Provisional chapter

Upper Cervical Involvement Due to Rheumatoid Arthritis: Morphological Evaluations Using the CT Reconstruction View

Haku Iizuka, Yoichi Iizuka and Kenji Takagishi

Additional information is available at the end of the chapter

1. Introduction

The pathophysiology of rheumatoid arthritis (RA) involves inflammation of the synovial membrane, and the cervical spine is a common focus of destruction and instability from RA. In particular, the atlanto-axial complex is frequently affected. These instabilities often induce not only neck pain and cervical myelopathy, but also lower cranial symptoms; furthermore, they affect the prognosis of patients. Paus et al.[1] assessed the mortality rate in a cohort of patients treated with and without surgery, and noted that RA with neck involvement is a progressive and serious condition associated with a reduced life expectancy.

The common features of this instability consist of atlanto-axial subluxation (AAS) and vertical subluxation (VS), or a combination of both (Figures 1A-C). AAS is the most common deformity, representing approximately 65% of all cervical subluxations [2]. In AAS patients, the degree of displacement between the atlas and axis appears to be highly variable in lateral radiographs taken at the neutral position. Oda *et al.* [3] noted that upper cervical lesions progressed from reducible AAS to irreducible AAS with VS. They also noted that this extent of progression was different based on the RA subset, which was also related to the development of subaxial subluxation. Moreover, Matsunaga *et al.* [4] noted that all of the irreducible AAS patients who did not undergo surgical treatment were bedridden within three years after the onset of myelopathy, and the survival rate was 0% in the first eight years. Regarding spinal canal-related cervical myelopathy, Oda *et al.* [5] evaluated the diagnostic validity of the space available for the spinal cord (SAC) at the C1 level for myelopathy in patients with RA, and noted that a value of 14 mm or less was recommended as a cut-off point for the SAC when screening patients with a high risk for myelopathy.

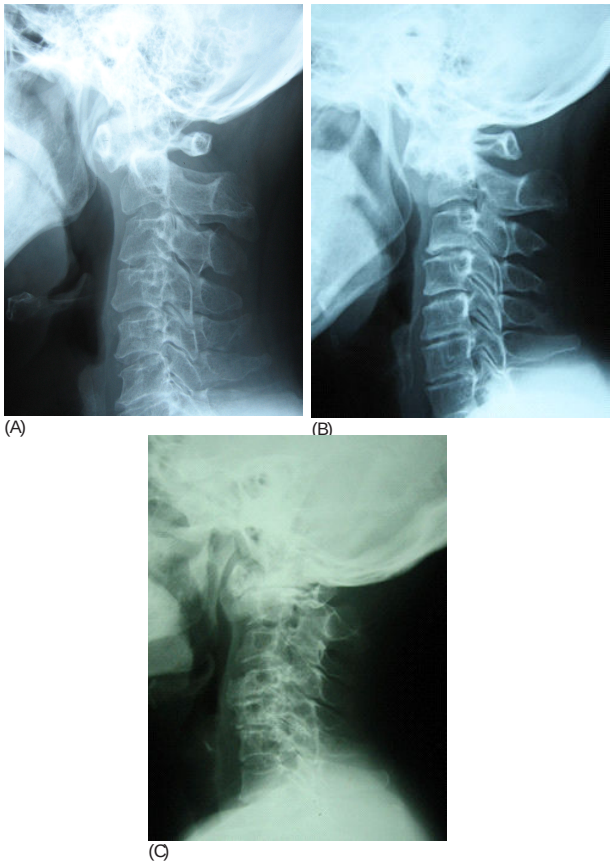

Figure 1. Morphology of upper-cervical spine instability due to RA A: Atlanto-axial subluxation, B: Atlantoaxial subluxation with vertical subluxation, C: Vertical subluxation.

Recently, some authors investigated this upper cervical spine instability due to RA using axial computed tomography (CT) or the CT reconstruction view. We have also investigated the pathology of these instabilities using the CT reconstruction view [6], [7], [8], paying special attention to ankylosis or fusion in the upper cervical spine facet joint. In this chapter, we will introduce our recent findings about upper cervical involvement due to RA by referring to related reports.

2. Morphologic evaluation of the atlanto-occipital joint using the sagittal CT reconstruction view [6]

The atlanto-axial complex is frequently affected by RA, and the atlanto-axial joint (AOJ) plays an important role in induce various types of instability. However, only a few authors have

investigated the AOJ. Eurderink *et al*. [9] investigated the pathology of the cervical spine in RA patients, and described that AOJ lesions were demonstrated in 42% of patients. We sometimes encounter AAS patients who show no motion between the occipital bone and atlas on a dynamic cervical radiograph due to RA (Figure 2). Moreover, the degree of displacement of the atlas against the axis appears to be highly variable on a lateral cervical radiograph in the neutral position. We recently investigated the morphology of AOJ in AAS patients due to RA using the CT sagittal reconstruction view, and examined the relationship between the morphology of the AOJ and other radiographic results [6].

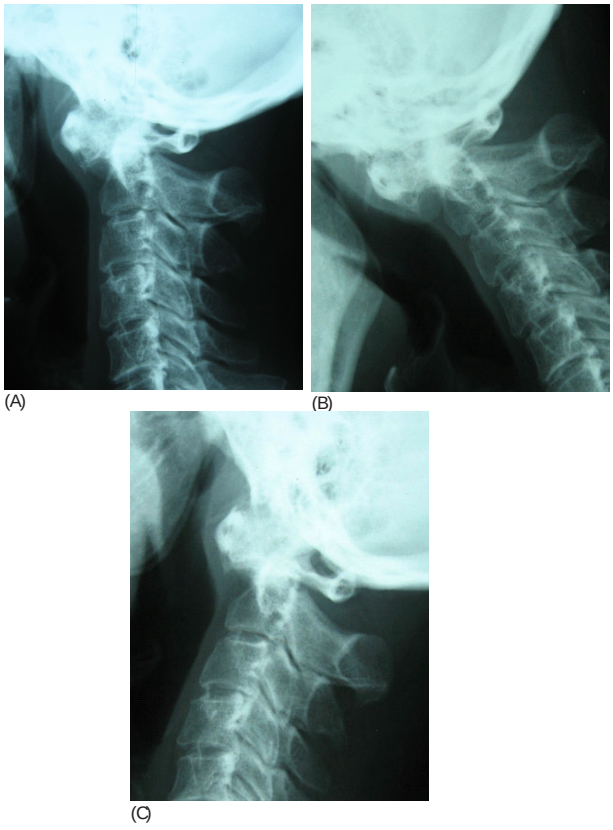

Figure 2. There was no detectable movement between the occipital bone and atlas, despite reduction of atlanto-axial subluxation observed on an extension radiograph. A: Neutral, B: Flexion, C: Extension

Twenty-six consecutive patients with AAS due to RA who were treated by surgery were reviewed. The subjects included 18 females and eight males. The average patient age was 59.3 years (34~73 years). The duration of RA ranged from three years to 33 years, and the mean was 14.3 years. The average atlanto-dental interval (ADI, Figure 3A) values in the neutral and

flexion positions before surgery were 6.1 mm and 11.6 mm, respectively. We performed selective atlanto-axial arthrodesis for all patients.

In all patients, the AOJ was morphologically evaluated using the sagittal reconstruction view (slice thickness: 2 mm) on CT (slice thickness: 1.25 mm) before surgery. Moreover, the ADI value was investigated at the neutral and maximal flexion positions, and the atlanto-axial angle (AAA, Figure 3B) was assessed in the neutral position in preoperative lateral cervical radiographs. The morphology of the AOJ on a CT sagittal reconstruction view was classified into one of three types as follows: a normal type, which showed maintenance of the joint space (Figure 4A), a narrow type, which showed a disappearance of the joint space (Figure 4B), and a fused type, which showed the fusion of the AOJ (Figure 4C).

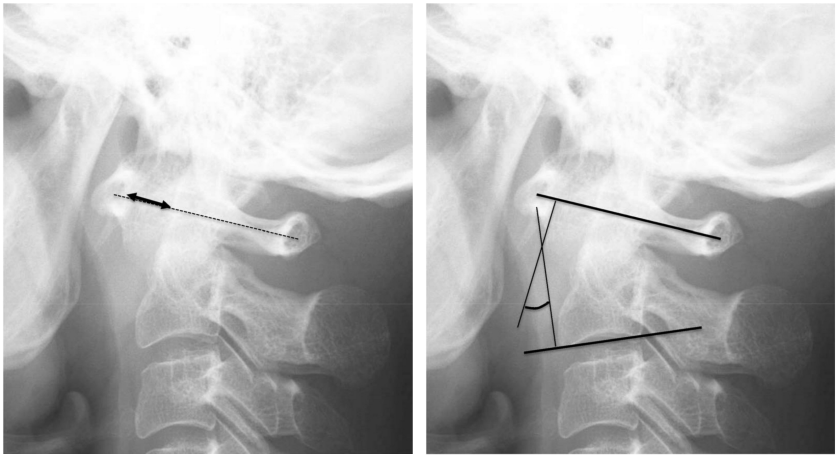

Figure 3. Method of radiological measurement. A: Atlanto-dental interval (ADI), B: Atlanto-axial subluxation (AAA)

The pre-operative CT sagittal reconstruction image of the AOJ demonstrated a normal type bilaterally in six cases (23.1%, Group A). In 15 cases (57.6%, Group B), the CT image demonstrated narrowing on at least one side of the AOJ (one side: three cases, both sides: 12 cases). In five cases (19.2%, Group C), the CT images demonstrated fusion on at least one side of the AOJ (one side: three cases, both sides: two cases). The average ADI value at the flexion position was 10.7 mm in Group A, 11.7 mm in Group B, and 12.6 mm in Group C. There was no significant difference among the groups ($p > 0.551$). The average ADI value at the neutral position before surgery was 2.8 mm in Group A, 5.9 mm in Group B, and 10.4 mm in Group C. There was a significant difference among the groups ($p < 0.012$). Although there was no

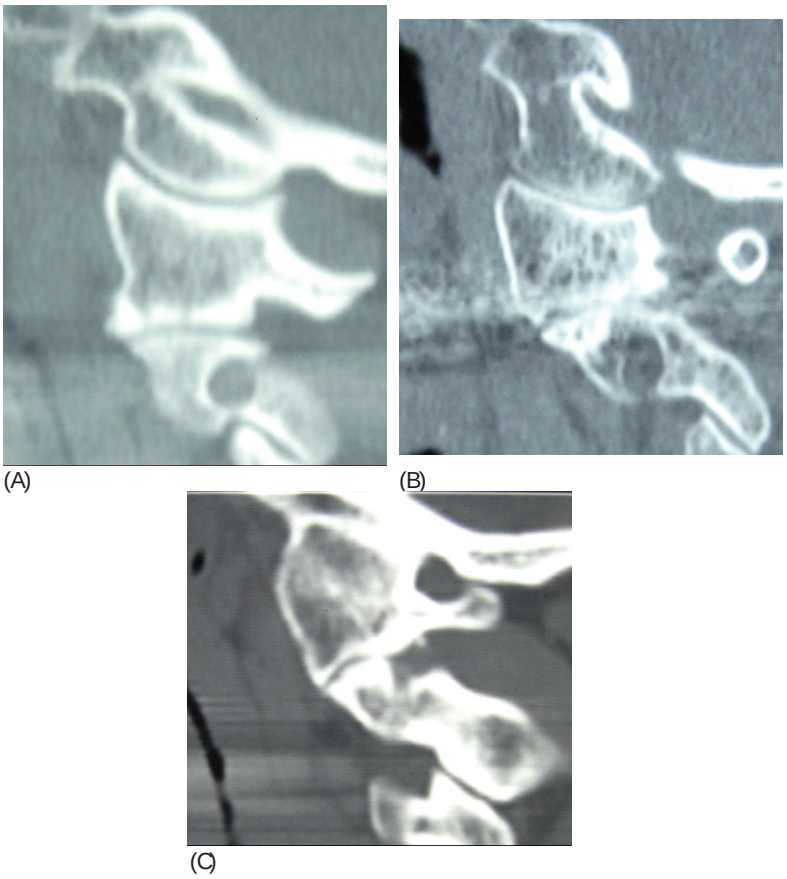

Figure 4. Classification of the morphology of the atlanto-occipital joint. A: Normal type, B: Narrow type, C: Fused type

significant difference between Groups A and B ($p > 0.105$), or Groups B and C ($p > 0.032$), there was a significant difference between Groups A and C ($p < 0.004$) in these values. The average AAA values were 25.3 degrees in Group A, 19.3 degrees in Group B and 3.4 degrees in Group C, which were significantly different ($p < 0.006$). There was no significant difference between Group A and B ($p > 0.230$), however, there were significant differences between Groups A and C ($p < 0.002$), and between Groups B and C ($p < 0.007$).

Eurderink *et al*. [9] noted that a bony ankylosis of the AOJ was demonstrated in 15% of RA patients, and in some cases, this ankylosis showed complete bony union. This suggests that the morphological fused type is associated with pathological fusion or ankylosis. In fact, it was possible to acquire the extension of the atlas through extension of the head during surgery in Group C, although this was not possible in other groups, since the AOJ often offset this extension.

Nagayoshi *et al.* [10] investigated the upper cervical spine using a CT coronal reconstruction view, and noted that these images of the AOJ are useful for evaluating joint subluxation in RA patients. In the current study, enlargement of the ADI at the neutral position was demonstrated in Group C, showing fusion of the AOJ on at least one side, although it was close to the normal value in Group A, which showed the normal type bilaterally. Nojiri *et al.* [11] evaluated 330 asymptomatic volunteers to establish standard values for the normal alignment of the upper cervical spine and noted that the mean AAA was 26.5 ± 7 degrees in males and 28.9 ± 6.7 degrees in females. Although the AAA value in Group A in the present series was similar to this value, a severe anterior inclination of the atlas was demonstrated in Group C. Therefore, this demonstrated that either fusion or ankylosis of the AOJ on at least one side induced an enlargement of the ADI and anterior inclination of the atlas, despite the fact that the patients with a normal type bilaterally showed a slight displacement between the atlas and axis.

In conclusion, this study showed that fusion or ankylosis of the AOJ as demonstrated in the CT sagittal reconstruction view, induced an enlargement of the ADI and anterior inclination of the atlas in the neutral position, despite the fact that normal findings of the AOJ showed a slight displacement of the atlas to axis in RA patients showing AAS involvement.

3. The atlanto-axial joint of AAS patients before and after surgery: A morphological evaluation using the CT sagittal reconstruction view[7]

Atlanto-axial transarticular screw fixation (TSF) [12], [13] is a common treatment for AAS due to RA. The fusion mass between the C1 posterior arch and C2 lamina must be examined to determine whether fusion has been achieved after atlanto-axial arthrodesis [14]. Interestingly, Ito *et al*. [15] reported that in patients with AAS due to RA, atlanto-axial transarticular screws achieved fusion in the atlanto-axial joint (AAJ) and yielded a stable C1-2 even with posterior graft failure. No study has so far evaluated the AAJ before atlanto-axial arthrodesis. Therefore, this study investigated the preoperative morphology and postoperative fusion of the AAJ in patients with AAS due to RA using CT. Furthermore, we examined the relationship between the preoperative morphology of the AAJ and other radiographic results [7].

Thirty patients with AAS due to RA treated by C1-2 TSF were reviewed. The morphology of the AAJ was evaluated using sagittal reconstruction views on CT before and one year after surgery. Thereafter, the ADI value (Figure 3A) at the neutral and maximal flexion position and the AAA (Figure 3B) at the neutral position were assessed in preoperative lateral cervical radiographs. The preoperative morphology of the AAJ on CT reconstruction views was graded as follows: Grade 1 showed maintenance of the joint space (Figure 5A), Grade 2 showed joint space narrowing (Figure 5B) and Grade 3 showed destructive abnormalities of the subchondral bone (Figure 5C). The ADI value at the neutral position was assessed in lateral cervical radiographs after surgery. Furthermore, the fusion in the AAJ was investigated using CT sagittal reconstruction views taken one year after surgery.

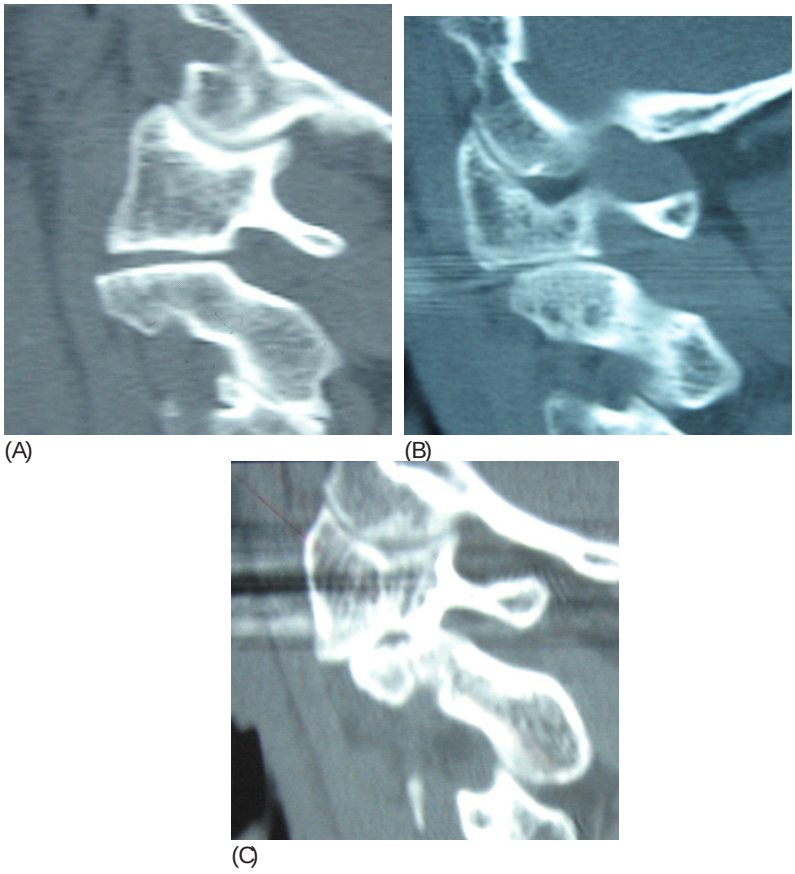

Figure 5. Classification of morphology of the atlanto-axial joint on CT sagittal reconstruction view before surgery. A: Grade 1, B: Grade 2, C: Grade 3

The preoperative CT image of the AAJ demonstrated Grade 1 in 12 cases (Group A), Grade 2 in nine cases (Group B) and Grade 3 in nine cases (Group C). There were no significant differences in the age, gender and duration of RA among the three groups. The average ADI value at the flexion position was 11.0 mm in Group A, 12.3 mm in Group B and 12.7 mm in Group C ($p > 0.313$). The average ADI value in the neutral position before surgery was 4.5 mm in Group A, 7.3 mm in Group B and 11.4 mm in Group C ($p < 0.003$). The mean AAA value was 20.8 degrees in Group A, 21.8 degrees in Group B and 8.4 degrees in Group C ($p < 0.033$). The average ADI value after TSF was 1.7 mm in Group A, 2.1 mm in Group B and 3.0 mm in Group C ($p > 0.144$). Fusion in the AAJ (Figure 6) one year after surgery was demonstrated in 14 cases (46.7%, Group A: 0 case, Group B: 5 cases, Group C: 9 cases). The preoperative grading of the AAJ revealed postoperative fusion in the AAJ to be demonstrated in none of the 32 Grade 1 joints (0%), in seven of the 18 Grade 2 joints (38.9%) and in all 10 Grade 3 joints (100%).

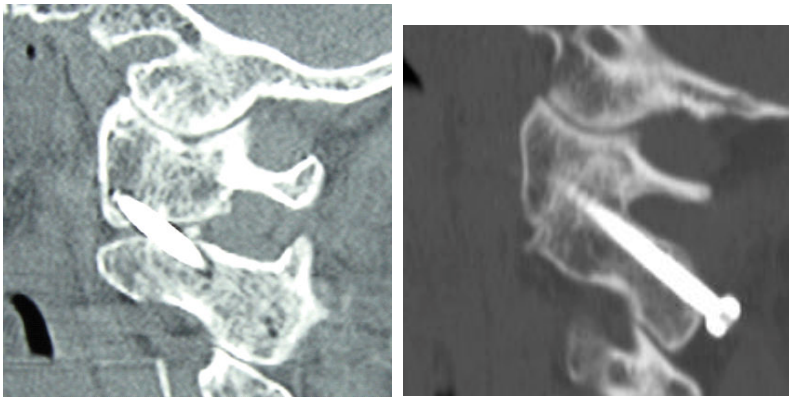

Figure 6. Fusion of the atlanto-axial joint on CT after surgery.

Regarding the results after C1/2 arthrodesis in AAS patients due to RA, Grob [16] noted that once atlanto-axial arthrodesis was achieved, the resolution of the inflammatory process with destruction of the lateral masses of the atlas prevented further deterioration with vertical cranial migration. Ito *et al*. [15] evaluated the AAJ after TSF in patients with AAS due to RA using CT reconstruction, and noted facet fusion and a stable C1/2 in five out of seven patients showing posterior graft failure.

In the current study, the average ADI value at the neutral position in Group C, showing destructive abnormalities of the subchondral bone in the AAJ on at least one side, was significantly larger than the value of Group A, which showed maintenance of the joint space in the AAJ bilaterally, although no difference was observed in the values in the flexion position. The mean AAA values in Group C were significantly lower than those in Groups A and B. The findings of this study therefore suggest that the destructive abnormality of the subchondral bone in the AAJ on at least one side induced an enlargement of the ADI and anterior inclination of the atlas in the neutral position, and consequently, and a severe displacement between C1 and C2 in the neutral position was demonstrated in Group C.

Fusion in the AAJ was demonstrated in 14 patients (46.7%) using CT reconstruction views one year after C1-2 TSF. According to the preoperative grading of AAJ on the CT views, the postoperative fusion in the AAJ was demonstrated in none of the 32 joints (0%) classified as Grade 1, seven of 18 Grade 2 joints (38.9%) and all 10 Grade 3 joints (100%). Therefore, the findings of this study suggest that fusion in the AAJ after TSF tended to occur in the AAS patients showing severe destructive changes in the AAJ before surgery. This also suggests that when the AAS patients showed severe displacement between C1 and C2 before surgery, it appears to be easy to acquire fusion after C1/2 arthrodesis, even if a reduction position can be achieved.

In conclusion, this study showed that a destructive abnormality of the subchondral bone in the AAJ induced an enlargement of the ADI and anterior inclination of the atlas in patients

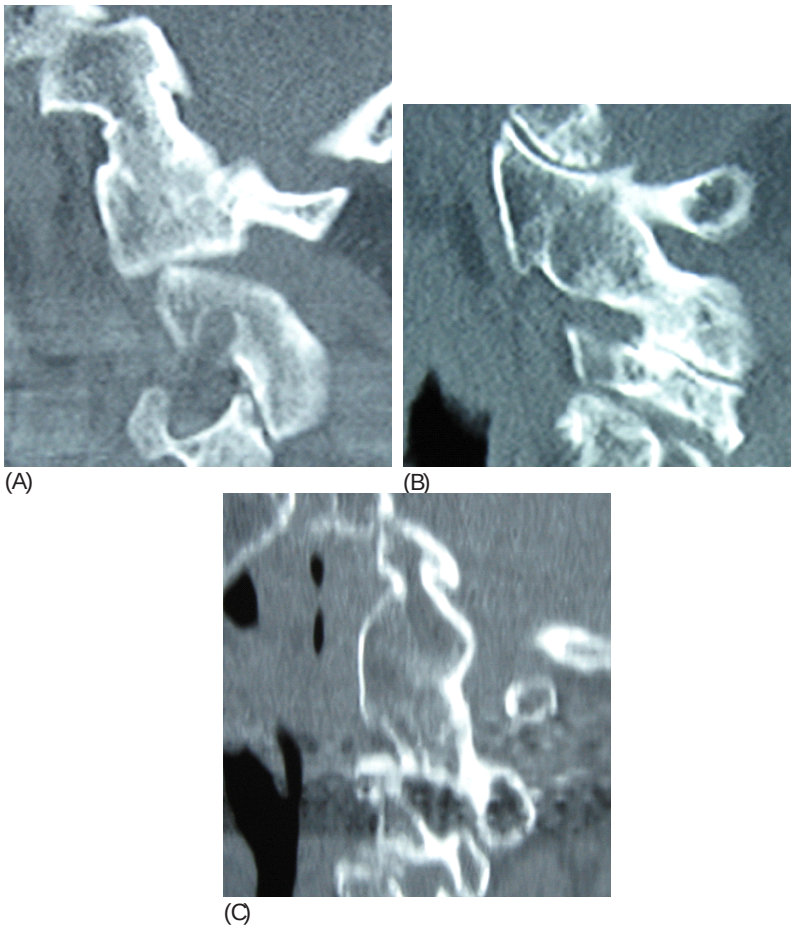

Figure 7. Ankylosis of the upper-cervical spine facet joint on CT A: O/C1 type, B: C1/2 type, C: O/C2 type

with AAS due to RA. The current study also showed that fusion in the AAJ was demonstrated in 14 of 30 patients after C1/2 TSF. This was especially true in AAS patients whose joint destruction extended to the subchondral bone.

4. Bony ankylosis of the facet joint of the upper cervical spine in patients with cervical spine involvement due to RA: A morphological evaluation using the CT reconstruction view[8]

It is well known that cervical spine instabilities due to RA often induce not only cervical myelopathy, but also lower cranial symptoms; furthermore, they affect the prognosis of

patients. We frequently encounter progressive destruction of the facet joints of the upper cervical spine in RA patients with upper cervical spine involvement, however, we sometimes encounter patients with subluxation, without demonstrated motion in the upper cervical spine on a dynamic cervical radiographic study. Furthermore, a pathological study showed that ankylosis of the facet joint of the cervical spine may occur in RA patients [9]. This study investigated the bony ankylosis of the upper cervical spine facet joint in patients with a cervical spine disorder due to RA using CT, and then examined the characteristics of the patients showing such ankylosis[8].

Forty-six consecutive patients who underwent surgical treatment for RA involving the cervical spine were reviewed. The subjects included 35 females and 11 males. The average patient age was 60.6 years (range, 34~79 years). The mean duration of RA was 16.9 years (range, 3~39 years). The radiographic diagnoses included AAS in 30 cases, VS in 10 cases, VS + subaxial subluxation (SAS) in three cases and cervical spondylotic myelopathy (CSM) in three cases.

The occurrence of bony ankylosis of the facet joint of the upper cervical spine (AOJ and AAJ) was investigated using sagittal and coronal reconstruction views on CT before surgery. The patients were classified into two groups, those who were developing bony ankylosis or not, and then the differences in the patient characteristics between the two groups (age, gender, duration of RA and neurological status before surgery) were investigated. Furthermore, cervical spine disorders and surgeries were also evaluated in patients who demonstrated such bony ankylosis. Bony ankylosis was defined as disappearance of the joint space. The extent of neurological impairment and clinical severity of the disease before surgery was assessed by the Ranawat Grading system [17].

The CT reconstruction image demonstrated bony ankylosis in 12 patients (Group BA). The level at which the bony ankylosis occurred was the AOJ in eight cases (O/C1 type), AAJ in twi cases (C1/2 type) and AOJ and AAJ (O/C2 type) in two cases. Group BA included 10 females and two male, and the remaining 34 cases (Group NB) included 25 females and nine males. The average age at surgery in Groups BA and NB was 59.1 years and 61.2 years, respectively. The duration of RA in the groups was 17.8 years and 16.6 years, respectively. No significant differences were observed between the two groups (Age: $P>0.54$, Gender: $P>0.39$, Duration of RA: $P>0.72$). In the BA group, one patient was classified as Ranawat Grade 1, two were Ranawat Grade 2, seven were Ranawat Grade 3A and two were bed-bound, nonambulant Ranawat Grade 3B. In the NA group, nine patients were classified as Ranawat Grade 1, 13 were Ranawat Grade 2, eight were Ranawat Grade 3A and four were Ranawat Grade 3B. There was a significant difference between the two groups in the patients showing obvious neurological impairment (Ranawat grades 3A and 3B, $P=0.017$).

In the O/C1 type, bony ankylosis was demonstrated bilaterally in two cases and unilaterally in the other five patients. The cervical disorders included AAS in four cases and VS in three cases. Atlanto-axial arthrodesis was carried out in four AAS cases and in two mild VS cases, while occipito-cervical fusion was performed on one VS case. In the C1/2 type cases, ankylosis was demonstrated unilaterally and bilaterally in each case, respectively. Multisegmental canal

stenosis of the subaxial region without listhesis was demonstrated, and cervical spondylotic myelopathy (CSM) was present in both cases; therefore, laminoplasty was selected as the surgical procedure. In the O/C2 type, fusion was detected bilaterally in both patients. The cervical disorders diagnosed included cervical myelopathy due to spondylolisthesis of C2 and SAS in one case, and cervical myelopathy due to multisegmental canal stenosis of the subaxial region without listhesis in one case. Posterior fusion from C2 to the thoracic spine and laminoplasty were adapted for these patients, respectively.

Eurderink *et al*. [9] performed a detailed pathological analysis of the facet joint of the cervical spine in RA patients, and demonstrated that a bony ankylosis of the facet joint in RA patients was demonstrated in an average of 9.3% of cases. In addition, such ankylosis in the AOJ and AAJ was observed in 15% and 10% of the patients, respectively. They also noted in some cases that this ankylosis showed complete bony union. In the current study, bony ankylosis of the facet joint of the upper-cervical spine was detected in 12 of 46 surgical cases by evaluation of the CT reconstruction images. In addition, the BA group included more patients showing Ranawat Grade 3 in comparison to the NA group. It is thought that this bony ankylosis of the facet joint is correlated with the degree of severity of cervical myelopathy induced by rheumatoid arthritis.

Crockard [18] suggested that there was a combination of subaxial bony ankylosis of the facet joint with an increased axial movement which encouraged subluxation in the atlanto-axial joint. However, we reported that bony ankylosis of the AOJ induces enlargement of the atlanto-dental interval and anterior inclination of the atlas in AAS patients, and consequently induces severe displacement between the atlas and axis [6]. In the current study, in the O/C1 type cases, all surgeries performed included the AAJ. Furthermore, in the C1/2 type and O/C2 type cases, cervical myelopathy due to SAS or CSM was demonstrated, and decompression or arthrodesis were adapted for the subaxial region. The above findings suggest that bony ankylosis of the facet joint of the upper cervical spine in RA patients is a risk factor for instability of the atlanto-axial joint, and subaxial stenosis or instability.

In conclusion, bony ankylosis of the facet joint of the upper cervical spine was detected in 12 of 46 RA patients with involvement of the cervical spine who thus required surgery. These findings showed that the patients demonstrating such ankylosis exhibited severe cervical myelopathy. In addition, we suggest that this ankylosis in RA patients is a risk factor for instability of the atlanto-axial joint, and subaxial stenosis or instability.

5. Conclusion

We have investigated the morphology of the facet joint of the upper cervical spine involvement due to RA using the CT reconstruction view. The advances in the CT technology have allowed for imaging of not only ankylosis of the facet joint, but also its detailed morphology. We consider that these advances will play an important role in improving the future surgical results.

Author details

Haku Iizuka*, Yoichi Iizuka and Kenji Takagishi

*Address all correspondence to: ihaku@gunma-u.ac.jp

Department of Orthopedic Surgery, Gunma University Graduate School of Medicine, Showa, Maebashi, Gunma, Japan

References

[1] Paus AC, Steen H, Roislien J, Mowinckel P, Teigland J. High mortality rate in rheumatoid arthritis with subluxation of the cervical spine, a cohort study of operated and nonoperated patients. *Spine* 2008; 33: 2278-2283.

[2] Nguyen HV, Ludwig SC, Silber J, et al. Rheumatoid arthritis of the cervical spine. *Spine J* 2004; 4: 329-334

[3] Oda T, Fujiwara K, Yonenobu K, Azuma B, Ochi T. Natural course of cervical spine lesions in rheumatoid arthritis. *Spine* 1995; 20: 1128-1135.

[4] Matsunaga S, Sakou T, Onishi T, et al. Prognosis of patients with upper cervical lesions caused by rheumatoid arthritis, comparison of occipitocervical fusion between C1 laminectomy and nonsurgical management. *Spine* 2003; 28: 1581-1587.

[5] Oda T, Yonenobu K, Fujimura Y, et al. Diagnostic validity of space available for the spinal cord at C1 level for cervical myelopathy in patients with rheumatoid arthritis. *Spine* 2009; 34: 1395-1398.

[6] Iizuka H, Sorimachi Y, Ara T *et al*. Relationship between the morphology of the atlanto-occipital joint and the radiographic results in patients with atlanto-axial subluxation due to rheumatoid arthritis. *Eur Spine J* 2008; 17: 826-830.

[7] Sorimachi Y, Iizuka H, Ara T *et al*. Atlanto-axial joint of atlanto-axial subluxation patients due rheumatoid arthritis before and after surgery, morphological evaluation using CT reconstruction. *Eur Spine J* 2011: 20: 798-803.

[8] Iizuka H, Nishinome M, Sorimachi Y *et al.* The characteristics of bony ankylosis of the facet joint of the upper cervical spine in rheumatoid arthritis patients. *Eur Spine J* 2009; 18: 1130-1134.

[9] Eulderink F, Meijers KAE. Pathology of the cervical spine in rheumatoid arthritis: a controlled study of 44 patients. *J, Pathology* 1976; 120: 91-108

[10] Nagayoshi R, Ijiri K, Takenouchi T, *et al*. Evaluation of occipitocervical subluxation in rheumatoid arthritis patients, using coronal-view reconstructive computed tomography. *Spine* 2009; 34: E879-E881.

[11] Nojiri K, Matsumoto M, Chiba K, et al. Relationship between alignment of upper and lower cervical spine in asymptomatic individuals. *J Neurosurg (Spine 1)* 2003; 99: 80-83.

[12] Magerl F, Seemann PS. Stable posterior fusion of the atlas and axis by transarticular screw fixation. In: Kehr P, Weidner A, eds. Cervical Spine. Wien: Springer-Verlag, 1987: 322-327.

[13] Grob D, Jeanneret B, Aebi M, Markwalder TM. Atlanto-axial fusion with transarticular screw fixation. *J Bone Joint Surg Br* 1991; 73: 972-976.

[14] Wang C, Yan M, Zhou H, Wang S, Dang G. Atlantoaxial transarticular screw fixation with morselized autograft and without additional internal fixation: technical description and report of 57 cases. *Spine* 2007; 32: 643-646.

[15] Ito H, Neo M, Fujibayashi S, Miyata M, Yoshitomi H, Nakamura T. Atlantoaxial transarticular screw fixation with posterior wiring using polyethylene cable: facet fusion despite posterior graft resorption in rheumatoid patients. *Spine* 2008; 33: 1655-1661.

[16] Grob D. Atlantoaxial immobilization in rheumatoid arthritis: a prophylactic procedure? *Eur Spine J* 2000; 9: 404-409.

[17] Ranawat CS, O'Leary P, Pellicci P, Tsairis P, Marchisello P, Dorr L. Cervical spine fusion in rheumatoid arthritis. *J Bone Joint Surg Am* 1979; 61: 1003-1010.

[18] Crockard A. Surgical management of cervical rheumatoid problems. *Spine* 1995; 20: 2584-2590.