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ORIGINAL ARTICLE

# Use of multi-planar reconstruction (MPR) and 3-dimentional (3D) CT to assess stability criteria in C2 vertebral fractures

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**Abstract:** The aim of the research was to assess the possibility of use of Roy-Camille's criteria to estimate the stability of axis fractures on CT images using multi-planar (MPR) and 3-dimensional (3D) reconstructions. 10 patients, aged 17-73 (mean 48.7), with C2 fractures and cervical spine radiograms performed previously, underwent CT examinations supplemented with secondary MPR and 3D reconstructions. A dental fracture of type III, according to Anderson, was diagnosed in 4 patients, a Hangman's fracture in 1 patient and a Roy-Camille's fractures in 5 patients, with a co-existing C1 fracture in 1 patient. To estimate translations of vertebral bodies or bone fragments of the fractured dens, we used sagittal MPR and 3D reconstructions in the median plane and calculated the anterior translation (AT), posterior translation (PT) and regional angulation (RA). In 3 cases of dental fractures, PT of the dental fragment and of the axis vertebral body measured 5.5-7 mm. In 1 case of these fractures, AT was 3.5 mm. In 1 case of Hangman's fracture we did not observe any translations. In 5 cases of Roy-Camille's fractures, AT was < 3.5 mm in 1 patient and > 3.5 mm in 4 patients. The biggest AT measured 6 mm. On axial CT images translations could be visualised only in 3 cases. In 2 patients, RA was -1 and 6°. It was concluded that the use of multi-planar and 3D reconstructions on CT images enables assessment of AT, PA and RA in order to determine the stability criteria in C2 vertebral fractures.

**Key words:** CT, axis, cervical spine fracture, stability

**Abbreviations:** MPR – multi-planar reconstruction, 3D – 3-dimensional, CT – computed tomography, AT – anterior translation, PT – posterior translation, RA – regional angulation

## INTRODUCTION

Because of the complicated structure of C2 vertebra and the risk of serious neurological complications in the case of its fracture, fractures of the axis constitute a serious diagnostical and medical problem. Assessment of fracture stability is essential in qualification for operative or conservative treatment. Various systems of C2 fracture assessments, resulting from a long clinical practice, are based mainly on radiograms analysis. Roy-Camille's criteria are recognised as reliable and clinically useful.

Computed tomography (CD) is the examination of choice in diagnosis of cervical spine traumas with high risk of fractures [1, 2]. CT is also performed in patients with fractures diagnosed with the use of classical radiography. This is also necessary in patients after traumas and with clinical symptoms, in whom plain radiograms did not show any fractures [3]. In such cases, CT examination should always precede radiograms in flexion and hyperextension.

In the case of a vertebral fracture, it is important to assess the stability criteria in order to qualify a patient for operative or conservative treatment. The assessment of Roy-Camille's criteria, widely used to evaluate the vertebral stability, is usually unreliable or even impossible on axial CT images. In such cases, lateral plain radiograms are necessary [3, 4, 5].

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The criteria described by White and Panjabi, together with their variants and elaborated by Francis et al., define instability as anterior translation (AT) of the C2 vertebral body ≥ 3.5 mm and regional angulation (RA) ≥ 11°. These criteria are similar to those reported by Roy-Camille et al. in 1977 [3].

The aim of the present study was to assess the possibility of using Roy-Camille's criteria to estimate the stability of axis fractures on CT images with the use of multi-planar (MPR) and 3-dimensional (3D) reconstructions.

## MATERIALS AND METHODS

10 patients, aged 17-73 (mean 48.7), with C2 fractures underwent CT examinations supplemented with secondary MPR and 3D reconstructions. CT examinations were performed with a Somatom ART and Emotion scanners (Siemens) in 2 mm axial images, further supplemented with MPR reconstructions in sagittal planes and 3D reconstructions in the bone window.

All patients had cervical spine radiograms previously performed. We diagnosed a dental fracture of type III, according to Anderson, in 4 patients, a Hangman's fracture in 1 patient and Roy-Camille's fractures in 5 patients, with a co-existing C1 fracture in 1 patient. To estimate translations of vertebral bodies or bone fragments of the fractured dens, we used sagittal MPR and 3D reconstructions in the median plane and calculated the anterior translation (AT), posterior translation (PT), and regional angulation (RA).3D

reconstructions were cut in the median plane, along the spinal canal and evaluated from its interior.

## RESULTS

In all cases, MPR and 3D reconstructions enabled calculation of AT, PT and RA (Fig.1-5). In 3 cases of dental fractures, PT of the dental fragment and of the axis vertebral body measured 5.5-7 mm. In 1 case of these fractures, AT was 3.5 mm (Fig. 6, 7). The patient was treated with direct cranial traction and had a control CT examination performed 6 weeks after trauma. The MPR reconstructions then showed an AT of 2.5 mm, caused by a loose ligament system.

In 1 case of Hangman's fracture, no translations were observed. In 5 cases of Roy-Camille's fractures, AT was < 3.5 mm in 1 patient and > 3.5 mm in 4 patients. The largest AT measured 6 mm (Fig. 8). On axial CT images, translations could be visualised only in 3 cases. In 2 patients, RA was -1 and 6°. All results are presented in Table I.


**Figure 1** Lateral topogram of a patient with C2 fracture and 4 mm anterior translation of the fractured vertebral body.

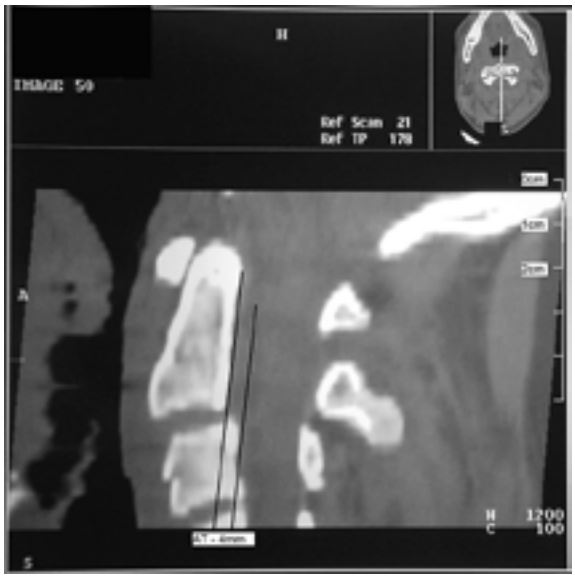


**Figure 2** MPR sagittal reconstruction showing 4 mm anterior translation of axis vertebral body.


**Figure 3** 3D sagittal reconstruction seen from the interior of the spinal canal, showing 4 mm anterior translation of axis vertebral body.

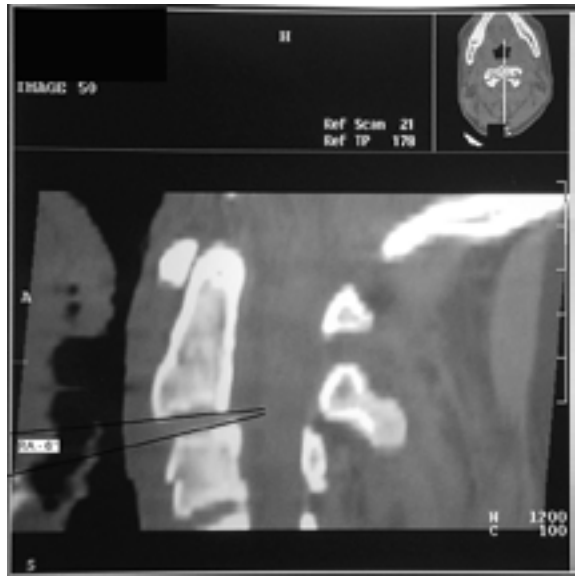


**Figure 4** MPR sagittal reconstruction showing regional angulation between C2-C3 of 6°.


**Figure 5** 3D reconstruction cut in the sagittal plane and seen from the interior of the spinal canal, showing regional angulation between C2-C3 of 6°.

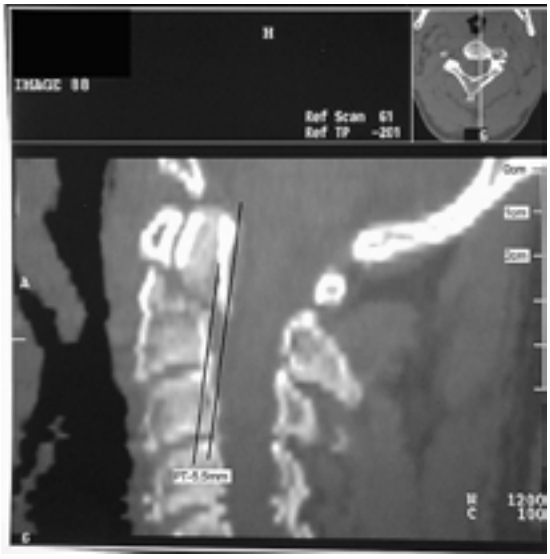

**Figure 6** MPR sagittal reconstruction in a patient with dental fracture showing 5.5 mm posterior translation of the dens bone fragment.

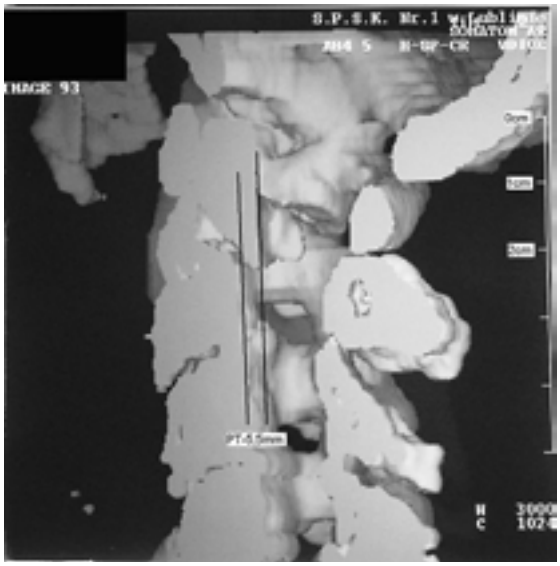

**Figure 7** 3D reconstruction cut in the sagittal plane and seen from the interior of the spinal canal, showing 5.5 mm posterior translation of the dens bone fragment.

**Figure 8** 3D reconstruction cut in the sagittal plane and seen from the interior of the spinal canal, showing 6 mm anterior translation of C2 vertebral body. Fracture of C2 left pedicle.

**Table 1** Group characteristics and observed translations

| No. | Sex | Age | Fracture | Translation AT/PT (mm) | | | RA | | | St/NSt |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A | MPR | 3D | A | MPR | 3D | |
| 1. | M | 17 | C2 | - | 6 | 6,25 | - | 1° | 1° | NSt |
| 2. | F | 64 | C2 | 5 | 5 | 5 | - | - | - | St |
| 3. | M | 73 | C2 | 5 | 5,4 | 5,6 | - | - | - | NSt |
| 4. | M | 40 | C2 | - | 5,5 | 5,3 | - | - | - | St |
| 5. | M | 35 | C2 | - | 4 | 4 | - | 6° | 6° | NSt |
| 6. | M | 49 | C2 | - | - | - | - | - | - | St |
| 7. | M | 63 | C2 | 5 | 7 | 7 | - | - | - | St |
| 8. | M | 25 | C2 | - | 6 | 5 | - | - | - | NSt |
| 9. | F | 49 | C2 | - | 3 | 3 | - | - | - | St |
| 10. | M | 72 | C1, C2 | - | 6 | 6 | - | - | - | NSt |

A – axial CT images.
MPR – median MPR reconstructions.
3D – 3D reconstructions cut in the median plane and seen from the interior of the spinal canal.
AT – anterior translation.
PT – posterior translation.
RA – regional angulation.
St/NSt – fracture type (stable / unstable).
St – stable fracture, AT < 3.5mm, RA < 11°
NSt – unstable fracture, AT ≥ 3.5mm, RA ≥ 11°

## DISCUSSION

Computed tomography (CT) has revolutionised the diagnostic process in bones and articulations diseases. It is of a particularly high value in the assessment of bone structures. It can be supplemented by sagittal multi-planar (MPR) and 3D reconstructions, which are commonly used nowadays. CT volume analysis in routine skeletal system imaging may change the diagnostic and treatment processes in a large number of cases. This is particularly true for traumas and fractures, including subtle ones [2, 4, 6, 7].

Commercial CT units are nowadays equipped with programmes enabling 2D and 3D analysis in any plane of the studied structures [8]. 3D reconstructions are considered easier to be understood than 2D images [2].

CT images are more valuable than plain radiograms in diagnosing cervical spine fractures. This is especially true for the upper part of the cervical spine. C2 fractures are difficult to diagnose on plain films, and positioning a patient for filming C2 vertebra through the open mouth runs the risk of iatrogenic damages. Diagnosis of C2 fractures by CT is therefore potentially less dangerous for patients.

In cervical spine fractures, CT – compared to classical radiography – enables the diagnosis of a fracture in more cases, and if a fracture has already been diagnosed on plain film, it provides a better diagnosis of multiple traumas [3, 9].

Axial CT images are not ideal for assessment of the cervical spine because of its complicated spatial configuration. 3D reconstructions improve the value of CT in diagnosing cervical fractures only when it comes to axial images [9].

Assessment of stability is necessary in qualifying patients with spine fractures for operative treatment. The criteria of stability have been established with the use of plain radiograms in lateral projections [3, 4, 5].

The difficulty or impossibility of assessing vertebral luxations or PTs of dental fragments of the fractured axis on axial CT images lowers the diagnostic value of CT in such cases [7, 10, 11]. At the same time, it is necessary to perform lateral plain radiograms of the cervical spine to qualify a patient for operative treatment. Some centres use topograms of the cervical spine in pre- and postoperative assessment of fractures [7].

In our material, MPR and 3D reconstructions were better for assessing both ATs of vertebral bodies, and PTs of the fractured dental parts of the axis.

The method proposed here for assessing the fracture stability with the use of MPR, 3D reconstructions and the established criteria enables a fast diagnosis, without the necessity of performing additional plain films. This reduces the time needed for diagnosis and decreases the risk of iatrogenic complications while positioning a patient.

Because axial CT images offer no improvement on MPR and 3D reconstructions, neither for diagnosing vertebral translations in the sagittal plane, nor assessing the degree of their translations, we consider it necessary to perform sagittal MPR and cut 3D reconstructions in cases of C2 traumas. Such reconstructions allow the diagnosis of instability more often than axial CT images. 3D reconstructions, as well as thin image slices, are considered to be the main factor of the high sensitivity of CT in diagnosing cervical spine fractures [3].

Missing the diagnosis of an unstable cervical fracture often leads to spondylolysis and further neurological symptoms, which can be revealed even long after the injury [9, 12].

## CONCLUSIONS

The use of multi-planar and 3D reconstructions on CT images enables the assessment of AT, PA and RA in order to determine the stability criteria in C2 vertebral fractures. However, additional research is needed to confirm their exact diagnostic value.

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