CT Scan Study of Atlantoaxial Rotatory Mobility in Asymptomatic Adult Subjects

A Basis for Better Understanding C1–C2 Rotatory Fixation and Subluxation

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Study Design. Normal rotation was evaluated in a group of 40 asymptomatic adults.

Objective. To determine the normal rotational limits of C1–C2 in adults and define when a rotatory fixation occurs in the limits of normality or in subluxation. The term subluxation should be used only when C1–C2 is rotated beyond normal limits.

Summary of Background Data. Concepts about rotatory fixation were established by accepting that it may occur within the limits of normal range of motion. Although nowadays CT is the current image method used to evaluate any case of torticollis, no study has been performed in adult population on what really normal rotation look like in CT scans.

Methods. The study included the measurement of the rotational movement of the neck and a CT scan study of the articular processes of C1–C2 in maximal, left and right, active rotation. A superposition of 6 consecutive slices was carried out, obtaining a linear contour of the axial view of C1–C2. Rotation angle and contact surface loss were measured.

Results. The average neck rotation angle was 79° (range: 74° to 81°). The superposition of the images taken in every rotational direction showed a wide contact loss between the correspondent C1–C2 articular surfaces (42.4%–85.7%; average: 70%). The report of these images, carried out by 3 independent radiologists, concluded that there was a rotatory subluxation in all these cases.

Conclusion. Our results coincide with our previous published ones conducted in children, and lead us to conclude that a CT scan showing wide—but incomplete—rotational facet displacement is not sufficient to define subluxation. We perceive that there is a risk of overdiagnosis and overtreatment (C1–C2 arthrodesis) when evaluating upper cervical spine rotational problems. The concept of both rotatory fixation and subluxation should be revised, and quantifying the rotational angle and contact surface loss between C1–C2 can be very useful.

The neutral position is the one in which the corresponding C1 and C2 articular process surfaces are in full contact. Rotational movements imply a displacement of C1 on C2, thus leading to a varying degree of contact surface loss between the corresponding facets.

Normal range of motion between C1 and C2 generates a 40° rotation to each side (left and right),1–3 therefore it is expected that an entirely normal rotation should cause a wide contact loss between the corresponding articular surfaces.

In our review of published literature, there was no mention whatsoever of this “expected fact” despite some articles depict images in which the previously mentioned contact surface loss could be observed when dealing with an entirely different topic.4

The Fielding and Hawkins5,6 reports on atlantoaxial rotatory fixation have become a point of reference that are constantly referred to in almost all published articles concerning C1–C2 rotational instability or dislocation. They described 4 types or degrees of C1–C2 rotatory fixation, subluxation or dislocation. Wortzman and Dewar7 had previously proposed similar terminology in which rotatory fixation and subluxation were not differentiated accurately and they correlated with Fielding and Hawkins’ type I. At times the diagnosis of rotatory instability, fixation, or subluxation may require a C1–C2 arthrodesis—especially in young people—with possible complications and sequels.8–14

In 1999, Villas et al15 published an article reporting a CT scan study on 10 healthy asymptomatic children. Rotational mobility was 36° (32–44) and it correlated with a broad uncovered area of the C1–C2 corresponding facets (ranging from 72%–85% of the total surface). The report of 3 independent radiologists stated atlantoaxial rotational subluxation in all cases.

Our purpose is to prove the correlation between normal C1–C2 rotational mobility and its corresponding CT appearance within the adult population. This correlation could provide an appropriate basis to better understand all concepts related to rotatory fixation.
Material and Methods

Our research was carried out on a group of 40 healthy asymptomatic white adults, 32 of them being men and 8 women. Ages ranged from 23 to 61 years.

CT scan studies were performed by means of a 64 B Siemens apparatus during a low dose radiation session. Slices were taken in the maximum left and right side active rotation at the level of the C1–C2 articular process joints (Figure 1A, B). A superposition of 6 consecutive slices of the images taken in each direction was carried out to design the complete contour of C1 and C2 in rotated position. The angle between the C1 and C2 transverse axes (rotational angle) and the C1 and C2 articular surface contact loss (uncovered surface area) were then measured. Facet uncovering was determined by measuring the area of the C1 articular surface in contact with its corresponding C2 surface by using 2 different methods, namely, lineal and digital (Figures 2 and 3). The lineal method was the one which we reported in our preliminary study.

The digital system enabled us to calculate the contact or uncovered surface area of the articular processes by direct digitalization of the CT scan images. Direct digitalization was automatically achieved in a vectorial way through the C1 articular processes, whose contours were outlined by means of a Genius Hisketch 1212 digitizer tablet. Its error margin was 0.2 mm. Noncontact (uncovered) and contact (covered) areas were measured separately and the percentage of contact loss during rotation was calculated by using the following formula:

\[
\text{Noncontact area} \times 100/\text{Contact-loss area (uncovered)}
\]

\[
\text{Noncontact area + contact area} = \%
\]

Differences between the lineal and digital methods were established by using the Student t statistical method for independent samples. Pearson correlation was used to evaluate the correlation between the percentage of contact loss and the C1–C2 rotation angle.

Figure 1. A, B show 3 of the 6 CT scan slices that have been used to draw a schematic figure. With this figure we can measure the facet uncovering and the rotation angle between C1 and C2.

Figure 2. Depicts the lineal method which was made use of to calculate the percentage of surface contact loss between the articular processes of C1 and C2 in maximum active left rotation.

Figure 3. Shows the digital system used to calculate the percentage of contact loss between the articular processes of C1 and C2 in maximum active left rotation.
All volunteers were physicians employed at our institution. The ethical committee requirements were as follows: (1) Information concerning the amount of irradiation received and its possible long-term effects; (2) No cost for the person acting as a volunteer.

In addition all CT scans were evaluated by 3 independent radiologists and the patients’ characteristics were kept a secret from them.

■ Results

The average rotational angle was 38° (range: 36° to 43°). A wide contact surface loss between the corresponding C1 and C2 facets was detected in all volunteers. Contact surface loss or facet uncovering ranged from 42.4% to 85.7% (average 70%) by means of the lineal method and 67% to 83% (average 71%) resorting to the digital one. No statistical differences were found when comparing both measurement techniques (P > 0.05) which furthermore correlated highly with the rotational angle (r = 92).

The reports submitted by the 3 independent radiologists, who worked as blind referees, were identical in all cases: rotatory subluxation.

■ Discussion

Our findings (38° bilateral rotation) agree with the previously established and accepted value of approximately 40° for bilateral rotation. However, in addition, we have reported that a 38° rotation implies a wide contact loss of the corresponding facets of C1 and C2 (average: 70%–71%, much more than expected). This normal contact surface loss, which we shall coin “facet uncovering,” is not reported as a usual event in current literature.

The result of our research has led us to the conclusion that CT scan views portraying broad contact loss between the C1 and C2 facets may simply be reflecting rotation at C1–C2, fixed but within the limits of the normal range of motion. This range of normal motion must be understood by those whose job it is interpret advanced image studies of the cervical spine.

CT scan is a definitive complementary image examination, mandatory in case of painful torticollis. The fact that—in our cases—the diagnosis provided by all consulted radiologists agreed–rotatory subluxation (Fielding and Hawkins’s type I) led us to think that cases of torticollis are likely to be diagnosed as subluxation if the radiologic point of view is the one taken into consideration. Diagnosis of a pathologic occurrence of the C1–C2 junction should not be made without clinical correlation. Fixation should not be made unless maximum rotation to the right and left side are performed and there is no movement after articulation. Nevertheless, dynamic CT scan studies should be more accurate if they were performed under anesthesia.

Coming back to semantics and trying to differentiate fixation and subluxation, we are certain that absolutely no one in the scientific community would define a hip or knee joint fixed at 30° of flexion as subluxated.

The term rotatory subluxation should be used only to define a position beyond the limits of normal rotation.

From this moment on, this normalcy will be better known and we propose some useful methods to quantify (or quantify) the degree of rotation and the facet uncovering.

As a conclusion and always bearing in mind the Fielding and Hawkins’s type I of rotatory fixation, we propose that a CT scan showing a rotational angle under 36° and a facet contact (uncovering) under 60% be accepted as defining a rotatory fixation within the limits of normal motion.

■ Key Points

- Only in neutral position is the one in which the correspondent surfaces of C1 and C2 articular processes are in full contact.
- CT scan showing wide—but incomplete—rotational facet displacement is not sufficient to define subluxation.
- The concept of both rotatory fixation and subluxation should be revised and quantifying the rotational angle and contact surface loss between C1–C2 can be very useful.

References