narrowing of the spinal canal and with preserved free cerebrospinal fluid spaces can be treated conservatively with mandatory fixation of CS with a rigid head holder for at least 6 weeks. It is necessary to monitor the bisegmental kyphotic angle. Minimal growth of kyphotic angulation is an indication for surgical stabilization;

Table 1. The range of normal values of segmental kyphosis of the cervical spine at the subaxial level according to M. Reinhold et al. [9]

Segment	Angle, °
C2-C3	-1,9±5,2
C3-C4	-1,5±5,0
C4-C5	-0,6±4,4
C5-C6	-1,1±5,1
C6-C7	-4,5±4,3
C2-C7	**-9,6**

Note: The arithmetic mean and standard deviation are shown.

A4 - fractures are characterized by significant tension band injury to the spinal column involving both endplates and intervertebral discs and are considered as unstable injuries. The risk of posterior migration of bone fragments with compression of anatomical structures of the spinal canal, as well as secondary kyphotic angulation is significantly higher compared to A3. Fractures of the A4 subtype are an absolute indication for ventral bisegmental corporadesis;

B1 - injuries are unstable, posterior bisegmental spondylodesis is recommended from the point of view of restoring the integrity of the posterior tension band. Ventral corporadesis is not indicated, since in case of consolidation and removal of implants, motor segment remobilization is possible. Despite instability, these injuries tend to be well fused, in some cases they can be treated conservatively with hyperextension in a cervical collar set (spinal halo). However, such therapy requires dynamic radiological monitoring, both in the process of immobilization and at the stage of rehabilitation;

B2 - injuries are unstable, surgical stabilization is recommended. Surgical approach (anterior, posterior or combined), as well as the decision on the length of fixation (mono- or bisegmental) depends mainly on the A-component (the degree of destruction of the vertebral body);

B3 - unstable injuries, anterior monosegmental corporadesis is recommended;

C - injuries are extremely unstable and in some cases require urgent surgical stabilization. Considering the high variability of C-injuries, an individual surgical strategy is appropriate. However, the surgical approach (anterior or combined anteroposterior), as well as the issue of the length of fixation (mono, bi or multisegmental) is largely determined by the A-component;

F1 - injuries are stable. Conservative therapy with early rehabilitation and adequate pain relief is indicated. A cervical collar is used to reduce the intensity of pain. In order to exclude secondary dislocations, X-ray control is recommended at the stage of treatment and 6 weeks after injury;

F2 - unstable facet fractures, usually components of unstable B- or C-injuries, which determine the surgical strategy. At such injuries compression of a nerve root by a facet fragment is possible that can cause additional posterior approach in case of performance of anterior stabilization;

F3 is the lateral floating mass. Similarly to F2 injuries are components of B- or C-injuries, compression of a nerve root is also possible. These injuries usually require an extensional spondylodesis than F2;

F4 - subluxation or dislocation of the facet. F4 injuries are components of unstable C injuries that actually determine the surgical strategy. In this case, compression of a nerve root by a facet is possible which may require additional posterior decompression in case of performance of anterior fusion. Unilateral or bilateral convoluted dislocations require a differentiated approach to ensure safe reduction of deformity without the risk of developing neurological disorders. Usually closed reduction is performed under X-ray examination in the presence of a free operating room or immediately in the operating room. Relaxation of the patient is recommended for convenience of performance.

Closed reduction of subaxial dislocations is recommended to be performed as early as possible, taking into account inversely proportional relationship between the time that elapsed after the injury before the attempt of closed reduction, and the success of the latter.

In neurologically intact patients, it is recommended to perform closed reduction under anesthesia directly in the operating room. If it is impossible to restore an adequate proportion of facets, an anterior decompression is immediately performed, followed by an attempt of open indirect repositioning using distractors. The effectiveness of this method, according to M. Aebi, is more than 95% [11]. In rare cases, when the anterior open indirect reduction is ineffective, open direct reduction is performed from the posterior approach, but only after mandatory complete ventral decompression.

Some surgeons prefer to perform the initial posterior direct repositioning without preliminary ventral decompression, however the prerequisite for the safety of such tactics is the presence of adequate intraoperative neuroimaging, which prevents compression of the spinal canal, which may occur immediately after the restoration of the spinal axis (for example, the appearance / increase of traumatic extrusion of the intervertebral disc).

However, the given scheme of treatment strategy for patients with traumatic injury to CS at the subaxial level, despite the logic and consistency, does not in all cases consistent with previously developed principles [12].

Thus, O. Turolo da Silva et al. based on the results of a retrospective analysis of treatment strategy in 51 patients with trauma to the subaxial part of the CS, it was demonstrated that type C injuries in most cases are subject to surgical treatment with restoration of facet congruence in F4 lesions [13]. Patients with minor bone injuries of the A0 subtype may receive conservative therapy. B fractures group require mainly surgical treatment, and F1, F2 and F3 are subject to conservative therapy. The authors failed to establish a clearer relationship. Initially, the choice of therapy was made using the Subaxial Injury Classification and Severity Scale.

Somewhat different results on the treatment strategy of different types of injuries according to the AOSpine Subaxial Classification System were obtained by H. Mushlin et al. [14]. The paper presents the results of a retrospective analysis of surgical treatment strategy of 82 patients. When choosing an approach to the treatment of patients, the authors followed the principles of decompression, stabilization and restoration of the sagittal profile, but a clear algorithm for making a decision in favor of one method or another is not given. For example, out of 36 patients with morphological subtype A0 32, surgical treatment was performed (63% - ACDF, 34% - laminectomy, 3% - combination of ACDF with laminectomy). Only 4 patients are recommended to wear a head holder. On the other hand, in the subtype A3-A4 laminectomy was performed in 56% of cases, and wearing a collar was recommended in 11%. This strategy is quite radically different from the above recommendations.

Analysis of literature data regarding the optimal timing of decompression for different types of injuries revealed certain contradictions. Thus, Du Jin Peng et al. according to the analysis of treatment strategy, 402 patients who underwent surgical decompression for traumatic injury of the subaxial part of CS it was found that type A and F1-F3 injuries do not require early decompression-stabilizing intervention, unlike types B and C / F4 [15]. Some authors noted that subtypes A3-A4, along with type C, are accompanied by the most severe neurological disorders and, accordingly, require the fastest decompression [14].

Scale of severity

As repeatedly noted, the original AOSpine Subaxial Classification System does not provide any quantitative assessment of the degree of damage to CS at the subaxial level, limiting itself to the statement of morphological changes and neurological disorders. The experience of using the Subaxial Injury Classification and Severity Scale demonstrates the effectiveness of using the digital characterization of the degree of damage. In December 2020, a group of researchers led by J. Canseco proposed a quantitative interpretation of the severity of various morpho-functional classes of AOSpine Subaxial Classification System [16]. The authors analyzed the results of a survey of 189 spinal surgeons ***(Table 2).***

The proposed scale is currently being verified. However, it is obvious that this assessment tool is relevant and, in case of successful approbation, will be introduced into practical healthcare, which will make the use of AOSpine Subaxial Classification System clinically more convenient and appropriate.

Table 2. Scale for assessing the severity of classes AOSpine Subaxial Classification System (Subaxial Cervical AO Spine Injury Score)

Class	Score	Class	Score	Class	Score
A0	0	F1	2	N0	0
A1	1	F2	4	N1	1
A2	2	F3	5	N2	2
A3	4	F4	7	N3	4
A4	5	M1	2	N4	4
B1	5	M2	4	NX	3
B2	6	M3	4		
B3	6	M4	–		
C	7				

Conclusions

The data presented in the review give grounds to consider AOSpine Subaxial Classification System as a convenient tool that allows one to reflect in an alphanumeric code a significant part of the morpho-functional characteristics of traumatic CS injury at the subaxial level. The undoubted advantages include the similarity of the principles of constructing classification codes with AO-classifications of injuries of other parts of the spine, high consistency with AO / OTA classification of traumatic injuries of the human osteo-ligamentous apparatus, widespread introduction both in scientific research and in clinical practice. The main disadvantage, in our opinion, is the initial lack of practical orientation, which makes it difficult, based on the available classification features, to develop clear clinical guidelines necessary for making a reasoned tactical decision in a particular case.

Disclosure

Conflict of interest

The authors declare no conflict of interest.

Ethical norms

This article is a literature review, therefore no ethics committee approval was required.

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References

1. Müller ME, Nazarian S, Koch P. Classification AO des fractures: les os longs. Springer-Verlag; 1987.
2. Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, Prokuski L, Sirkin MS, Ziran B, Henley B, Audigé L. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. J Orthop Trauma. 2007 Nov-Dec;21(10 Suppl):S1-133. doi: 10.1097/00005131-200711101-00001.
3. Kellam JF, Meinberg EG, Agel J, Karam MD, Roberts CS. Introduction J. Orthop. Trauma. 2018 Jan;32:S1–10. doi: 10.1097/BOT.0000000000001063.
4. Vaccaro AR, Koerner JD, Radcliff KE, Oner FC, Reinhold M, Schnake KJ, Kandziora F, Fehlings MG, Dvorak MF, Aarabi B, Rajasekaran S, Schroeder GD, Kepler CK, Vialle LR. AOSpine subaxial cervical spine injury classification system. Eur Spine J. 2016 Jul;25(7):2173-84. doi: 10.1007/s00586-015-3831-3.
5. Schnake KJ, Schroeder GD, Vaccaro AR, Oner C. AOSpine Classification Systems (Subaxial, Thoracolumbar). J Orthop Trauma. 2017 Sep;31 Suppl 4:S14-S23. doi: 10.1097/BOT.0000000000000947.
6. Vaccaro AR, Oner C, Kepler CK, Dvorak M, Schnake K, Bellabarba C, Reinhold M, Aarabi B, Kandziora F, Chapman J, Shanmuganathan R, Fehlings M, Vialle L. AOSpine thoracolumbar spine injury classification system: Fracture description, neurological status, and key modifiers Spine (Phila. Pa. 1976). 2013 Nov 1;38(23):2028–37. doi: 10.1097/BRS.0b013e3182a8a381.
7. Divi SN, Schroeder GD, Oner FC, Kandziora F, Schnake KJ, Dvorak MF, Benneker LM, Chapman JR, Vaccaro AR. AOSpine-Spine Trauma Classification System: The Value of Modifiers: A Narrative Review With Commentary on Evolving Descriptive Principles. Global Spine J. 2019 May;9(1 Suppl):77S-88S. doi: 10.1177/2192568219827260.
8. Aarabi B, Oner C, Vaccaro AR, Schroeder GD, Akhtar-Danesh N. Application of AOSpine Subaxial Cervical Spine Injury Classification in Simple and Complex Cases J. Orthop. Trauma. 2017 Sep;31:S24–32. doi: 10.1097/BOT.0000000000000944.
9. Reinhold M, Knop C, Lange U, Rosenberger R, Schmid R, Blauth M. Reposition von verrenkungen und verrenkungsbrüchen der unteren halswirbelsäule Unfallchirurg. 2006 Dec;109(12):1064–72. doi: 10.1007/s00113-006-1188-0.
10. Slynko II, Nekhlopochin AS, Verbov VV. [The classifications of subaxial cervical spine traumatic injuries. Part 1. General principles]. Ukrainian Neurosurgical Journal. 2019 Sep 28;25(3):12–26. Russian. doi: 10.25305/unj.171334.
11. Aebi M. Surgical treatment of upper, middle and lower cervical injuries and non-unions by anterior procedures. Eur. Spine J. 2010;19 Suppl 1:S33–9. doi: 10.1007/s00586-009-1120-8.
12. Vaněk P. New AOSpine subaxial cervical spine injury classification and its clinical usage. Rozhl Chir. 2018 Spring;97(6):273-278.
13. da Silva OT, Rodrigues SA, Ghizoni E, Tedeschi H, Joaquim AF. Can Injury Type/Subtype of the New Aospine Subaxial Cervical Trauma Classification Dictate Patient's Treatment? International Journal of Orthopaedics. 2020 Dec 28;7(6):1397-401. doi: 10.17554/j.issn.2311-5106.2020.07.396.
14. Mushlin H, Kole MJ, Chryssikos T, Cannarsa G, Schwartzbauer G, Aarabi B. AOSpine Subaxial Cervical Spine Injury Classification System: The Relationship Between Injury Morphology, Admission Injury Severity, and Long-Term Neurologic Outcome. World Neurosurg. 2019 Oct 1;130:e368–74. doi: 10.1016/j.wneu.2019.06.092.
15. Du JP, Fan Y, Zhang JN, Liu JJ, Meng Y Bin, Hao DJ. Early versus delayed decompression for traumatic cervical spinal cord injury: application of the AOSpine subaxial cervical spinal injury classification system to guide surgical timing Eur. Spine J. 2019 Aug 1;28(8):1855–63. doi: 10.1007/s00586-019-05959-6.
16. Canseco JA, Schroeder GD, Paziuk TM, Karamian BA, Kandziora F, Vialle EN, Oner FC, Schnake KJ, Dvorak MF, Chapman JR, Benneker LM, Rajasekaran S, Kepler CK, Vaccaro AR. The Subaxial Cervical AO Spine Injury Score. Global Spine J. 2020 Dec 11:2192568220974339. doi: 10.1177/2192568220974339.