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Inadvertent C2–C3 Union After C1–C2 Posterior Fusion in Adults

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Abstract *Introduction:* Some authors pointed out that there were more than a few patients with inadvertent C2–C3 union after C1–C2 posterior fusion, although few detailed studies of C2–C3 union have been reported. The purpose of this study was to clarify whether C2–C3 union accelerated adjacent C3–C4 disc degeneration after C1–C2 posterior fusion and to investigate the related factors for C2–C3 union. *Methods:* Sixteen patients with rheumatoid arthritis (RA group) (4 males, 12 females, mean age 60 years, mean follow-up period 4 years and 3 months) and fifteen patients without RA (non-RA group) (11 males, 4 females, mean 52 years, mean follow-up period 3 years and 10 months) who underwent C1–C2 posterior fusion were radiologically assessed. The C2–C3 union was defined as trabecular bone formation at C2–C3 interlamina in lateral radiograph. C3–C4 disc height was measured to evaluate the disc degeneration. *Results:* C2–C3 union rate was 56%

and 60% in RA group and non-RA group, respectively. In RA group, postoperative C3–C4 disc height was lower (Student's *t*-test, $P = 0.029$) and the decrease rate of C3–C4 disc height was higher (Student's *t*-test, $P = 0.015$) in patients with C2–C3 union than in patients without C2–C3 union. In non-RA group, the age at operation was older (Student's *t*-test, $P = 0.0007$), and the C1–C2 fusion angle (Student's *t*-test, $P = 0.012$) was smaller in patients with C2–C3 union than in patients without C2–C3 union. *Conclusions:* C2–C3 union after C1–C2 posterior fusion occurred in more than half of both groups. Inadvertent C2–C3 union should be considered a radiological complication and a potential risk factor due to acceleration of C3–C4 disc degeneration in RA.

Keywords Atlanto-axial subluxation · Disc degeneration · Posterior fusion · Rheumatoid arthritis · Union

Introduction

With the change of C1–C2 posterior fusion procedure from wiring methods to transarticular screw fixation of the Magerl method, C1–C2 fixation has been achieved with a high rate of success [5, 7, 12, 29, 30]. On the other hand, some authors pointed out that there were more

than a few patients inadvertently fused to C3 (Table 1). However, there are few detailed studies about inadvertent C2–C3 union, and it has not as yet been taken up clinically as a problem.

Many clinical studies about degenerative change at the adjacent segments after anterior cervical fusion have been reported [1, 2, 4, 8–11, 13, 14, 20, 34]. It

Table 1 C2–C3 union rate after C1–C2 posterior fusion

Series [Ref. no.]	C2–C3 union rate (%)	No. of patients (C2–C3 union/total)	Age
Brooks and Jenkins [3]	7	1/15	8–70
Toyama et al. [32]	47	42/90	3–74
Parisini et al. [24]	42	5/12	7–12

was also shown that significant increases in intradiscal pressure and segment motion occur at levels adjacent to fusion during normal range of motion (ROM) in a biomechanical study [6]. After C1–C2 posterior fusion, on the other hand, subaxial kyphotic changes due to compensation for ROM at the middle and lower cervical spine [31, 32] or development of ossification of the posterior longitudinal ligament due to increase of the mechanical stress at the middle and lower cervical spine [16] has been reported. The authors presumed that adjacent C3–C4 disc degeneration, which is similar to that after anterior cervical fusion, might occur in patients who developed C1–C3 fusion due to inadvertent C2–C3 union after C1–C2 posterior fusion. The onset of cervical myelopathy is a concern at the C3–C4 level especially in elderly patients, because cervical spondylotic myelopathy in elderly patients has been reported to occur at C3–C4 level at a high rate in their natural course of the cervical spine [21]. On the other hand, acceleration of progression of subaxial subluxation (SAS) is a concern at C3–C4 level in patients with rheumatoid arthritis (RA), because subadjacent anterior listhesis has also been reported to occur more frequently in RA patients with small ROM at the adjacent segment [18, 25, 26].

This retrospective radiographic study clarified whether inadvertent C2–C3 union accelerated adjacent C3–C4 disc degeneration after C1–C2 posterior fusion with distinction between RA and non-RA and investigated the preoperative and postoperative related factors for C2–C3 union. This knowledge might be useful in C1–C2 posterior fusion procedure.

Materials and Methods

Patient group

The population consisted of 31 patients who underwent C1–C2 posterior fusion, between 1986 and 2000, with a minimum follow-up period of roentgenographic evaluation of 1 year (mean follow-up period, 4 years and 1 month). All the 31 patients were divided into two groups: RA group of 16 patients with atlanto-axial subluxation (AAS) with RA, and non-RA group of 15 patients without RA (Table 2). Non-RA group included

Table 2 Summary of RA group and non-RA group

	RA group	Non-RA group
Number of cases	16	15
Gender (male:female)	4:12	11:4
Age (years)	60 (46–75)	52 (22–74)
Operative method		
Brooks and Jenkins [3]	2	2
Magerl and Seeman [19]	0	3
Magerl–Brooks [15]	14	10
Collar periods (weeks)	9 (2.5–13)	11 (3–30)
Follow-up (months)	51 (13–132)	46 (12–102)

Note: RA, rheumatoid arthritis.

four dens fractures, two os odontoideum, six traumatic AAS and three idiopathic AAS.

Our surgical indications for C1–C2 posterior fusion are reducible atlanto-axial (A-A) instability preoperatively and as follows: (1) obvious symptom of compression of the medulla oblongata or spinal cord at C1–C2, (2) restrictive limitation on the patient's activity of daily living with severe nuchal or occipital pain and/or (3) severe A-A instability with measurable space within the canal of 13 mm in the radiograph. Five differential surgeons operated in this series. The muscles including the rectus capitis posterior major, inferior oblique and semispinalis cervicis were cut off subperiosteally from the C2 spinous process, and the rectus capitis posterior minor was cut off from the C1 lamina. The dissection was performed proximally to separate the posterior atlanto-occipital membrane, distally to the C3 or C4 lamina and laterally to the lateral edges of the C2–C3 facet joints. The extensor musculature was not repaired after the C1–C2 fusion procedure. Cortical bone was removed from the ilium and grafted on the C1 and C2 laminae. Bone grafts were not brought down to C3 to specifically avoid extending fusion from C2 to C3. Periosteum was also dissected only at the site of bone graft of the C1 and C2 laminae in all cases. Although the period of postoperative cervical orthosis was for 3 months after Brooks method and for 8 weeks after Magerl method in principle, the periods were altered according to the intensity of pain, patient's understanding of the treatment and the degree of bone union and stability. In RA group, the period of postoperative external fixation varied from 2.5 to 13 weeks (mean period, 9 weeks) in 15 patients, except one patient who wore a collar for 6 years because of the occurrence of SAS. In non-RA group, the period varied from 3 to 30 weeks (mean period, 11 weeks).

C1–C2 fusion was achieved in 29 out of 31 patients, and the fusion rate was 94%. Pseudoarthrosis was found in two RA patients after Brooks method. Of the two RA patients who developed pseudoarthrosis, one patient

underwent a reoperation. Transarticular screw fixation was performed for late deterioration caused by C1–C2 pseudoarthrosis at 10 years after the first operation. No other patient required reoperation for late deterioration.

Radiologic evaluation

Interlaminar bone union was investigated from O–C1 to C6–C7. Bone union was evaluated by trabecular bone formation in lateral radiograph (Fig. 1). The ROM was measured as an angle between C2 and C7 on lateral flexion and extension radiographs of the cervical spine. C1–C2 fusion angle was measured according to Toyama et al. [32] (Fig. 2). Lordotic angle at C2–C3 and C2–C7 was measured with Cobb's method on lateral radiograph in neutral view. The C3–C4 disc height was measured at the maximum part of C3–C4 disc on lateral radiograph in neutral view. The width of neck of mandible was also measured for normalization of roentgenographic errors (Fig. 3). The ratio of C3–C4 disc height to mandible width was defined as C3–C4 disc height index (D.I.).

$C3-C4 \text{ D.I.} = C3-C4 \text{ disc height} / \text{mandible width.}$

Preoperative and postoperative C3–C4 D.I. and the decrease rate of C3–C4 D.I. were statistically analyzed to evaluate the disc degeneration at C3–C4. All the measurements were performed using software CANVAS 7.

Fig. 1 Evaluation of interlaminar bone union. Bone union was evaluated by trabecular bone formation (arrow) in lateral radiograph

Fig. 2 Measurement of C1–C2 fusion angle. According to Toyama et al. [32], the angle formed by the inferior line of ventral and dorsal arch of C1, and the line formed by the inferior border of the vertebral body of C2 was measured

Statistical analysis

Related factors for C2–C3 union were statistically analyzed in both groups. Preoperative factors, including gender and age were analyzed. Postoperative factors,

Fig. 3 Measurements of C3–C4 disc height and the width of neck of mandible. On lateral radiograph in neutral view, C3–C4 disc height was measured at the maximum part (a) of C3–C4 disc, and the width of neck of mandible was measured (b)

including collar period, C2–C7 ROM, C1–C2 fusion angle and lordotic angle at C2–C3 and C2–C7 were analyzed. Student's *t*-test and the chi-squared test were used in the statistical analysis. All *P*-values <0.05 were considered statistically significant.

Results

RA group

Interlaminar union

Inadvertent C2–C3 union was found in 9 of 16 patients, and the union rate was 56%. According to surgical procedures, C2–C3 union was found in all of 2 patients after Brooks method and 7 of 14 patients (50%) after Magerl–Brooks method. O–C1 union was also found in four patients, and the union rate was 25%. There was no interlaminar union at C3–C4, C4–C5, C5–C6 and C6–C7.

Comparison between C2–C3 union group and C2–C3 non-union group

All the 16 patients in RA group were divided into two groups: C2–C3 union group of nine patients, and C2–C3 non-union group of seven patients. Mean follow-up period was 58 months in C2–C3 union group and 42 months in C2–C3 non-union group, with no significance between the two groups (Table 3).

Preoperative C3–C4 D.I. was similar in both groups. Postoperative C3–C4 D.I. was significantly smaller ($P = 0.029$) in C2–C3 union group (0.29) than in C2–C3 non-union group (0.45). The mean decrease rate of C3–C4 D.I. was significantly larger ($P = 0.015$) in C2–C3

union group (40%) than in C2–C3 non-union group (6%) (Fig. 4).

Preoperative factors, including gender and age at the time of operation, did not significantly relate to C2–C3 union. Postoperative factors, including collar period, C2–C7 ROM, C1–C2 fusion angle, and lordotic angle at C2–C3 and C2–C7 were similar in both groups.

Non-RA group

Interlaminar union

C2–C3 union was found in 9 of 15 patients and the union rate was 60%. According to surgical procedures, C2–C3 union was found in one of 2 patients after Brooks method, all of 3 patients after Magerl method and 5 of 10 patients after Magerl–Brooks method. O–C1 union was found in one patient. There was no interlaminar union at C3–C4, C4–C5, C5–C6 and C6–C7.

Comparison between C2–C3 union group and C2–C3 non-union group

All the 15 patients in non-RA group were divided into two groups: C2–C3 union group of 9 patients and C2–C3 non-union group of 6 patients. Mean follow-up period was 47 months in C2–C3 union group and 45 months in C2–C3 non-union group, with no significance between the two groups (Table 4).

Pre- and postoperative C3–C4 D.I. and the decrease rate of C3–C4 D.I. were similar in both groups.

Between the two preoperative factors, age at the time of operation was significantly higher ($P = 0.0007$) in C2–C3 union group (61 years) than in C2–C3 non-union group (37 years). Among the postoperative factors, C1–

Table 3 Comparison between C2–C3 union group and non-union group in RA group

	C2–C3 union group	C2–C3 non-union group	<i>P</i> -value
Number of cases	9	7	–
Follow-up (months)	58.0 ± 44.6	42.1 ± 21.5	n.s.
C3–C4 disc degeneration			
Preoperative C3–C4 D.I.	0.48 ± 0.10	0.49 ± 0.05	n.s.
Postoperative C3–C4 D.I.	0.29 ± 0.17	0.45 ± 0.05	0.029
Decrease rate of C3–C4 D.I.	0.40 ± 0.31	0.06 ± 0.07	0.015
Preoperative factors			
Gender (male:female)	2:7	2:5	n.s.*
Age (years)	60.7 ± 9.2	59.0 ± 7.9	n.s.
Postoperative factors			
Collar periods (weeks)	8.2 ± 2.6	9.4 ± 2.8	n.s.
C2–C7 ROM (degree)	30.8 ± 13.5	39.1 ± 14.7	n.s.
C1–C2 fusion angle (degree)	21.6 ± 4.3	25.3 ± 7.5	n.s.
C2–C3 lordotic angle (degree)	0.2 ± 3.8	–1.0 ± 3.5	n.s.
C2–C7 lordotic angle (degree)	8.8 ± 14.1	8.6 ± 9.7	n.s.

Note: n.s., not significant; RA, rheumatoid arthritis; D.I., disc height index; ROM, range of motion.

Mean ± standard deviation. Student's *t* test.

*Chi-squared test.

Fig. 4 Correlation between the rate of decrease of C3–C4 D.I. and C2–C3 union in RA group. Rate of decrease of C3–C4 D.I. was significantly higher in C2–C3 union group than in C2–C3 non-union group

C2 fusion angle was significantly smaller ($P = 0.012$) in C2–C3 union group (20°) than in C2–C3 non-union group (31°) (Fig. 5).

Discussion

Postoperative subaxial kyphotic changes after C1–C2 posterior fusion have been reported [31, 32]. Recently, development of ossification of the posterior longitudinal ligament at C3 or at a lower level after C1–C2 posterior fusion was also reported in three cases [16]. Compensation for ROM and increase of the mechanical stress at the middle and lower cervical spine were pointed out to be one of the factors responsible. On the other hand, it was also reported that there were more than a few patients with inadvertent C2–C3 union after C1–C2 posterior fusion. However, few studies have been done on

Fig. 5 Correlation between C1–C2 fusion angle and C2–C3 union in non-RA group. C1–C2 fusion angle was significantly smaller in C2–C3 union group than in C2–C3 non-union group

C2–C3 union after C1–C2 posterior fusion, and it is unknown whether C2–C3 union accelerated the adjacent C3–C4 disc degeneration, which is similar to that after anterior cervical fusion. To the authors' knowledge, the current radiographic study may be the first to analyze the inadvertent interlaminar union after C1–C2 posterior fusion.

In the present study, more than half of the patients in both RA and non-RA groups after C1–C2 posterior fusion resulted in disappointing C1–C3 fusion due to C2–C3 union, and furthermore, C2–C3 union accelerated the adjacent C3–C4 disc degeneration in RA group. Figure 6 shows one RA patient with SAS adjacent to the C3–C4 level of an O–C3 fusion at 6 years after C1–C2 posterior fusion in this series. Although SAS has been reported to progress at 20–30% in RA patients in the natural course of their disease [27, 28, 33], there is every possibility that C2–C3 union accelerated progression of SAS in this patient.

Table 4 Comparison between C2–C3 union group and non-union group in non-RA group

	C2–C3 union group	C2–C3 non-union group	P-value
Number of cases	9	6	–
Follow-up (months)	46.6 ± 30.1	44.8 ± 43.0	n.s.
C3–C4 disc degeneration			
Preoperative C3–C4 D.I.	0.48 ± 0.10	0.47 ± 0.05	n.s.
Postoperative C3–C4 D.I.	0.43 ± 0.07	0.46 ± 0.04	n.s.
Decrease rate of C3–C4 D.I.	0.07 ± 0.14	0.03 ± 0.05	n.s.
Preoperative factors			
Gender (male:female)	6:3	5:1	n.s.*
Age (years)	61.0 ± 9.7	37.3 ± 11.0	0.0007
Postoperative factors			
Collar periods (weeks)	10.5 ± 1.9	10.8 ± 7.0	n.s.
C2–C7 ROM (degree)	25.8 ± 16.4	40.4 ± 14.2	n.s.
C1–C2 fusion angle (degree)	19.9 ± 7.7	31.0 ± 6.4	0.012
C2–C3 lordotic angle (degree)	–1.5 ± 4.7	–6.9 ± 8.1	n.s.
C2–C7 lordotic angle (degree)	12.6 ± 11.7	11.2 ± 10.6	n.s.

Note: n.s., not significant; RA, rheumatoid arthritis; D.I., disc height index; ROM, range of motion.

Mean ± standard deviation.

Student's *t*-test.

*Chi-squared test.

Fig. 6 A 61-year-old woman with RA. AAS occurred adjacent to the C3–C4 level of O–C3 fusion, which resulted from inadvertent union at 6 years after C1–C2 posterior fusion. (A) Lateral radiograph in neutral view; (B) computed tomography in sagittal view; (C) T2-weighted sagittal MR image

Fig. 7 Correlation between age and C1–C2 fusion angle. There was a significant negative correlation between age and C1–C2 fusion angle in both groups. (A) RA group (Pearson's coefficient, $r = -0.499$; $P = 0.048$). (B) Non-RA group (Pearson's coefficient, $r = -0.588$; $P = 0.019$)

Although there was no patient who underwent a reoperation for late deterioration at C3–C4 in this series, C2–C3 union after C1–C2 fusion might be a radiological complication and a potential risk factor for late deterioration in RA patients. On the other hand, C2–C3 union did not accelerate C3–C4 disc degeneration in non-RA group. However, it is important to know the longer-term result because there was a case report of acute progression of paresis due to instability of the adjacent level that had resulted from spontaneous fusion at 30 years after A–A fusion for os odontoideum [23].

Brooks and Jenkins [3] presumed that overzealous subperiosteal stripping caused the extension of the union. In the current study, bone grafting and subperiosteal stripping were performed only on the C1 and C2 laminae in all cases. However, there is a possibility that the bone graft inadvertently extended across the laminar spacing to C3 during the healing process. The related factors for C2–C3 union were elderly patient age and small C1–C2 fusion angle in non-RA group. Although C1–C2 fusion angle was smaller in C2–C3 union group (22°) than in C2–C3 non-union group (25°) in RA group, the difference was not statistically significant. To reveal the related factors for C2–C3 union, larger numbers of patients might be needed to analyze statistically the related factors. In both groups, C1–C2 fusion angle was significantly smaller in elderly patients (Fig. 7). Cervical spondylotic change was reported to

progress with aging [17]. The authors presumed that the C1–C2 fusion angle was smaller in elderly patients, because reduction of AAS was insufficient due to cervical spondylotic changes with aging.

What degree should the optimal position of C1–C2 fusion be set up at? Nojiri et al. [22], in analyzing 313 normal subjects, reported that the mean A–A angle, which was defined as the same measurement as C1–C2 fusion angle, in normal subjects was 26.5° in males and 28.9° in females. In all of the 31 patients, C2–C3 union was found in 4 cases of 14 (29%) with over 25° C1–C2

Fig. 8 Correlation between C1–C2 fusion angle and C2–C3 union in all of the 31 patients

fusion angle and 14 cases of 17 (82%) who had $<25^\circ$ C1–C2 fusion angle (Fig. 8). From the results of this study, the authors concluded that the C1–C2 fusion angle should be $>25^\circ$ for prevention of C2–C3 union. Concerning C1–C2 fusion angle after C1–C2 posterior fusion, Toyama et al. [32], in analyzing the sagittal postoperative cervical curvature in 75 patients, reported that the optimal position of C1–C2 fusion for maintenance of postoperative lordosis should average 20° because a compensatory subaxial change was found in all patients whose C1–C2 fusion angle exceeded 30° . In the current study, however, the C1–C2 fusion angle of 20° recommended by Toyama et al. [32] was the most frequent angle associated with C2–C3 union. In consideration of the report by Toyama et al. and the present

study, the optimal position of C1–C2 fusion should be between 25° and 30° .

Conclusions

C2–C3 union after C1–C2 posterior fusion occurred in more than half of the patients in both of RA and non-RA groups. Inadvertent C2–C3 union should be considered a radiological complication and a potential risk factor for late deterioration due to acceleration of C3–C4 disc degeneration in RA patients. For prevention of C2–C3 union, especially in elderly patients, it is important to obtain a C1–C2 fusion angle over 25° .

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