A RETROSPECTIVE ANALYSIS OF SUBAXIAL SUBLUXATION FOLLOWING ATLANTO-AXIAL ARTHRODESIS IN PATIENTS WITH RHEUMATOID ARTHRITIS

Ruifeng Yang[#], Shuhua Lan[#], Quanzhou Wu, Shuming Huang, Yuanhua Fang[*]
Department of Orthopedics, Lishui Municipal Central Hospital (The Fifth Affiliated Hospital of Wenzhou Medical University), Lishui, Zhejiang 323000, China
[#]*They contributed equally to this work*

ABSTRACT

Objective: *To evaluate the association between A-A fusion angle and postoperative subaxial subluxation following atlantoaxial arthrodesis in patients with rheumatoid arthritis, and clarify the characteristics of SAS after surgery and to determine the optimal fusion angle for preservation of physiologic subaxial alignment.*

Methods*: 25 patients with cervical spine involvement in rheumatoid arthritis who underwent transarticular screw fixation between September 2015 and August 2017 in Lishui Municipal Central Hospital were retrospectively studied. Three patients died of complications unrelated to surgery 3 years after surgery. Ultimately, 20 of 22 patients had sufficient clinical data for the analysis. The patients included 15 females and 5 males. The duration of RA ranged from 5 to 30 years, with a mean duration of 12.5 years. The average patient age at surgery was 50.6 years (range 35-70 years). The research included 5 males and 15 females, whose average age was 50.4±5.6. Twenty patients with AAS treated with surgery were reviewed. In all patients, lateral cervical radiographs were obtained neutral, hyperflexion and hyperextension positions every year for 3 years after surgery. The cervical sagittal parameters were measured on X-ray, including C1-C2 angle, C2-C7 angle. We investigated the occurrence and progression of SAS using these annual radiographs.*

Results*: There were no significant differences between pre-and postoperative value in AAA and subaxial angle (SAA), respectively. Before surgery, SAS was found in 8 patients. The occurrence and progression of SAS after surgery was found in 9 cases (SAS P+ group). There were no significant differences in age, gender or the duration of RA between the SAS P+ group and the remaining 11 cases. We also found no differences in the pre-and post-op AAA and SAA between the two groups.*

Conclusion*: We did not find any relationships between the occurrence of SAS and the C1-C2 angle and C2-C7 angle before and after surgery. our findings suggest that select 20°±5° of C1-C2 angle in patients with atlantoaxial arthrodesis does not affect the occurrence of SAS at 3 years after surgery.*

Keywords: *atlantoaxial subluxation, subaxial subluxation, Rheumatoid Arthritis, atlantoaxial arthrodesis.*

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Introduction

There are three main forms of cervical instability in cervical rheumatoid arthritis (RA): atlantoaxial subluxation (AAS), vertical subluxation (VS), and subaxial subluxation (SAS), and/or multiple forms coexist.

AAS is a dislocation of one side of the block on both sides of the atlantoaxial pivot, while the other side is not dislocated. The anterior atlantodental interval (AADI) is generally 3 to 5 mm, not exceeding 5 mm. The AAS is assessed by AADI, which is the distance from the posterior edge of the anterior atlantoaxial arch to the anterior edge of the dentition. The diagnosis is made if the lateral radiograph indicates an AADI > 3 mm and if there is a change in the measured value on the posterior extension and anterior flexion X-ray of the cervical spine. The posterior atlantoodontoid interval (PADI) is the distance between the posterior edge of the odontoid and the anterior edge of the posterior atlantoaxial arch, with a normal PADI of

≥14 mm. PADI is more closely related to the degree of nerve injury and is clinically more reliable. VS is assessed by the distance from the anterior-posterior atlantoaxial arch line to the central C2 arch root, which is ≥15 mm in men and ≥13 mm in women, suggesting VS when it is less than the normal value. Its common measurement methods include McRae, McGregor, Ranawat and Redland-Johnell, and generally multiple methods are combined to improve accuracy. SAS is indicated when the relative displacement between each adjacent vertebral body below the pivot is ≥ 20% or >3.5 mm.

AAS has been reported[1] to be the most common, accounting for 65% of all cases of cervical subluxation. SAS usually develops late in the disease process and is the least common of the cervical spine RA deformities, accounting for approximately 15% of cases. Moreover, it usually occurs in a multisegmental plane with "stepped" changes. Many scholars noticed that SAS also occurred after upper cervical fusion surgery[1, 2]. Clarke et al[2] found that 39% of patients with AAS developed SAS after atlantoaxial fusion. Ishii et al[3] reported that overcorrection of the C1-C2 angle may cause anterior cervical convexity and postoperative SAS in patients with rheumatoid arthritis, requiring further surgical treatment. In addition, many authors have noted that overcorrection of the atlantoaxial angle (C1-C2 angle) can lead to SAS by fixing the atlantoaxial spine in a hyperextended position resulting in reduced compensatory anterior convexity of the lower cervical spine postoperatively[4, 5]. The atlantoaxial fusion angle is the key factor affecting lower cervical curvature[6,7].

In this study, we retrospectively analyzed the imaging data of 20 cases of cervical spine rheumatoid arthritis causing cervical instability 3 years after surgery to study their cervical sagittal parameters. The main objectives of this study are to assess the correlation between posterior atlantoaxial fusion angle and postoperative SAS in cervical rheumatoid arthritis, to elucidate the characteristics of postoperative SAS, and to determine the most appropriate atlantoaxial fusion angle.

Materials and methods

General Information

All RA patients included in this study met the revised criteria of the 2010 ACR/EULAR. In 25 patients with AAS surgically treated by the same group of surgeons admitted to our institution between September 2015 and August 2017, 3 patients died of non-surgical complications at 3 years postoperatively. Ultimately, sufficient clinical data were available for analysis in 20 of the 22 patients, including 15 women and 5 men. The duration of RA ranged from 5 to 30 years, with a mean duration of 14.5 years. The mean age of patients who underwent surgery was 50.4 years (range 34-72 years). The AAS was assessed by AADI, which was the distance from the posterior edge of the anterior atlantoaxial arch to the anterior edge of the dentition. The diagnosis was made if the lateral radiograph indicated an AADI > 3 mm and if there was a change in the measured value on the posterior extension and anterior flexion X-ray of the cervical spine. We considered 20° ± 5° as an acceptable range. The C1-C2 angle was formulated preoperatively in conjunction with the imaging data (Figure 1). We attempted to maintain the lower cervical spine structure without stripping the lower cervical spine musculature. AADI was evaluated preoperatively, postoperatively and during the follow-up period. The sagittal angles of C1-C2 and C2-C7 were measured in neutral lateral slices. Autologous iliac bone block grafting was performed in each case. Atlantoaxial fusion was defined as the absence of atlantoaxial motion on lateral cervical hyperextension-hyperflexion X-rays and the lack of continuous cancellous bone formation in the implant block between the atlantoaxial and pivotal spine.

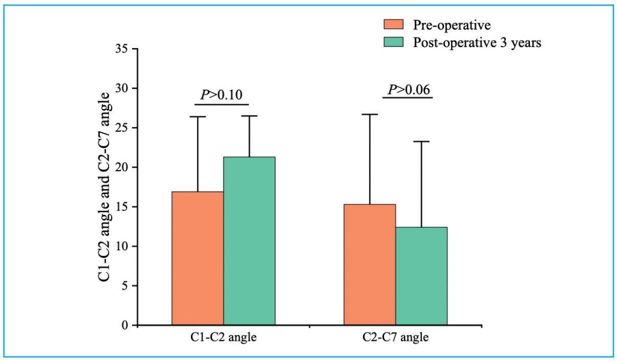

Figure 1: Comparison of C1-C2 angle and C2-C7 angle before and after operation ($\bar{x}$±s).

Inclusion criteria: (1) patients admitted with a diagnosis of cervical rheumatoid arthritis; (2) patients treated with posterior cervical spine surgery in our hospital; (3) patients with complete preoperative and postoperative imaging data in our hospital.

Exclusion criteria: (1) patients admitted for trauma; (2) patients with combined systemic diseases such as spinal tumor, spinal tuberculosis, and infection; (3) patients with cable internal fixation surgery; (4) patients with incomplete clinical and imaging data; (5) patients with simultaneous lower cervical spine surgery; (6) Patients with occipitocervical fusion and cervical 2 and 3 cone fusion; patients with RA with existing lower cervical spine damage or SAS.

Imaging measurement methods

All included cases had preoperative and 3-year postoperative cervical spine annual cervical neutral, hyperextension, and hyperflexion radiographs performed at our institution. Imaging parameters were measured 3 times for all parameters, by 2 spine surgeons with more than 5 years of experience, one of whom was not involved in the surgery and had no knowledge of the patient's clinical data. The mean value was used as the final value for each evaluator, and if there were inconsistent values, the mean of the two values was used.

Measurement index

C1-C2 angle: the angle formed by the line connecting the lower edge of the anterior and posterior arches of Cl and the tangent line of the lower edge of the C2 vertebral body.

C2-C7 angle: the angle between the plumb line of the inferior endplate of C2 and the plumb line of the inferior endplate of C7.

Surgical approach

Anesthesia was considered for tracheal intubation using fiberoptic bronchoscopy. The patient was placed in a prone position with the head fixed on a special plaster bed. The head was slightly posteriorly extended and the cervical spine was kept in a neutral position to avoid pressure on the eyes. Spinal cord function was detected intraoperatively using somatosensory evoked potentials. C-arm fluoroscopy was performed intraoperatively to detect the repositioning of atlantoaxial subluxation under cranial traction after anesthesia and to monitor the implantation of internal fixation at the same time.

Atlantoaxial lateral block screw and pivot pedicle screw fixation

A posterior median cervical incision was made to expose the corresponding cervical segment and determine the needle entry point. A probe was used to identify the four walls of the pedicle. C-arm X-ray machine fluoroscopy was used to determine the position and depth of the needle guide. Cl lateral block screws were placed under intraoperative fluoroscopic guidance. When the C2 pedicle screw was successfully placed, a titanium rod of appropriate length was selected and pre-bent, attached to the tail of the screw, and fixed after lifting and repositioning. A cancellous bone graft was placed between the decorticated posterior atlantoaxial arch, the pivot plate, and the spinous process. Drainage tubes were placed and the incision was closed layer by layer.

Transcatheter atlantoaxial joint space with screw technique combined with cable fixation

Fluoroscopy was performed using C-arm X-ray to determine atlantoaxial repositioning before surgery. The skin and muscles were incised sequentially to reveal the posterior structures of Cl and C2 and to expose the cardinal spinal plates. The medial aspect of the pivot roots was exposed to determine the angle of needle entry. The Kirschner guide pin was drilled in the correct direction and angle through the Cl and C2 articular surfaces using an electric drill, pointing to the Cl and anterior nodes on lateral fluoroscopy. The entire procedure was performed under C-arm x-ray. Autologous iliac bone graft block was fixed by Brooks method. Drainage tubes were placed to close the incision layer by layer.

Postoperative management

Routine postoperative cardiac monitoring was performed for 24h. After surgery, four patients were placed in the intensive care unit for observation, and were transferred to the general ward after their autonomic respiratory function was normalized. The drains were removed from 48h to 72h.

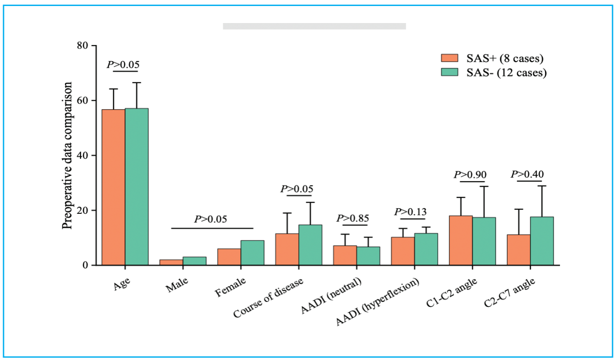

Figure 2: Preoperative data comparison between SAS + group and SAS - group ($\bar{x}$±s).

Routine blood tests and biochemical tests were repeated, and transfusion therapy was decided according to the situation. It was also supplemented with symptomatic supportive treatment such as nebulized inhalation, hormones, dehydration, stress ulcer prevention, neurotrophy, and application of sensitive antibiotics for 3 d to 5 d. The endocrinology department was consulted and anti-rheumatic drugs were administered. If MRI indicated severe compression of the spinal cord (as shown in Figure 2), hyperbaric oxygen therapy was given. Postoperatively, the head and neck were protected by a conventional neck collar with appropriate movement at the head of the bed. CR films, CT and 3D reconstruction were reviewed regularly to keep track of the fusion of implants and the position of internal fixation.

Statistical analysis

The statistical software SPSS 20.0 (SPSS Inc., USA) was used for statistical analysis of the measurements, expressed as mean ± standard deviation (x ± s). All parameters were analyzed by chi-square test, paired t-test, paired t-test, Wilcoxon rank sum test and Mann Whitney test. $p<0.05$ was significant difference.

Results

The preoperative and postoperative atlantoaxial angles were 16.9±9.5° and 21.3±5.2°, respectively, with no statistically significant difference. The preoperative and postoperative lower cervical angles were 15.3 ± 11.4° and 12.4 ± 10.86°, respectively, with no statistically significant differences (as in Figure 3, $P > 0.05$).

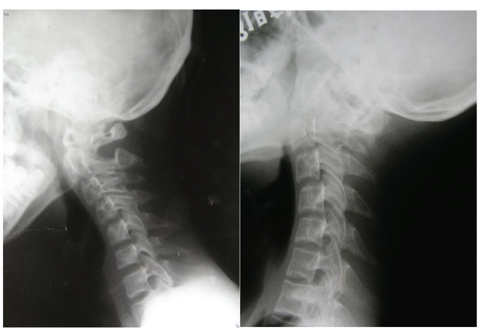

Figure 3: Comparison of C1-C2 angle and C2-C7 angle of SAS P+ and SAS P- before and after operation ($\bar{x}$±s).

Preoperatively, SAS was present in 10 patients with 14 segments (1 segment: 7 cases, 2 segments: 2 cases, 3 segments: 1 case, SAS+ group). The differences in preoperative information between the SAS+ and SAS- groups were not statistically significant (as in Figure 4, $P > 0.05$). Preoperative lateral radiographs showed: anterior displacement of C2/3 segment: 1 case; anterior displacement of C3/4 segment: 1 case and posterior displacement: 2 cases; anterior displacement of C4/5 segment: 2 cases and posterior displacement: 2 cases; posterior displacement of C5/6 segment: 2 cases; posterior displacement of C6/7 segment: 1 case (Table 1). There was no significant difference in age, gender or duration of RA between the SAS P+ group and the remaining 11 patients ($p>0.05$) (Table 2).

Figure 4: Preoperative flexion-extension radiographs showed instability of C1/C2.

Group	Pre-operative	Post-operative			Total
		1Y	2Y	3Y	
C2/3	1A	2A	1A	0	4A
C3/4	1A/2P	1A	1A/1P	0	3A/3P
C4/5	2A/2P	1A	1A	0	4A/2P
C5/6	2P	1A/1P	1A	0	2A/4P
C6/7	1P	1P	0	0	1P

Table 1: Occurrence and progression of SAS before and 3 years after surgery.
Note: anterior subluxation (A); posterior subluxation (P).

	SAS P+ (9 cases)	SAS P- (11 cases)	*P-value*
Age	57.3±8.1	56.7±10.1	*P*>0.05
Sex (M: F)	2:6	3:6	*P*>0.05
Course of disease	12.4±6.5	16.4±8.6	*P*>0.05

Table 2: Comparison of SAS P+ group and SAS P- data after operation $\bar{x}$±s).

The occurrence and development of SAS in the postoperative period were demonstrated by neutral lateral radiographs in the first year after surgery: anterior displacement of C2/3 segment: 2 cases; anterior displacement of C3/4 segment: 1 case; anterior displacement of C4/5 segment: 1 case; anterior displacement of C5/6 segment: 1 case and posterior displacement: 1 case; posterior displacement of C6/7 segment: 1 case (as shown in Figure 5).

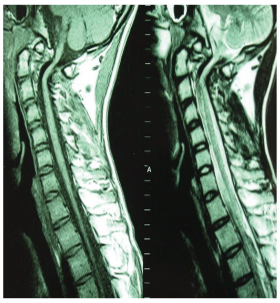

Figure 5: MRI showed periapical vascular opacification and spinal cord compression.

The neutral lateral radiographs in the second year after surgery showed: anterior displacement of C3/4 segment: 1 case, posterior displacement: 1 case; anterior displacement of C4/5 segment: 1 case; anterior displacement of C5/6 segment: 1 case.

The lateral radiographs in the third year after surgery showed: anterior displacement of the C2/3 segment: 1 case and posterior displacement of the C5/6 segment: 1 case. The three cephalad (C2/3, C3/4 and C4/5) segments were more likely to be displaced than the caudal (C5/6 and C6/7) segments (Figure 6). There were no patients who underwent further surgery of the lower cervical region within 3 years after surgery.

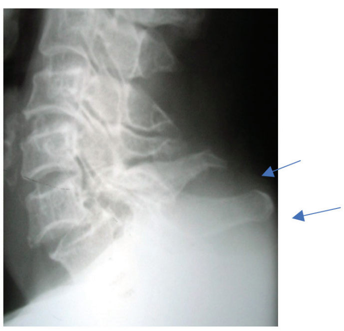

Figure 6: Lateral CR radiograph showed subluxation of the lower cervical spine (C6-7).

Discussion

Cervical internal fixation techniques have achieved satisfactory results in restoring atlantoaxial stability, improving implant fusion rates, and maintaining repositioning. However, some scholars have also identified the occurrence of SAS after atlantoaxial fusion in patients with cervical RA, which can be extremely detrimental to patients. Sagittal imbalance can lead to postoperative pain and/or dysfunction, which can seriously affect the clinical outcome. Hence, spine surgeons are paying more and more attention to the sagittal balance of the cervical spine. The reconstruction and maintenance of normal cervical sagittal balance has become an issue that cannot be ignored in cervical spine surgery[8].

Some authors considered the development of postoperative SAS as a normal progression of the RA course, but more authors believed that it was the result of the biomechanical action of the atlantoaxial fusion angle on the various structures of the lower cervical spine and that there was a link between atlantoaxial fixation angle and abnormal postoperative lower cervical curvature[9, 10]. The high incidence of postoperative SAS may be due to mechanical stress caused by changes in cervical alignment. Some patients with cervical RA developed progressive kyphosis or segmental instability in the lower cervical spine after atlantoaxial fusion. Moreover, this led to additional postoperative spinal symptoms that required further surgical treatment. Clarke et al[2] found that 13 of 33 patients (39%) with AAS developed asymptomatic or symptomatic SAS after atlantoaxial fusion, and those who developed symptomatic SAS, in turn, required reoperation. Mukai et al[11] reported a 14% probability of developing lower cervical kyphosis 6 years after transcatheter screw fixation of the atlantoaxial spine in patients with RA. Ishii et al[3] reported that overcorrection of the C1-C2 angle may lead to postoperative SAS in patients with cervical RA, requiring further surgical treatment. Therefore, cervical sagittal parameters are important for preoperative guidance on the recovery, reconstruction, and sagittal balance of cervical anterior convexity.

In terms of the relationship between Cl-C2 angle and C2-C7 angle after atlantoaxial fusion, it has been shown (5, 12) that there was a negative correlation between Cl-C2 angle and C2-C7 angle after posterior atlantoaxial fusion, with increased anterior cervical convexity in the upper cervical spine leading to decreased compensatory anterior convexity in the lower cervical spine. The percentage of patients with cervical rheumatoid arthritis is low, but the incidence of postoperative lower cervical lordosis (SAS) is high. The occurrence of postoperative lower cervical kyphosis in patients with cervical RA is also more influenced by the angle of postoperative atlantoaxial fixation.

In this study, there was no significant change in C2-C7 angle postoperatively, but 9 of 20 (45%) patients with AAS developed SAS after atlantoaxial fusion. According to the literature[3, 13], the percentage of SAS varied in a range between 5.5% and 39.4%. The prevalence in the present study was higher. Presumably, the reason for this discrepancy is that we defined subluxation as 2 mm in order to clarify the characteristics of the postoperative SAS, including the imaging information acquired on the hyperextension-hyperflexion slice. However, most previous authors defined Hemi-dislocation as only 2.5 mm or 3 mm in neutral uptake.

In this study, 7 of the 12 SAS cases were identified during the first postoperative year and 5 SAS cases were identified in the second postoperative year, but no SAS cases were observed in the third postoperative year. In addition, no further surgery was required for SAS at 3 years in this study. The results of a study by Kurogochi D et al(14) scholars showed that patients who maintained the C2-C7 anterior convexity angle for 5 years after surgery did not develop SAS. Advanced and unstable Advanced and unstable RA cervical spine lesions are routinely reconstructed using Cl-C2 joint and cervical pedicle screw internal fixation. With regard to the segments most commonly affected by SAS after atlantoaxial fusion, the C3/4 level is usually the most susceptible due to the presence of a large bony fusion containing the C2/3 intervertebral level after atlantoaxial fusion. The results at 2 years after surgery were good, while the results at 5 years after surgery decreased. In the present study, we did not observe this phenomenon. In previous studies, most cases of C2-C3 spontaneous fusion were associated with the Brooks technique and were thought to be related to excessive subperiosteal stripping. We speculate that the reason why no osseous fusion of C2-C3 was found in this study is that, first, there was no excessive stripping of cervical musculature, reducing the damage to the soft tissues between the spinous processes and the intervertebral plates of C2-C3, and second, all patients had block bone grafting, avoiding the problem of excessive fusion with fragmentary bone grafting. Our study also found that the cephalic segment level (C2/3, C3/4, C4/5) was more prone to dislocation or subluxation than the caudal segment level (C5/6, C6/7). However, we did not find any association between the incidence of SAS before and after surgery and AAA, SAA.

The preoperative course of a patient with cervical RA requires close design. A successful procedure requires a great deal of expertise to achieve stable decompression of the craniocervical junction region. Therefore, skilled preoperative evaluation, appropriate surgical approach selection, the use of appropriate hemostasis, sealing devices, and stabilization instruments are all necessary to achieve optimal functional results and avoid surgical complications.

To reduce the incidence of postoperative SAS, the optimal atlantoaxial fusion angle should be determined preoperatively. Restoring or re-establishing balance in the sagittal position of the cervical spine allows for minimal energy consumption to maintain the balance of the spine and the level of the visual field. The development of SAS after atlantoaxial fixation is influenced by a number of factors: atlantoaxial fixation angle, disruption of the extensor muscles, damage to the lower cervical spine including the progression of lower cervical subluxation, etc. Therefore, we tried to find the appropriate atlantoaxial angle from atlantoaxial fusion patients without stripping the musculature of the lower cervical spine. Researchers(15,16) stated that the optimal fixed fusion angle for C1-C2 should be 20°, but the physiological angle of the atlantoaxial spine is highly variable for each individual. According to the measurement data of Nojiri et al(17), the average C1-C2 angle in normal adults was 28°, while in the study of Hardacker et al(18), the average C1-C2 angle was 32.2°. In a study by Toyama et al(19), 25° to 30° was considered as the optimal fusion angle. The study by Wang Jian et al(20) suggested that the C1-C2 fusion angle should be within 20°. Guo Qunfeng et al (21) showed that the optimal fusion angle should be 25° to 30°. Our results showed that the choice of 20° ± 5° of C1-C2 angle in patients with atlantoaxial fixation did not affect the incidence of SAS at 3 years after surgery. We believe that the optimal atlantoaxial fixation angle should not be a certain absolute fixation value, but should be determined by combining each patient's preoperative original atlantoaxial angle and lower cervical curvature to achieve as much anatomic repositioning as possible.

Conclusion

It is important to point out the shortcomings of this paper. Due to the small number of patients and the inevitable errors in data mapping statistics, strong statistical support is lacking. Moreover, this investigation was conducted only for a period of 3 years, and it was likely that some patients would require surgery related to lower cervical subluxation after 3 years. The occurrence of SAS requiring reoperation was possible in cases with a persistent decrease in the C2-C7 anterior convexity angle. Therefore, further long-term studies are needed. Further prospective clinical studies are required regarding the optimal fusion angle of cervical RA for postoperative SAS association, and exactly what angle is the optimal fusion angle.

References

1) Wasserman B R, Moskovich R, Razi A E. Rheumatoid arthritis of the cervical spine--clinical considerations[J]. Bull NYU Hosp Jt Dis, 2011, 69(2): 136-148.
2) Clarke M J, Cohengadol A A, Ebersold M J, et al. Long-term incidence of subaxial cervical spine instability following cervical arthrodesis surgery in patients with rheumatoid arthritis. [J]. Surgical Neurology, 2006, 66(2): 136.
3) Ishii K, Matsumoto M, Takahashi Y, et al. Risk factors for development of subaxial subluxations following atlantoaxial arthrodesis for atlantoaxial subluxations in rheumatoid arthritis. [J]. Spine, 2010, 35(16): 1551-1555.
4) Mukai Y, Hosono N, Sakura H, et al. Sagittal alignment of the subaxial cervical spine after C1-C2 transarticular screw fixation in rheumatoid arthritis. [J]. Journal of Spinal Disorders & Techniques, 2007, 20(6): 436.
5) Yoshida G, Kamiya M, Yoshihara H, et al. Subaxial sagittal alignment and adjacent-segment degeneration after atlantoaxial fixation performed using C-1 lateral mass and C-2 pedicle screws or transarticular screws[J]. Journal of Neurosurgery Spine, 2010, 13(4): 443.
6) Bazmandegan G, Shamsizadeh A, FathiNajafi M, Assadollahi Z, Allahtavakoli M, Vakilian A, et al. Iranian brown propolis possesses neuroprotective effect against ischemic neuronal damage in mice. J Herbmed Pharmacol. 2020; 9(2): 121-129. doi: 10.34172/jhp.2020.16.
7) Rezai M, Mahmoodi M, Kaeidi A, Noroozi Karimabad M., Khoshdel A, Hajizadeh MR. Effect of crocin carotenoid on BDNF and CREB gene expression in brain ventral tegmental area of morphine treated rats. Asian Pac J Trop Biomed 2018; 8(8): 387-393.
8) Mansouri, F, Sheibani, H, Javedani Masroor, M, Afsharian, M. Extended-spectrum beta-lactamase (ESBL)-producing Enterobacteriaceae and urinary tract infections in pregnant/postpartum women: A systematic review and meta-analysis. Int J Clin Pract. 2019; 73: e13422. https://doi.org/10.1111/ijcp.13422.
9) Kato Y, Itoh T, Kanaya K, et al. Relation between atlantoaxial (C1/2) and cervical alignment (C2-C7) angles with Magerl and Brooks techniques for atlantoaxial subluxation in rheumatoid arthritis[J]. Journal of Orthopaedic Science, 2006, 11(4): 347-352.
10) Yoshimoto H, Ito M, Abumi K, et al. A retrospective radiographic analysis of subaxial sagittal alignment after posterior C1-C2 fusion. [J]. Spine, 2004,29(2):175-181.
11) Mukai Y, Hosono N, Sakura H, et al. Sagittal alignment of the subaxial cervical spine after C1-C2 transarticular screw fixation in rheumatoid arthritis. [J]. Journal of Spinal Disorders & Techniques, 2007, 20(6): 436.
12) Oshima S, Sudo H, Ito M, et al. Subaxial Sagittal Alignment after Atlantoaxial Fixation Techniques. [J]. Journal of Spinal Disorders & Techniques, 2015,28(1).
13) Ito H, Neo M, Sakamoto T, et al. Subaxial subluxation after atlantoaxial transarticular screw fixation in rheumatoid patients. [J]. European Spine Journal, 2009, 18(6): 869.
14) Kurogochi D, Takahashi J, Uehara M, et al. Ten-Year Results of Reconstruction for Rheumatoid Cervical Spine Lesions and Occurrence Factor of Subaxial Subluxation[J]. Asian spine journal, 2019, 13(5): 730-737.
15) Kato Y, Itoh T, Kanaya K, et al. Relation between atlantoaxial (C1/2) and cervical alignment (C2-C7) angles with Magerl and Brooks techniques for atlantoaxial subluxation in rheumatoid arthritis[J]. Journal of Orthopaedic Science, 2006, 11(4): 347-352.
16) Tabatabaei, Fatemeh Sadat and M. Masoumzadeh. "Dislocated intrauterine devices: clinical presentations, diagnosis and management." The European Journal of Contraception & Reproductive Health Care 26 (2021): 160 - 166.
17) Nojiri K, Matsumoto M, Chiba K, et al. Relationship between alignment of upper and lower cervical spine in asymptomatic individuals. [J]. Journal of Neurosurgery, 2003,99(1 Suppl):80-83.
18) Hardacker J W, Shuford R F, Capicotto P N, et al. Radiographic standing cervical segmental alignment in adult volunteers without neck symptoms. [J]. Spine, 1997, 22(13): 1472.
19) Toyama Y, Matsumoto M, Chiba K, et al. Realignment of postoperative cervical kyphosis in children by vertebral remodeling. [J]. Spine, 1994, 19(22) :2565-2570.
20) Wang J, Ni B, Tao CH, et al. Correlation between posterior atlantoaxial fusion angle and lower cervical curvature[J]. Chinese Journal of Traumatology and Orthopaedics, 2008, 10(11): 1036-1039.
21) Guo Q, Ni B, Yang J, et al. Relation between alignments of upper and subaxial cervical spine: a radiological study[J]. Archives of Orthopaedic & Trauma Surgery, 2011, 131(6): 857-862.
21) Guo Q, Ni B, Yang J, et al. Relation between alignments of upper and subaxial cervical spine: a radiological study[J]. Archives of Orthopaedic & Trauma Surgery, 2011,131(6):857-862.

Corresponding Author:
Yuanhua Fang
Department of Orthopedics, Lishui Municipal Central Hospital (The Fifth Affiliated Hospital of Wenzhou Medical University), No. 289, Kuocang Road, Liandu District, Lishui, Zhejiang 323000, China
Email: 397538942@qq.com
(China)