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Complex Fractures of C2 Vertebra, Retrospective Study

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Abstract

The high cervical spine is a highly mobile segment that contains and protects the transition zone from the brainstem to the spinal cord, structures of crucial importance. As a transitional vertebra, the C2 vertebra has a unique structure with different anatomic peculiarities and high mobility, that explains why the fractures patterns are different from other regions. Injuries of the high cervical spine are frequent, lately with more incidence in elderly people, fracture of the C2 vertebra occurs in approximately one quarter of cases of acute cervical fractures. Axial vertebra trauma has been the focus of different types of classification, mostly oriented to odontoid fractures and Hangman's fractures. As life longevity is increasing, C2 fractures tend to involve the elderly with their diseases, fragility, bone quality and thus the fractures are more complex. The purpose of the paper is to revise retrospectively the C2 fracture cases mostly focused on the classification of them, as we feel difficulties in classification of some cases. As a result, we attempted to adjust and tune the existed classification systems of C2 vertebra classifications.

Keywords

Fracture, Isthmus, C2 Vertebra

1. Introduction

Traumatic axial trauma, especially of C2 vertebra is largely illuminated in the literature, many articles have been published on this topic and the majority of them classify C2 fractures according to Anderson and D'Alonzo classification [1], subtypes by Grauer [2] or Hangman's type fracture, described by Effendi [3], modified by Levine and Edwards [4].

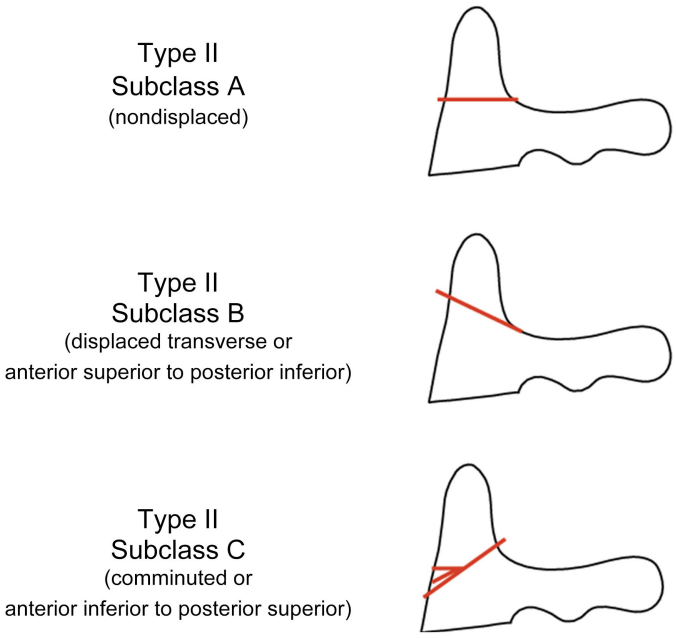


Figure 1. Grauer classification of odontoid fractures.

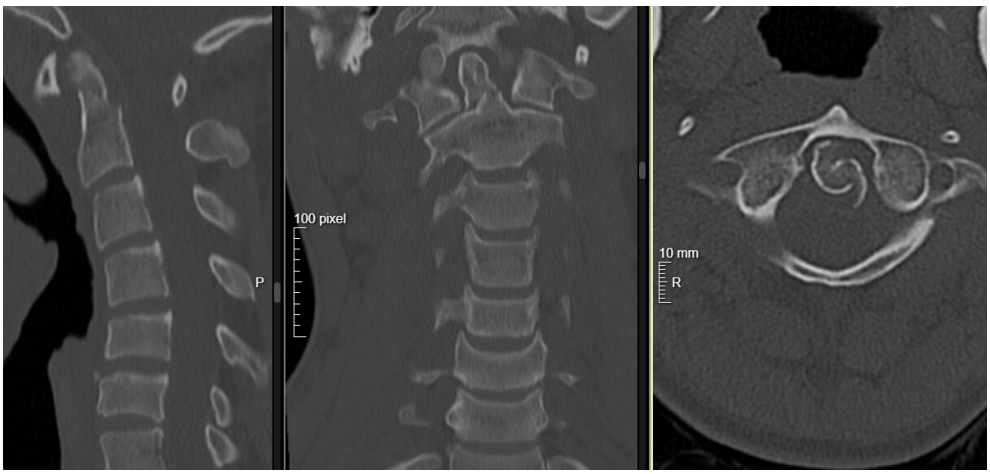
Grauer's three subtypes of type II fractures (**Figure 1**):

Subtype IIa, transverse fractures without comminution and with <1 mm displacement;

Subtype IIb, fractures that pass from anterior superior to posterior inferior or displaced transverse fractures;

Subtype IIc, fractures that pass from anterior inferior to posterior superior or fractures with significant comminution [2].

In this classification rare type of odontoid fracture is not included, let's call it IId fracture with rotational component. It usually happens in the context of acrobatic sports associated to complex mechanism of fracture with torsion of the fractured odontoid process with lateral inclination of the odontoid. As it is seen on the CT scan the odontoid process is dislocated to lateral and rotated on axial slices.



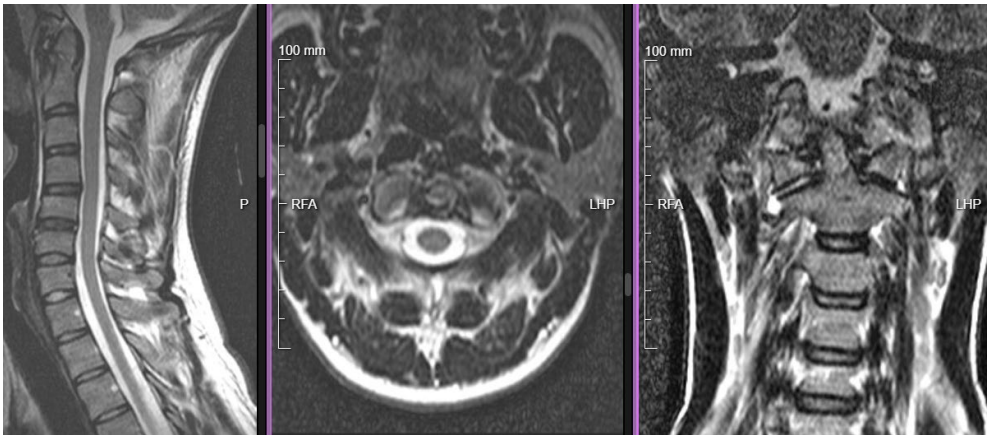


Figure 2. Type IId: odontoid fracture with rotation of the fractured odontoid and lateral bend.

Effendi classification (**Figure 2**):

Type I Isolated hairline fracture of ring of axis;

Type II Displacement of anterior fragment and abnormal disk below axis;

Type III Displacement of anterior fragment and locked facet at C2-C3 [3].

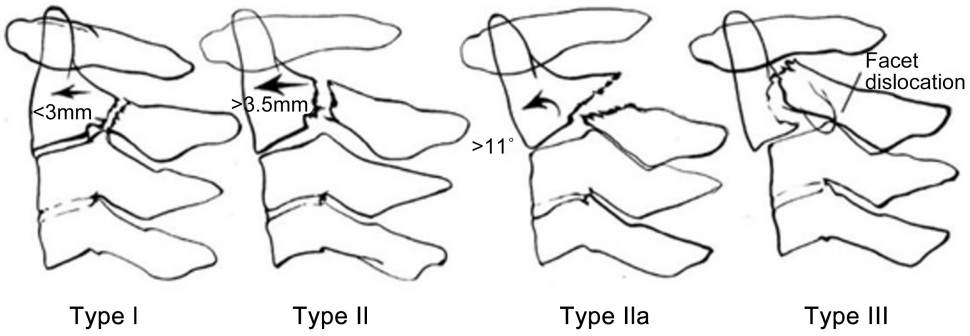


Figure 3. Levine ans Edwards hangman's fracture classification.

Levine and Edwards modification (**Figure 3**):

Type I Nondisplaced fracture (<3 mm);

Type II Significant angulation (>11 degrees) and translation (>3 mm);

Type IIa Very severe angulation without translation;

Type III Severe angulation and displacement with facet dislocation [4].

Li *et al.* divided atypical Hangman fractures subtypes:

Type A1 Fracture line through the posterior aspect of the C2 body with contralateral pars fracture;

Type A2 Fracture line through the posterior aspect of the C2 body with contralateral lamina fracture;

Type B1 Bilateral oblique fracture lines through the posterior aspect of the C2 body;

Type B2 Bilateral fracture lines through the posterior aspect of the C2 body, one is oblique and another is vertical [5].

Type III Anderson and D'Alonzo fractures involve the body of C2, not the

odontoid bone, and are not genuine odontoid fractures. Unless they are substantially displaced, these fractures are typically stable [6]. The incidence of odontoid fractures is globally increasing in the elderly population. The morphology and bone densities are different in elderly people due to their metabolic diseases and senile osteoporosis [7]. Due to this fact the C2 fractures in elderly patients are complex fractures, not easy to classify them using the existing classification systems.

There are different other classification trying to classify C2 more complex fractures, except Type I, II Anderson and D'Alonzo.

Benzel *et al.* note two types of vertical C-2 body fractures coronally oriented (Type 1) and sagittal oriented (Type 2). A third type of C-2 body fracture, the horizontal rostral C-2 fracture (Type 3), is added for completeness; this Type 3 fracture is the previously described Type III odontoid process fracture described by Anderson and D'Alonzo [8].

Fujimura *et al.* classified 31 cases of axis body fracture by the type of bony injury on radiographic images into the four types: avulsion, transverse, burst, and sagittal fractures [9].

Al-Mahfoudh et al distinguish typical and atypical hangman's fracture. Atypical hangman's fracture includes a coronally orientated fracture line through the body of C2 and oblique fractures through one side of the C2 body with contralateral fracture of posterior elements of the axis ring (either the pars or the lamina) [10]. It looks an extension of hangman's fracture classification, that was defines as a fracture through isthmus, to fracture involving vertebral body or posterior elements.

Kim *et al.* determines Type 1, fracture trajectories that involve the C2 superior articular facet on both sides; Type 2, fracture trajectories that involve the superior articular facet on one side and the lateral cortex on the other side; Type 3, fracture trajectories that involve the lateral cortex on both sides [11]. All classification systems are important, but practically it seems that are not too useful.

Anatomy of transitional axial vertebra C2 is different from other vertebrae, it consists of a different shape of vertebral body with odontoid process, articular facets and isthmus between them, foramen transversum, laminas, spinous process. The pedicle is still the cause of debate in the literature. It is almost a virtual structure, because the superior articular facets are like a lateral prolongation of the C2 body that are linked by the isthmus to the posterior vertebral structures. From the inferior aspect of C2 vertebra it is still possible to define the pedicle. It seems not too important to focus on the pedicle; the anatomy of the isthmus defines the surgical strategy.

The isthmus is the interarticular pars, that unites the anterior part of C2 vertebra with posterior elements, and it is also a border of the vertebral canal. The screw insertion for fractures, either isthmic short screws or trans-isthmic somatic screws, need good preoperative study of the anatomy of the isthmus.

According to Klepinowski *et al.*, the high ridding vertebral artery is defined by

internal height less than 2 mm and isthmic height less than 5 mm. They determined three types of high riding vertebral artery: type 1 (isthmic), type 2 (internal), and type 3 (isthmo-internal). In addition, recommendations have been stated regarding instrumentation techniques for each type [12].

Every classification is more useful when it is simple, like Grauer classification for C2 type II odontoid fractures management and the Hangman's fracture classification by Effendi for isthmus fractures. For complex fractures there is a necessity of a simple and efficient classification that simplifies the choice of surgical strategy.

With the introduction in 1994 of C1-C2 fixation with screws to the lateral masses of C1 and to the pedicles of C2 united with a plate (Goel and Laheri technique), a new concept of atlantoaxial stabilization has emerged, maintaining excellent rates of bone fusion and lower risk of vertebral artery injury [13]-[15], emphasizing the necessity to classify the fractures of C2 and determination of stability.

In this sequence of thoughts, some simple fractures are easily classified by Andreson and D'Alonzo, Grauer, Effendi known classifications, the rest patterns of fractures we considered as complex fractures. The cases more difficult to classify are the ones with different types of fracture incuded, like odontoid fracture associated to vertebral body and isthmus fracture the study is not purpose is not involving the criteria of the instability of the fractures.

Objectives

Describe the classifications of the second cervical vertebra fractures;

Outline the easy classification types of c2 fractures;

Define complex fractures types;

Summarize the fracture feature, based on the specific fracture type;

Identify interprofessional team importance of the second cervical vertebra fractures approach.

2. Material and Methods

After analyzing retrospectively 116 surgically treated axial fracture cases between 2014 and 2025, by one neurosurgeon and one imageology specialist, we tried to classify the most difficult complex C2 fractures and find fracture patterns not included in existing contemporary classifications systems. We propose to introduce the Grauer IId type of odontoid fractures and some patterns of complex fractures. From 116 cases 6 cases of C1 isolated fractures were excluded, not involving C2 vertebra, and 2 cases of multiple myeloma involving C2 vertebra and fracture. From the remaining 108 C2 vertebra fractures, 78 cases were easily classified using existing classification systems, from which 30 cases were fractures with atypical patterns. From these 30 cases we distinguished: 18 coronal fractures including 2 incomplete coronal fractures, 7 coronal oblique fractures, 3 communitive fractures and 2 oblique sagittal. The most encountered pattern was a coronal type fracture, that is typically classified by other authors as a typical Hangman fracture.

We disagree because the coronal fracture is a somatic fracture involving the vertebral body, not disrupting the vertebral canal ring and if instable the movements of the affected segment is more dangerous for the medulla as the vertebral ring moves entirely and harms a medulla like scissors mechanism. In case of Hangman fracture the vertebral canal ring is divided in two parts and during the movement the canal enlarges at the nivel od affected segment, also dangerous by scissor mechanism also but at the another level. This distinguish this two different fracture patterns, both very important in clinical practice. In the general group, the male/female distribution was 62/44%, mean age male/female was 67.6/76.2 years. The cause of the injury was mainly by falling 62%, car crash 27%, high energy trauma (falls from the height) 16% and in 1% trauma caused by heavy object. In the group of complex fractures, the statistical distribution was: male/female 45%/55%, mean age 65.45/74.81, the causality of injury: car crash 27.58%, high energy trauma 20.68%, simple falls 51.72%.

The patients we revised independently by an experienced neurosurgeon and neuroimagiology specialist, we agree in all 78 simple cases classification. We defined the Hangman fractures as the pattern of fracture that violates vertebral canal ring by fracturing the isthmus bilaterally. All other fractures that do not violate the ring or disrupt it unilaterally involving other vertebral structures we included in complex fractures. After defining the types of complex fractures, the rest of 30 cases were classified with small divergence between us, solved easily after constructive discussions.

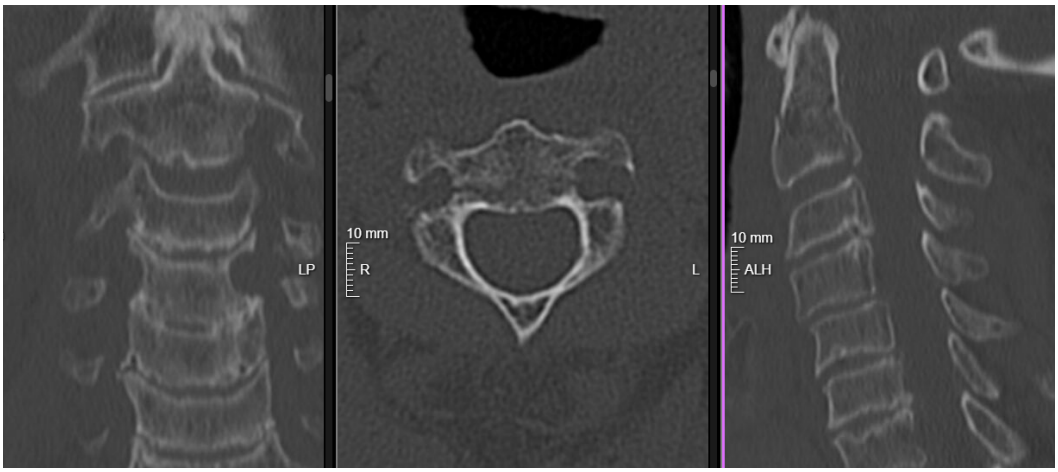
The limitation of the study is the inclusion of only hospitalized and surgically treated patients. We can explain it by the retrospective manner of the study and the conservative cases we not selected by the impossibility to trace them.

3. Complex C2 Body Case-Based Classification

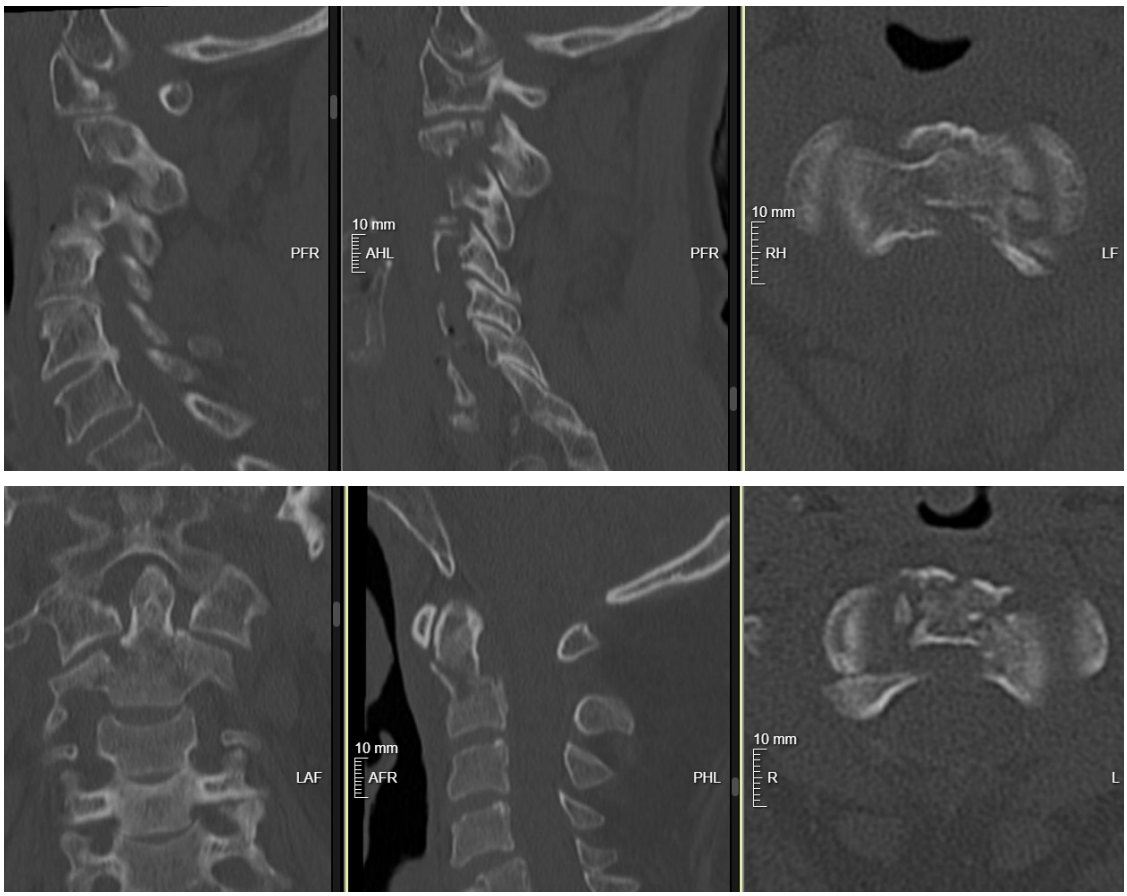
1) Coronal fracture: coronal trans-somatic fracture dividing the C2 vertebral into two parts: anterior part: odontoid process with two thirds of the C2 body and posterior part: posterior elements with one third of posterior part of the C2 body.

These fractures are seldom displaced, on coronal slices not seen.

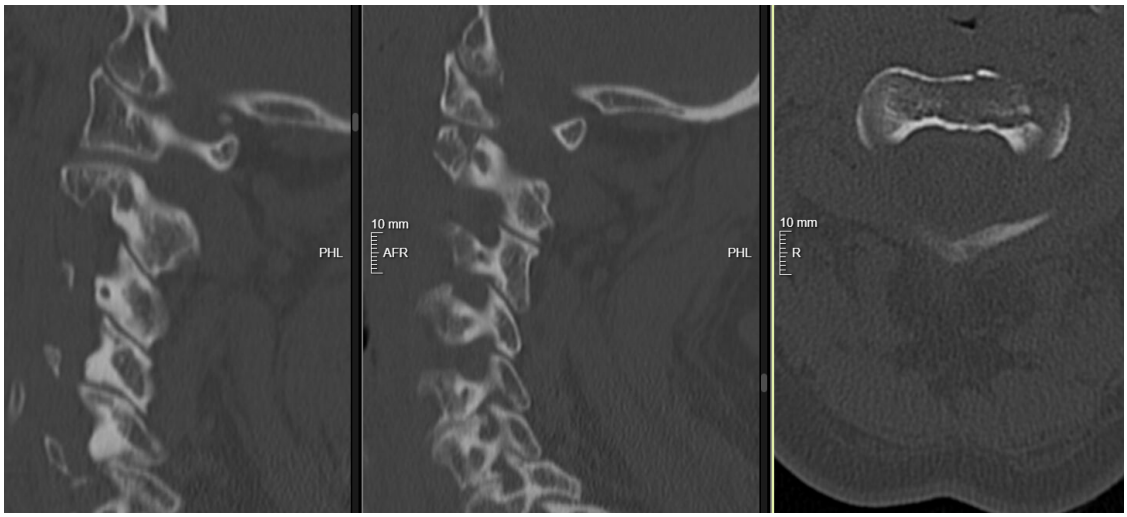
The general tendency of the coronal fractures is to be parallel to the coronal plane or to be slightly oblique from posterior to anterior. In rare cases, the fracture line is from anterior to posterior, like in the case bellow:



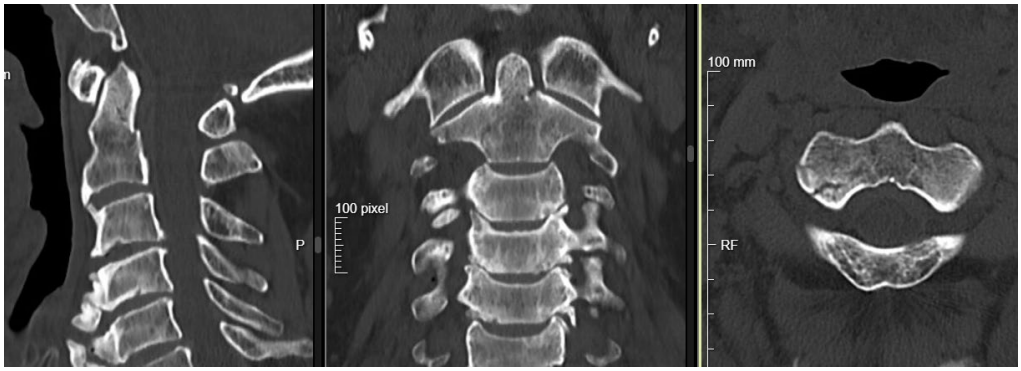
2) Oblique coronal fracture: trans-somatic line is slightly oblique with trans-isthmus fracture at one side, it is a transitional form between oblique coronal and oblique sagittal fracture.



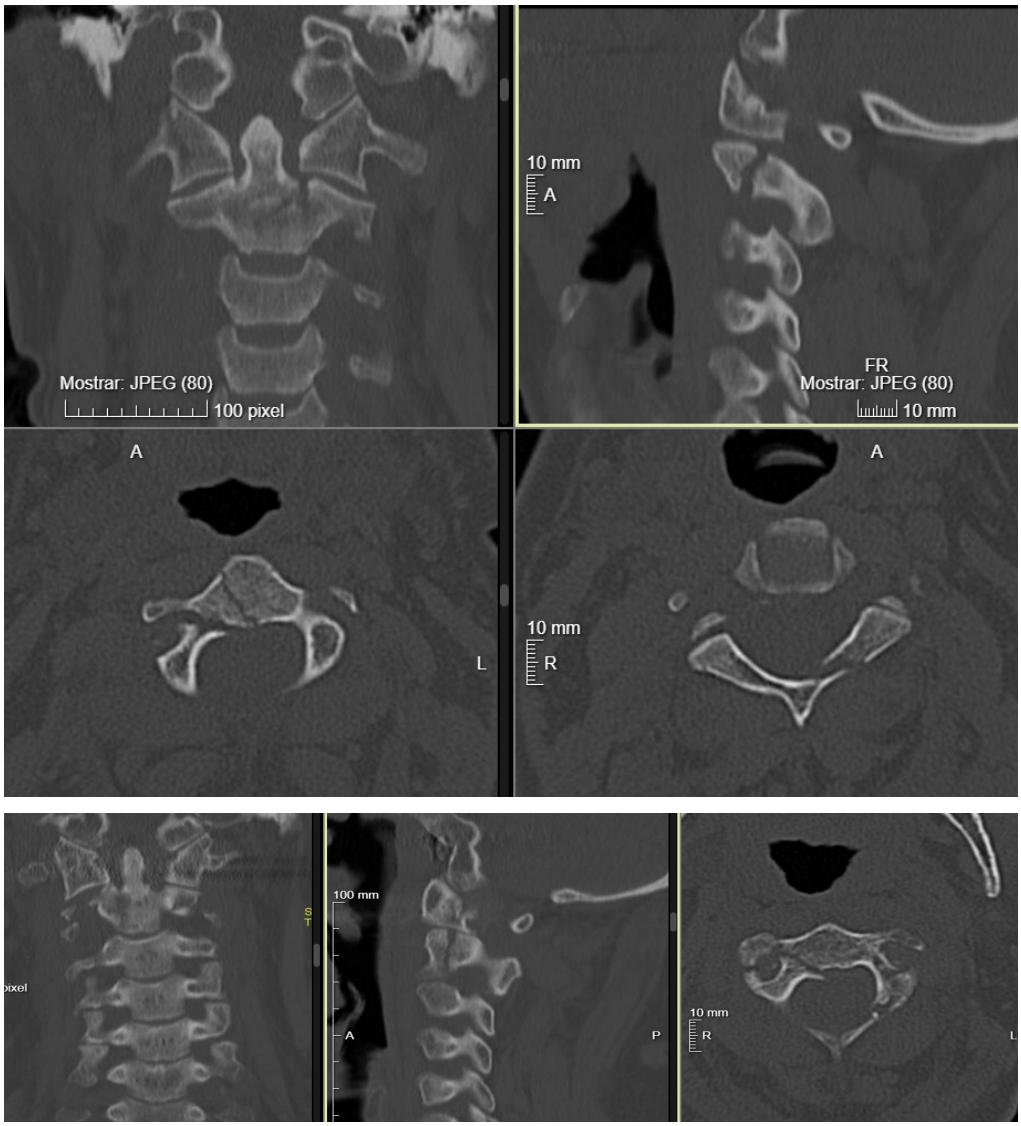
3) Unilateral, incomplete, coronal fracture: is almost the same fracture line as in cases of coronal fractures, but incomplete.



4) Oblique sagittal fracture: trans-somatic fracture associated without laminar fracture. The fracture line is from the odontoid and facet junction to caudal direction.



5) Oblique sagittal fracture: trans-somatic fracture associated with laminar fracture. The fracture line goes towards the C2 disc endplate.



6) Comminuted fracture: multiple comminuted C2 body fracture, usually associated with laminar fracture.

7) Comminuted fracture: multiple comminuted C2 body fracture, usually associated with laminar fracture, but in osteoporotic patients it can occur without laminar fracture when axial load during the impact is high.

4. Discussion

The majority of complex fractures of C2 body are coronal, coronal oblique. Pure sagittal split never happens because of odontoid bone. The coronal fractures are classified according to Li as atypical hangman's fractures. Hangman's fractures are defined as fractures through pars with or without dislocation and angulation as defined by Effendi and Levine and Edwards, but some authors classify coronal fractures through C2 body as atypical Hangman's fractures, it seems that it is a modification of the definition of Hangman's fracture. Hangman's fracture is a fracture that passes through pars bilaterally and the fractures outside of this pattern represent another type of fractures. Hangman's fracture is unstable and the canal enlarge at the level of fracture during the flexion/extension movement while the atypical Hangman's fracture or as we call it transverse, oblique fractures are more stable and if unstable, during flexion/extension it is more harmful for neural tissue, because the canal geometry is preserved and the canal moves entirely affecting the medulla, it means they have different stability behavior patterns. The coronal fractures can be divided into two groups: C2 coronal transromantic fracture that could involve foramen da arteria vertebral unilateral or bilateral and coronal oblique usually with involvement of one side pars. Coronal fracture happens when the trauma mechanism is predominantly extension, coronal oblique fracture is due to extension associated with rotation. When the rotation force is predominant, the type of fracture is sagittal oblique (**Figure 1**). This type of lesion involves an oblique split of C2 body associated with contralateral lamina fracture. Practically, the C2 vertebra gets divided by trauma forces into two hemivertebrae and the smallest hemivertebra can get dislocated laterally. The comminuted fractures are a result of a mix of forces such as axial compression with flexion.

The treatment of these unstable fractures is mostly aggressive, surgical as advocated by different authors [16]-[21]. The majority of complex fractures occur in elderly patients during low energy trauma, because of their bone fragility, ligaments rigidity, relative sarcopenia, that augment cervical spine stiffness. These factors and the lack of bonny stock of the elderly patients emphasize the need of early surgical treatment as recommended by authors above. Later treatment has poorer results, as more time the elderly patients are bed bounded the sarcopenia progresses and another further complication can occur.

The C2 vertebra fractures are sometimes polymorph and individual that make them difficult to classify and characterize, I hope this description will help to make it clearer and easier. Most frequent complex C2 fractures found:

- coronal complete and incomplete C2 fracture;
- oblique fracture with or without laminar fracture;
- comminuted C2 body fracture with or without laminar fracture;

We should analyze the CT scan images properly and try to imagine the trauma mechanism, including the finding in one of these subtitles of classification (**Figure 4**).

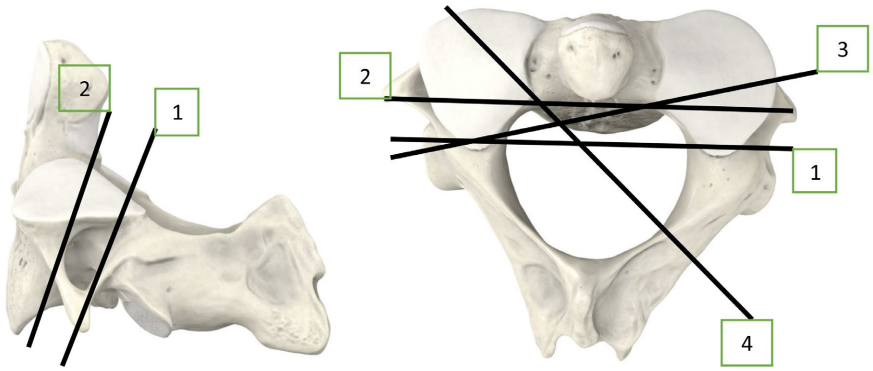


Figure 4. 1 Hangman's fracture line, 2 coronal fracture line, 3 coronal oblique fracture line, 4 sagittal oblique fracture line.

5. Conclusion

Axial trauma remains of great interest among spinal neurosurgeons and orthopedic surgeon, optimal treatment remains a point of argument. The surgical decision of high cervical injuries depends on correct imagological interpretation, classification and right treatment applied. The best way to managed C2 vertebra fractures is by an interprofessional team, including an imageology specialist. The outlook depends on the correct classification assessment and respectively treatment algorithm strategy.

Declaration of Patient Consent

Patient's consent not required as patient's identity is not disclosed or compromised and the study is retrospective.

Statement

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

Conflicts of Interest

The authors declare no conflicts of interest.

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