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Published in:
Clinical Anatomy

DOI:
10.1002/ca.22817

Publication date:
2017

Document Version
Peer reviewed version

Citation for published version (APA):
Badshah, M., Soames, R., Khan, M. J., Marwat, M. I., & Khan, A. (2017). Revisiting thoracic surface anatomy in an adult population: a Ct evaluation of vertebral level. Clinical Anatomy, 30(2), 227-236. DOI: 10.1002/ca.22817

REVISITING THORACIC SURFACE ANATOMY IN AN ADULT POPULATION: A CT EVALUATION OF VERTEBRAL LEVEL

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This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process which may lead to differences between this version and the Version of Record. Please cite this article as an 'Accepted Article', doi: 10.1002/ca.22817

REVISITING THORACIC SURFACE ANATOMY IN AN ADULT POPULATION: A CT EVALUATION OF VERTEBRAL LEVEL

Abstract

Introduction: To compare key thoracic anatomical surface landmarks between healthy and patient adult populations using Computed Tomography (CT).

Materials and Methods: Sixteen slice CT images of 250 age and gender matched healthy individuals and 99 patients with lung parenchymal disease were analyzed to determine the relationship of 17 thoracic structures and their vertebral levels using a 32-bit Radiant DICOM viewer. The structures studied were: aortic hiatus, azygos vein, brachiocephalic artery, gastroesophageal junction, left and right common carotid arteries, left and right subclavian arteries, pulmonary trunk bifurcation, superior vena cava junction with the right atrium, carina, cardiac apex, manubriosternal junction, xiphisternal joint, inferior vena cava (IVC) crossing the diaphragm, aortic arch and junction of brachiocephalic veins.

Results: The surface anatomy of all structures varied among individuals with no significant effect of age. Binary logistic regression analysis showed a significant association between individual health status and vertebral level for: brachiocephalic artery (p=0.049), gastroesophageal junction (p=0.020), right common carotid (p=0.009) and subclavian arteries (p=0.009), pulmonary trunk bifurcation (p=0.049), carina (p=0.004), and IVC crossing the diaphragm (p=0.025).

Conclusion: These observations differ from those reported in a healthy white Caucasian population and from the vertebral levels of the IVC, esophagus and aorta crossing the diaphragm in an Iranian population. The differences observed in the current study provide insight into the effect of lung pathology on specific thoracic structures and their vertebral levels. Further studies are needed to determine whether these are general changes or pathology-specific.

Key words: surface anatomy; ethnic group; cross-sectional anatomy; CT scans

Introduction

An appreciation of surface anatomy is essential for promoting safe clinical practice, so it must be accurate, clinically relevant and defined within an evidence-based framework (Hale et al., 2010). Teaching surface anatomy is now considered an integral part of medical education, which should improve the practical skills of medical students in their future clinical practice (Aggarwal et al., 2006).

Surface anatomy is extremely important for thoracic surgeons, particularly regarding interventional procedures such as tube thoracostomy. Although the surface anatomy of the thorax is often a neglected aspect of traditional topographic anatomical teaching, a proper understanding of the relationship between superficial and deep structures is important for the clinical assessment of patients and for interpreting clinical images (Sayeed and Darling, 2007). Clearly, surface anatomy needs to be accurate to ensure safe clinical patient assessment (Hale et al., 2010). Modern imaging techniques provide an opportunity to determine the accuracy of surface anatomy in living individuals (Mirjalili et al., 2012a). Indeed, modern imaging studies such as computed tomography (CT) have been used during the last two decades to assess traditional surface anatomical landmarks (Chukwuemeka et al., 1997; Glodny et al., 2009).

There are two main reasons for determining the relationship between thoracic structures and their vertebral levels: (i) to guide catheter placement and the position of surgical incisions (Hunt and Harris, 1996; Soleiman et al., 2005; Chakraverty et al., 2007, cited in Mirjalili et al., 2012a), and (ii) to educate medical students for future clinical practice. Surgeons must be familiar with relevant surface markings as a prerequisite for donor site reconstruction (Cunningham et al., 2004). An understanding of surface anatomy also provides convenient standard reference points for radiologists in approximating the vertebral levels of thoracic structures. Interestingly, surface anatomy is more effectively learned when body painting is used (McMenamin, 2008).

Although most of the surface anatomical landmarks stated in standard anatomical textbooks are valid (Keough et al., 2016), there are differences with respect to some clinically important surface markings among and within such texts (Shen et al., 2016). Anatomy and clinical textbooks may therefore need revision using data collected from the most recent studies, also taking account of ethnic and racial differences (Uzun et al., 2016).

Apart from cadaveric studies, radiographic imaging is essential for understanding surface anatomy (Lachman, 1942). The main aims of the present study are therefore to: (i) compare key thoracic anatomical surface landmarks in healthy and patient (lung parenchymal disease) adult Pakistani populations using Computed Tomography (CT), and (ii) compare the data collected with those reported in the literature.

Materials and Methods:

After informed consent was obtained from each patient, CT scans were taken in the supine position with the arms abducted. Sixteen slice CT images of 215 age and gender matched individuals were obtained from Northwest General Hospital using a Light RT-16 CT scanner with slice thickness 1mm (GE (General Electronics)® USA) and a 16 slice scanner (Toshiba® Alexion Japan) with slice thickness 0.5mm. Sixteen individuals were excluded from further analysis owing to severe spinal deformity, while the remainder were categorized into healthy (n=100) and patient (n=99) groups. The healthy group consisted of individuals scanned for a suspected pathology but found to be healthy. Ethical approval for access to the archived scans was requested from and granted by the ethics committee of the Northwest General Hospital and Research Center Peshawar (Ref No. NwGH/Res/Eth/2039). Each image was analyzed by noting the relationship of specific thoracic structures and their vertebral levels using a 32-bit Radiant DICOM viewer®. The structures of interest were: aortic hiatus, azygos vein, brachiocephalic artery, gastroesophageal junction (this was observed to be at the level at which the esophagus crossed the diaphragm), left and right common carotid arteries, left and right subclavian arteries, pulmonary trunk bifurcation, junction of the superior vena cava (SVC) with the right atrium, tracheal bifurcation (carina), cardiac apex, manubriosternal junction, xiphisternal joint, inferior vena cava (IVC) crossing the diaphragm, aortic arch, and junction of the brachiocephalic veins.

The following definitions, taken from Mirjalili et al. (2012a), were used to identify the vertebral level at which each structure listed above occurred.

Aortic Hiatus: maximum diameter of the descending aorta where it abutted the diaphragm, identified in the coronal plane.

Azygos Vein: the point at which the last tributary of the azygos vein joined, identified in the coronal plane slice.

Branches of Aorta: the upper part of the aortic arch from where the brachiocephalic, left common carotid and left subclavian arteries originated, identified in the coronal plane. Similarly, in the coronal plane, the level at which the brachiocephalic trunk bifurcated into right common carotid and right subclavian arteries was identified.

Gastroesophageal Junction: the point at which the esophagus met the stomach at the cardiac notch, identified in the coronal plane.

Pulmonary Trunk Bifurcation: a point midway between the midpoints of the left and right pulmonary arteries at their origin, identified in the coronal plane.

Superior Vena Cava Junction with Right Atrium: where the SVC entered with the right atrium, identified in the coronal plane.

Carina: the area between the division of the trachea into right and left main bronchi, identified in the coronal plane.

Cardiac Apex: the most lateral point of the lateral border of the heart with reference to the distance from the midline, identified in the coronal plane.

Manubriosternal Junction: the articulation between the manubrium and body of the sternum, identified in the coronal plane.

Xiphisternal Joint: the articulation between the body of the sternum and the xiphoid process, identified in the coronal plane.

Inferior Vena Cava crossing the Diaphragm: the point of maximum diameter of the IVC in contact with the dome of the diaphragm, identified in the coronal plane.

Aortic Arch: the mid portion of the maximum concavity where the great vessels arose, identified in the coronal plane.

Junction of Brachiocephalic Veins (i.e. formation of the SVC): the point where the right and left brachiocephalic veins met, identified in the coronal plane.

Statistical analysis:

The data were analyzed using Minitab® Version 17 (Minitab Inc. Illinois USA); categorical data were expressed as frequency and percentage. Binary logistic regression analysis was applied to determine the association between individual health status and thoracic surface marking in relation to vertebral level. A P-value of less than 0.05 was considered significant.

Results:

The mean (standard deviation) age of all participants was 47.2 (16.21) years, with no significant difference between groups [mean (SD): healthy 45.0 (15.31) years, patients 49.3 (16.83) years, p=0.110, 2-sample t-test]. In the healthy group there were 54 males (mean age 49.1 years) and 46 females (mean age 51.7 years), while in the lung pathology group there were 56 males (mean age 51.0 years) and 43 females (mean age 48.3 years).

The vertebral levels of all structures varied among individuals, but there was no significant effect of age. Binary logistic regression analysis revealed a significant association between health status and the vertebral level of the brachiocephalic artery (odds ratio; 1.2952, 95%CI; 0.9974,1.6818; p=0.049), the gastroesophageal junction (odds ratio; 1.2415, 95%CI; 1.0303,1.4959; p=0.020), the right common carotid artery (odds ratio; 1.4238, 95%CI; 1.0861, 1.8664; p=0.009), the right subclavian artery (odds ratio; 1.4238, 95%CI; 1.0861, 1.8664; p=0.009), the pulmonary trunk bifurcation (odds ratio; 1.2688, 95%CI; 0.9982,1.6129; p=0.049), the carina (odds ratio; 1.4456 , 95%CI; 1.1133,1.8771; p=0.004), and the IVC crossing the diaphragm (odds ratio; 1.2206, 95%CI; 1.0214,1.4586; p=0.025) (Table 1). These observations show differences from a white Caucasian healthy population (Mirjalili et al., 2012a). The vertebral levels of thoracic structures are compared between healthy individuals and those with lung pathology in Table 2, while the predominant location of each structure with respect to vertebral level is presented in Figure 5.

Discussion:

The current study has again demonstrated that the surface anatomy of thoracic structures varies among individuals, and there were also significant differences between the healthy and lung-pathology populations studied. These observations differ from the vertebral levels of specific structures reported in the literature and those presented in anatomy and clinical textbooks. In terms of vertebral level, the surface anatomy of the structures investigated in the present study merit revisiting, especially in the context of the health of the individual and the population being investigated. This is the first study to report surface anatomy in an Indian subcontinent population. Moreover, vertebral levels tend to be reported in terms of the predominant vertebral level at which each structure lies, with no range being given. The current study reveals the range of topographical variations.

The following thoracic structures were reviewed and compared with previous reports and with the vertebral levels given in anatomy and clinical textbooks.

Manubriosternal Junction: The most consistent vertebral level in the present study was T5 (31%), although in a further 33% the junction was at T4/5 or T4, which is similar to that reported in clinical anatomy reference texts, i.e. the T4/5 intervertebral disc (Moore et al., 2014).

Xiphisternal Joint: The vertebral level of this joint was consistent with the observations of Mirjalili et al. (2012a) and Pak et al. (2016) in an Iranian population and that reported by Snell (2012). However, Pak et al. (2016) observed a higher level in males (T8) than females (T9).

Junction of Brachiocephalic Veins (superior vena cava): This occurred mostly at the T3/4 vertebral level in the current study. Anatomical texts describe its location as just posterior to the manubriosternal junction (Moore et al., 2014).

Superior Vena Cava (SVC) Junction with the Right Atrium: The vertebral level found here was similar to that reported by Connolly et al. (2000), i.e. T6 in 92.5% of patients.

Aortic Arch: In the current study, the concavity of the aortic arch occurred most frequently at the T4 vertebral level. Regarding the limits of the aortic arch, no consistent definition was found in the literature: Sinnatamby (2011) referenced it to the manubriosternal junction.

Pulmonary Trunk Bifurcation: The current study showed the pulmonary trunk to bifurcate at the T6 vertebral level. According to Moore et al. (2014) it occurs in the plane of the sternal angle.

Brachiocephalic Artery: Standard texts highlight its vertebral level as being at the convexity of the aortic arch just posterior to the center of the manubrium of the sternum (T3/4 level) (Standring, 2016): the current study supports this.

Left Common Carotid Artery: Anatomical texts locate it at the vertebral level from which the brachiocephalic artery originates (T3/4) (Osborn, 1998 cited in Standring, 2016): this was confirmed in the current study.

Left Subclavian Artery: Standard texts mention two parts of the left subclavian artery, the first originating at the T3/4 level and the second arising at the C3-6 vertebral level behind the scalenus anterior (Standring, 2016). In the current study the subclavian artery arose at the T3/4 vertebral level in 28.64%.

Right Common Carotid and Subclavian Arteries: Anatomical reference texts place its origin behind the upper border of the right sternoclavicular joint (T1 vertebral level) (Standring, 2016). In the current study the most frequent level was T2 (31.16%), with a further 28.14% at T1/2.

Carina: Its vertebral level in standard texts (Drake et al. 2015) differs slightly from that observed in the present study, i.e. T4/5.

Azygos Vein: The vertebral level at which the azygos vein meets the SVC could not be clearly identified on the CT scans, so the level at which the azygos vein receives the last intercostal vein was identified; this was the T8 level. In contrast, Mirjalili et al. (2012a) located the junction of the azygos vein with the SVC at vertebral level T5.

Cardiac Apex: The current observations showed that this most frequently occurred at the T9 level. Ellis and Mahadeva (2010), among others, state that the cardiac apex is in the left fifth intercostal space in the mid-clavicular line, approximately 9cm from the mid-line: this definition is considered a useful and important surface landmark.

Aortic Hiatus: In the present study the aorta pierced the diaphragm at T11, different from the T12 reported by Pak et al. (2016) in an Iranian population and in some anatomy texts (Standring, 2016; Sinnatamby, 2011).

Inferior Vena Cava: According to Snell (2012) and Sinnatamby (2011) the IVC crosses the diaphragm at T8, while Mirjalili et al. (2012a) stated T11, as did Pak et al. (2016) in an Iranian population. In the present study it passed through the diaphragm at T10, similar to the level given by McMinn (1998).

Gastroesophageal Junction (GEJ): The most common vertebral level of the GEJ in the present study was T10, in contrast to the level of T11 reported by Mirjalili et al. (2012b) in 49% of their population and Pak et al. (2016) in 65% in their Iranian population.

It is acknowledged that the present study had some limitations, including the height, weight, body composition data and other factors that could affect the relationships of the structures studied with their vertebral levels. It is suggested that these should be considered in future studies to determine whether they influence the relationship between thoracic structures and their vertebral levels.

Conclusion:

Revisiting human surface anatomy using modern imaging techniques in specific populations and incorporating the findings into anatomical and clinical texts would help clinicians to improve their clinical skills. In light of new evidence, thoracic surface anatomy needs to be redefined to increase its clinical application and value. Furthermore, it should be revisited in healthy populations and compared with specific pathologies as in the current study.

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ACKNOWLEDGMENTS

We would like to thank Ahsan Shafiq, Chief Medical Transcriptionist at the Northwest General Hospital, and the Research Center for their invaluable assistance in obtaining the CT scans.

Conflict of Interest
None

Funding
None

Informed Consent

This study received approval from the Northwest General Hospital and Research Center Peshawar Ref No. NwGH/Res/Eth/2039.

Contributions

The study was designed by MB and RS; MB, MIM and AK collected the data, which were analyzed by MJK; the manuscript was written by MB and RS.

Table 1. Binary logistic regression analysis of vertebral levels within the lung pathology group.

Variable	Odds ratio	95% CI	p-value adjusted for gender
Aortic Hiatus	1.1528	(0.9526, 1.3951)	0.141
Azygos Vein	1.0088	(0.8799, 1.1566)	0.900
Brachiocephalic Artery	1.2952	(0.9974, 1.6818)	**0.049**
Gastroesophageal Junction	1.2415	(1.0303, 1.4959)	**0.020**
Left Common Carotid Artery	1.0996	(0.8876, 1.3622)	0.384
Right Common Carotid Artery	1.4238	(1.0861, 1.8664)	**0.009**
Left Subclavian Artery	1.1055	(0.8929, 1.3686)	0.356
Right Subclavian Artery	1.4238	(1.0861, 1.8664)	**0.009**
Pulmonary Trunk Bifurcation	1.2688	(0.9982, 1.6129)	**0.049**
SVC-Right Atrial Junction	1.0844	(0.8755, 1.3430)	0.457
Carina	1.4456	(1.1133, 1.8771)	**0.004**
Cardiac Apex	1.1812	(0.9907, 1.4083)	0.060
Manubriosternal Junction	1.0248	(0.5582, 1.8816)	0.146
Xiphisternal Joint	0.9515	(0.7800, 1.1607)	0.623
IVC crossing the Diaphragm	1.2206	(1.0214, 1.4586)	**0.025**
Aortic Arch	1.3150	(0.9612, 1.7990)	0.083
Brachiocephalic Veins Junction	1.0569	(0.8535, 1.3089)	0.611

SVC; Superior vena cava, IVC; Inferior vena cava

Table 2. Comparison of the vertebral level of thoracic structures between healthy individuals and those with lung pathology. The level with the greatest number of individuals is highlighted for each parameter.

Parameter	Level	Total		Healthy		Patient	
		N	%	N	%	N	%
Aortic Hiatus (AH)							
	T9	4	2.01	3	3	1	1.01
	T9-10	2	1.01	1	1	1	1.01
	T10	25	12.56	16	16	9	9.09
	T10-11	30	15.08	18	18	12	12.12
	T11	**59**	**29.65**	**22**	**22**	**37**	**37.37**
	T11-12	32	16.08	20	20	12	12.12
	T12	43	21.61	18	18	25	25.25
	T12-L1	3	1.51	2	2	1	1.01
Azygos Vein (AV)							
	T5-6	2	1.01	2	2	0	0.00
	T6	7	3.52	3	3	4	4.04
	T6-7	3	1.51	3	3	0	0.00
	T7	12	6.03	5	5	7	7.07
	T7-8	9	4.52	4	4	5	5.05
	T8	**28**	**14.07**	**15**	**15**	**13**	**13.13**
	T8-9	10	5.03	5	5	5	5.05
	T10	20	10.05	13	13	7	7.07
	T10-11	2	1.01	1	1	1	1.01
	T11	5	2.51	1	1	4	4.04
Brachiocephalic Artery (BA)							
	T2	4	2.01	1	1	3	3.03
	T2-3	21	10.55	14	14	7	7.07
	T3	50	25.13	27	27	23	23.23
	T3-4	**68**	**34.17**	**40**	**40**	**28**	**28.28**
	T4	48	24.12	14	14	34	34.34
	T4-5	5	2.51	4	4	1	1.01
	T5	2	1.01	0	0	2	2.02
Gastroesophageal Junction (GEJ)							
	T7-8	1	0.50	0	0	1	1.01
	T8	2	1.01	1	1	1	1.01
	T8-9	5	2.51	3	3	2	2.02
	T9	35	17.59	24	24	11	11.11
	T9-10	24	12.06	12	12	12	12.12
	T10	**68**	**34.17**	**39**	**39**	**29**	**29.29**
	T10-11	23	11.56	9	9	14	14.14

	T11	29	14.57	8	8	21	21.21
	T11-12	7	3.52	3	3	4	4.04
	T12	1	0.50	1	1	0	0.00
Left Common Carotid Artery (LCCA)							
	T1-2	4	2.01	3	3	1	1.01
	T2	14	7.04	4	4	10	10.10
	T2-3	27	13.57	16	16	11	11.11
	T3	50	25.13	27	27	23	23.23
	T3-4	**57**	**28.64**	**35**	**35**	**22**	**22.22**
	T4	40	20.10	11	11	29	29.29
	T4-5	5	2.51	4	4	1	1.01
	T5	1	0.50	0	0	1	1.01
Right Common Carotid Artery (RCCA)							
	T1	19	9.55	13	13	6	6.06
	T1-2	56	28.14	37	37	19	19.19
	T2	**62**	**31.16**	**21**	**21**	**41**	**41.41**
	T2-3	44	22.11	23	23	21	21.21
	T3	10	5.03	4	4	6	6.06
	T3-4	2	1.01	0	0	2	2.02
Left Subclavian Artery (LSCA)							
	T1-2	4	2.01	3	3	1	1.01
	T2	14	7.04	4	4	10	10.10
	T2-3	28	14.07	17	17	11	11.11
	T3	49	24.62	26	26	23	23.23
	T3-4	**57**	**28.64**	**35**	**35**	**22**	**22.22**
	T4	40	20.10	11	11	29	29.29
	T4-5	5	2.51	4	4	1	1.01
	T5	1	0.50	0	0	1	1.01
Right Subclavian Artery (RSCA)							
	T1	19	9.55	13	13	6	6.06
	T1-2	56	28.14	37	37	19	19.19
	T2	**62**	**31.16**	**21**	**21**	**41**	**41.41**
	T2-3	44	22.11	23	23	21	21.21
	T3	10	5.03	4	4	6	6.06
	T3-4	2	1.01	0	0	2	2.02
Pulmonary Trunk Bifurcation (PTB)							
	T4	2	1.01	0	0	2	2.02
	T4-5	8	4.02	7	7	1	1.01
	T5	44	22.11	25	25	19	19.19
	T5-6	36	18.09	20	20	16	16.16
	T6	**83**	**41.71**	**39**	**39**	**44**	**44.44**
	T6-7	18	9.05	6	6	12	12.12

	T7	7	3.52	2	2	5	5.05
	T8	1	0.50	1	1	0	0.00
Superior Vena Cava junction with the Right Atrium (SVC-RA)							
	T4	1	0.50	0	0	1	1.01
	T4-5	3	1.51	2	2	1	1.01
	T5	31	15.58	14	14	17	17.17
	T5-6	28	14.07	16	16	12	12.12
	T6	**85**	**42.71**	**50**	**50**	**35**	**35.35**
	T6-7	24	12.06	9	9	15	15.15
	T7	20	10.05	7	7	13	13.13
	T7-8	2	1.01	1	1	1	1.01
	T8	2	1.01	1	1	1	1.01
Tracheal Bifurcation (TB) (Carina)							
	T3-4	3	1.51	1	1	2	2.02
	T4	34	17.09	24	24	10	10.10
	T4-5	34	17.09	20	20	14	14.14
	T5	**89**	**44.72**	**41**	**41**	**48**	**48.48**
	T5-6	24	12.06	12	12	12	12.12
	T6	10	5.03	1	1	9	9.09
	T6-7	1	0.50	1	1	0	0.00
	T7	1	0.50	0	0	1	1.01
Cardiac Apex (CA)							
	T7	2	1.01	2	2	0	0.00
	T7-8	2	1.01	0	0	2	2.02
	T8	26	13.07	12	12	14	14.14
	T8-9	17	8.54	10	10	7	7.07
	T9	**62**	**31.16**	**38**	**38**	**24**	**24.24**
	T9-10	30	15.08	16	16	14	14.14
	T10	43	21.61	17	17	26	26.26
	T10-11	8	4.02	2	2	6	6.06
	T11	7	3.52	1	1	6	6.06
	T11-2	1	0.50	1	1	0	0.00
Manubriosternal Junction (MJ)							
	T3	3	1.51	1	1	2	2.02
	T3-4	16	8.04	8	8	8	8.08
	T4	32	16.08	15	15	17	17.17
	T4-5	34	17.09	14	14	20	20.20
	T5	**62**	**31.16**	**38**	**38**	**24**	**24.24**
	T5-6	15	7.54	8	8	7	7.07
	T6	9	4.52	5	5	4	4.04
	T6-7	1	0.50	1	1	0	0.00
	T7	1	0.50	1	1	0	0.00

Xiphisternal Joint (XJ)							
	T6-7	1	0.50	0	0	1	1.01
	T7	3	1.51	1	1	2	2.02
	T7-8	2	1.01	1	1	1	1.01
	T8	17	8.54	7	7	10	10.10
	T8-9	22	11.06	9	9	13	13.13
	T9	**70**	**35.18**	**41**	**41**	**29**	**29.29**
	T9-10	32	16.08	15	15	17	17.17
	T10	34	17.09	16	16	18	18.18
	T10-11	6	3.02	2	2	4	4.04
	T11	2	1.01	1	1	1	1.01
Inferior Vena Cava crossing the Diaphragm (IVC-D)							
	T7	1	0.50	1	1	0	0.00
	T7-8	1	0.50	0	0	1	1.01
	T8	14	7.04	8	8	6	6.06
	T8-9	9	4.52	7	7	2	2.02
	T9	52	26.13	30	30	22	22.22
	T9-10	28	14.07	12	12	16	16.16
	T10	**63**	**31.66**	**32**	**32**	**31**	**31.31**
	T10-11	11	5.53	6	6	5	5.05
	T11	12	6.03	1	1	11	11.11
	T11-12	3	1.51	1	1	2	2.02
	T12	1	0.50	1	1	0	0.00
Aortic Arch (AA)							
	T3	26	13.07	14	14	12	12.12
	T3-4	29	14.57	17	17	12	12.12
	T4	**115**	**57.79**	**58**	**58**	**57**	**57.58**
	T4-5	20	10.05	6	6	14	14.14
	T5	9	4.52	4	4	5	5.05
Brachiocephalic Veins Junction (BVJ)							
	T1-2	4	2.01	3	3	1	1.01
	T2	10	5.03	3	3	7	7.07
	T2-3	18	9.05	9	9	9	9.09
	T3	43	21.61	23	23	20	20.20
	T3-4	**58**	**29.15**	**34**	**34**	**24**	**24.24**
	T4	55	27.64	22	22	33	33.33
	T4-5	7	3.52	4	4	3	3.03
	T5	1	0.50	0	0	1	1.01

Table 3. Comparison of the vertebral levels for specific thoracic structures in the present study and those reported previously.

Parameters	**Level**	**Present study (%)**	**Previous studies (%)**	**Reference**
Aortic Hiatus	T11 T12	29.7 21.6	24.5 62	Mirjalili et al. (2012a) Pak et al. (2016)
Pulmonary Trunk Bifurcation	T6	41.7	42	Uzun et al. (2015)
SVC junction with Right Atrium	T6	42.7	92.5	Connolly et al. (2000)
Carina	T5	44.7	40	Shen et al. (2016)
Xiphisternal Joint	T9	35.2	46 56	Mirjalili et al. (2012a) Pak et al. (2016)
IVC crossing Diaphragm	T10 T11	31.7 6.0	39 65	Shen et al. (2016) Pak et al. (2016)
Aortic Arch	T4	57.8	30	Shen et al. (2016)

SVC; superior vena cava, IVC; inferior vena cava

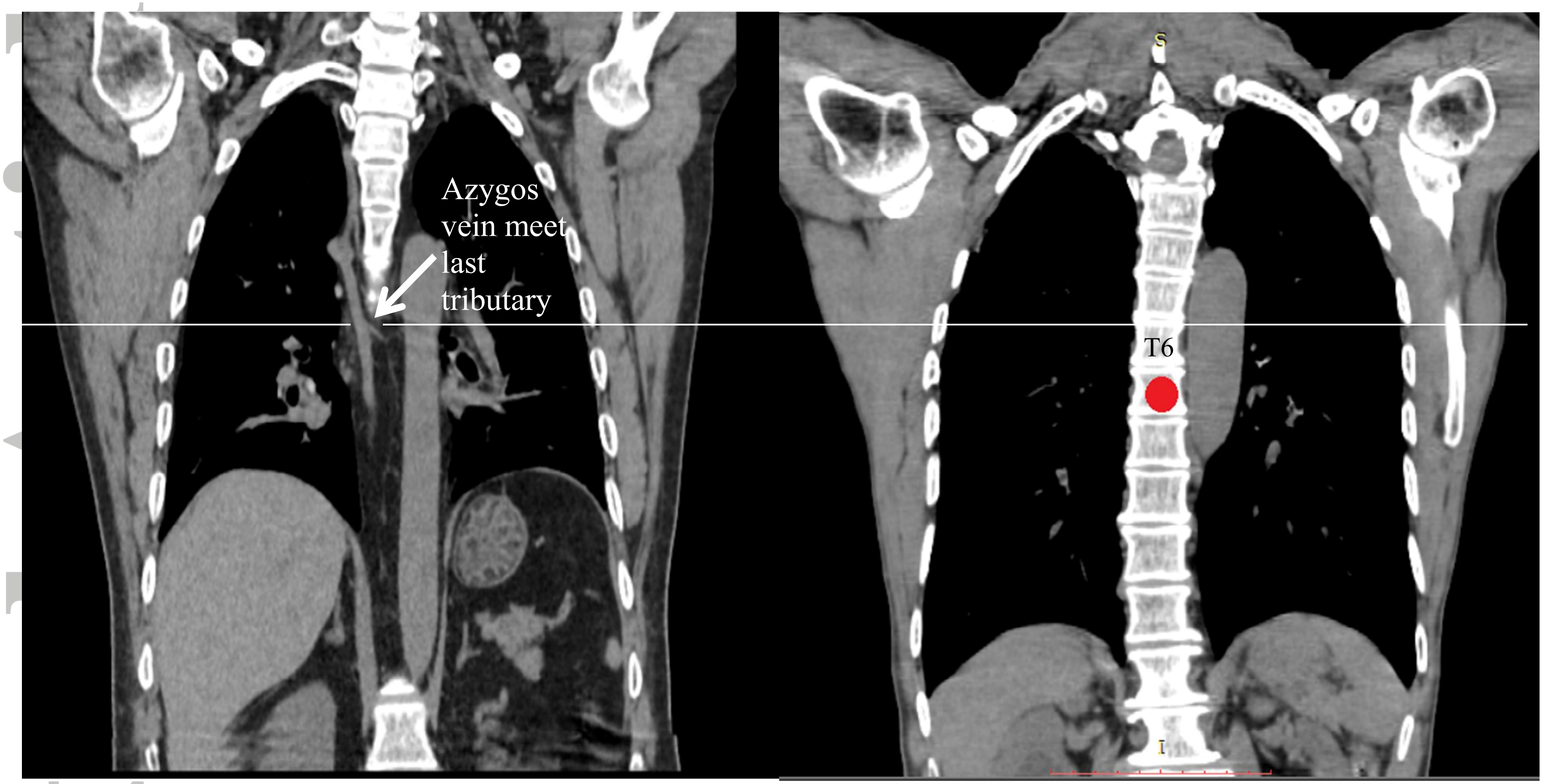

Figure 1. The vertebral level at which the azygos vein receives its last tributary.

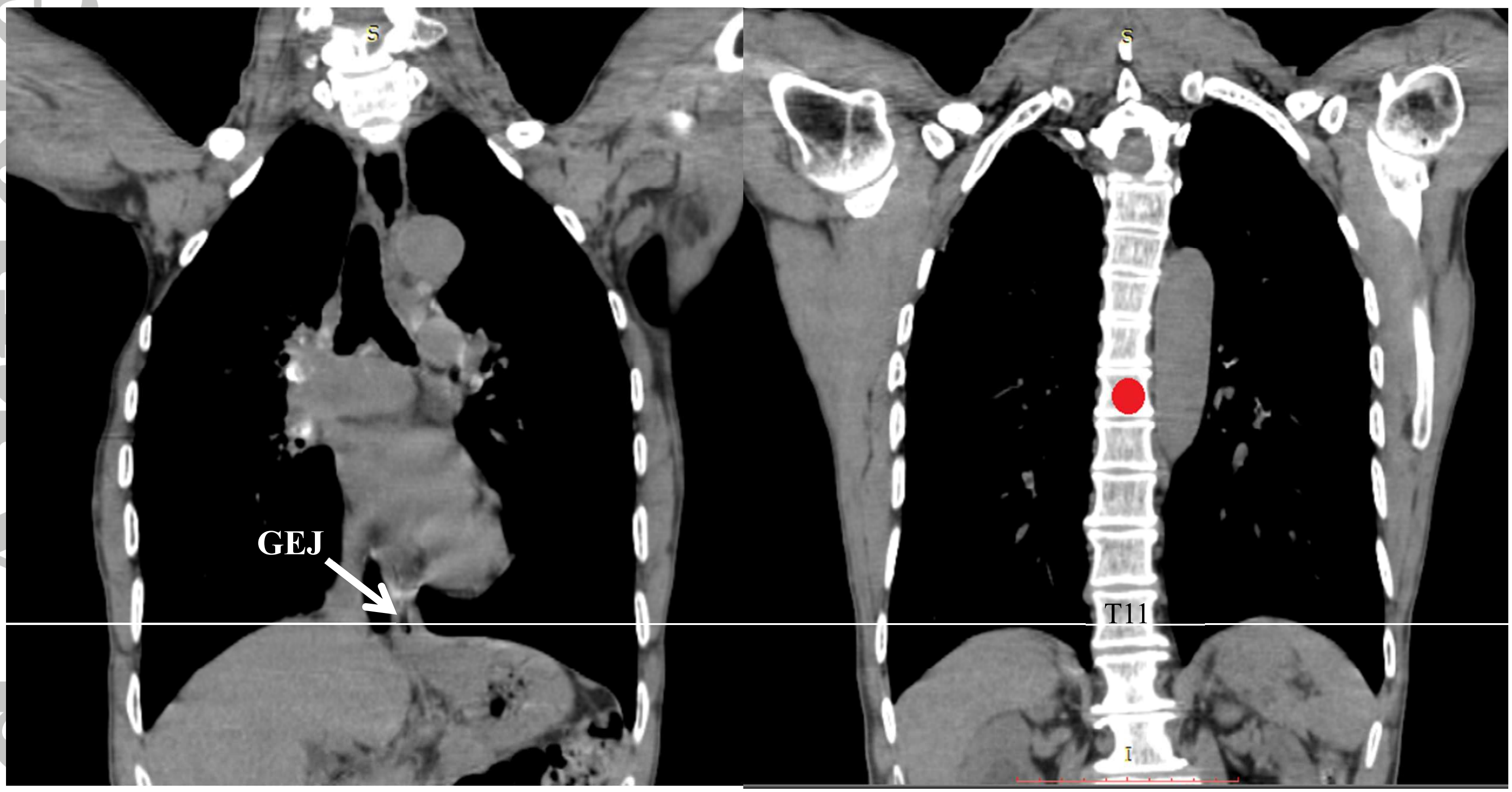

Figure 2. The vertebral level at which the esophagus meets the stomach at the cardiac notch (GEJ).

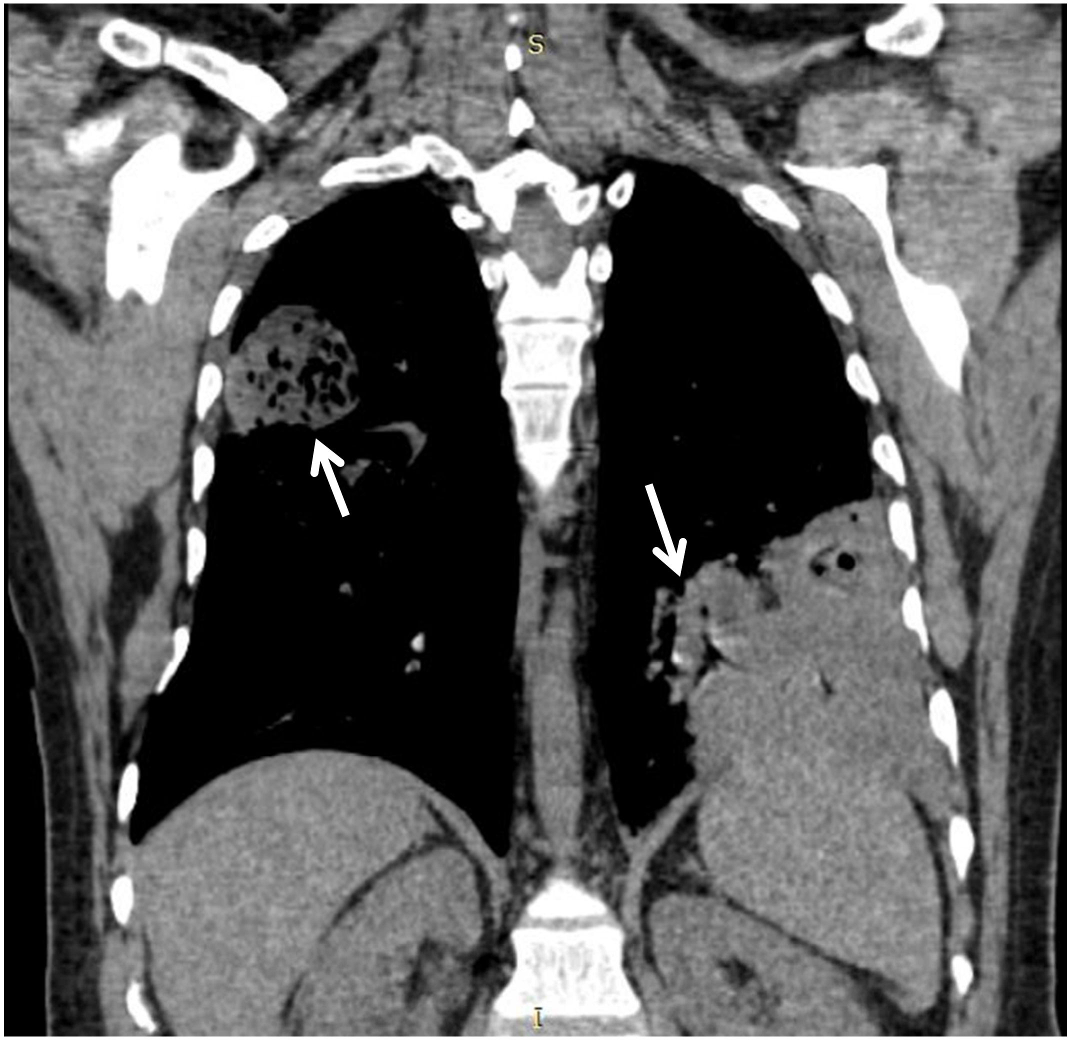

Figure 3. Coronal scan showing scar formation in both right and left lungs.

Figure 4. Axial scan showing cavity formation in the right lung.

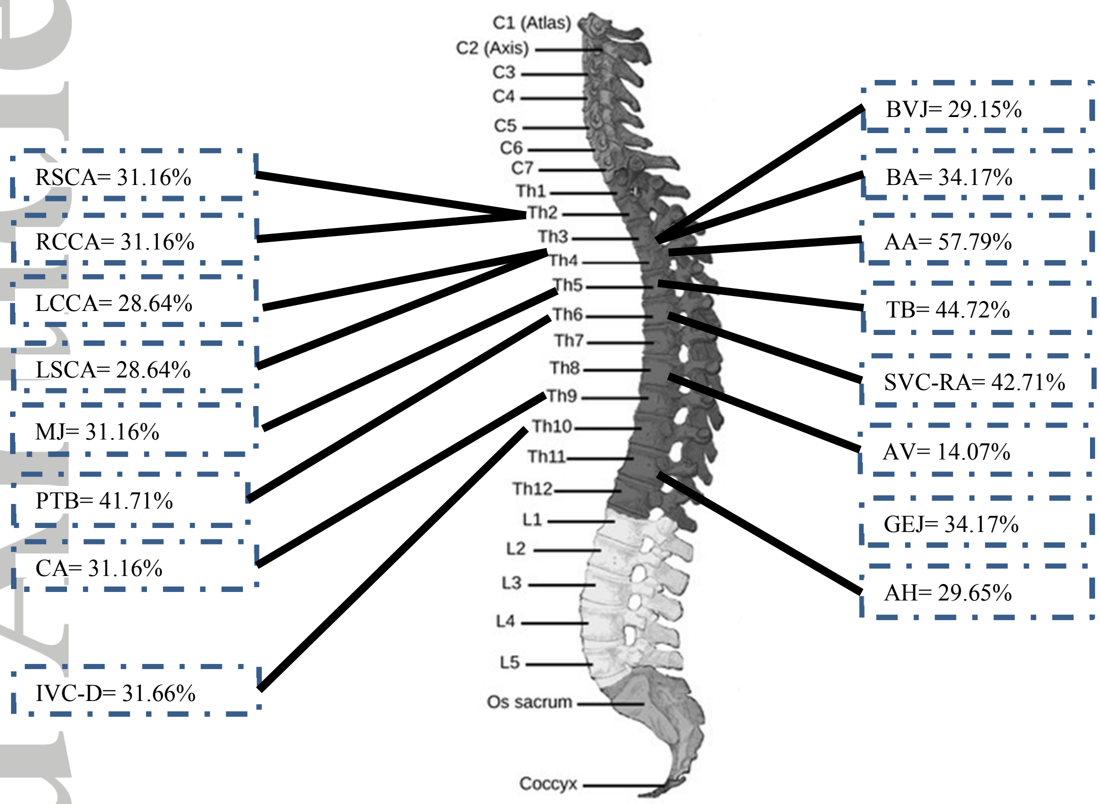

Figure 5. Predominant location of thoracic structures in relation to vertebral level in all individuals (RSCA, right subclavian artery; RCCA, right common carotid artery; LCCA, left common carotid artery; LSCA, left subclavian artery; MJ, manubriosternal junction; PTB, pulmonary trunk bifurcation; CA, cardiac apex; IVC-D, inferior vena cava crossing the diaphragm; BVF, brachiocephalic veins junction; BA, brachiocephalic artery; AA, aortic arch; TB, tracheal bifurcation (carina); SVC-RA, superior vena cava junction with the right atrium; AV, azygos vein; GEJ, gastroesophageal junction; AH, aortic hiatus).