Alterations in axial curvature of the cervical spine with a combination of rotation and extension in the conventional anterior cervical approach

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Abstract

Purpose Alterations of three-dimensional cervical curvature in conventional anterior cervical approach position are not well understood. The purpose of this study was to evaluate alignment changes of the cervical spine in the position. In addition, simulated corpectomy was evaluated with regard to sufficiency of decompression and perforation of the vertebral artery canal.

Methods Fifty patients with cervical spinal disorders participated. Cervical CT scanning was performed in the neutral and supine position (N-position) and in extension and right rotation simulating the conventional anterior approach position (ER-position). Rotation at each vertebral level was measured. With simulation of anterior corpectomy in a vertical direction with a width of 17 mm, decompression width at the posterior wall of the vertebrae and the distance from each foramen of the vertebral artery (VA) were measured.

Results In the ER-position, the cervical spine was rotated rightward by $37.2^\circ \pm 6.2^\circ$ between the occipital bone and C7. While the cervical spine was mainly rotated at C1/2, the subaxial vertebrae were also rotated by several degrees. Due to the subaxial rotation, the simulated corpectomy

resulted in smaller decompression width on the left side and came closer to the VA canal on the right side.

Conclusions In the ER-position, the degrees of right rotation of subaxial vertebrae were small but significant. Therefore, preoperative understanding of this alteration of cervical alignment is essential for performing safe and sufficient anterior corpectomy of the cervical spine.

Keywords Anterior approach · Cervical spine · Subaxial vertebrae · Vertebral artery · Corpectomy

Introduction

In the surgical treatment of cervical spinal disorders, the anterior approach is mainly indicated for myelopathy or radiculopathy by anterior protruding intervertebral discs or ossification of the posterior longitudinal ligament (OPLL). The anterior approach has several advantages. First, the spinal cord or nerve roots can be decompressed directly without damaging posterior elements. Decompression for extensive continuous ossification of the posterior longitudinal ligament is possible by anterior corpectomy [1–3]. Second, it results in only minor damage to the muscles. Third, with regard to position, anesthetic management is easier. However, there are also several complications associated with the approach, including dysphagia, instrumentation backout, esophageal injury, cerebrospinal fluid leakage, wound infection, radiculopathy, C5 nerve palsy, and vertebral artery (VA) injury [2, 4–12].

Patients are prepared for the approach by (1) slight extension or (2) slight extension and right rotation of the cervical spine [13]. We prefer the latter position, as slight right rotation of the cervical spine can keep the jaw away from the approach site, which occasionally acts as an

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obstacle for approaching the upper cervical spine. However, due to the possibility of vertebrae rotation in subaxial vertebrae, care is required with regard to orientation. While cervical spinal movement has been widely studied [2, 4, 6–11], the three-dimensional motion in coupling of extension and right rotation, which is relevant in the anterior approach position, is not well understood. There will be differences between the two cervical positions, i.e., the neutral supine position (N-position) and the conventional anterior approach position with extension and rotation (ER-position), which may lead to misdirection of drilling of the cervical vertebrae. Some of the above complications have been reported to be potentially caused by asymmetric or insufficient corpectomy [12].

Based on the above, we planned to analyze alignment changes in the cervical spine in the ER-position using computed tomography (CT). In addition, simulated corpectomy was evaluated with regard to sufficiency of decompression and perforation of the VA canal.

Methods

Subjects

We evaluated 50 patients who had been examined by myelography with CT associated with various cervical disorders. The study population consisted of 34 men and 16 women with a mean age of 63.0 ± 12.6 years (range: 32–87). Diagnosis was cervical spondylotic myelopathy (CSM) in 34 cases, OPLL in 7 cases, cervical disc herniation in 5 cases, cervical spinal tumor in 3 cases (1 epidural tumor and 2 intradural-extramedullary tumors), and spondylolisthesis in 1 case.

Experimental protocol

In all participants, CT scans of the cervical spine in two cervical alignments, i.e., N-position (Fig. 1, upper row) and ER-position, were performed. In the ER-position, the cervical spine was passively extended using a 3-cm thickness folded operative sheet under the scapulae with passive rotation through 45° . This simulated the situation in which a surgeon stands on the left and approaches the anterior aspect of the cervical spine from the left (Fig. 1, lower row). To consistently achieve 45° rotation in all participants, the subjects wore a cap with marker lines indicating rotation angles. In all patients, firstly, CT scanning at the N-position was performed. Then, CT scanning at the ER-position was performed within 0.5 h after conventional myelography with Omnipaque contrast medium (Daiichi Sankyo, Tokyo, Japan) using a SOMATOM Sensation16 CT Scanner (Siemens, Berlin, Germany) with a slice

Fig. 1 Experimental setups for subjects for axial CT scans of the cervical spine in the N-position and ER-position used for the anterior approach to the cervical spine

thickness of 0.6 mm, 400 WL, 2,000 WW, and 120 kV. The order of CT scanning of the two alignments was randomly determined.

Evaluation items

Relative cervical motion in each position was measured by sagittal, coronal, and axial plane CT to determine the translational motion and angular variation of cervical vertebrae. Cervical rotation, extension, and bending in each vertebra, including the occipital bone (O), and at each intervertebral disc level including the occipitocervical junction and C1–2 joint under the N-position and ER-position were measured. To assess the effects of the ER-position on decompression, simulated corpectomy which was done vertically from the center of anterior wall of the vertebra with a width of 17 mm was drawn on the CT images, because we usually use about 17 mm width, and the width of corpectomy at the vertebral canal was measured. In addition, the distance from the VA canal and the margin of the simulated corpectomy was measured at the level of the foramen of the VA. To evaluate the effects of change to the ER-position, the following parameters were compared with those of the N-position using Wilcoxon's signed-rank test. The degrees of variance of the parameters in both positions were assessed by intraclass correlation (ICC). Measurements in the CT images were obtained using image analysis software (ShadeQuest/ViewRPortable Version 1.01.03; Yokokawa Electric Corporation Ltd., Tokyo, Japan) at a resolution of 512×512 pixels. All measurements were performed by a single examiner (an orthopedic surgeon with 9 years of experience).

Vertebral right rotation angle (VRA) and segmental right rotation angle (SRA)

VRA was measured on a horizontal line guided by the VA canal of each vertebra. SRA was defined as the angle between adjacent vertebrae, e.g., the VRA of O against VRA of C1.

Width of corpectomy at the vertebral canal

The distances from the center of the posterior vertebral cortex to the lateral osteotomy edge were measured in the assumed corpectomy (Fig. 2). The ratio of drilled posterior vertebral cortex compared to the total posterior vertebral cortex was measured separately at the right side and the left side, and this was defined as the corpectomy ratio (Fig. 3, left side).

Fig. 2 Example of axial CT sections of the two positions

Fig. 3 Corpectomy ratio and distance from the vertebral artery. Corpectomy ratio (CR) was defined as the percentage of decompression width by simulated corpectomy per the width of the bony canal. The bony canal was divided into the right and left sides, and then the CRs of the right and left were calculated separately ($CR = RC/R'C'$). The left ratio of corpectomy is $LC/L'C'$

Distance between lateral bound of osteotomy and foramen of vertebral artery (DOAF)

The distances from the foramen of the VA to the lateral osteotomy edge were measured on axial CT scans. The osteotomy was assumed as above (Fig. 3, right side).

ICC

All parameters were compared by two examiners.

Ethical approval

The design of this study was approved by the institutional ethical committee for medical research. All of the participants understood and agreed to the design of this study. Signed informed consent forms were obtained from all participants prior to enrollment in the study.

Statistical analysis

Comparisons of each measurement in the examination were performed using Wilcoxon's signed-rank test, and $P < 0.05$ was taken to indicate significance. For validation of the measurements, the intraclass coefficient (ICC) was calculated. SPSS15.0 (SPSS Inc., Chicago, IL) was used for statistical analyses.

Results

Vertebral rotation angle (VRA) and segmental rotation angle (SRA)

The increases in VRA were $40.5^\circ \pm 7.0^\circ$ (average $\pm$ S.D.) at the occipital bone (O), $40.3^\circ \pm 7.1^\circ$ at C1, $10.6^\circ \pm 5.7^\circ$ at C2, $12.0^\circ \pm 6.0^\circ$ at C3, $8.9^\circ \pm 4.8^\circ$ at C4, $6.7^\circ \pm 4.1^\circ$ at C5, $5.6^\circ \pm 3.7^\circ$ at C6, and $5.3^\circ \pm 3.4^\circ$ at C7 (Fig. 4, left panel). In the ER-position, increases in SRA were $-0.4^\circ \pm 3.9^\circ$ at O/C1, $31.8^\circ \pm 5.9^\circ$ at C1/2, $-1.0^\circ \pm 3.5^\circ$ at C2/3, $2.7^\circ \pm 2.8^\circ$ at C3/4, $2.7^\circ \pm 2.7^\circ$ at C4/5, $1.1^\circ \pm 2.2^\circ$ at C5/6, and $0.2^\circ \pm 1.7^\circ$ at C6/7 (Fig. 4, right panel).

Corpectomy ratio (CR)

In the N-position, CR showed no significant difference between right and left sides in all vertebrae. However, in the ER-position, it was larger on the right side and smaller on the left side in all vertebrae. The CRs at the right in the ER-position were 0.90 ± 0.18 at C3, 0.82 ± 0.16 at C4, 0.70 ± 0.12 at C5, 0.69 ± 0.11 at C6, and 0.72 ± 0.11 at C7, compared to the ratios in the N-position 0.70 ± 0.07 at C3, 0.67 ± 0.06 at C4, 0.63 ± 0.06 at C5, 0.64 ± 0.06 at C6, and 0.68 ± 0.06 at C7. The CRs at the left in the ER-position were 0.51 ± 0.18 at C3, 0.52 ± 0.16 at C4, 0.56 ± 0.12 at C5, 0.59 ± 0.11 at C6, and 0.63 ± 0.11 at C7, compared to the ratios in the N-position 0.71 ± 0.06 at C3, 0.68 ± 0.07 at C4, 0.66 ± 0.8 at C5, 0.66 ± 0.07 at C6, and 0.69 ± 0.09 at C7 (Fig. 5). On the left side, the CR was significantly smaller in the ER-position compared to

the N-position. Importantly, this tendency was stronger at the upper cervical vertebrae.

Distance between lateral margin of corpectomy and foramen of vertebral artery (DOAF)

The DOAF at the right in the ER-position was 3.8 ± 1.8 mm at C3, 4.3 ± 1.8 mm at C4, 5.8 ± 1.3 mm at C5, 6.5 ± 1.4 mm at C6, and 8.0 ± 1.6 mm at C7, compared to the DOAF in the N-position 4.9 ± 1.2 mm at C3, 5.1 ± 1.0 mm at C4, 5.9 ± 1.1 mm at C5, 6.6 ± 1.2 mm at C6, and 8.2 ± 1.6 mm at C7 (Fig. 6, left panel). In the ER-position, DOAF on the left was significantly larger than that on the right side at all vertebral levels (Fig. 6, left panel). The DOAF at the left in the ER-position was 6.2 ± 1.4 mm at C3, 6.3 ± 1.3 mm at C4, 6.6 ± 1.3 mm at C5, 7.1 ± 1.4 mm at C6, and 9.1 ± 1.7 mm at C7, compared to the DOAF in the N-position 5.0 ± 1.1 mm at C3, 5.3 ± 1.1 mm at C4, 6.1 ± 1.2 mm at C5, 6.7 ± 1.2 mm at C6, and 8.6 ± 1.7 mm at C7 (Fig. 6, right panel). The DORF on the right was significantly smaller at C3 and C4 in the ER-position than in the N-position.

Discussion

The present results indicated that not only the upper cervical spine, but also the subaxial vertebrae show rightward rotation in the ER-position. While the major alteration of the cervical spinal curvature in the ER-position showed rightward rotation at C1/2 similar to previous studies

Fig. 4 Vertebral right rotation angle (VRA: left panel) and segmental right rotation angle (SRA: right panel) in the axial plane

Fig. 5 Corpectomy ratios of the right and left sides. In the ER-position, corpectomy ratio on the right side (*left panel*) was significantly larger than that on the left side (*right panel*)

Fig. 6 Distance between lateral margin of corpectomy and foramen of vertebral artery (DOAF) on the right and left sides. On the right, the DOAF was significantly smaller at C3 and C4 in the ER-position than in the N-position (*Left panel*). On the left, the DOAF was significantly larger in the ER-position than in the N-position at all levels (*Right panel*)

[14–16], the axial and subaxial vertebrae also showed rightward rotation. The angles of rotation of each vertebra were approximately 11° at C2, 12° at C3, and 9° at C4. In addition, slight simultaneous rightward bending was also seen.

These observations raise questions regarding what will happen during anterior corpectomy with slight rotation of the axial and subaxial vertebrae. In the ER-position, while surgeons dig the vertebrae using burrs perpendicularly, the bony gutter will consequently be directed rightward. Presumably, this rotation would not be identifiable during operation based on anatomical landmarks due to degenerative changes in the cervical spine, including anterior osteophytes, vertebral slippage, and disc narrowing.

Asymmetry in corpectomy can lead to insufficient decompression. Furthermore, the insufficiency may lead to unsatisfactory improvement of root pain and C5 palsy.

Saunders et al. [17] reported that asymmetric decompression caused root stretching by anterior shifting of the spinal cord after decompression. Kaneyama et al. [18] reported that asymmetric decompression by open-door laminoplasty may introduce imbalanced rotational movement of the spinal cord and result in C5 palsy. In this study, simulated corpectomy using axial scanned images in the ER-position showed that the width of corpectomy was directed to the right. This tendency was significant at all levels. Due to the difference in magnitude of vertebral rotation, the rightward deviation of corpectomy was more remarkable in C3 and C4. To avoid the risk of asymmetrical decompression, knowledge of the positions of the vertebrae is important.

The incidence of iatrogenic VA injury in anterior cervical decompression procedures has been reported to range from 0.18 to 2.78 % [1, 19–22]. James et al. [19] reported that VA injury can occur if decompression is asymmetric

or overly aggressive. In the present study, the distances to VA from the corpectomy wall in ER-position were significantly smaller on the right side at all vertebral levels. In addition, in the ER-position, the distances were significantly smaller at C3 and C4 compared to the N-position. Although VA injury may occur also along the soft tissues lateral to the body, the results indicated potential risk of VA injury in the ER-position, especially on the right.

Given the present overall experimental results, when surgeons install patients in the ER-position, anterior cervical corpectomy should not be directed perpendicular to the dorsal side, but should be directed slightly leftward to gain accurate perpendicular access to the vertebral sagittal axis. Importantly, this tendency is remarkable at C3 and C4, which showed greater rotation angle. However, the rotational change was variably affected by degenerative spinal condition and the wall of vertebrae must be identified to avoid misjudging the positions of vertebrae. To facilitate precise preoperative planning, preoperative CT in the ER-position is useful for avoiding the risk of corpectomy. In addition, intraoperative use of image-guided navigation or intraoperative ultrasonography can be beneficial [1, 5, 23, 24]. Thus, the anterior approach without rotation may be better and safer than that with rotation.

The present study had several limitations. First, the study population was small and only disordered subjects were examined. Studies in larger numbers of subjects including healthy controls are required. Second, alignments and distances were measured in two dimensions. Three-dimensional analyses would enable more accurate measurement [16]. Third, the effect of soft tissue was not considered. Fourth, right rotation angle in the ER-position was consistently regulated at 45° in all patients. In future studies, usage of non-invasive vertebral rotation measurement with a variety of rotation angles would enable providing appropriate rotation angle of each patient for safe surgery. Fifth, while several pathological conditions were included in the subjects, pathology-related difference of the results was not shown, mainly due to inconsistency in patients' number of each pathological condition. In future studies, comparative analyses of the data due to a variety of pathological conditions should be performed.

Conclusions

In the ER-position, the degrees of right rotation of the axial and subaxial vertebrae were slight but significant. Therefore, preoperative understanding of this alteration of cervical alignment is essential to perform accurate anterior corpectomy and minimize complications.

Conflict of interest None.

References

1. Nardone EM, Chen JW, Maggio WW, Nauta HJ (1996) The value of intraoperative ultrasonography in cervical corpectomy: assessment by postoperative computed tomography. *Neurosurgery* 39(5):971–974 (discussion 974–975)
2. Fountas KN, Kapsalaki EZ, Nikolakakos LG, Smisson HF, Johnston KW, Grigorian AA, Lee GP, Robinson JS Jr (2007) Anterior cervical discectomy and fusion associated complications. *Spine (Phila Pa 1976)* 32(21):2310–2317. doi:10.1097/BRS.0b013e318154c57e
3. Sugrue PA, McClendon J Jr, Halpin RJ, Liu JC, Koski TR, Ganju A (2011) Surgical management of cervical ossification of the posterior longitudinal ligament: natural history and the role of surgical decompression and stabilization. *Neurosurg Focus* 30(3):E3
4. Bertalanffy H, Eggert HR (1989) Complications of anterior cervical discectomy without fusion in 450 consecutive patients. *Acta Neurochir (Wien)* 99(1–2):41–50
5. Daentzer D, Deinsberger W, Boker DK (2003) Vertebral artery complications in anterior approaches to the cervical spine: report of two cases and review of literature. *Surg Neurol* 59(4):300–309. (discussion 309) doi:S0090301903001137
6. Fielding JW (1992) Complications of anterior cervical disk removal and fusion. *Clin Orthop Relat Res* 284:10–13
7. Flynn TB (1982) Neurologic complications of anterior cervical interbody fusion. *Spine (Phila Pa 1976)* 7(6):536–539
8. Graham JJ (1989) Complications of cervical spine surgery. A five-year report on a survey of the membership of the Cervical Spine Research Society by the Morbidity and Mortality Committee. *Spine (Phila Pa 1976)* 14(10):1046–1050
9. Jung A, Schramm J (2010) How to reduce recurrent laryngeal nerve palsy in anterior cervical spine surgery: a prospective observational study. *Neurosurgery* 67(1):10–15. (discussion 15) doi:10.1227/01.NEU.0000370203.26164.24
10. Nasser R, Yadla S, Maltenfort MG, Harrop JS, Anderson DG, Vaccaro AR, Sharan AD, Ratliff JK (2010) Complications in spine surgery. *J Neurosurg Spine* 13(2):144–157. doi:10.3171/2010.3.SPINE09369
11. Tew JM Jr, Mayfield FH (1976) Complications of surgery of the anterior cervical spine. *Clin Neurosurg* 23:424–434
12. Deinsberger R, Regatschnig R, Ungersbock K (2005) Intraoperative evaluation of implants in anterior cervical spine surgery by three-dimensional fluoroscopy. *J Spinal Disord Tech* 18(3):216–218
13. Smith GW, Robinson RA (1958) The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. *J Bone Jt Surg Am* 40-A(3):607–624
14. Iai H, Moriya H, Goto S, Takahashi K, Yamagata M, Tamaki T (1993) Three-dimensional motion analysis of the upper cervical spine during axial rotation. *Spine (Phila Pa 1976)* 18(16):2388–2392
15. Mimura M, Moriya H, Watanabe T, Takahashi K, Yamagata M, Tamaki T (1989) Three-dimensional motion analysis of the cervical spine with special reference to the axial rotation. *Spine (Phila Pa 1976)* 14(11):1135–1139
16. Nagamoto Y, Ishii T, Sakaura H, Iwasaki M, Moritomo H, Kashii M, Hattori T, Yoshikawa H, Sugamoto K (2011) In vivo three-dimensional kinematics of the cervical spine during head rotation in patients with cervical spondylosis. *Spine (Phila Pa 1976)* 36(10):778–783. doi:10.1097/BRS.0b013e3181e218cb

17. Saunders RL, Pikus HJ, Ball P (1998) Four-level cervical corpectomy. *Spine (Phila Pa 1976)* 23(22):2455–2461
18. Kaneyama S, Sumi M, Kanatani T, Kasahara K, Kanemura A, Takabatake M, Nakatani T, Yano T (2010) Prospective study and multivariate analysis of the incidence of C5 palsy after cervical laminoplasty. *Spine (Phila Pa 1976)* 35(26):E1553–E1558. doi: [10.1097/BRS.0b013e3181ce873d](https://doi.org/10.1097/BRS.0b013e3181ce873d)
19. Burke JP, Gerszten PC, Welch WC (2005) Iatrogenic vertebral artery injury during anterior cervical spine surgery. *Spine J* 5(5):508–514. (discussion 514) doi: [S1529-9430\(05\)00003-3](https://doi.org/10.1097/BRS.0b013e3181ce873d)
20. Neo M, Fujibayashi S, Miyata M, Takemoto M, Nakamura T (2008) Vertebral artery injury during cervical spine surgery: a survey of more than 5600 operations. *Spine (Phila Pa 1976)* 33(7):779–785. doi: [10.1097/BRS.0b013e31816957a7](https://doi.org/10.1097/BRS.0b013e31816957a7)
21. Smith MD, Emery SE, Dudley A, Murray KJ, Leventhal M (1993) Vertebral artery injury during anterior decompression of the cervical spine. A retrospective review of ten patients. *J Bone Jt Surg Br* 75(3):410–415
22. Macdonald RL, Fehlings MG, Tator CH, Lozano A, Fleming JR, Gentili F, Bernstein M, Wallace MC, Tasker RR (1997) Multi-level anterior cervical corpectomy and fibular allograft fusion for cervical myelopathy. *J Neurosurg* 86(6):990–997
23. Golfinos JG, Dickman CA, Zabranski JM, Sonntag VK, Spetzler RF (1994) Repair of vertebral artery injury during anterior cervical decompression. *Spine (Phila Pa 1976)* 19(22):2552–2556
24. Lee HY, Lee SH, Son HK, Na JH, Lee JH, Baek OK, Shim CS (2011) Comparison of multilevel oblique corpectomy with and without image guided navigation for multi-segmental cervical spondylotic myelopathy. *Comput Aided Surg* 16(1):32–37. doi: [10.3109/10929088.2010.535317](https://doi.org/10.3109/10929088.2010.535317)