Original Article Clinics in Orthopedic Surgery 2023;15:818-825 • https://doi.org/10.4055/cios22394

Anatomical Consideration for Anterior Approach of Cervicothoracic Junction: A Computed Tomography Image Analysis

Eugene J. Park, MD, Bo-Gil Jeong, MD, Woo-Kie Min, MD

Department of Orthopedic Surgery, Kyungpook National University Hospital, School of Medicine, Kyungpook National University, Daegu, Korea

Background: In the cervicothoracic junction (CTJ), there is limited working space to perform the posterior-only approach. Therefore, a combined anterior approach is required in some cases. However, the great vessels and sternum obstruct the anterior corridor and make the anterior approach difficult. We analyzed relevant anatomical structures encountered during the anterior approach in the CTJ and evaluated the feasibility of previously reported surgical corridors.

Methods: We retrospectively examined 49 patients who underwent neck computed tomography angiography between January 2015 and May 2020. Using the coronal images, we measured the intercarotid artery angle (ICAA), intercarotid artery distance (ICAD), shape of the brachiocephalic trunk (BCT), and position of the BCT base. We then measured the most cranial level requiring manubriotomy for the anterior approach (ML), the most caudal level accessible through the superior corridor (SC), and the most caudal level through the inferior corridor (IC) according to the surgeon's line of sight using the sagittal axis image.

Results: The mean ICAA and ICAD were 50.83° ± 15.23° and 33.38 ± 12.11 mm, respectively. Notably, BCT shape was of the convex type in most cases (42.9%), followed by the straight type (36.7%). In addition, the base of BCT was most commonly located inside the body (49%). Moreover, ICAA and ICAD were significantly greater in men. Although men mostly had the BCT base inside the body (64.3%), female mostly had it on the edge of the body (47.6%). Notably, ML showed the highest frequency (16.3%) in the T1 lower and upper bodies. Furthermore, through SC and IC, it was possible to approach the T4 lower body and T6 midbody, respectively. SC showed the highest frequency (16.3%) in the T3 lower body, and IC showed the highest frequency (20.4%) in the T5 midbody.

Conclusions: ICAA and ICAD were larger and higher in men. BCT was convex and located inside the body in most cases. The accessible level of ML, SC, and IC were T1, T3, and T5, respectively. For the anterior approach in the CTJ, preoperative vascular and accessible level analysis of corridors is essential to decide on the appropriate corridor and reduce complications.

Keywords: *Thoracic spine, Orthopedic procedures, Brachiocephalic trunk, Manubrium*

The cervicothoracic junction (CTJ)—defined as C7–T4—is a technically challenging level for spine surgery.[1-3] One of the challenges associated with CTJs in spine surgery is that the lateral fluoroscopic view of CTJ can be obscured by the upper extremity. In the posterior approach, the surgeon must solely rely on anteroposterior images, and the lateral view may not be helpful in assessing implant position. Furthermore, in the anterior approach, unlike the subaxial cervical spine, bony structures (including the sternum and clavicle) and other structures (such as the

Received December 19, 2022; Revised March 8, 2023;
Accepted April 13, 2023
Correspondence to: Woo-Kie Min, MD
Department of Orthopedic Surgery, Kyungpook National University Hospital, School of Medicine, Kyungpook National University, 130 Dongdeok-ro, Jung-gu, Daegu 41944, Korea
Tel: +82-53-200-5638, Fax: +82-53-422-6605
E-mail: oswkmin@gmail.com

great vessels, thoracic duct, and sympathetic ganglion) obstruct the surgical corridor. Additionally, the tilted access to the kyphotic thoracic spine makes CTJ surgery more difficult.[3,4] The anterior approach around the T4 level is further challenging because of the transverse left brachiocephalic vein (BCV).[1,4] Although some researchers have reported that the left BCV can be safely ligated and resected, such techniques should be reserved for extreme cases considering the complications.[5]

Notably, wide exposure is required for safe and efficient surgery in cases where the anterior approach is required for CTJ. Moreover, wide exposure is particularly important in tumor cases that may require total en bloc spondylectomy (TES) rather than piecemeal removal, and in such cases, even manubriotomy may be unavoidable. Falavigna et al.[2] introduced a simple radiological algorithm to determine whether a manubriotomy is required in the anterior approach for CTJ. The decision to perform a manubriotomy was made based on a surgeon's line of sight (inferior plateau of superior healthy vertebra) using mid-sagittal computed tomography (CT) images. Specifically, the conventional corridor for the anterior approach of CTJ is the space between the right subclavian artery/common carotid artery (CCA) and the left CCA; additionally, the middle corridor and inferior corridor (IC) have been introduced in previous studies.[3,6] Huang et al.[1] radiologically evaluated the accessible levels of these three corridors using CT images via simple transverse lines. However, we suspected that the use of transverse lines, which they used to determine the accessible level, could lead to erroneous results as the curvature of the spine was not considered. Therefore, we analyzed the accessible CTJ levels using different anterior corridors according to the surgeon's line of sight considering vascular anatomy. As the intraoperative manipulation and retraction of the great vessels may lead to hemodynamic changes, we also analyzed the morphology and measurements of relevant vessels encountered during the approach.

METHODS

This study was approved by the Institutional Review Board of Kyungpook National University Hospital (No. 2020-07-014-001). Informed consent was waived due to the retrospective nature of this study. Neck CT angiographies ordered from our department between January 2015 and May 2020 were retrospectively reviewed in the study. Neck CT angiographies were performed before anterior cervical surgery in cases that have the potential of intraoperative uncinectomy or to confirm the suspected aberrant vertebral artery in magnetic resonance imaging (MRI). The inclusion criterion was patients aged >20 years. Exclusion criteria were patients with acute trauma, as they may have distorted vascular anatomy, and patients with images that did not include the aortic arch (AA) and pulmonary artery. Based on the coronal images, we measured the intercarotid artery angle (ICAA), the intercarotid artery distance (ICAD), the shape of the brachiocephalic trunk (BCT), the position of the BCT base, and the type of the AA. In addition, based on the sagittal images, for each case, we measured the most cranial level requiring manubriotomy for the anterior approach (ML), the most caudal level accessible through the superior corridor (SC), and the most caudal level accessible through IC according to the surgeon's line of sight. Moreover, the levels measured in the sagittal view were categorized as follows: vertebral body level divided into three levels (upper, middle, and lower) and the disk space.

ICAA, which is useful when using SC, was measured as the angle between the left CCA and right BCT (the branch point of the right CCA from the right brachiocephalic artery [BCA], the midpoint of the right BCA and CCA, and the point with a height similar to that of the left CCA) (Fig. 1A). In addition, the greater the ICAA, the lower the retraction tension on the vessels during the anterior approach of the CTJ. ICAD was measured between the base of the right BCT and the base of the left CCA (Fig. 1B). Notably, a larger ICAD provides a wider surgical view of the vertebral pathology. Further, the location of the BCT base was classified as follows: in the body (within the pedicles) (Fig. 2A), on the edge of the body (medial

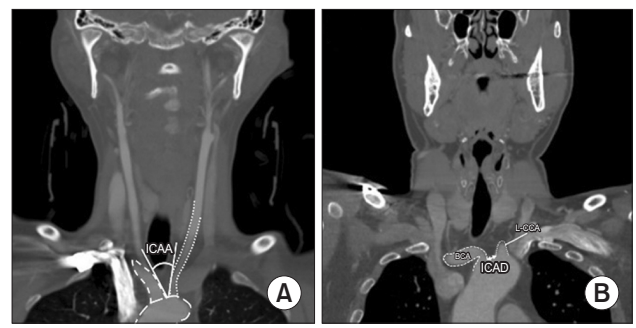

Fig. 1. Coronal computed tomography images of the cervicothoracic spine. (A) A dotted line surrounds the left common carotid artery (L-CCA), a dashed line surrounds the brachiocephalic trunk, and a densely dashed line surrounds the aortic arch. The angle between the two solid lines makes intercarotid artery angle (ICAA). (B) A densely dashed line surrounds the brachiocephalic artery (BCA), and a dotted line surrounds the L-CCA. The distance between the base of each structure indicates intercarotid artery distance (ICAD).

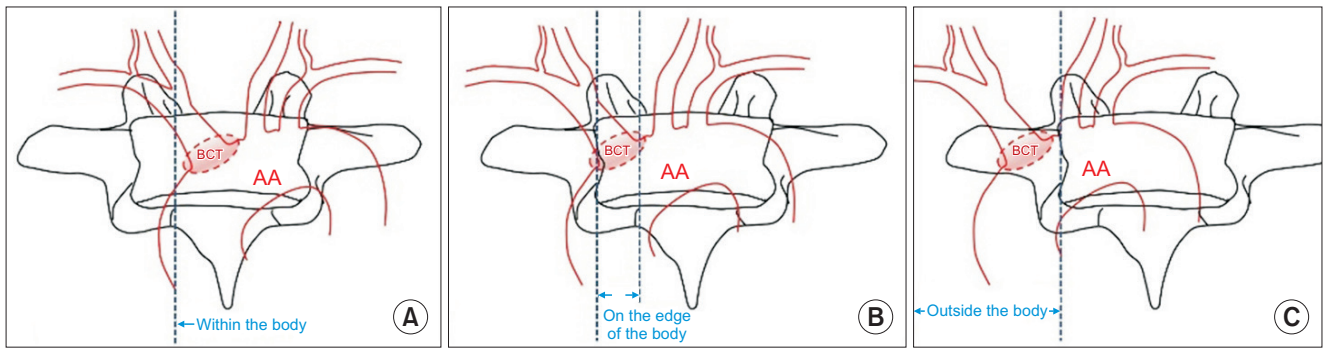

Fig. 2. Location of the brachiocephalic trunk (BCT) base. (A) Within the vertebral body. (B) On the edge of the vertebral body. (C) Outside the vertebral body. AA: aortic arch.

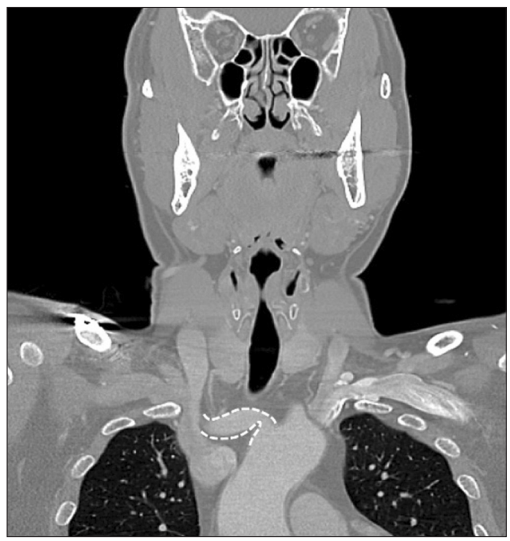

Fig. 3. A representative case of an angled type brachiocephalic trunk.

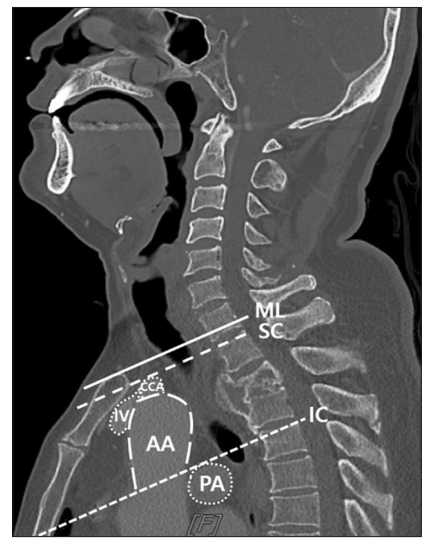

Fig. 4. Mid-sagittal computed tomography image of the cervicothoracic spine. The solid straight line above indicates the most cranial level requiring manubriotomy (ML). The straight dashed line represents the accessible level through the superior corridor (SC). The straight densely dashed line indicates the most accessible level through the inferior corridor (IC). The other dotted and dashed lines encircle the innominate vein (IV), common carotid artery (CCA), aortic arch (AA), and pulmonary artery (PA).

pedicle margin to lateral border of the vertebral body) (Fig. 2B), and outside the vertebral body (Fig. 2C). In addition, the BCT morphology was divided into straight, convex, and angled (> 90°) types (Fig. 3). Moreover, the AA branch type was divided into the following branches: normal, bovine AA, isolated left vertebral artery, and aberrant right subclavian artery.[7]

We measured ML, SC, and IC on mid-sagittal CT images showing the most prominent vertebral spinous process (Fig. 4). Furthermore, SC—evaluated using the suprainnominate window—is at the level of the surgeon's line of sight, touches the superior end of the left BCV, and is the most distal level accessible via minimal great vessel retraction. IC—evaluated using the subinnominate window—refers to the level directly above the pulmonary artery.[6]

RESULTS

Overall, 55 patients underwent neck CT angiography, and finally, 49 patients (28 men and 21 female) who met the inclusion and exclusion criteria were included. The mean age of the patients was 57.78 ± 14.68 years (range, 25–84 years). For the coronal measurements of the entire cohort, the mean ICAA and ICAD were 50.83° ± 15.23° and 33.38 ± 12.11 mm, respectively. Notably, the BCT base was most commonly located inside the body (49%). Moreover, the BCT shape was of the convex type in most cases (42.9%), followed by the straight type (36.7%) (Table 1). For mea-

Table 1. Anatomical Measurements of the Whole Cohort

Parameter	Value
ICAA (°)	50.83 ± 15.23
ICAD (mm)	33.38 ± 12.11
BCT base	
Inside body	24 (49.0)
Body edge	19 (38.8)
Outside body	6 (12.2)
BCT shape	
Straight	18 (36.7)
Convex	21 (42.9)
Angled	10 (20.4)

Values are presented as mean ± standard deviation or number (%).
ICAA: intercarotid artery angle, ICAD: intercarotid artery distance, BCT: brachiocephalic trunk.

Table 2. Anatomical Measurements of the Patients According to Sex

Parameter	Male (n = 28)	Female (n = 21)	*p*-value
ICAA (°)	53.90 ± 13.88	46.73 ± 16.30	0.069*
ICAD (mm)	37.01 ± 12.57	28.55 ± 9.78	0.013*
BCT base			0.019†
Inside body	18 (64.3)	6 (28.6)	
Body edge	9 (32.1)	10 (47.6)	
Outside body	1 (3.6)	5 (23.8)	
BCT shape			0.294†
Angled	13 (46.4)	5 (23.8)	
Convex	10 (35.7)	11 (52.4)	
Straight	5 (17.9)	5 (23.8)	

Values are presented as mean ± standard deviation or number (%).
ICAA: intercarotid artery angle, ICAD: intercarotid artery distance, BCT: brachiocephalic trunk.
*Mann-Whitney test. †Fisher's exact test.

surements in terms of sex, ICAA (53.90° ± 13.88°, p = 0.069) and ICAD (37.01 ± 12.57 mm, p = 0.013) were significantly greater in men than in women. Although most male patients had the BCT base inside the body (64.3%), most female patients had the BCT base at the edge of the body (47.6%) (p = 0.019) (Table 2). For the sagittal measurements, ML was distributed from the T1 upper body to the T3 midbody level. ML showed the highest frequency (16.3%) in the T1 lower and upper bodies. Notably, the most caudal levels of SC and IC were T4 lower body and T6 midbody, respectively. SC showed the highest frequency (16.3%) in the T3 lower body, and IC showed the highest frequency (20.4%) in the T5 midbody (Fig. 5).

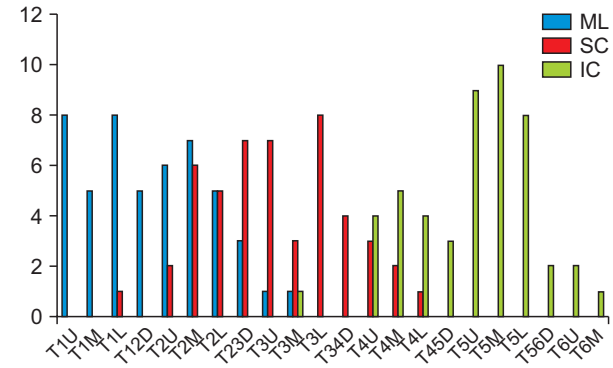

Fig. 5. Bar graph of the results of the most cranial level requiring manubriotomy (ML), the caudal end of the superior corridor (SC), and the caudal end of the inferior corridor (IC) in our case series. U: upper body, M: midbody, L: lower body, D: disk level.

DISCUSSION

Spine surgery involves the use of different corridors, such as the anterior, posterior, and lateral corridors. Unlike posterior vertebral column resection, which could be performed in a piecemeal fashion, TES requires laminectomy and vertebrectomy in an en bloc fashion, which is technically more demanding. Some studies have reported that TES can be achieved using the posterior-only approach; however, when TES needs to be performed on a large tumor mass, a combined anterior and posterior approach is required to achieve an adequate margin. Louie et al.[8] reported two cases of TES successfully performed using a posterior-only approach. Notably, these cases invaded the vertebral body without involving the anterior portion, thereby eliminating the need for an anterior release. They concluded that a posterior-only approach is possible at the level of the superior thoracic or thoracolumbar junction when the pathology is restricted to the vertebral body without invading adjacent organs and blood vessels and when at least one pedicle or lamina is mostly tumor-free. In particular, a surgical procedure using a posterior-only approach at the level of CTJ is associated with a high potential risk owing to the blind manipulation of major vessels located anterior to the body.[9-12]

Cohen et al.[6] first introduced IC (also known as the interaortocaval subinnominate window), a novel corridor

of anterior approach at CTJ, and compared to the use of the conventional corridor, it was possible to expose more distal portions with the use of the conventional corridor. Specifically, in this case report, proximal screw fixation and T2 corpectomy were performed via the conventional corridor, and only distal screw fixation was performed via the subinnominate window. Notably, the boundaries of this window are the superior vena cava (SCV), trachea, and esophagus on the right and AA on the left. We found that fixing the screw using a protective sleeve is possible; however, the sleeve may be narrow for TES.

Xiao et al.[3] introduced the space between the right CCA/BCA and right BCV as well as between the right AA and SVC (C3), which is not the conventional corridor between the right CCA/BCA and left CCA. Based on the results of the analysis of 28 cases requiring an anterior approach of the upper thoracic spine, with the use of corpectomy, surgeons could reach up to the T3, T4, and T5 levels for the superior, middle, and ICs, respectively, with satisfactory results. Huang et al.[1] examined each of these corridors using CT. Moreover, the level of most caudal accessibility seen in the coronal scout image of each key structure observed in the mid-sagittal plane was analyzed, and it was reported that the T6 level could be reached using the IC. However, this method does not take into account the sagittal inclination indicated by each level, and when applied in this way, excessive retraction of the soft tissues (particularly the vessels) is required; however, the over- or underestimation of the actual possible level might occur. Mirjalili et al.[13] analyzed the tracheal bifurcation, which is one of the anatomical obstacles of IC, using CT; however, it has been considered that there will be limitations in the actual use of the corridor when calculating via a simple horizontal line alone that does not account for sagittal curvature. In our study, IC could reach the T6 level but not the T6–7 disk level or even the T6 lower body. Therefore, according to the results of our study, a corpectomy of T6 via the anterior approach would be technically challenging or even impossible. For the actual clinical application, considering the surgeon's line of sight by drawing a parallel line at the index level on the sagittal image is considered to be more clinically relevant as it is possible to secure the working space.

Among our cases, a 56-year-old male patient had a collapsed T2 vertebral body with a mass extending outside the body on MRI. The patient was diagnosed with a giant cell tumor via a CT-guided biopsy. We considered TES for this case because en bloc resection demonstrated a low recurrence rate. Moreover, because the lesion was located close to the vulnerable organs, we decided to first perform the posterior approach and then remove the mass via the anterior approach. After posterior fixation of the two levels above and two levels below with decompression through the posterior approach, the chest surgeon (THO) performed the anterior approach with combined manubriotomy (Fig. 6). However, after we retracted the BCT to expose the tumor, the blood pressure of the patient significantly declined and recovered after removing the retractor. Therefore, we could only release the soft tissues and were unable to remove the lesion from the anterior approach. Moreover, removal was eventually performed using the posterior approach, and a mesh cage was placed anteriorly (Fig. 7). After reviewing the CT angiography images, we found that the patient had an angled-type BCT, short ICAD, and a BCT base located within the body. We hypothesized that the excessive vessel retraction due to the angled shape of the BCT resulted in compression of the baroreceptor of the carotid bulb. Notably, after the carotid sinus and AA send afferent signals to the cardiovascular control center via the glossopharyngeal nerve, this input, in turn, stimulates the parasympathetic tone and inhibits sympathetic tone. This lowers the heart rate and reduces

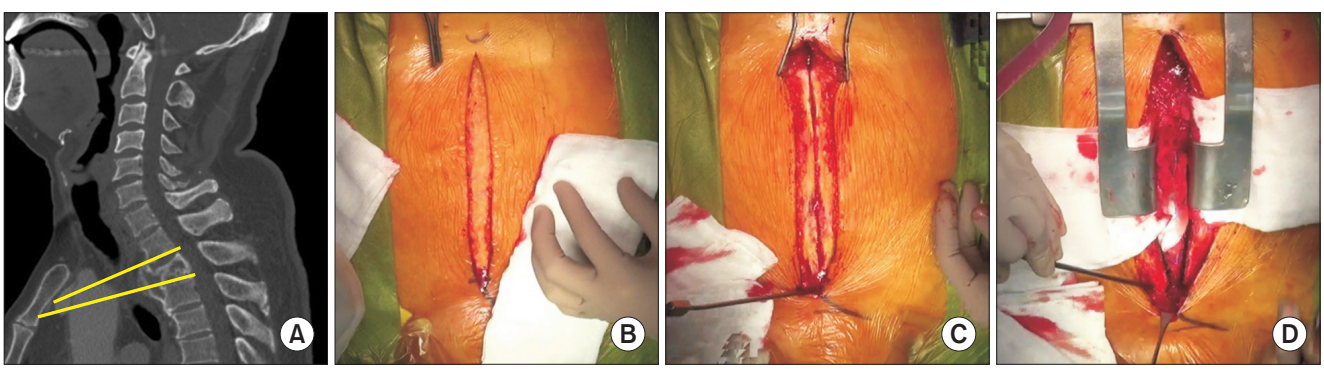

Fig. 6. A case requiring manubriotomy. (A) Manubriotomy was necessary according to the surgeon's line of view. (B) Skin incision above the manubrium. (C) Vertical opening of the manubrium. (D) Working space exposure with a self-retaining retractor placed on the manubrium.

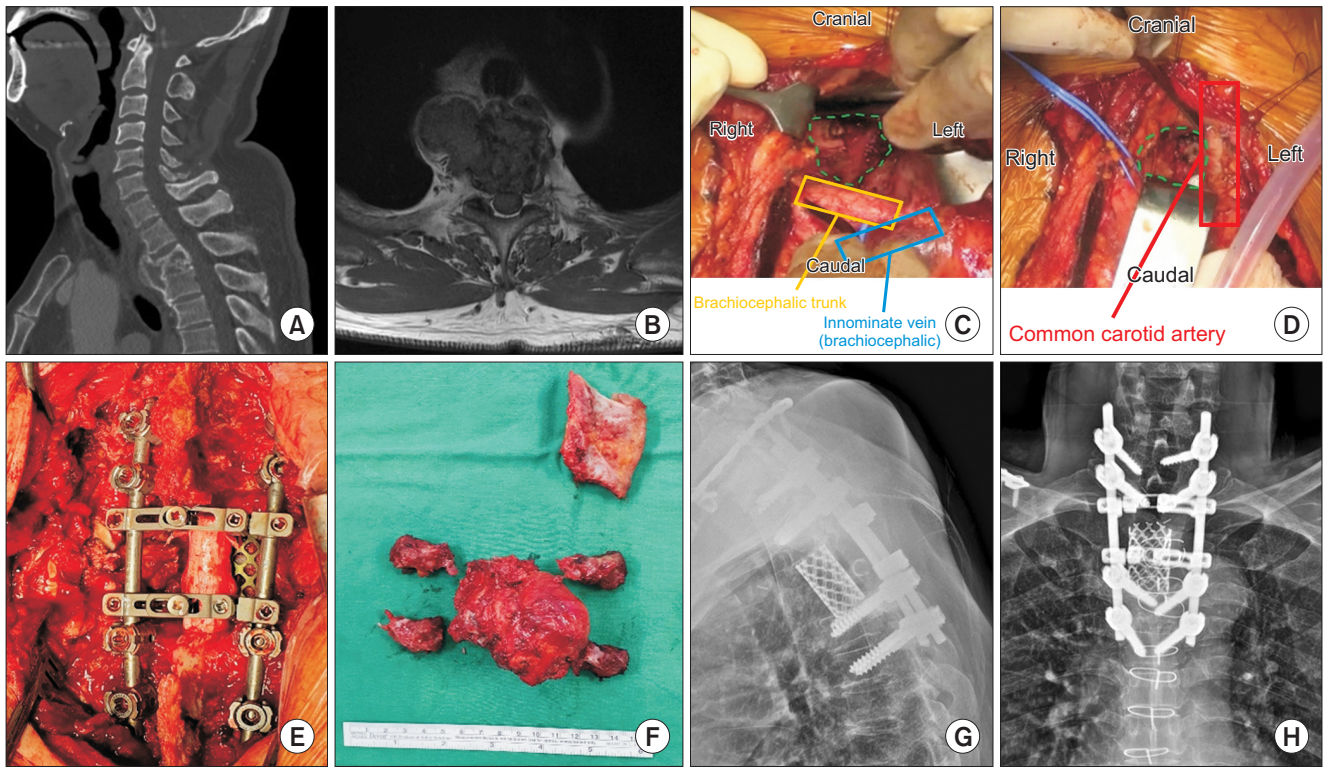

Fig. 7. A 56-year-old man with a giant cell tumor in T2. (A, B) Preoperative sagittal computed tomography and axial T1 magnetic resonance image. Note the anterior extension of the tumor adjacent to the esophagus and great vessel. (C, D) Intraoperative images during the anterior approach. The dotted green line encircles the working space. (D) The caudolateral retraction of the brachiocephalic trunk induced a sudden blood pressure drop. (E) Final intraoperative view of posterior instrumentation, mass removal, and mesh cage insertion. (F) Gross photo of the removed bony structures. (G, H) Postoperative 2-year lateral and anteroposterior plain radiographs showing well-maintained implants.

blood pressure.[14] Therefore, we measured the shape of BCT, ICAA, ICAD, and the location of BCT which may influence the intraoperative manipulation and retraction of the BCT in order to expose the spine pathology.

The results of our study revealed that most patients had a BCT shape of convex or straight type. Although the angled BCT shape, which could hinder the surgical approach, was the least common type of BCT, its incidence was 20%, which cannot be neglected. Notably, men tended to exhibit a wider surgical corridor than female as they had a significantly greater ICAA and ICAD. In addition, men were more likely to have their BCT base inside the body, whereas women more often had their BCT base on the edge of the body, thereby making the approach more difficult.

We found that the accessible level with the use of different corridors varied from person to person. Although ML ranged from T1 body upper to T3 body middle, SC ranged from T1 body lower to T4 body lower and IC ranged from T3 body middle to T6 body middle. When preparing for the anterior approach on CTJ, we recommend using a two-step plan: First, using a mid-sagittal CT image based on the surgeon's line of sight to determine which corridor is appropriate; Second, analyzing the coronal images to assess the morphology of the great vessel before approaching the corridor. We also found that the SC (the traditional corridor) is the most clinically applicable of all the corridors. Using SC is a method of retracting the esophagus and trachea to the right and the left BCT and CCA to the left. Notably, retraction force is low in this method, resulting in less possibility of recurrent laryngeal nerve (RLN) injury; moreover, less BCV manipulation minimizes the risk of venous injury. Another consideration is that when the contact point of BCT and BCV is higher than the index level, removing the entire vertebral body is difficult because a clear view below cannot be secured. Therefore, when the contact point of BCA and BCV is lower than the index level, the anterior approach is implemented after the posterior approach, and when the contact point is higher than the index level, posterior resection after anterior release is considered safer. When performing the approach posteriorly, the rib is cut and

fully exposed laterally. Subsequently, the vertebral body can be rotated and removed. Given that the middle and ICs are too narrow, the risk of soft-tissue injury in TES is high, and excessive manipulation and traction of the great vessels and nerves is likely to cause problems, such as blood pressure changes and neuropraxia.[15,16] There is a possibility of damaging the RLN or BCV if the excision is performed anteriorly in a condition where a working space is not secured.[17] In the case of the middle corridor, the right BCA is passed to the left over the midline, and there is a risk of right RLN problems and blood pressure changes caused by continuous BCT retraction. In IC, access to the vertebral body is difficult unless the bifurcation of the trachea is disturbed.

Surgeons should pay attention to the high-lying innominate artery because the right BCA in it, which is located more than 2 cm above the sternal notch on the midline of the trachea, may be associated with interference and complications during anterior approach neck surgery.[18] In addition, attention should be paid to the branching pattern of the AA. In type 2 bovine arch (also known as truncus bicaroticus), which is the second most common pattern, the left CCA originates directly from the BCA and is anterior to the vertebral body, potentially interfering with the corridor.[7,19]

The strength of our study is that this is the first to analyze the numeric values related to the great vessel morphologies encountered during the anterior approach of the CTJ. An angled-shaped BCT, smaller ICAA, shorter ICAD, and BCT base located inside the vertebral body are potential factors that require more manipulation of the BCT and may make the anterior approach more difficult. Fortunately, the angled-shaped BCT and BCT base located outside were the least common types comprising 12.2% and 20.4% of the cohort, respectively. Specifically, BCT base was more frequently located on the body edge or outside body rather than inside body in women, making the anatomical corridor more difficult than in men. The mean value of ICAA and ICAD was 50.83° and 33.28 mm, respectively, and both values were lower and smaller in women, which may be technically more demanding. In addition, we assume that the analysis of the accessible level of each corridor using the surgeon's view line is more accurate than the previous reports solely relying on the transverse line, which does not regard the actual intraoperative view. Our analysis showed that the most common levels for the most cranial level that required manibriotomy, the most caudal level accessible through the SC and the IC were T1, T3, and T5, respectively.

This study has some limitations. First, the CT images analyzed in this study were performed preoperatively in patients scheduled for elective cervical surgery and not in asymptomatic patients. Moreover, the surgery was accompanied by a degenerative change in the cervical spine; therefore, a selection bias may have occurred. However, because this study considered the relationship between the upper thoracic spine and the great vessels, degenerative changes are not expected to have a significant impact on the results of this study. Second, as individual evaluation and approach are important in actual cases, this study only serves to present indications and guidelines. Third, the actual intraoperative anatomy of an encountered vessel may differ from that measured on a CT scan. Nevertheless, considering the surgeon's line of sight and the measurements of the ICAA, we improved the applicability as much as possible. Finally, we cannot provide the exact cut-off value for the difficult anterior approach of the CTJ due to limited cases. Future studies aiming to analyze such results are warranted for clinical application.

CONFLICT OF INTEREST

Woo-Kie Min is an editorial board member of the journal but was not involved in the peer reviewer selection, evaluation, or decision process of this article. No other potential conflicts of interest relevant to this article were reported.

ACKNOWLEDGEMENTS

We would like to thank Tak-Hyuk Oh, MD, for performing the anterior surgical approach in the patients.

ORCID

Eugene J. Park https://orcid.org/0000-0002-3974-9460
Bo-Gil Jeong https://orcid.org/0000-0003-2862-1370
Woo-Kie Min https://orcid.org/0000-0003-2079-5085

REFERENCES

1. Huang YX, Ni WF, Wang S, et al. Anterior approaches to the cervicothoracic junction: a study on the surgical accessibility of three different corridors based on the CT images. Eur Spine J. 2010;19(11):1936-41.

2. Falavigna A, Righesso O, Teles AR. Anterior approach to the cervicothoracic junction: proposed indication for manubriotomy based on preoperative computed tomography findings. J Neurosurg Spine. 2011;15(1):38-47.
3. Xiao ZM, Zhan XL, Gong DF, De Li S. Surgical management for upper thoracic spine tumors by a transmanubrium approach and a new space. Eur Spine J. 2007;16(3):439-44.
4. Brogna C, Thakur B, Fiengo L, et al. Mini transsternal approach to the anterior high thoracic spine (T1-T4 vertebrae). Biomed Res Int. 2016;2016:4854217.
5. McPhee A, Shaikhrezai K, Berg G. Is it safe to divide and ligate the left innominate vein in complex cardiothoracic surgeries? Interact Cardiovasc Thorac Surg. 2013;17(3):560-3.
6. Cohen ZR, Fourney DR, Gokaslan ZL, Walsh GL, Rhines LD. Anterior stabilization of the upper thoracic spine via an "interaortocaval subinnominate window": case report and description of operative technique. J Spinal Disord Tech. 2004;17(6):543-8.
7. Popieluszko P, Henry BM, Sanna B, et al. A systematic review and meta-analysis of variations in branching patterns of the adult aortic arch. J Vasc Surg. 2018;68(1):298-306.
8. Louie PK, Khan JM, Miller I, Colman MW. All-posterior total en bloc spondylectomy for thoracic spinal tumors. Ann Transl Med. 2019;7(10):227.
9. Acosta FL, Shapovalov VS, Lobo BM, Liker MA. Radiographic evaluation of low back pain after lumbar fusion using Technetium-99 single-photon emission computed tomography: impact on clinical decision-making and outcome. Interdiscip Neurosurg. 2021;24:101089.
10. Eleraky M, Setzer M, Vrionis FD. Posterior transpedicular corpectomy for malignant cervical spine tumors. Eur Spine J. 2010;19(2):257-62.
11. Liao JC, Chen WJ, Chen LH. Surgery for metastatic epidural spinal cord compression in thoracic spine, anterior or posterior approach? Biomed J. 2022;45(2):370-6.
12. Tomita K, Kawahara N, Murakami H, Demura S. Total en bloc spondylectomy for spinal tumors: improvement of the technique and its associated basic background. J Orthop Sci. 2006;11(1):3-12.
13. Mirjalili SA, Hale SJ, Buckenham T, Wilson B, Stringer MD. A reappraisal of adult thoracic surface anatomy. Clin Anat. 2012;25(7):827-34.
14. Kikuta S, Iwanaga J, Kusukawa J, Tubbs RS. Carotid sinus nerve: a comprehensive review of its anatomy, variations, pathology, and clinical applications. World Neurosurg. 2019;127:370-4.
15. Cheung JP, Luk KD. Complications of anterior and posterior cervical spine surgery. Asian Spine J. 2016;10(2):385-400.
16. Miscusi M, Bellitti A, Peschillo S, Polli FM, Missori P, Delfini R. Does recurrent laryngeal nerve anatomy condition the choice of the side for approaching the anterior cervical spine? J Neurosurg Sci. 2007;51(2):61-4.
17. Lu J, Ebraheim NA, Nadim Y, Huntoon M. Anterior approach to the cervical spine: surgical anatomy. Orthopedics. 2000;23(8):841-5.
18. Cai Q, Zhu H, Yu T, et al. Risk assessment of high-lying innominate artery with neck surgery. Acta Otolaryngol. 2017;137(3):315-9.
19. Becker C, Csatari Z, Pfeiffer J. Truncus bicaroticus: an underestimated anatomic variation. Laryngoscope. 2014;124(5):1141-2.