Anterior approaches to the cervicothoracic junction: a study on the surgical accessibility of three different corridors based on the CT images

Yi-xing Huang · Wen-fei Ni · Sheng Wang ·
Hui Xu · Xiang-yang Wang · Hua-zi Xu ·
Yong-long Chi · Jia-wei He

Received: 11 December 2009 / Revised: 23 May 2010 / Accepted: 3 June 2010 / Published online: 13 June 2010
© Springer-Verlag 2010

Abstract To determine the location of left brachiocephalic vein (BCV) and tracheal bifurcation (TB) relative to the vertebral levels, and to ascertain the accessibility of three different corridors (C1: between the esophagus and trachea medially and the carotid sheath laterally, C2: between the right BCV and the brachiocephalic artery, and C3: between the ascending aorta and superior vena cava) for preoperative planning. From August 2008 to April 2009, normal chest CT scans of 150 subjects ranging in age from 18 to 78 years were selected. According to our definition, of the 150 studies, 132 T2 vertebral bodies (VBs) could be accessed through C1 (88.0%), 100 T3 VBs could be reached through C2 (66.7%), and 110 T4 VBs could be exposed through C3 (73.3%). The results suggest that the surgical accessibility of three different corridors is different and we conclude that T2, T3, and T4 are, respectively, readily accessible through C1, C2, and C3.

Keywords Surgical corridor · Cervicothoracic junction · CT scan · Anatomy

Introduction

No region of the spine is easily treated, and the cervicothoracic junction (CTJ) is perhaps the most difficult. The CTJ is usually defined by most authors as an area extending from C7 to T4, or to even more levels in some literature [12, 13, 16, 20, 23, 25]. The anterior approaches to the CTJ remain challenging because of the close proximity of vital vascular and neural structures over the operative field and the bony obstacle caused by the manubrium sterni, clavicles, and ribs [12, 13, 17]. Furthermore, reported complications of anterior approaches to the CTJ include injury to the recurrent laryngeal nerves, thoracic duct, esophagus, and vascular structures [4–6, 10, 12–14, 16, 20, 23, 24]. Consequently, several different surgical corridors have been developed [6, 12, 16, 20, 24].

The traditional corridor (C₁) lies between the esophagus and trachea medially and the left common carotid or the brachiocephalic artery (BCA) laterally (Fig. 1). However, caudal access to T3 or T4 remains a problem due to the limitation imposed mainly by the left brachiocephalic vein (LBCV). Xiao et al. [24] presented a new surgical corridor (C₂) which located between the right brachiocephalic vein (RBCV) and the BCA (Fig. 2). Their study showed that the anterior aspect of the vertebral body from C7 to T4 could be easily exposed through this corridor, compared with the traditional one. In 2004 Cohen et al. [6] described an “interaortocaval subinnominate window” (C₃) bordered by the superior vena cava (SVC) on the right, the ascending aorta (AA) on the left, the LBCV and BCA superiorly, and the right pulmonary artery (RPA) inferiorly (Fig. 3). They used this corridor successfully to apply the T3 screws of a T1–T3 locking plate and screw construct.

After an extensive literature search, however, there is little information about the exact surgical accessibility of

Y. Huang · W. Ni · S. Wang · H. Xu · X. Wang · H. Xu ·
Y. Chi (✉)
Department of Orthopaedic Surgery,
Second Affiliated Hospital of Wenzhou Medical College,
109 Xueyuan Road, Wenzhou, China
e-mail: sunnyknight@126.com

J. He
Department of Radiology, Second Affiliated Hospital
of Wenzhou Medical College, Wenzhou, China

Fig. 1 The superior corridor (C1). AA ascending aorta, BCA brachiocephalic artery, L-BCV left brachiocephalic vein, L-CCA left common carotid artery, R-BCV right brachiocephalic vein, SVC superior vena cava, T trachea, T3 the third thoracic vertebral body, the black triangle represents the intersection between the superior margin of the LBCV and the mid-sagittal plane which determines the caudal accessibility of C1

Fig. 2 The middle corridor (C2). AA ascending aorta, BCA brachiocephalic artery, L-BCV left brachiocephalic vein, L-CCA left common carotid artery, R-BCV right brachiocephalic vein, SVC superior vena cava, T4 the fourth thoracic vertebral body, the black triangle represents the superior border of the confluence of the left and right BCV which determines the caudal accessibility of C2

these three corridors to the CTJ. A thorough understanding of the caudal accessibility of the corridors and the location of some vital anatomic structures in this region would be of much value in selecting an appropriate surgical corridor to the anterior aspect of the CTJ and could help minimize the surgical complications. We mainly aimed our research for this purpose.

Materials and methods

From August 2008 to April 2009, consecutive chest CT images were acquired from the picture archiving and communication system (PACS, INFINTT Co. Ltd, Seoul, Korea). All of the images were taken by using a General

Fig. 3 The inferior corridor (C3). AA ascending aorta, BCA brachiocephalic artery, L-BCV left brachiocephalic vein, L-CCA left common carotid artery, R-BCV right brachiocephalic vein, SVC superior vena cava, TB tracheal bifurcation, T5 the fifth thoracic vertebral body, the black triangle represents the superior border of the TB which determines the caudal accessibility of C3

Electric CT scanner (Philips Brilliance 16-slice, Philips Medical Systems, Eindhoven, Netherlands) at a 7.5-mm interval. Subjects with any diseases which might change the position of the anatomic structures in this region were excluded. And subjects with significant rotation (assessed by the position of the pedicles and spinous processes) were discarded too. These CT images were scrutinized carefully for a clear display of the demarcation of the LBCV, TB, and vertebral bodies. In total, 150 subjects ranging in age from 18 to 78 years (mean 40.2 ± 12.4 years) were selected including 78 women ranging in age from 18 to 70 years (mean 39.7 ± 12.8 years) and 72 men ranging in age from 18 to 78 years (mean 40.7 ± 12.0 years).

We presumed the circumstances of vertical visualization and no downward retraction of the vital neurovascular structures in the superior mediastinum, the caudal accessibility of C₁, C₂, and C₃ are, respectively, defined as the level of the intersection between the superior margin of the LBCV and the mid-sagittal plane, the level of the superior border of the confluence of the left and right BCV (L-RBCV), and the level of the superior border of the TB with respect to the corresponding vertebral body or inter-vertebral space (Figs. 1, 2, 3).

To better determine the level of the three points mentioned above, the anterior aspect of each vertebral body was divided into three equal parts (upper, middle, and lower thirds) by two transverse lines as determined on coronal CT scout images. The level of the superior border of the aortic arch (AO) was also defined. Each measurement was made by an orthopedic spine surgeon and a musculoskeletal radiologist utilizing a PACS workstation (Figs. 4, 5, 6, 7). There was a high degree of interobserver reliability (0.947, 0.967, 0.953, 0.960). Any discrepancy between identification of anatomic landmarks was resolved by the two authors in concert.

Fig. 4 A chest CT image (right) and its scout image (left) on the PACS workstation

Fig. 5 The transverse plane of the intersection between the superior margin of the LBCV and the mid-sagittal plane. 1 left brachiocephalic vein, 2 right brachiocephalic vein, 3 trachea

Fig. 6 The transverse plane of the superior border of the confluence of the left and right brachiocephalic veins. 1 left brachiocephalic vein, 2 right brachiocephalic vein, 3 trachea

Fig. 7 The transverse plane of the superior border of the tracheal bifurcation. 1 tracheal bifurcation, 2 superior vena cava, 3 ascending aorta, 4 descending aorta

Statistical analysis

Statistical software SPSS 12.0 (SPSS Inc., Chicago, IL) was used to compare the caudal accessibility of C1, C2, and C3 by using the rank-sum test, with $P < 0.05$ considered to be statistically significant.

Results

The intersection between the superior margin of the LBCV and the mid-sagittal plane most commonly occurs opposite T3 (64.0%). The superior border of the confluence of the L-RBCV commonly occurs opposite T4 (41.3%). The superior border of the AO most commonly occurs opposite T4 (54.7%). The superior border of the TB commonly occurs opposite T5 (44.0%) (Table 1).

According to our definition, the caudal accessibility of C₁, C₂, and C₃ to the anterior aspect of the CTJ, respectively, could be determined.

T3 was seldom accessible through C1 except in 10 out of 150 specimens (6.7%), whereas T2 was readily accessible in 132 out of 150 instances (88.0%). T4 could not be accessed through C1 according to our definition. T3 was readily accessible through C2 in 100 out of 150 specimens (66.7%), whereas T2 was almost always accessible in 147 out of 150 (98.0%). T4 could not be accessed through C2 except one subject (0.7%). As all the TBs were located below T3 in the current study, T2 and T3 were accessible through C3 all the time (100%). T4 was readily accessible through C3 in 110 out of 150 specimens (73.3%) according to our definition. Occasionally, T5 was accessible through C3 in 8 out of 150 (5.3%) (Table 2).

Table 1 Vertebral level of the intersection between the superior margin of the left brachiocephalic vein and the mid-sagittal plane, the superior border of the confluence of the left and right brachiocephalic veins, and the superior border of the tracheal bifurcation

Vertebral level ^a	The intersection between the superior margin of the LBCV and the mid-sagittal plane	Superior border of the confluence of the L-RBCV	Superior border of the AO	Superior border of the TB
T1/2	1 (0.7%)	0	0	0
T2 U	2 (1.3%)	0	0	0
T2 M	4 (2.7%)	2 (1.3%)	0	0
T2 L	11 (7.3%)	1 (0.7%)	0	0
T2/3	26 (17.3%)	2 (1.3%)	1 (0.7%)	0
T3 U	39 (26.0%)	8 (5.3%)	8 (5.3%)	0
T3 M	45 (30.0%)	22 (14.7%)	8 (5.3%)	0
T3 L	12 (8.0%)	15 (10.0%)	15 (10.0%)	0
T3/4	10 (6.7%)	37 (24.7%)	29 (19.3%)	0
T4 U	0	34 (22.7%)	34 (22.7%)	6 (4.0%)
T4 M	0	22 (14.7%)	33 (22.0%)	13 (8.7%)
T4 L	0	6 (4.0%)	15 (10.0%)	21 (14.0%)
T4/5	0	1 (0.7%)	5 (3.3%)	36 (24.0%)
T5 U	0	0	2 (1.3%)	30 (20.0%)
T5 M	0	0	0	26 (17.3%)
T5 L	0	0	0	10 (6.7%)
T5/6	0	0	0	6 (4.0%)
T6	0	0	0	2 (1.3%)

^a The anterior aspect of each vertebral body was divided into three equal parts (upper, middle and lower thirds) by two transverse lines on coronal CT scout images

U the upper one-third, M the middle third, L the lower one-third, LBCV left brachiocephalic vein, L-RBCV left and right brachiocephalic vein, AO aortic arch, TB tracheal bifurcation

Table 2 Caudal accessibility of three corridors to the anterior aspect of the cervicothoracic junction in 150 cases

Surgical corridors	Numbers of vertebral bodies		
	T2	T3	T4
C1	132 (88.0%)	10 (6.7%)	0
C2	147 (98.0%)	100 (66.7%)	1 (0.7%)
C3	150 (100%)	150 (100%)	110 (73.3%)

C1 the surgical corridor between the esophagus and trachea medially and the left common carotid or the brachiocephalic trunk laterally, C2 the surgical corridor between the right brachiocephalic vein and the brachiocephalic artery, C3 the surgical corridor between the ascending aorta and superior vena cava

Comparison among the caudal accessibility of three corridors, $P < 0.05$

Comparison among the caudal accessibility of C1, C2, and C3 was performed. There was significant difference among the caudal accessibility of C1, C2, and C3 ($P < 0.05$). C3 had the greatest caudal accessibility of the three, followed by C2. And there was no statistical difference between males and females ($P > 0.05$).

Discussion

Three most common lesions in the CTJ requiring surgical treatment from an anterior approach are infections, tumor, and unstable fractures [3, 11]. However, anterior surgical approaches in this region can be particularly challenging due to the bony obstacle caused by the manubrium sterni, clavicles, and the crossing of vital structures over the operative field in the superior mediastinum [3, 10, 21].

As for the bony obstacles, they could be removed by transclavicular trans-manubrial [5, 14], trans-sternal [4], and modified trans-sternal approaches [2, 12, 15, 16]. However, we should be aware that splitting the manubrium sterni or resecting part of unilateral clavicle, which would increase pain of patients and may lead to some complications, is not necessary for every patient. Some could be managed by the traditional low anterior cervical approach. Previous authors have investigated this problem by using MR imaging [8, 10, 17, 22, 23].

As for the vital structures over the operative field, such as the LBCV, aortic arch, thoracic duct, recurrent laryngeal nerves, esophagus, and trachea, they are vulnerable to

injury and act as obstructions for exposure during operation. The only way is to bypass them and to reach the spine through neurovascular space. So far, mainly three surgical corridors in clinical application have been reported [5, 6, 12, 15, 16, 20].

The superior corridor (C1) is a traditional one (Fig. 1). It was familiar to spine surgeons. Most surgeons preferred the left side. Because the left recurrent laryngeal nerve (RLN) is almost in the tracheoesophageal groove and is more constant than the right one [7, 19]. Some authors, however, believe that the right corridor is safer than the left one because the thoracic duct in this region lies on the left side of midline and exposing the RLN may decrease the risk of injuring it. The caudal accessibility of the superior corridor is markedly affected by the position of the LBCV. In the current study, the most caudal accessible level is the T3/4 intervertebral space. Through this corridor, T2 is readily accessible (88.0%), and T1 is always accessible (100%). Although this corridor was familiar to surgeons and regarded as a relatively safe one, T4 could hardly be exposed through it, even T3. In order to expose the T3 and T4, the LBCV is always needed to be retracted downward. This might result in the tear of LBCV. Some authors advocated that the LBCV should be cut in order to expose the T3 and T4 and be reconstructed later. As a result, this would augment the difficulty of the procedures and increase the incidence of complication.

The middle corridor (C2) is bordered medially by the BCA, laterally by the right brachiocephalic vein, and inferiorly by the confluence of the left and right brachiocephalic veins (Fig. 2). It locates slightly on the right side of the midline. Compared with the superior corridor, the greater caudal accessibility to the CTJ could be acquired through this corridor. In the current study, T2 is almost always accessible through this corridor (98.0%), and T3 is readily accessible (66.7%). In order to expose the T4 or T5, the LBCV is always needed to be retracted downward. Because the thoracic duct does not locate in this corridor, injury usually can be avoided. However, the right vagus nerve runs through this corridor and gives off the right RLN and its cardiac branches. These nerves should be identified through blunt dissection and well protected during operation.

The inferior corridor (C3) is bordered by the superior vena cava on the right, the ascending aorta on the left, the LBCV and BCA superiorly, and the right pulmonary artery (RPA) inferiorly (Fig. 3). In 2004, Cohen et al. [6] described it and named it an “interaortocaval subinnominate window”. They used this corridor successfully to apply the T3 screws of a T1–T3 locking plate and screw construct in a patient who underwent a T2 vertebrectomy and polymethylmethacrylate (PMMA) reconstruction. Then, Xiao et al. [24] used and recommended it. They

believed that T3–T5 could be easily exposed through this corridor according to their clinical experience. According to the description by Cohen, the caudal structure of this corridor is the RPA. In our study, however, we found the dilated TB, which was always cephalic to the RPA, was the real obstacle to caudal access. Through this corridor, T3 is always accessible (100%), T4 is readily accessible (73.3%), and T5 occasionally could be exposed (5.3%). However, this corridor is relatively narrow and its cephalic accessibility is limited by the LBCV and BCA superiorly. It is suitable for a single-level procedure involves T4 or T5. For an extensive exposure, it can be used in combination with C2 or C1. But care must be taken to use this corridor. If the great vessels or the trachea or the esophagus were injured, it would be very dangerous. The safety of this corridor needs further investigation in clinical practice.

Through these surgical corridors, procedures at the CTJ, such as a corpectomy, a discectomy, and instrumentation, could be done well. Some previous authors have performed such procedures successfully [2, 5, 6, 12, 15, 16, 24]. If an extensive C6 to T4 exposure is required, C2 may be adequate with the caudal retraction of the root of the LBCV [24]. If T5 must be reached, C3 combined with C2 or C1 is recommended. Some surgeons advocate a posterior-based costo-transversectomy or even consider a standard thoracotomy to gain access to T4, T5, and below. However, the lower cervical spine cannot be accessed and the upper thoracic spine is difficult to expose via these two approaches [11].

Generally, textbooks have underestimated the variability in the anatomy of the vital structures and their relation to the anterior elements of the CTJ. Some authors confirmed this variability in their studies. Based on an anatomical study of 6 cadavers, An et al. [1] found that the LBCV was located on the anterior aspect of T1 in 2 cases and of T2 in 4 cases. In a cadaveric study involving 30 specimens, Xu et al. [25] came to a conclusion that the LBCV is at T1 and T2 level in 80%, the aortic arch is at T2 and T3 level in 90%. In a MR imaging study, Teng et al. [23] found that the LBCV is at T3 level in 51% and at T2 level in 37%, the aortic arch is at T4 level in 52% and at T3 level in 27%. In the present study, LBCV is at T3 level in 64.0% and at T2/3 level in 17.3%, and the aortic arch is at T4 in 54.7% and T3 level in 20.6%. Additionally, the anomalous course of the LBCV also has been reported in the literature [9, 18].

Most of the previous studies on the anatomy of this region have used cadavers. The method of cadaveric dissection has some shortcomings. The morphology and spatial position of the soft tissues in cadavers might change during processing. Therefore, the corresponding relation between the blood vessels anterior and the vertebral bodies posterior may change. Another drawback to gross dissection is that exposure of the involved anatomic structure

often results in destruction of surrounding structures so that the spatial relationships may be altered or destroyed. In the current study we used the CT scans of living subjects. And we investigated a sample of 150 cases. The number of cases is much larger than the previous studies.

So far, there has been no report regarding the exact surgical accessibility of three different corridors to the anterior aspect of the CTJ in the literature. However, several limitations existed in this study. The measurements were obtained from 150 Chinese patients, but no patients from other racial or ethnic backgrounds. In addition, how much could the great vessels or the nerves be retracted remains unclear which deserves further investigation.

In conclusion, the results of the current study confirm the work of previous authors who have noted the marked variability of the anatomy anterior to the CTJ. Furthermore, according to our definition, the exact surgical accessibility of the three different corridors to the CTJ was determined. These results could provide valuable information on selecting an appropriate surgical corridor to the anterior aspect of the CTJ and could help minimize the surgical complications. Therefore, preoperative computerized tomographic imaging evaluation of the location of some vital anatomic structures with respect to the vertebral levels is strongly recommended.

References

1. An HS, Wise JJ, Xu R (1999) Anatomy of the cervicothoracic junction: a study of cadaveric dissection, cryomicrotomy, and magnetic resonance imaging. *J Spinal Disord* 12:519–525
2. Birch R, Bonney G, Marshall RW (1990) A surgical approach to the cervicothoracic spine. *J Bone Jt Surg Br* 72:904–907
3. Boockvar JA, Philips MF, Telfeian AE et al (2001) Results and risk factors for anterior cervicothoracic junction surgery. *J Neurosurg* 94:12–17
4. Cauchoix J, Binet JP (1957) Anterior surgical approaches to the spine. *Ann R Coll Surg Engl* 21:237–243
5. Charles R, Govender S (1989) Anterior approach to the upper thoracic vertebrae. *J Bone Jt Surg Br* 71:81–84
6. Cohen ZR, Fourny DR, Gokaslan ZL et al (2004) Anterior stabilization of the upper thoracic spine via an “Interaortocaval Subinnominate Window”: case report and description of operative technique. *J Spinal Disord Tech* 17:543–548
7. Ebraheim NA, Lu J, Skie M et al (1997) Vulnerability of the recurrent laryngeal nerve in the anterior approach to the lower cervical spine. *Spine* 22:2664–2667
8. Fraser JF, Diwan AD, Peterson M et al (2002) Preoperative magnetic resonance imaging screening for a surgical decision regarding the approach for anterior spine fusion at the cervicothoracic junction. *Spine* 27:675–681
9. Gerlis LM, Ho SY (1989) Anomalous subaortic position of the brachiocephalic (innominate) vein: a review of published reports and report of three new cases. *Br Heart J* 61:540–545
10. Gieger M, Roth PA, Wu JK (1995) The anterior cervical approach to the cervicothoracic junction. *Neurosurgery* 37:704–709
11. Kaya RA, Türkmenoğlu ON, Koç ON et al (2006) A perspective for the selection of surgical approaches in patients with upper thoracic and cervicothoracic junction instabilities. *Surg Neurol* 65:454–463
12. Kurz LT, Pursel SE, Herkowitz HN (1991) Modified anterior approach to the cervicothoracic junction. *Spine* 16:S542–S547
13. Lehman RM, Grunberg B, Hall T (1997) Anterior approach to the cervicothoracic junction: an anatomic dissection. *J Spinal Disord* 10:33–39
14. Lesoin F, Thomas CE 3rd, Autricque A et al (1986) A transsternal biclavicular approach to the upper anterior thoracic spine. *Surg Neurol* 26:253–256
15. Liu YL, Hao YJ, Li T et al (2009) Trans-upper-sternal approach to the cervicothoracic junction. *Clin Orthop Relat Res* 467:2018–2024
16. Luk KD, Cheung KM, Leong JC (2002) Anterior approach to the cervicothoracic junction by unilateral or bilateral manubriectomy. A report of five cases. *J Bone Jt Surg Am* 84-A:1013–1017
17. Miscusi M, Bellitti A, Polli FM (2005) Surgical approaches to the cervico-thoracic junction. *J Neurosurg Sci* 49:49–57
18. Morhy Borges Leal S, Andrade JL, de Souza M et al (2002) Anomalous subaortic course of the left brachiocephalic (innominate) vein: echocardiographic diagnosis and report of an unusual association. *Cardiol Young* 12:159–163
19. Netterville JL, Koriwchak MJ, Winkle M et al (1996) Vocal fold paralysis following the anterior approach to the cervical spine. *Ann Otol Rhinol Laryngol* 105:85–91
20. Pointillart V, Aurouer N, Gangnet N et al (2007) Anterior approach to the cervicothoracic junction without sternotomy: a report of 37 cases. *Spine* 32:2875–2879
21. Prabhakar MM, Thakker T (2006) Anterior decompression for cervicothoracic pathology: a study of 14 patients. *J Spinal Cord Med* 29:163–166
22. Sharan AD, Przybylski GJ, Tartaglino L (2000) Approaching the upper thoracic vertebrae without sternotomy or thoracotomy: a radiographic analysis with clinical application. *Spine* 25:910–916
23. Teng H, Hsiang J, Wu C et al (2009) Surgery in the cervicothoracic junction with an anterior low suprasternal approach alone or combined with manubriectomy and sternotomy: an approach selection method based on the cervicothoracic angle. *J Neurosurg Spine* 10:531–542
24. Xiao ZM, Zhan XL, Gong de F et al (2007) Surgical management for upper thoracic spine tumors by a transmanubrium approach and a new space. *Eur Spine J* 16:439–444
25. Xu R, Grabow R, Ebraheim NA et al (2000) Anatomic considerations of a modified anterior approach to the cervicothoracic junction. *Am J Orthop* 29:37–40