Comparison of Atlantoaxial Functional and Radiographic Outcomes after Posterior Temporary Fixation Preserving with Detaching the Semispinalis Cervicis for Odontoid Fracture

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Research article

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Abstract

Background: The semispinalis cervicis (SSC) is attached to the spinous process of the C2–C5 vertebra and distally to the transverse process of the T1–T6 vertebra, like a primary power source for extension of the cervical spine. This study was to compare the outcomes following temporary posterior fixation in two cohorts of patients who either underwent our technique of preserving SSC (P-SSC) or traditional technique of detaching the SSC (D-SSC).

Methods : The conventional posterior temporary fixation was modified by preserving the SSC inserted into the C2 process. A total of 16 patients with odontoid fracture underwent the temporary posterior fixation preserving the SSC (P-SSC) or detaching the SSC (D-SSC). We measured the frequencies of postoperative axial symptom and cervical range of motion (ROM) in the rotation. The cross-sectional areas of posterior cervical muscles were also measured using axial CT.

Results: At the final follow-up, in 16 cases from each group fracture healing was achieved. The total extension ROM of C1-C2 in the P-SSC was $56.8 \pm 3.5^\circ$, while it was larger than $52.0 \pm 4.6^\circ$ in the D-SSC. The frequency and severity of limitations of ADL accompanying each of three neck movements i.e. extension, flexion and rotation were 2.8 ± 0.5 , 1.9 ± 0.6 and 2.0 ± 0.5 , respectively in the P-SSC; and 2.9 ± 0.4 , 2.3 ± 0.5 and 2.6 ± 0.5 , respectively in the D-SSC. Regarding the average atrophy rate, it was $6.0 \pm 2.9\%$ at the level C3 and $6.7 \pm 4.3\%$ at the level C5 in the P-SSC; and $17.9 \pm 7.4\%$ at the level C3 and $7.5 \pm 4.7\%$ at the level C5 in the D-SSC.

Conclusion: The frequencies of ADL limitations, the incidence of axial symptoms and loss of ROM accompanying neck extension, and atrophy rate of the posterior cervical muscles were lower for the atlantoaxial posterior temporary fixation preserving the SSC.

Background

Currently, there is a lack of consensus on how Anderson-D'Alonzo type II odontoid fractures, which are the most common odontoid fractures, should be treated.[1, 2] Anterior screw fixation is regarded as the treatment of choice for the fractures with intact transverse ligament because this approach can preserve the motion of the atlantoaxial joint. Although posterior screw-rod fixation possess a unique three-dimensional fixation, posterior C1-C2 fusion has to be conducted in cases with contraindications to anterior fixation, sacrificing atlantoaxial joint motion and posterior cervical muscles. Since Harms and Melcher have introduced a posterior temporary-fixation technique, it has been progressively employed to treat odontoid fractures with the intact transverse ligament.[3] This non fusion technique has also shown the ability to spare the motion of the atlantoaxial joint and to achieve satisfactory clinical outcomes.[4] However, in order to completely expose the C2 lamina and pedicle during C2 screws fixation, it is generally necessary to detach the deep extensor muscles attached to the C2 spinous process that have a principal role in stabilizing and mobilizing the neck with five bilateral muscular attachments.

Over recent years, a great deal of attention has been paid to axial symptoms as postoperative complications, which adversely affect patients' quality of life after posterior cervical fixation.[5] Although the causes of axial symptoms remain uncertain, many studies have shown that when the C-2 and C-7 spinous processes are preserved, the frequency of persistent postoperative axial neck pain is reduced.[5–7] The semispinalis cervicis (SSC) is attached to the spinous process of the C2–C5 vertebra and distally to the transverse process of the T1–T6 vertebra, like a primary power source for extension of the cervical spine[8]. The surgeon usually ignores the function of SSC. Accordingly, for complete preservation of the function of SSC after the operation, we modified the conventional temporary posterior fixation by preserving the SSC inserted into the C2 process. To evaluate the role of SSC in the atlantoaxial posterior approach, this retrospective study compared the preservation of the SSC with the temporary posterior fixation with the conventional fixation process, in which the muscle is detached from C2 spinous.

Methods

2.1 Patient Population

The Changzheng Hospital institutional review board approved of this retrospective comparative study. All the participants were over 16 years old, and the written informed consent were obtained from the participants. Data from 16 patients who underwent temporary posterior fixation due to fresh Anderson-D'Alonzo type II odontoid fractures were retrospectively reviewed at the Department of Spine Center of Changzheng Hospital between June 2015 and December 2017. The inclusion criteria were Grauer type IIC fractures or IIB fractures that could not be fixed by the anterior approach. Patients who were older than 65 years or had severe osteoporosis, and those with irreducible fractures or disruption of the transverse atlantal ligament were excluded from the study. Eight patients who underwent the temporary posterior fixation by preserving the SSC were allocated to Group P-SSC. Eight patients who underwent conventional temporary fixation with detaching the SSC from the axis, were assigned to Group D-SSC. The patients' general information are listed in *Table 1*, there was no significant difference among general information.

2.2 Operative Technique and Postoperative Management

The surgical procedure for Group P-SSC included the SSC insertion that was completely preserved in C2. Off the midline, splenius capitis and semispinalis capitis were dissected for the exposure of the deep cervical muscles. The C2 lamina, and pedicle were exposed by blunt dissection through the intermuscular plane between the SSC muscle and the obliquus capitis inferior muscle without damaging the attachments to the C2 spinous process. Then, suboccipital muscles and obliquus capitis inferior muscles were detached and the entry points for the C1 lateral mass screw were identified. The insertion points for the C1 and C2 screw were located at the position described by Harms and Melcher[3]. The surgical procedure for Group D-SSC included the conventional temporary fixation technique previously described, in which the SSC was detached from the C2 spinous process.[4] The postoperative collar period was 6–8 weeks. Once fracture healing occurred, the instrumentation was removed in both groups.

2.3 Radiological Assessment

Plain radiographs were taken before surgery, and at 3, 6, and 12 months after surgery. Computed tomography (CT) and reconstruction were performed at three months postoperatively or later to evaluate fracture healing that was defined as evident bridging bone across the odontoid fracture site.

2.4 Measurements of flexion to extension ROM (F-E ROM) and rotation ROM (R ROM).

The postoperative O–C7 angles at flexion and extension position were measured using McGregor line and the posterior tangents of the C7 vertebral body on lateral cervical extension and flexion radiographs, respectively. Then the F-E ROM was calculated as the difference between the two angles (*Figure 1*).. The postoperative R ROM of the patients with spectacles that served as measure lines were photographed in the cranial view using a digital camera (*Figure 2*).[9]

2.5 Measurements of Cross-Sectional Areas (CSA) of the Cervical Posterior Muscles

CT of the cervical spine was taken before surgery and at three months postoperatively. The CSA at the C3–4 and C5–6 levels was measured for evaluation. The preoperative and postoperative CSA of the posterior cervical muscles, including the trapezius, splenius capitis, semispinalis capitis, SSC and multifidus muscles were measured on axial CT scanning with soft tissue window at C5, while SSC and multifidus muscles were measured at the level C3 (*Figure 3*).. The rate of muscle atrophy was calculated at each levels using the following formula[6, 10]: *Atrophy rate (%) = (1 - postoperative area/preoperative area) * 100%*

The measurement was performed using ImageJ imaging software (version 1.43, National Institutes of Health, Bethesda, Maryland, downloadable at <http://rsbweb.nih.gov/ij/download.html>). Two observers did the measurements, and interobserver reliability was calculated. The measurements were repeated twice, and the results were averaged. The second observer was blinded to the findings of the first observer. Reliability was studied in relation to the intraclass correlation coefficient.

2.6 Evaluation of ADL and axial symptoms

The frequencies of postoperative limitations of activities of daily living (ADL) accompanying each of the following neck movements were investigated: (1) ADL (E): extension, (2) ADL (F): flexion, and (3) ADL (R): rotation. The severity of the limitations of each ADL was assessed using a questionnaire (*Table 2 and 3*).. The postoperative limitations of ADL were compared between the two groups.

Axial symptoms were evaluated using an axial symptom scoring system (Ass) that was reported in the previous study.[11] In this scoring system, there were four parameters (including posterior neck pain,

posterior neck stiffness, shoulder pain, and shoulder stiffness), and each parameter was classified into four grades (none: 3, occasional mild: 2, continuous mild or occasionally severe: 1, continuously severe: 0). The total of the axial symptom system score was calculated as the sum score of the parameters.

2.7 Statistical analysis

The data were presented as the mean $\pm$ standard error of the mean. The SPSS statistical software package (Version 19.0.0; SPSS, Inc., Chicago, IL) was used to complete the statistical analyses. Continuous data were compared using Student's *t* tests, Spearman's rank correlation test, and Mann-Whitney U tests based on assumptions of normality. Comparisons of categorical variables were performed with the Chi-square test or Fisher's Exact Test. A $p < 0.05$ was considered statistically significant.

Results

In total, 16 patients with type II odontoid fracture were enrolled during the study period (8 cases in each group). All patients were treated with posterior temporary non-fusion fixation technique that included preserving the SSC or dethatching the SSC.

No infections, Cerebrospinal fluid leakage, neurological injuries, vascular injuries or any other complications were identified during or after operations. All the patients experienced fracture healing within six months after temporary fixation (average 5.3 months). Outcomes from 16 patients were analyzed (*Figure 4 and 5*).

At the final follow-up, the total ROM in rotation of C1-C2 on both sides in the posterior temporary-fixation Group P-SSC was $48.4 \pm 4.1^\circ$, which was larger than $47.5 \pm 3.8^\circ$ observed in the Group D-SSC. Yet, there was no statistical difference between two groups ($P > 0.05$, *t* test). The total extension ROM of C1-C2 in the Group P-SSC was $56.8 \pm 3.5^\circ$, which was larger than $52.0 \pm 4.6^\circ$ observed in the Group D-SSC; the observed differences were significant between the two groups ($P < 0.05$, *t* test) (*Table 4*).

The frequency and severity of limitations of ADL in both groups are shown in *Table 5*. In the Group P-SSC, the ADL(R) was 2.8 ± 0.5 , the ADL (E) was 1.9 ± 0.6 , and the ADL (F) was 2.0 ± 0.5 ; in the Group D-SSC, the ADL(R), ADL (E), and ADL (F) were 2.9 ± 0.4 , 2.3 ± 0.5 , and 2.6 ± 0.5 respectively. The higher the ADL score was, there were more limitation in activities of daily living. Even though only the ADL (F) revealed the significant difference between the two groups ($P < 0.05$), all the mean values of ADL in the Group P-SSC were smaller than ADL in the Group D-SSC. Axial symptom score in the Group P-SSC was 10.5 ± 0.5 , and in the Group D-SSC was 9.6 ± 0.7 . The incidence and severity of axial symptom were significantly lower in the Group P-SSC ($P < 0.05$).

The average preoperative CSA of the preoperative cervical posterior muscles at the level C3 was $4.6 \pm 0.9 \text{ cm}^2$ in the Group P-SSC, and $4.3 \pm 0.7 \text{ cm}^2$ in the Group D-SSC. Average preoperative CSA at the level C5

was $20.8 \pm 2.6 \text{ cm}^2$ in the Group P-SSC, and $18.3 \pm 3.6 \text{ cm}^2$ in the Group D-SSC. Average postoperative CSA at level C3 was larger in Group P-SSC ($4.3 \pm 1.0 \text{ cm}^2$) than in Group D-SSC ($3.5 \pm 0.5 \text{ cm}^2$). Area at level C5 was $19.4 \pm 2.8 \text{ cm}^2$ in the Group P-SSC and $17.2 \pm 2.7 \text{ cm}^2$ in the Group D-SSC. According to the atrophy rate formula mentioned before, the average atrophy rate at the level C3 in the Group P-SSC was $6.0 \pm 2.9\%$, and in the Group D-SSC it was $17.9 \pm 7.4\%$. There was a significant difference between the two groups in the atrophy rate at the level C3 ($P < 0.05$) (Figure 6).. While the average atrophy rate at the level C5 was $6.7 \pm 4.3\%$ in Group P-SSC, and in Group D-SSC $7.5 \pm 4.7\%$, there was no significant difference between the two groups in terms of atrophy. The mean value of the atrophy rate at the level C5 was lower in the Group P-SSC (Figure 7)..

Discussion

Based on fracture line obliquity, displacement, and comminution to guide treatment options, Grauer *et al* have classified Anderson-D'Alonzo type II of odontoid fractures into three subtypes (II A, II B, II C).[12] The type IIC fracture, which has an oblique fracture line from posterosuperior to anteroinferior that parallels screw trajectory, is a contraindication to anterior screw fixation since interfragmentary compression cannot be achieved using the odontoid screw.[13] Recently, temporary posterior fixation has been reported as a new cervical posterior surgery for treatment of Anderson-D'Alonzo type II odontoid fractures, which does not include the fusion of atlantoaxial joint thus preserving the cervical movement. By comparing clinical outcomes and the range of motion (ROM) in rotation of these two non-fusion techniques, Guo *et al.* have reported that temporary posterior fixation could spare the motion of C1-C2 complex and achieve similar clinical outcomes to anterior screw fixation in the treatment of Anderson-D'Alonzo type II odontoid fracture.[13, 14]

Unlike the posterior atlantoaxial fixation and fusion surgery, it is unnecessary to place autologous iliac crest graft between the posterior C1/2 articulation after grinding the cortical bone in temporary posterior fixation, thus avoiding the detachment of the deep extensor musculature.[8]

The SSC, which are mostly inserted into the C2 spinous process, act as the primary dynamic stabilizers and as extensors of the cervical spine. According to existing research, the SSC and multifidus muscle pair show significant relative activation during head extension. They also have an essential postural role, which is likely to be affected by atrophy and loss of strength during exposure to microgravity or long-term bedrest.[15] Current research suggests that the posterior cervical deep muscles should be preserved without detachment from the C2 spinous process during atlantoaxial posterior approach.[7, 16, 17] Therefore, it is crucial to preserve SSC, especially in the upper cervical spine surgery. Kazunari and colleagues have reported that the posterior cervical approach preserving the SSC insertion into C2 could reduce the postoperative axial symptoms compared to conventional approach, which implies reattaching the muscle to the C2 spinous process.[18] Besides, some authors have verified that the preserving of neck extensor could benefit patients by restoring the lordotic angle of the cervical spine and reduce pain in patients with loss of cervical lordosis.[18–20]

In the current study, we evaluated and compared outcomes of ADL, ROM, axial symptoms and CSA of cervical muscles of 2 nonfusion techniques in the treatment of fresh Anderson-D'Alonzo type II odontoid fractures. To our knowledge, there are no previous detailed clinical studies on the effect of preserving the SSC inserted in the C2 [spinous](#) process in the atlantoaxial posterior approach.

Clinical data demonstrated that the frequency of limitations of ADL accompanying extension or rotation in the Group P-SSC was lower than in the Group D-SSC. Moreover, objective data showed that the postoperative ranges of motion from flexion to extension (F-E ROM) in the Group P-SSC were significantly larger than those in the Group D-SSC. Since most of the SSC inserted into the C2 spinous process as an essential extensor of the cervical spine were preserved, the posterior approach preserving the SSC might cause the larger angle at extension and the reduction of limitations of ADL accompanying extension.[15, 19] Nevertheless, Yukawa *et al* have compared a laminoplasty that preserved the SSC with skip laminectomy observing no significant differences in the extension ROM.[21] In our study, we found that atlantoaxial posterior approach for preserving the SSC inserted into C2 did not influence the postoperative neck rotation ROM and limitations of ADL accompanying rotation.

As reported, the CSA of the posterior cervical muscles has a strong relationship with the movement strength during flexion and rotation.[6, 20] Decrease in the CSA of posterior extensor muscles was significantly associated with the development of shoulder stiffness, which has been related to dysfunctions or spasms in the posterior extensor muscles of the cervical spine.[22] Takeuchi *et al* have evaluated the CSA of the posterior cervical muscles prospectively after laminoplasty by preserving or reattaching the SSC inserted into C2 and have reported that only the preservation of the SSC inserted into C2 could maintain the whole cervical posterior muscular volume.[6] Some studies have also reported that posterior surgeries may lead to atrophy and cause damage to these muscles, leading to instability or malalignment of the cervical spine [22, 23].

In our study, the average atrophy rate in the group preserving the SSC was significantly lower in the atrophy rate at the level C3, and average in the atrophy rate at level C5. The difference was not significant at the level C5, which might be due to the limited motion of the upper cervical fixation and increased compensatory activity of the lower cervical muscles, which in turn lead to the less obvious atrophy at lower levels.

In order to minimize muscle substance destruction and to maximally preserve both the mobility and stability of the cervical spine, various modified minimally invasive atlantoaxial fixation such as intramuscular and intermuscular exposure techniques have been used for preserving the posterior elements.[17, 24] They all achieved satisfactory clinical outcomes verifying the importance of the deep extensor muscles of the neck. However, due to increased surgery risks and a steeper learning curve this approach should only be taken by surgeons with rich experience.

Even though the C1–C2 temporary fixation preserving SSC technique leads to good outcomes, it cannot be used as the treatment of choice for all the types of odontoid fracture. This technique has been indicated in Grauer type IIC fractures with good reduction. For irreducible fractures and elderly patients

with severe osteoporosis, posterior C1–C2 fixation and fusion are more suitable approaches. The posterior approach is not considered for fractures with Grauer type IIA and Anderson-D'Alonzo type III fractures that can be fixed by the anterior approach.

There are some limitations in the present study that need to be pointed out. This was a retrospective study, with small sample size. Future studies should include more cases to further verify the outcomes of the current study. Moreover, the follow-up time was relatively short. Considering the individual variation of cervical rotation/extension ROM and cervical muscles CSA following long-term function exercise, we did not evaluate further clinical effect of patients when removing the implants after fracture healing. These factors may neglect the difference between the two groups in long-time period clinical outcomes.

Conclusions

This retrospective study suggested that the frequencies of limitations of ADL, the incidence of axial symptoms, loss of ROM accompanying neck extension and atrophy rate of the posterior cervical muscles were lower after atlantoaxial posterior temporary fixation preserving the SSC inserted into C2 than after conventional fixation and dethatching the muscle to C2.

Declarations

Abbreviations

SSC: semispinalis cervicis; *P-SSC*: preserving SSC; *D-SSC*: detaching the SSC; *ROM*: range of motion; *CT*: Computed tomography; *ADL*: activities of daily living; *MRI*: magnetic resonance imaging.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Authors' contributions

JL, EZJ; study design, analyses and interpretation of data, draft of manuscript with tables and figures. JL, EZJ, GHX; substantial contributions to conception and critical revision for important intellectual content. JL, EZJ, GHX; substantial contributions to study design and data acquisition, JL, EZJ. XGB, LJZ, DYN; data acquisition. All authors read and approved the final manuscript.

Author information

Displayed on title page

Ethics approval and consent to participate

The study was approved by the ethical committee of Changzheng Hospital of Second Military Medical University. All the patients gave written consent to for research applications of their clinical data. The patient data was anonymized in this study.

Consent for publication

The patients (all adults) all gave their explicit written consent to have all their outcome data, images and demographics included in this article write-up and for publication.

Competing interests

The authors declare that they have no competing interests.

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Tables

Variable	Group A	Group B
Age (year)*	41.6±11.3	45.1±14.1
Sex (number) [‡]		
Male	5	5
Female	3	3
Cause of fracture [‡]		
Fall from a considerable height	2	3
Motor vehicle accident	6	5
Fracture classification [§]		
Type II A	0	0
Type II B	2	3
Type II C	6	5
Average follow-up time (months)	11.3±1.1	12.5±1.4
<i>Data expressed as mean standard deviation unless otherwise indicated.</i>		
* $P > 0.05$, <i>t</i> test.		
[‡] $P > 0.05$, <i>Chi-square</i> test.		
[§] $P > 0.05$, <i>Mann-Whitney U</i> test.		

Table 1 Patients’ general information

Table 2 ADL index for neck mobility in daily living

Movement	ADL
Extension	Gargling
Flexion	Watching one’s step when climbing down the stairs or tie one's shoes
Rotation	Looking right and left when driving car or crossing the street

ADL: activities of daily living

Table 3 The severity of the limitation of ADL

No	Severity
1	Easy (no limitation)
2	Mild difficulty (mild limitation)
3	Difficult (limitation)
4	Impossible (severe limitation)

ADL: activities of daily living

Table 4 Postoperative F-E ROM and Rotation ROM

Parameter	Group A	Group B
F-E ROM*	56.8±3.5	52.0±4.6
Rotation ROM[‡]	48.4±4.1	47.5±3.8

Data expressed as mean standard deviation unless otherwise indicated.

** $P < 0.05$, t test.*

[‡] $P > 0.05$, t test.

ROM, range of motion

Table 5 The frequency and severity of limitations of postoperative ADL

ADL, activities of daily living;

R, rotation; E, extension; F, flexion.

Parameter	Group A	Group B
ADL(R)*	2.8±0.5	2.9±0.4
ADL(E)[‡]	1.9±0.6	2.3±0.5
ADL(F)[§]	2.0±0.5	2.6±0.5

Data expressed as mean standard deviation unless otherwise indicated.

** $P > 0.05$, Mann-Whitney U test.*

[‡] $P > 0.05$, Mann-Whitney U test.

[§] $P < 0.05$, Mann-Whitney U test.

Figures

Figure 1

Measurements of O–C7 angle at flexion (a) or extension (b). The lines for measurements were obtained using McGregor line and posterior tangents of the C7 vertebral body on lateral extension or flexion radiographs. The F-E ROM was calculated as $(\beta^\circ - \alpha^\circ)$.

Figure 2

Measurements of rotation ROM. The lines for measurements were obtained using the glasses and the pattern of clothes. (a) Left rotation angle (α°); (b) Right rotation angle (β°). The total of the left and right rotation angles were calculated as rotation ROM ($\alpha^\circ + \beta^\circ$)

Figure 3

Outline of the cervical extensor. (a) Posterior extensor muscles visualized on axial CT images at the C5–C6 level. a multifidus, b semispinalis cervicis, c semispinalis capitis, d splenius capitis. (b) Outline of the semispinalis cervicis and multifidus at the C3-C4 level.

Figure 4

A type II C odontoid fracture managed with temporary posterior fixation. (a) preoperative CT scan; (b) postoperative sagittal view of CT scan; (c) axial view of CT at the C1 level; (d) axial view of CT at the C2 level; e preserved SSC attached to the C2 spinous process; (f) postoperative CT scan and reconstruction; (g) postoperative MRI; (h) postoperative coronal view of CT showing the intact signal of SSC.

Figure 5

axial view of CT at the C2 level; (e) preserved SSC in the operation; (f) preoperative SSC attached to the C2 showing in the CT scan; (g) postoperative atrophic SSC showing in the CT scan; (h) postoperative coronal view of CT showing the intact signal of SSC.

Figure 6

Box plot comparing atrophy rate of cervical posterior muscles between P-SSC and D-SSC at the C3 (*: Spearman's rank correlation test, $p < 0.05$) and C5 level (*: Spearman's rank correlation test, $p > 0.05$).