Acta Orthop. Belg., 2022, **88**, 667-674

ORIGINAL STUDY

doi.org/ 10.52628/88.4.10591

Prevertebral soft tissue swelling after anterior cervical internal fixation at different segments: a retrospective study

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Atlantoaxial segments have not been discussed in existing studies on prevertebral soft tissue (PVST) swelling after cervical operations. This study aimed to investigate the characteristics of PVST swelling after anterior cervical internal fixation at different segments. This retrospective study included patients who underwent transoral atlantoaxial reduction plate (TARP) internal fixation (Group I, n=73), C3/C4 anterior decompression and vertebral fixation (Group II, n=77), or C5/C6 anterior decompression and vertebral fixation (Group III, n=75) at our Hospital. The PVST thickness at C2, C3, and C4 segments was measured before and 3 days after the operation. Time of extubation, number of patients with postoperative re-intubation and dysphagia were collected. Results show that all patients had significant postoperative PVST thickening (all P<0.01). PVST thickening at C2, C3, and C4 was significantly greater in Group I than in Groups II and III (all P<0.01). PVST thickening at C2, C3, and C4 in Group I was 1.87 (14.12mm/7.54mm), 1.82 (12.90mm/7.07mm) and 1.71 (12.09mm/7.07mm) times of that in Group II, respectively. PVST thickening at C2, C3, and C4 in Group I was 2.66 (14.12mm/5.31mm), 1.50 (12.90mm/8.62mm) and 1.32 (12.09mm/9.18mm) times of that in Group III, respectively. The patients in Group I had significantly later postoperative extubation (Both P<0.01) than the patients in Groups II and III. None of the patients had postoperative re-intubation or dysphagia. We conclude that PVST swelling was greater in patients who underwent TARP internal fixation than in patients who underwent anterior C3/C4 or C5/C6 internal fixation. Hence, after TARP internal fixation, patients should be given proper respiratory tract management and monitoring.

Keywords: internal fixation; cervical vertebrae; prevertebral soft tissue; swelling; extubation.

INTRODUCTION

Anterior cervical internal fixation can be performed for various conditions like cervical spinal stenosis, cervical disk herniation, and radiculopathy *(1,2)*. Prevertebral soft tissue (PVST) swelling after anterior cervical internal fixation is related to dysphagia and dyspnea *(3-6)*. PVST swelling

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Conflict of interest and source of funding: No benefits or funds were received in support of this study. None of the authors have a conflict of interest.

can lead to airway obstruction *(6-11)*, which can be fatal, although such an occurrence is rare *(8,10)*. Nevertheless, it complicates recovery and healing *(6-10)*. PVST can also be used to indicate occult injury on cervical X-rays after trauma *(12)*.

Transoral atlantoaxial reduction plate (TARP) internal fixation is a special anterior cervical operation that requires only the mouth as the entry point to perform immediate atlantoaxial joint reduction, bone graft fusion, and internal fixation *(13,14)*. It enjoys unique advantages in treating refractory and relapsed atlantoaxial dislocation *(13,14)*. TARP internal fixation is performed through a straight incision in the posterior pharyngeal wall, with a small and deep operative field, difficulties in operation, and prolonged operation.

TARP internal fixation also causes postoperative PVST swelling, as after other anterior cervical operations. Hence, TARP internal fixation can lead to dysphagia, hematoma, airway obstruction, and reintubation *(11)*. Airway obstruction can be fatal, but no data currently allow its prediction. Identifying the patients at higher risk of airway obstruction after TARP internal fixation could allow better management. In addition, because of the anatomy of the different neck levels, different complications can arise when operating at different cervical levels *(15,16)*.

Atlantoaxial segments have not been discussed in existing studies on PVST swelling after cervical operations, so the changes in PVST in patients with atlantoaxial segment diseases need to be investigated. Hence, this study aimed to analyze the characteristics of PVST swelling by measuring PVST thickness in patients before and after TARP internal fixation to provide references for clinical practice. The results could provide some basis for identifying patients at higher risk of complication.

MATERIALS AND METHODS

This study was a retrospective analysis of adult patients who underwent anterior cervical operations at General Hospital of Southern Theatre Command from January 2015 to June 2021. The study (Ethical Committee no 91 of 2020) was approved by our Hospital on 1 November 2020. The requirement for informed consent was waived by the committee.

The inclusion criteria were 1) atlantoaxial diseases managed with TARP internal fixation, protrusion of C3/C4 intervertebral disc and cervical instability managed with C3/C4 anterior decompression and vertebral fixation, or protrusion of C5/C6 intervertebral disc and cervical instability managed with C5/C6 anterior decompression and vertebral fixation, and 2) underwent cervical lateral radiograph examination before and 3 days after the operation. The exclusion criteria were 1) acute cervical trauma, 2) severe cervical spondylolisthesis or C4 segment affected by the esophageal opening and larynx that interferes with PVST measurement, 3) the tracheal tube was not removed on day 3 after the operation, 4) significant hyperosteogeny or osteophyte formation on the anterior cervical border that affects the measurement, or 5) underwent an anterior or posterior cervical operation at the same time.

The patients who were managed with TARP internal fixation at an appropriate time were included in Group I. The patients with protrusion of the C3/C4 intervertebral disc and cervical instability who had undergone C3/C4 anterior decompression and vertebral fixation were included in Group II. The patients with protrusion of the C5/C6 intervertebral disc and cervical instability who had undergone C5/C6 anterior decompression and vertebral fixation were included in Group III.

All operations were performed by four chief surgeons with working experience of 22 to 33 years. The differences in the numbers of patients operated by the different surgeons among the three groups were not statistically significant.

After successful anesthesia induction, an enhanced tracheal tube was inserted by the nose in the patients in Group I. In contrast, the same tube was inserted by the mouth in the patients in Groups II and III. Anesthetic drugs were discontinued after the operation. After restoring consciousness preliminarily and having neurological functions evaluated as normal, a magnesium sulfate gauze and an iodoform gauze were placed in the mouth of the patients in Group I, and the tracheal tube was retained in the nose. The patients in Groups II

and III were required to undergo the cuff leak test (CLT). In the event of a negative CLT result, the tracheal tube was immediately removed, and in the event of a positive CLT result, the tube was retained. All patients in the three groups were sent back to the Orthopedic Intensive Care Unit.

After the operation, the patients in Group I were given 3 days of intravenous mannitol of 0.5 g/kg once every 8 h and intravenous methylprednisolone 40 mg once every 12 h. The patients in Groups II and III were given the same for 1 day. All patients in the three groups were given the same position management and the use of atomization drugs (2 ml (500 μg) of ipratropium bromide injection, 2 ml (5 mg) of terbutaline sulfate solution for atomization and 4 ml of normal saline for aerosol inhalation once every 8 h and one dose of ambroxol hydrochloride injection (15 mg/ampoule) once every 8 h. Every day, the patients were given CLT to evaluate the patency of the respiratory tract. In the event of a negative CLT result, the tracheal tube was immediately removed. In the event of a positive CLT result, the tube was retained until the next evaluation on the following day.

PVST thickness at the C2, C3, and C4 segments in each patient before and on day 3 after the operation was measured in cervical lateral radiographs with the hospital imaging system. For the C2 and C3 segments, the distance between the lower end of the anterior cervical edge and the posterior edge of the tracheal shadow was measured. For the C4 segment, the distance between the upper end of the anterior cervical edge and the posterior edge of the respiratory tract shadow was measured. If the measuring point was covered by the titanium plate in front of the cervical body during such measurement after the operation, the anterior border of the corresponding titanium plate was used as the start point of the measurement *(17)* (Figure 1). Each radiograph was measured by two orthopedists independently, and the mean value of their measures was used as the final measure.

The demographic characteristics of the patients (including sex, age, height, and weight), clinical characteristics (including the cause of disease, American Spinal Cord Injury Association (ASIA) grading, preoperative white blood cell (WBC) count, and albumin (ALB) levels), and operative characteristics (including operation duration, the amount of intraoperative blood loss and fluid infusion, time of extubation, number of patients with postoperative re-intubation and dysphagia and postoperative WBC and ALB levels) were collected from the medical information database of the hospital.

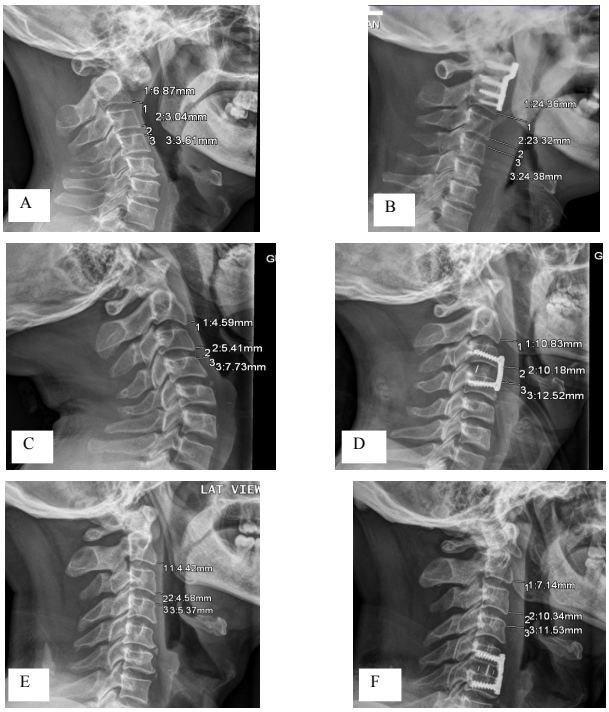

Figure 1. — Prevertebral soft tissue (PVST) thickness measurement. (A) Preoperative, Group I. (B) Postoperative, Group I. (C) Preoperative, Group II. (D) Postoperative, Group II. (E) Preoperative, Group III. (F) Postoperative, Group III.

SPSS 19.0 (IBM, Armonk, NY, USA) was used for statistical processing. All continuous data are expressed as mean ± standard deviations. The paired t-test was used to compare the measurement data of the same group before and after the operation. ANOVA was used to compare the continuous data among different groups. The categorical data are presented as n (%) and were analyzed using the chi-square test. P-values <0.05 were considered statistically significant.

RESULTS

A total of 73 patients were included in Group I, 77 in Group II, and 75 in Group III. In Group I, most patients were females, short stature and were caused by disease (P<0.01). All patients in the three groups were ASIA grade D or E, with more of grade D in Groups I and II than in Group III (P<0.01) (Table I).

The patients in Group I had significantly longer operations than those in Groups II and III(P<0.01). There were no significant differences in operations duration between Groups II and III. The amount of intraoperative blood loss and fluid infusion in patients in Group I were significantly greater than that in Groups II and III (all P<0.01). The amount of intraoperative fluid infusion in patients in Group II were greater than that in Group III (P<0.05) (Table I).

The patients in Group I had significantly later postoperative extubation (Both P<0.01) and significantly higher postoperative WBC counts (Both P<0.01) than the patients in Groups II and III. The patients in Group II had significantly higher postoperative WBC count than patients in Group III (P<0.01). None of the patients had postoperative re-intubation or dysphagia (Table I).

All patients in the three groups had significant postoperative PVST thickening (all P<0.01). In Group I, postoperative PVST thickening at C2, C3, and C4 segments declined gradually, and that at the C2 segment was significantly greater than that at the C3 and C4 segment, and postoperative PVST thickening at C3 was significantly greater than that at the C4 segment (all P<0.01). In Group II, there were no significant differences in postoperative PVST thickening among C2, C3, and C4. In Group III, postoperative PVST thickening at the C2 segment was significantly milder than that at C3 and C4 (P<0.01). Among the three groups, PVST thickening at C2, C3, and C4 was significantly greater in Group

Table I. — Comparison of the demographic, clinical, and operative characteristics and postoperative indicators.

Item	Group I (n=73)	Group II (n=77)	Group III (n=75)	P
Sex (n)				<0.001
Male/female	19/54	66/11	68/7	
Age (years)	46.4±10.0	49.6±10.5	48.2±10.8	0.175
Height (cm)	159.7±3.2**##	167.7±3.2	166.7±3.1	<0.001
Weight (kg)	60.5±7.3	61.2±7.2	62.7±6.8	0.146
Cause of disease (n)				<0.001
Disease/trauma	71/2	50/27	59/16	
ASIA grading (n)				<0.001
Grade D/E	56/17	48/29	26/49	
Preoperative WBC count (10^9/L)	6.75±0.96	7.07±1.01	6.99±0.99	0.116
Preoperative albumin (g/L)	40.59±1.42	41.07±1.57	40.85±1.51	0.147
Operation duration (min)	179.2±43.2**##	112.9±34.8	105.7±21.0	<0.001
Intraoperative blood loss (ml)	153±38**##	109±35	100±33	<0.001
Intraoperative fluid infusion (ml)	2008±335**##	1784±313#	1669±364	<0.001
Time of extubation (n)				<0.001
On the very day of operation	0	72	74	
Day 1 after operation	47	5	1	
Day 2 after operation	26	0	0	
Postoperative WBC count (10^9/L)	10.69±1.42**##	8.77±1.30##	8.13±1.42	<0.001
Postoperative albumin (g/L)	33.37±3.07	33.50±3.83	34.22±3.27	0.266

* P<0.05, ** P<0.01 vs. Group II.# P<0.05, ## P<0.01 vs. Group III. ASIA: American Spinal Cord Injury Association; WBC: white blood cells.

Table II. — Intra- and between-group comparison of the PVST thickness (mm).

Group	C2	C3	C4	P (among levels)
Group I (n=73)				
Preoperative	4.33±1.15 ^^	4.10±1.07^^	4.20±1.17 ^^	
After operation	18.45±2.90	17.00±2.51	16.30±2.67	
P (before/after operation)	<0.001	<0.001	<0.001	
Δ	14.12±1.75**##bbcc	12.90±1.44 ##bbcc	12.09±1.50 bbcc	<0.001
Group II (n=77)				
Preoperative	4.19±1.24 ^^	4.34±1.11 ^^	4.46±1.32 ^^	
After operation	11.73±2.71	11.41±2.75	11.52±2.66	
P (before/after operation)	<0.001	<0.001	<0.001	
Δ	7.54±1.47 cc	7.07±1.64 cc	7.07±1.62 cc	0.107
Group III (n=75)				
Preoperative	4.05±1.08 ^^	4.14±1.08^^	4.30±1.15 ^^	
After operation	9.36±2.89	12.76±3.20	13.47±3.29	
P (before/after operation)	<0.001	<0.001	<0.001	
Δ	5.31±1.96**##	8.62±2.42	9.18±2.28	<0.001
P (Δ among groups)	<0.001	<0.001	<0.001	

**P<0.01 vs. C3, ## P<0.01 vs. C4, ^^ P<0.01 vs. after operation, bb P<0.01 vs. Group II , cc P<0.01 vs. Group III.

I than in Groups II and III (all P<0.01). PVST thickening at C2, C3, and C4 in Group I was 1.87 (14.12mm/7.54mm), 1.82 (12.90mm/7.07mm) and 1.71 (12.09mm/7.07mm) times of that in Group II, respectively. PVST thickening at C2, C3, and C4 in Group I was 2.66 (14.12mm/5.31mm), 1.50 (12.90mm/8.62mm) and 1.32 (12.09mm/9.18mm) times of that in Group III, respectively. The patients in Group II had significantly greater PVST thickening at C2 (P<0.01), but PVST thickening at C3 and C4 was significantly milder (P<0.01) than in Group III (Table II).

DISCUSSION

PVST swelling after anterior cervical internal fixation often causes postoperative dyspnea and dysphagia *(6-11)*. This study aimed to investigate the characteristics of PVST swelling after TARP internal fixation. The results suggested that the patients had PVST swelling at C2, C3, and C4 after TARP internal fixation. PVST swelling was greater than in patients who underwent anterior C3/C4 or C5/C6 internal fixation. Hence, after TARP internal fixation, patients should be given proper respiratory tract management and monitoring.

Cervical tissues are dissected and drawn during anterior cervical fixation, which may cause local hyperemia or edema of tissues that manifests as PVST swelling in lateral radiographs. Postoperative PVST swelling may further compress the anterior pharynx, esophagus, or trachea, resulting in complications including dysphagia and respiratory tract obstruction *(18-25)*. PVST swelling peaks at about day 3 after the operation and gradually alleviates as time went on. Most patients recover within 6 weeks after operation *(6)*.

TARP internal fixation is a particular cervical operation in which the PVST is directly cut open through the mouth before atlantoaxial reduction, bone graft fusion, and internal fixation. It affects the PVST greatly and results in postoperative PVST swelling *(13,14,26-28)*. Nevertheless, atlantoaxial segments have not been discussed in existing studies on PVST swelling after cervical operations, so the changes in PVST in patients with atlantoaxial segment diseases need to be investigated.

Differences in sex, height, cause of disease, and ASIA grading among the three groups were significantly different, suggesting that females were more prone to congenital atlantoaxial diseases and males were more prone to C3/C4 and C5/C6 impairments. This could also be because cervical alignment is different between males and females *(29)*. The difference in sex among patients in the three groups might be a possible cause for the height difference *(30)*. Most patients in Groups I and II had neural impairment before the operation, possibly because the impairment in a more superior segment deteriorated as it was more challenging to diagnose and treat, and its treatment was more likely to be delayed.

The normal upper limit of PVST thickness at C2 and C3 was 6 and 7 mm, respectively, as reported by Rojas et al. *(31)*, and cervical PVST thickness was also measured and reported by Dai et al. *(32)* in Chinese. The preoperative PVST thickness was 4.05 to 4.46 mm in all patients, in line with the literature. All patients in the three groups had significant postoperative PVST swelling. The degree of PVST swelling in patients in Group I was the most significant at the C2 segment, followed by C3 and then C4, and PVST thickness at C2, C3, and C4 segments increased by 14.12, 12.90, and 12.09 mm, respectively, compared with baseline. The operation in Group I (i.e., after TARP internal fixation) was mainly performed at C2, probably explaining the higher swelling at C2 than at C3 and C4. The patients in Group I had significantly severer postoperative PVST swelling than the patients in Groups II and III at all three segments. In particular, at C2, where PVST swelling was the most significant, the patients in Group I had PVST swelling 2.66(14.12/5.31) times that of patients in Group III. At C4, where PVST swelling was the least significant, Group I had PVST swelling 1.32 (12.09/9.18) times that of patients in Group III. Such results suggest that patients undergoing TARP internal fixation have far severer postoperative cervical PVST swelling than patients undergoing anterior C3/C4 or C5/C6 internal fixation. Several reasons can be responsible. First, the patients in Group I had PVST directly cut open through the mouth, and the tracheal tube inserted via the nose also affected the posterior pharyngeal wall. Second, the patients in Group I had longer operation duration and a greater amount of intraoperative blood loss and fluid infusion than patients in Groups II and III, as well as severer operative injuries. Third, the patients in Group I had a refractory atlantoaxial dislocation and had the greatest changes in anatomical results of the entire vertebral body after reduction *(33-35)*. Besides, there were more female patients of shorter stature in Group I, so the exposure of the operative field and the performance of the operation were more difficult in them than in patients in the other groups. Fourth, the patients in Group I had type II incision that might cause more significantly elevated postoperative WBC count and severer inflammatory reactions than in Groups II and III. A previous study showed that the patients who developed PVST swelling-related complications had more elevated WBC and C-reactive proteins than those who did not have complications *(36)*, supporting the present study. It was once reported that if a patient had three or more vertebral segments exposed, C2, C3, and C4 segments involved, blood loss of over 300 ml, operation duration exceeding 5 h, or preoperative spinal dysfunction, he/she might be more likely to have postoperative PVST swelling and respiratory tract-related complications *(6)*. In this study, the patients had the same numbers of vertebral segments exposed. Still, the patients in Group I had greater intraoperative blood loss, longer operation duration, and severer preoperative spinal dysfunction than in Groups II and III, possibly resulting in more significant postoperative PVST swelling. The degree of PVST swelling at C2, C3, and C4 was 6.2, 9.2, and 8.6 mm, respectively, at 3 days after the anterior cervical operation, according to Suk et al. *(6)*, and that at the C3 segment was 6.02 mm after the anterior cervical operation, according to Kim et al. *(37)*. These two studies both included patients of a high risk of postoperative PVST swelling since they had two segments involved in the operation. Still, they all had milder postoperative PVST swelling than the patients who underwent TARP internal fixation in this study, suggesting that TARP internal fixation affects more significantly the PVSTs, while the swelling at the other levels was milder and more comparable to the literature.

The patients in Group II had the most significant postoperative PVST swelling at the C2 segment, although the operations were performed directly on the C3 or C4 segment. This could be because the C3 and C4 segments were covered by the titanium plate that compressed local tissues, and PVST thickness was measured from the front border of the titanium plate. In patients in Group III, PVST thickening at C2, C3, and C4 segments went gradually greater, possibly because of different distances from the operative field to the three segments. Group III had milder PVST thickening at C2, but PVST thickening at C3 and C4 was greater than in Group II, possibly because of different distances from the operative field to the three segments and the impact of the titanium plate and different measurements methods in patients in Group II.

After the operation, the patients in Group I were given oral gauzes to stop bleeding and alleviate swelling on the very day of the operation. All patients in the three groups were given routine hormones and dehydration drugs and CLT for extubation evaluation. All patients had the tracheal tube removed before day 3 after the operation. None of the patients had respiratory tract obstruction or stridor or required re-intubation even if they had significant PVST swelling in lateral cervical radiographs on day 3 after the operation. In addition, none of the patients had dysphagia during hospitalization. The reasons might be that all patients in the three groups underwent strict CLT before extubation and were subject to strict extubation indications. The patients having a positive CLT result had the tube retained until the next evaluation on the following day. The patients in Group I who had significant PVST swelling underwent TARP internal fixation, had their incisions located on the posterior pharyngeal wall, received only nasal feeding for 1 week after the operation. The patients in Group I had the tube removed significantly later than the patients in Groups II and III, possibly because the patients in Group I had substantially severer postoperative PVST swelling.

This study has limitations. It was a retrospective study, with all the inherent biases and limited to the data available in the patient charts. An eligibility criterion was that an X-ray was performed on day 3 after surgery, which led to many patients being excluded, which might cause a selection bias. Moreover, some patients who had undergone TARP internal fixation did not have the PVST thickness at C1, C5, and C6 segments measured as they had an atlantooccipital fusion, congenital malformation, or unclear display of the anterior atlantal tubercle and the esophageal opening and larynx were likely to affect the measurement of PVST thickness at C5 and C6 segments.

The patients had significant PVST swelling at C2, C3, and C4 segments on day 3 after TARP internal fixation. This PVST swelling was significantly greater than in patients who underwent anterior C3/C4 or C5/C6 internal fixation. Hence, patients who undergo TARP internal fixation should be given strict respiratory tract management and monitoring. The indications for extubation should be strictly followed to prevent PVST swelling-induced complications such as respiratory tract obstruction and dysphagia.

CONCLUSION

PVST swelling was greater in patients who underwent TARP internal fixation than in patients who underwent anterior C3/C4 or C5/C6 internal fixation. Hence, after TARP internal fixation, patients should be given proper respiratory tract management and monitoring.

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