Original article

Cervical spine trauma: impact of different imaging classification systems in the clinical decision-making

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Abstract. *Background and aim*: Considering the high rate of mortality and permanent disability related to vertebral traumas, an early and detailed diagnosis of the trauma and subsequently an immediate and effective intervention are crucial. Cervical vertebral injury classifications guide treatment choice through a severity grade based on radiological information. The purpose of the present study was to define which imaging classification system could provide the best morphological and clinical-surgical correlations for cervical spine traumas. *Methods*: We retrospectively analyzed patients evaluated for cervical spine trauma at our Institution in the period 2015-2020. Information regarding the morphological examination (using CT and MRI), the neurological evaluation, and the therapeutic management were collected. C3-C7 fractures were classified according to the SLIC and AOSpine criteria; axial lesions were classified according to the modified AOSpine for the C1-C2 compartment and through the Roy-Camille and the Anderson D'Alonzo system for the odontoid process of the axis. *Results*: 29 patients were included in the final study population. Nine patients with axial spine trauma and 21 with subaxial cervical spine trauma. A conservative approach was applied in 16 patients while nine patients underwent neurosurgery. Considering the therapeutical indications provided by the SLIC system, a 76.9% accordance was found for patients with a <4 score, while a 100% concordance was calculated for patients with a >4 score undergoing neurosurgery. Regarding the AOSspine classification, a 28.6% concordance was observed for patients classified group B being treated with a posterior neurosurgical approach, while for patients belonging to subgroup C, considered for anterior neurosurgical approach, a 66.7% accordance was calculated. *Conclusions*: The study demonstrated a better morphological correlation for the AOSpine classification in subaxial trauma and the AOSpine and Anderson D'Alonzo in axial trauma. The therapeutic indication found a better correlation in the SLIC classification for subaxial trauma and the Anderson D'Alonzo for axial ones. (www.actabiomedica.it)

Key words: Vertebral traumas, cervical vertebral injuries, vertebral injury classification, magnetic resonance imaging, neurosurgical intervention

Introduction

Vertebral traumas affect the integrity of the spine, undermining the fundamental functions of its static, dynamic, and neuroprotective support (1-5). For these reasons, they are burdened with a high rate of mortality and permanent disability, and accurate early diagnosis of the trauma entity is crucial to allow the most effective and immediate intervention (6-15).

Lesions of the cervical spine occur more frequently in young adults, especially in males (79.8%), following a bimodal age distribution with a first peak between 15-24 years and the second peak over 55yo (8, 14, 16-20). Metamers in the lower cervical segment and in particular C5- C6 are the most affected because they represent the fulcrum of cervical spine flexion, whereas C1 and C2 are less affected (about 28% of cases in total) (21-23).

The leading cause for cervical spine trauma is to be recognized primarily in road accidents (38%)- among which projective motorbike-car injuries stand out - followed by accidental falls (31%); the remainder of the injuries are attributable to assaults, contact sports, and work accidents (7, 24-29).

Acute mortality during hospitalization is estimated between 4-17%; after discharge, the mortality rate drops and remains stable at 3.8% in the first year, 1.6% in the second, and 1.2% in the following years. The risk of mortality increases in severe and high cervical trauma, patient's advanced age, and polytrauma patients (16, 30-34).

In the acute setting of cervical trauma, the first goal is to evaluate the clinical neurological status, and diagnostic imaging represents an invaluable tool for the assessment of anatomical derangement of osseous and ligamentous structures (6, 15, 16, 31, 35-38). During the years, the various range of imaging findings (e.g. fractures, dislocations) have been collected and graded into several different classification systems that could be useful to standardize the diagnostic findings and provide guidance for clinical decision making (21, 22, 32, 33, 39-42). Conventional plain film is usually indicated for trauma screening in low-energy injuries, while sectional imaging modalities – namely CT an MRI – are fundamental for accurate detection of involved bone, ligament, and nervous structures (1, 9, 11, 17, 23, 43-68). In particular, according to the NEXUS Criteria and Canadian rules for C-spine, imaging is recommended in patients over 65 years, or patients complaining extremity paresthesias or a dangerous mechanism trauma (69).

Absolute indications for cervical spine CT include high-speed motor vehicle accidents or fall from height, significant head injury/neurological deficits, and multiple associated fractures (70).

Cervical spine MRI may be indicated for suspected SCIWORA,Central Cord Syndrome, or vascular neck injury (71).

In recent years, applications of image-guided spinal procedure in traumatic lesions are also increasing (72-84).

Different classification systems have been drawn up for cervical trauma based on different anatomical and biomechanical criteria and with different clinical and therapeutic indications (15, 16, 36, 51, 55, 85, 86). Therefore the present study, focusing on the most used cervical vertebral trauma classifications, aimed to identify the system with the best morphological and clinical-surgical correlation.

Materials and Methods

Patients, aged 18 or more, who underwent diagnostic imaging examination at the Emergency Department of the S.Salvatore Hospital (L'aquila, Italy) in the period 2015-2020 for cervical spine trauma were included in this retrospective study.

Criteria for inclusion were the availability of good quality CT/MRI examinations and complete information regarding the patient's clinical and therapeutical management, retrieved from medical records.

Patients with incomplete radiological or medical records or poor-quality images were excluded from the final analysis. Patients with pathological fractures due to cancer or infection were also excluded.

All demographic details, including age, gender, and the etiology of trauma were collected. Similarly, any information regarding the conservative or surgical approach, complications, and follow-up were considered. The presence of any associated medical conditions and/or previous surgery were recorded.

Imaging analysis was performed on CT and MRI acquisitions carried out upon the patient's admission. In addition to imaging information, objective neurological examinations were used to assess the neurological status.

The selected patients were divided according to the lesion level into axial and subaxial groups in a first analysis (30).

Cervical spine injuries were categorized using all the available classifications depending on the level of the lesion. In particular, C3-C7 fractures were classified according to the SLIC - subaxial cervical

Table 1. SLIC classification system

SLIC		
Morphology	No abnormality	0
	Compression	1
	Burst	2
	Distraction	3
	Rotation/Translation	4
DLC (Discoligamentous complex)	Intact	0
	Indeterminate (only MR signal alteration)	1
	Disrupted	2
Neurological status	Intact	0
	Root injury	1
	Complete cord injury	2
	Incomplete cord injury	3
	Incomplete with ongoing compression	4

spine injury classification (85) and AOSpine criteria (15, 25).

Axial lesions were evaluated according to the modified AOSpine for the C1-C2 compartment.

The Roy Camille and the Anderson D'Alonzo systems were used for evaluation of odontoid process lesions (87, 88).

In order to establish which classification provided the best morphological correlation, CT and/or MRI scans were reviewed by two investigators who were blinded both to the clinical outcome and each other's findings. The agreement between the investigators' analyses was calculated, and conflicting cases were revised in consensus to find correspondence to the clinical data.

In order to determine the clinical-surgical correlation, a comparison between the expected treatment and the actual therapeutical approach was carried out.

Results

Twenty-nine patients (15 males, 14 females) with different cervical spine injuries were included in the study. Nine patients showed axial spine trauma, and 21 had subaxial cervical spine lesions; a single patient had multiple lesions in both study districts.

The mean age of patients was 66 years (median 66.3), respectively. The causes were road polytrauma (51%) and accidental falls (49%).

With regards to the subaxial trauma, the SLIC (86) and the AOSspine classifications were used.

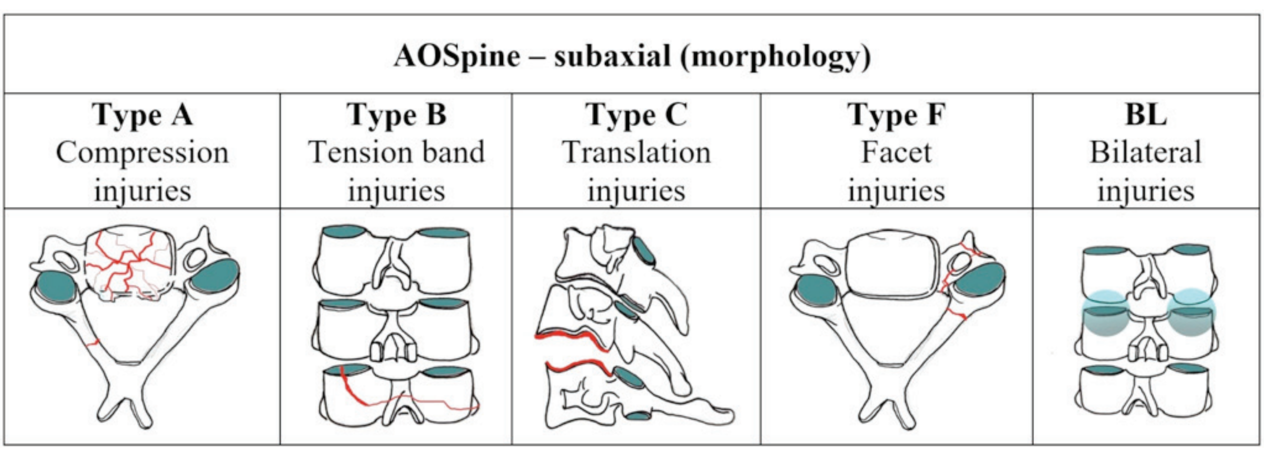

Figure 1. AOSpine subaxial classification system (adapted from AOSpine International, Switzerland)

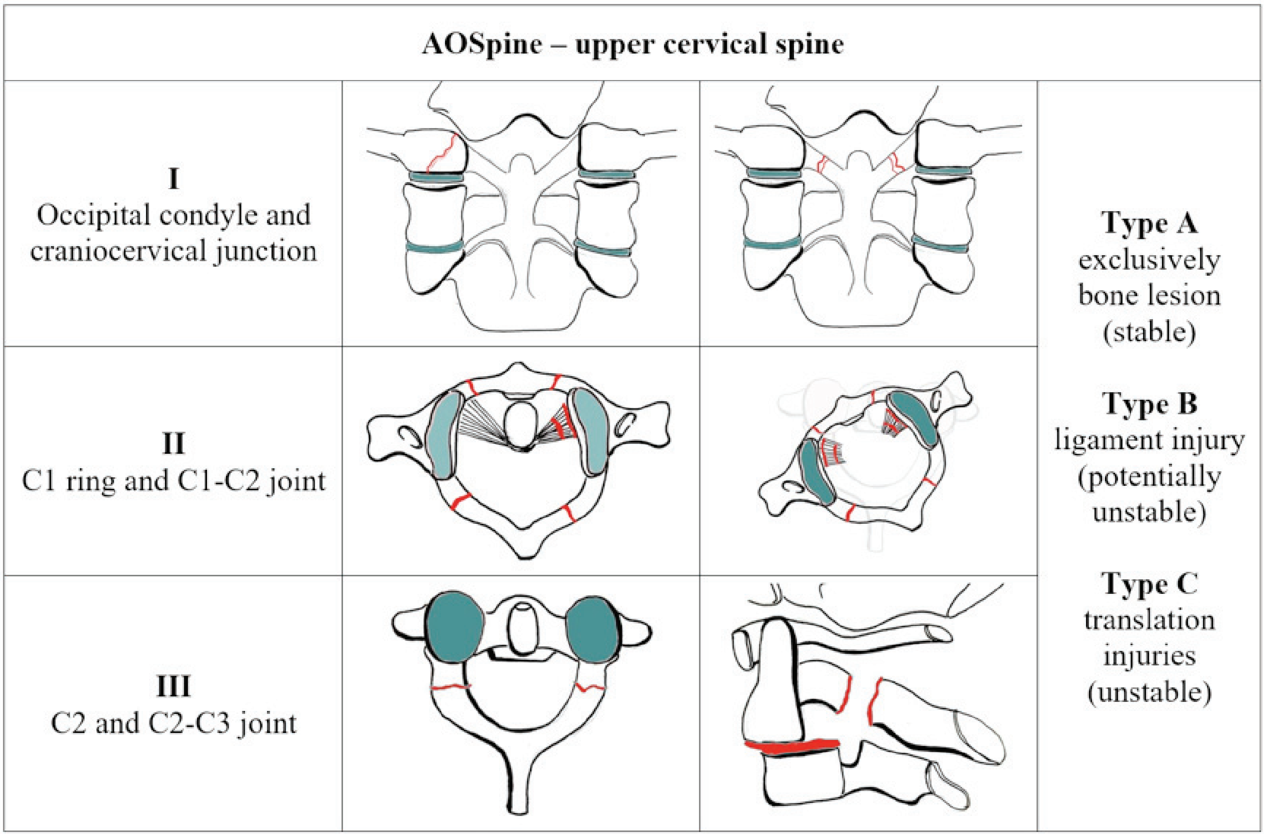

Figure 2. AOSpine classification system for upper cervical spine trauma (adapted from AOSpine International, Switzerland)

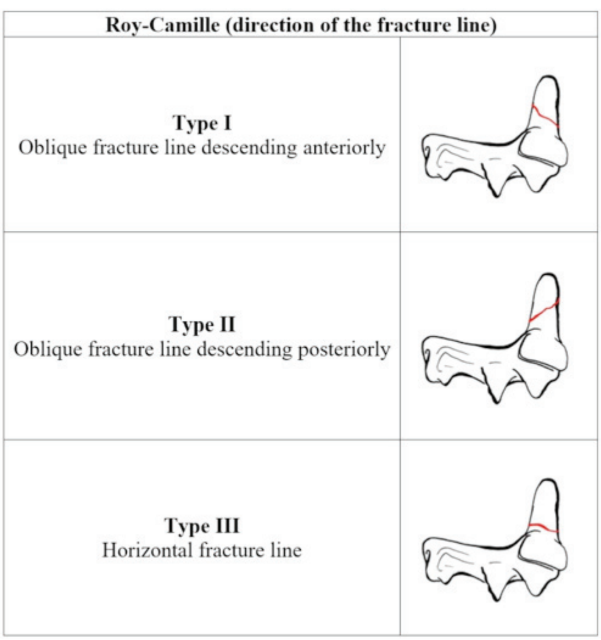

Figure 3. Roy-Camille classification system (adapted from: (87))

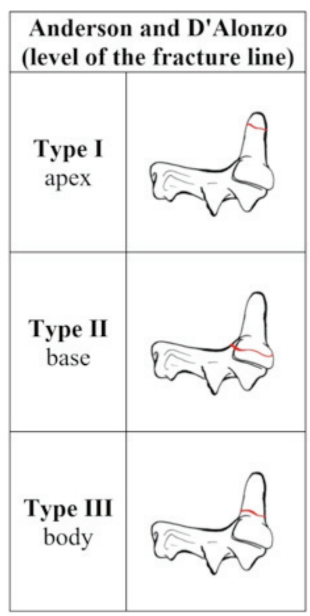

Figure 4. Anderson-D'Alonzo classification system (adapted from: (88))

According to the AOSspine classification, patients were divided into four subgroups: 5 patients were classified in the A subgroup, 7 in the subgroup B, 3 in subgroup C, and 4 in the subtype D.

Concerning the clinical neurological status, 19/29 patients presented an intact neurological state, with no evident deficits at the first physical examination. In 5/29 patients, it was not possible to perform a complete neurological examination as they were polytraumatized, intubated, or non-collaborating (conditions that define the NX parameter). A complete myelic lesion was found in a single patient, presenting with severe quadriplegia (N2). One patient had myelopathy from a compressive lesion in at C3-C4 level (N4), for which it was necessary to perform decompression before performing surgical arthrodesis. Two patients had focal sensorimotor deficits in the right hemisome (N3).

The SLIC classification was then revised in the light of the clinical data collected. In this perspective, 13 patients had a SLIC score <4, 5 patients had a SLIC score=4, while only one patient had a SLIC score >4.

With regards to the axial trauma, the AOSspine, the Roy-Camille and the Anderson D'Alonzo classifications were used.

Using the AOS spine criteria, three patients were classified as subtype A, two patients in subgroup B, and only one patient in subgroup C.

According to the Roy-Camille, one patient was included in subtype 1, 6 patients in subtype 2, and 2 patients in subtype 3.

Using the Anderson D'Alonzo classification, four patients were classified in subtype 1, 2 in subtype 2, and 3 in subtype 3.

A conservative approach was applied in 16 patients while nine patients underwent neurosurgery.

With regard to the neurosurgical intervention, an anterior approach was used in 5 cases, while in four patients, a posterior approach was performed.

Considering the therapeutical indications provided by the SLIC system, a 76.9% accordance was found for patients with a <4 score, undergoing a conservative approach. On the other hand, a 100%

Table 2. Distribution of sub-axial cervical injuries in the study population

SLIC partial score	**Distribution**
<4	14pz
=4	1pz
>4	4pz
AOSpine morphology	**Distribution**
A	5pz
B	7pz
C	3pz
F	4pz

Table 3. Distribution of axial cervical injuries in the study population

AOSpine criteria	**Distribution**		
Localization	1 (2pz)	2 (6pz)	3 (1pz)
Type	A (3pz)	B (2pz)	C (4pz)
Roy-Camille criteria	**Distribution**		
Type I	1		
Type II	6		
Type III	2		
Anderson & D'Alonzo criteria	**Distribution**		
Type I	4		
Type II	2		
Type III	3		

Table 4. Concordance between imaging classification and treatment

SLIC score	**Treatment**	**Expected**	**Effective**	**Concordance**
<4	Conservative	13	10	**76,9%**
>4	NCH	5	5	**100%**
AOSpine				
B (7pz)	Post. approach	7	2	**28,6%**
C (3pz)	Ant. approach	3	2	**66.7%**

concordance was calculated for patients with a >4 score undergoing neurosurgery.

For the AOSspine classification, a 28.6% concordance was observed for patients classified group B being treated with a posterior neurosurgical approach. For patients belonging to subgroup C, who were considered for an anterior neurosurgical approach, a 66.7% concordance was calculated.

Discussion and Conclusions

This study tries to define which imaging classification system has the best correlation with the morphology of the trauma of the cervical spine and the type of therapeutic approach adopted.

The morphological diagnosis was formulated through CT scans, possibly accompanied by MRI images. All fractures were reclassified according to the parameters applied above for the axial and subaxial segments. Regarding the subaxial segment, the best match was defined for the AOSpine system. It is a classification method that is easy and immediate to apply as it requires you to define the individual structures involved, including endplate, posterior wall and soma, as well as allowing you to include in the evaluation the state of the joint facets, which are essential to define the stability of the region. In fact, the patients with joint surface involvement all underwent a surgical intervention.

The morphological definition for subaxial trauma, adopting the AOSpine system, was found to be more immediate and easier, whereas the SLIC classification led to problems regarding the definition of the discoligamentous complex due to the partial lack of accompanying MRI.

For the morphological description of trauma to the axial spine, the AOSpine classification demonstrated a better sensitivity in defining the lesion; moreover, Anderson D 'Alonzo was found to be more applicable than Roy Camille in the treatment of lesions of the second cervical vertebra, as it stratifies according to the height of the lesion even trauma without dislocation of the fragments; Roy Camille excludes compound lesions without dislocation of the fragments.

In this classification, the proposed therapeutic indications found correlation in the study for degrees of agreement much lower than those demonstrated for SLIC, respectively by 28.6% for class B patients and 66.7% for class C patients.

This demonstrates a greater correlation of the SLIC classification of subaxial trauma with the neurosurgical treatment performed. For axial trauma, the neurosurgical indication can be correlated with the Anderson D'Alonzo classification. In particular, type I fractures are indicated by neurosurgery with a preferential posterior approach in the case of ligament ruptures, otherwise it is possible to proceed with cervical immobilization. Types 2 and 3 require operative treatment as they are unstable lesions, particularly if accompanied by major dislocations or ligament ruptures. The study involved 4 C2 fractures, on which the degree of concordance with the therapy was 100% compared to the indications postulated by the classification in question. For the patient with type II lesion it was not possible to follow the applied neurosurgical management.

This demonstrates the good correlation between classification and therapy with regard to Anderson D'Alonzo, taking into account the insufficiency of the data necessary for the definition of the therapeutic process and the limited sample.

A few study already investigated the importance of these classification in guiding the therapeutical approach. Differently from the present study, classifications were only analysed separately in previous articles (14, 41, 77, 89).

Interestingly. a review of the literature published in 2007 proposed a computer-based algorithm based on the SLIC classification system to guide the surgical approach of subaxial cervical traumas (39, 90).

Although complete and easy to apply, the SLIC classification system, does not give clear advice in terms of therapeutical management. Indeed, this severity score does not provide the clinicians with a clear conservative or surgical indication for patients with a score=4. Similarly it does not come up with any evidence on the best surgical approach (85, 86).

In conclusion, this experimental study aims to define the best classification, in terms of morphological description and therapeutic indications, for traumas of the cervical spine, whose classification is essential to define the degree of severity of the lesion and the expected outcome for the patient.

The study demonstrated a better morphological correlation for the AOSpine classification in subaxial trauma and the AOSpine and Anderson D'Alonzo in axial trauma.

The therapeutic indication found better correlation in the SLIC classification for subaxial trauma and the Anderson D'Alonzo for axial ones.

The results of the study must be evaluated taking into account several drawbacks, represented by the limited study group and the inability to better define the neurological status and the treatment applied in a proportion of patients analyzed. This study may represent an attempt to define unique indications among all the available classifications and clinical and/or radiological criteria for the management of cervical trauma. Unfortunately, this purpose is hardly achievable, especially considering that the choice between several conservative and/or surgical options depends on the clinical and anatomical features of the lesion and is subjected to the surgeon preferences and experience. Finally, this analysis has only been applied on adult patients with no reference to the pediatric population.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

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