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R. Lynch, G. Pitson, D. Ball, L. Claude, David Sarrut. Computed tomographic atlas for the new international lymph node map for lung cancer: A radiation oncologist perspective. *Practical Radiation Oncology: An official journal of the American Society for Radiation Oncology*, 2012, 3 (1), pp.54-66. 10.1016/j.prro.2012.01.007 . hal-00796801

HAL Id: hal-00796801

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Submitted on 20 Nov 2018

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Special Article

Computed tomographic atlas for the new international lymph node map for lung cancer: A radiation oncologist perspective

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Received 24 November 2011; revised 20 January 2012; accepted 23 January 2012

Abstract

Purpose: To develop a reproducible definition for each mediastinal lymph node station based on the new TNM classification for lung cancer.

Methods and Materials: This paper proposes an atlas using the new international lymph node map used in the seventh edition of the TNM classification for lung cancer. Four radiation oncologists and 1 diagnostic radiologist were involved in the project to put forward a reproducible radiologic description for the lung lymph node stations.

Results: The International Association for the Study of Lung Cancer lymph node definitions for stations 1 to 11 have been described and illustrated on axial computed tomographic scan images using a certified radiotherapy planning system.

Conclusions: This atlas will assist both diagnostic radiologists and radiation oncologists in accurately defining the lymph node stations on computed tomographic scan in patients diagnosed with lung cancer.

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Introduction

Lung cancer is the fifth most common cancer and is the leading cause of death due to cancer in Australia. Each year more than 8000 people are diagnosed with lung cancer in Australia.

The clinical and pathologic involvement of lymph nodes in lung cancer has been described using a nodal map since the 1960s. The descriptors for the nodal map must be universally accepted to permit outcome comparison and to assist in determining the best treatment for each patient.

The American Joint Committee on Cancer initially adopted the Naruke nodal map for the staging of lung cancer.¹ In 1983, the American Thoracic Society (ATS)² proposed a separate nodal map with some differences in the descriptors for the mediastinal nodal stations. These modifications defined anatomic structures that could be

Conflicts of interest: None.

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easily identified on mediastinoscopy. The Mountain-Dresler³ modification to the ATS map was an attempt to unify the Naruke and ATS nodal maps. The Mountain-Dresler map, however, was not universally accepted.

The lung cancer staging project was established by the International Association for the Study of Lung Cancer (IASLC) in 1998. One of the outcomes of this project was the development of a consensus node map that resolved differences between the Japanese and American classifications. The new map was published by Rusch et al⁴ and incorporated into the seventh edition of the TNM staging system for lung cancer published by the International Union Against Cancer and the American Joint Committee on Cancer.

Conformal radiotherapy treatment planning requires accurate delineation of various anatomic structures including lymph node regions. Various atlases have been created to aid in treatment planning. In 2005, Chapet et al⁵ published an atlas from the University of Michigan, defining on CT images the mediastinal lymph node stations for lung cancer. This atlas was based on the prior map and has therefore been superseded by the new IASLC lymph node map.

This paper aims to create a computed tomographic (CT) atlas based on the new IASLC lymph node map. It is hoped that this atlas will assist radiation oncologists in accurately and reproducibly outlining mediastinal lymph node stations when treating lung cancer.

Materials and methods

CT scan selection

Five patients diagnosed with non-small-cell lung cancer undergoing radical radiotherapy treatment were selected, and the data were collected as part of an approved protocol at the Centre Léon Bérard. All patients were scanned in the treatment position, supine with arms positioned above the head. The CT scans were performed using intravenous contrast. The nodal stations were delineated on all 5 patients to ensure reproducibility using the described definitions. One patient whose axial CT slice interval was 2 mm was selected for the published atlas.

Delineation procedure

The lymph node stations were initially delineated by 1 radiation oncologist using the Varian Eclipse planning system (Varian Medical Systems, Palo Alto, CA). All of the images were then reviewed by 3 further radiation oncologists and a diagnostic radiologist to establish a consensus for delineating the nodal stations using the IASLC recommendations. The nodal stations were deli-

neated using standard CT window setting as recommended by Harris et al.⁶ The soft tissue settings, to define the anatomic structures in the mediastinum, used a window width of 400 and a level of +20. The lung setting, with a window width of 850 and a level of -750, was used for stations 9 and 11 to define the anterior, posterior, and lateral boundaries.

The volumes were delineated using the new IASLC node station definitions. It was felt that there were some ambiguities submitted in the descriptions of several node stations and in some cases decisions were made to create ad hoc boundaries that would be consistent with the intent of the IASLC definitions. The prior atlas by Chapet et al⁵ was a comprehensive document and some additional boundaries were based on their recommendations. These variations from the IASLC definitions are highlighted in the relevant sections of the Results. In general, organs and vessels were excluded from node stations.

Results

Station 1: Low cervical, supraclavicular, and sternal notch nodes

The upper border of stations 1R and 1L is the lower margin of the cricoid cartilage (Fig 1A). The lower border for this nodal station is the clavicles bilaterally, while in the midline it is the upper border of the manubrium. Medially, station 1R and 1L are separated by the midline of the trachea while excluding the thyroid gland.

The remaining borders for station 1 have been previously described by Kepka et al.⁷ The anterior border is defined as the deep surface of the sternomastoid muscle and the deep cervical fascia and posterior parts of the ribs and clavicle excluding sternohyoid and sternothyroid muscles in the lower parts. The posterolateral border is the anterior and lateral border of the anterior scalene muscle, in the lower parts the medial anterior border of the subclavian artery. The posteromedial border is defined by the anterior borders of subclavian artery, vertebral vessels, and esophagus, with medial extension to include the carotid artery and internal jugular vein.

From a radiotherapy perspective, most patients undergoing radical treatment are planned and treated with arms above their head. As the clavicles mark the lateral inferior limits of station 1 and their lateral position will alter with the degree of arm elevation, this could result in a significant variation in the position of the inferior border. We note that this may lead to some case by case variation inferolaterally when delineating station 1.

Where there is superior or inferior overlap between station 1 and station 3p, the posterior limit of station 1 is defined for the purposes of this atlas as an imaginary

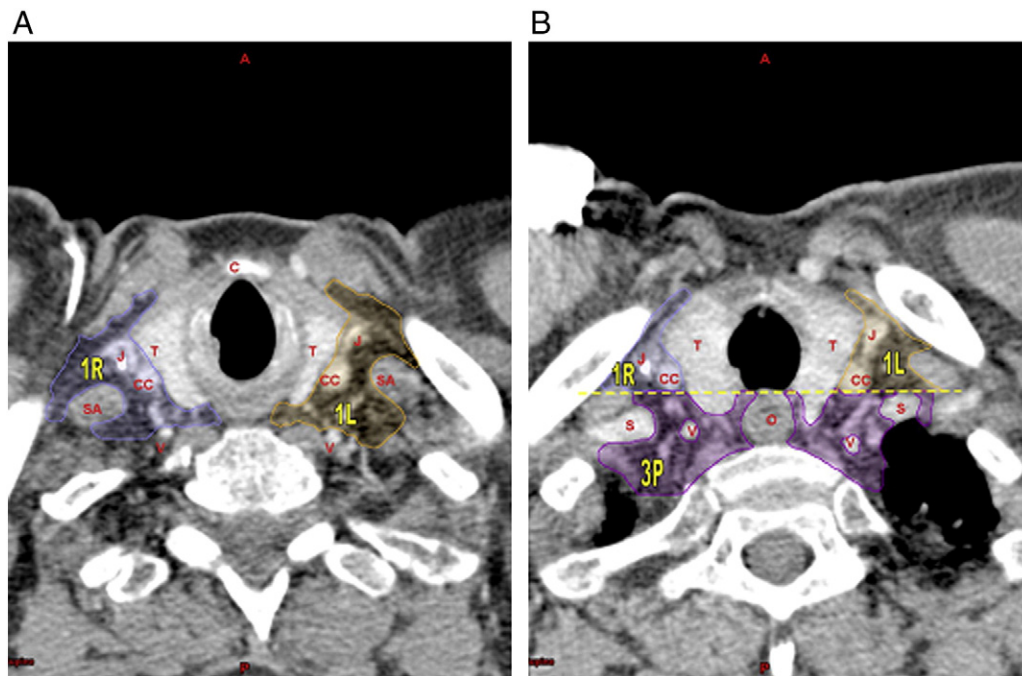


Figure 1 Station 1. (A) Upper border of station 1R and 1L defined as the lower margin of cricoid cartilage. (B) Inferior to the lung apex with the yellow dotted line running along the posterior wall of the trachea and separating 1R and 1L from 3P. Abbreviations: C, cricoid cartilage; CC, common carotid artery; J, internal jugular vein; O, esophagus; S, subclavian artery; SA, scalene anterior muscle; T, thyroid gland; V, vertebral artery.

horizontal line extending along the posterior wall of the trachea (Fig 1B).

Station 2: Upper paratracheal nodes

The IASLC upper border of station 2 is the apex of the lung (right and left side) and pleural space. In the midline, the upper border is the upper border of the manubrium. For station 2 there is a shift in the IASLC definition dividing 2R from 2L, from the midline to the left lateral tracheal border. This is represented in the atlas as a vertical line passing tangentially along the left lateral tracheal border (Fig 2C). For the inferior border, 2R stops at the intersection of the caudal margin of the brachiocephalic vein with the trachea, which can extend obliquely across the trachea. 2L extends less inferiorly to the superior border of the aortic arch. This point is best demonstrated on a sagittal image (Fig 2D).

Inferior to the sternal notch, the anterior border is posterior to the vessels (right subclavian vein, left brachiocephalic vein, right brachiocephalic vein, left subclavian artery, left common carotid artery, and brachiocephalic trunk), which are not included in the nodal station. The anterior border has been defined as an imaginary line drawn to the midpoint of the vessel in the anterior to posterior plane as per Chapet et al⁵ and it is here that station 2 contacts station 3a (Fig 2C).

In the IASLC definition laterally station 2 extends higher, to the lung apex. On axial images above the sternal

notch the anterior border is therefore defined in this atlas as an imaginary horizontal line from the most anterior point of the lung pleura, and the posterior border is an imaginary horizontal line extending from the posterior wall of the trachea (Fig 2A). The size of station 2 can be different, as shown, from the right to left side (Fig 2A, B). Within this superior region of station 2, the anterior border can abut the posterior border of station 1.

Some patients have retrosternal thyroid extension, and in these cases, as for station 1 above, the thyroid is excluded from the lymph node station.

Station 3a: Prevascular nodes

The superior border has been defined as the apex of the chest (right and left side). In order to prevent overlap with station 1 and to assist in delineation on axial CT images, the superior border has been defined for this atlas as the upper border of the manubrium (Fig 3A). Above this point, the nodal stations are covered by stations 1L and 1R. Inferiorly, station 3a stops at the carina. The left brachiocephalic vein is included within station 3a, as per Chapet et al,⁵ until it reaches the superior junction of right and left brachiocephalic vessels (Fig 3B, C).

Posteriorly, the station is limited by station 2R and 2L, but excludes the great vessels. An imaginary line joins the midpoint of the vessel in the anterior to posterior plane. It is here that station 2 contacts station 3a (Fig 3B, C).

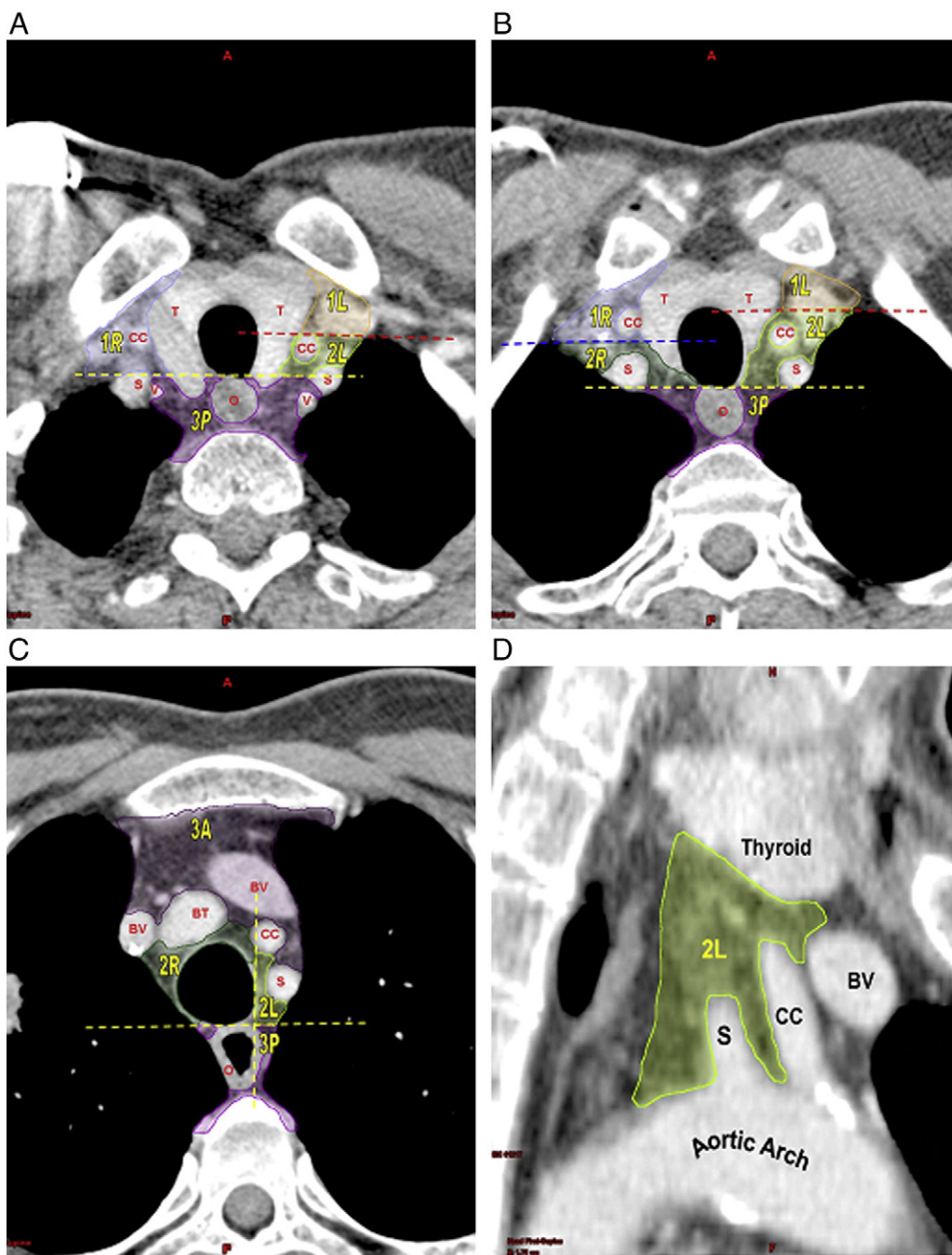


Figure 2 Station 2. (A) and (B) Above the sternal notch, the anterior border on the left is shown by the red dotted line running horizontally from anterior point of left lung pleura separating 1L from 2L. The anterior border on the right is shown by the blue dotted line running horizontally from anterior point of right lung pleura separating 1R from 2R. (C) Vertical yellow dotted line runs along left lateral border of trachea separating 2R from 2L. (D) Sagittal view of station 2L extending inferiorly to the superior border of the aortic arch. Abbreviations: BT, brachiocephalic trunk; BV, brachiocephalic vein; CC, common carotid artery; O, esophagus; S, subclavian artery; T, thyroid gland; V, vertebral artery.

From the top of the aortic arch, station 3a abuts the anterior border of station 6 on the left side of this vessel. The division between the 2 nodal stations is represented by an imaginary horizontal line running from the anterior aspect of the aortic arch. Below the lower border of the aortic arch level, station 3a abuts station 5 (Fig 3D). The posterior border with station 5 is the same as for station

6 with an imaginary horizontal line extending from the anterior wall of the ascending aorta on the left side.

Station 3p: Retrotracheal nodes

As with station 3a, the upper border is the apex of the chest (right and left side). On the midline sagittal image

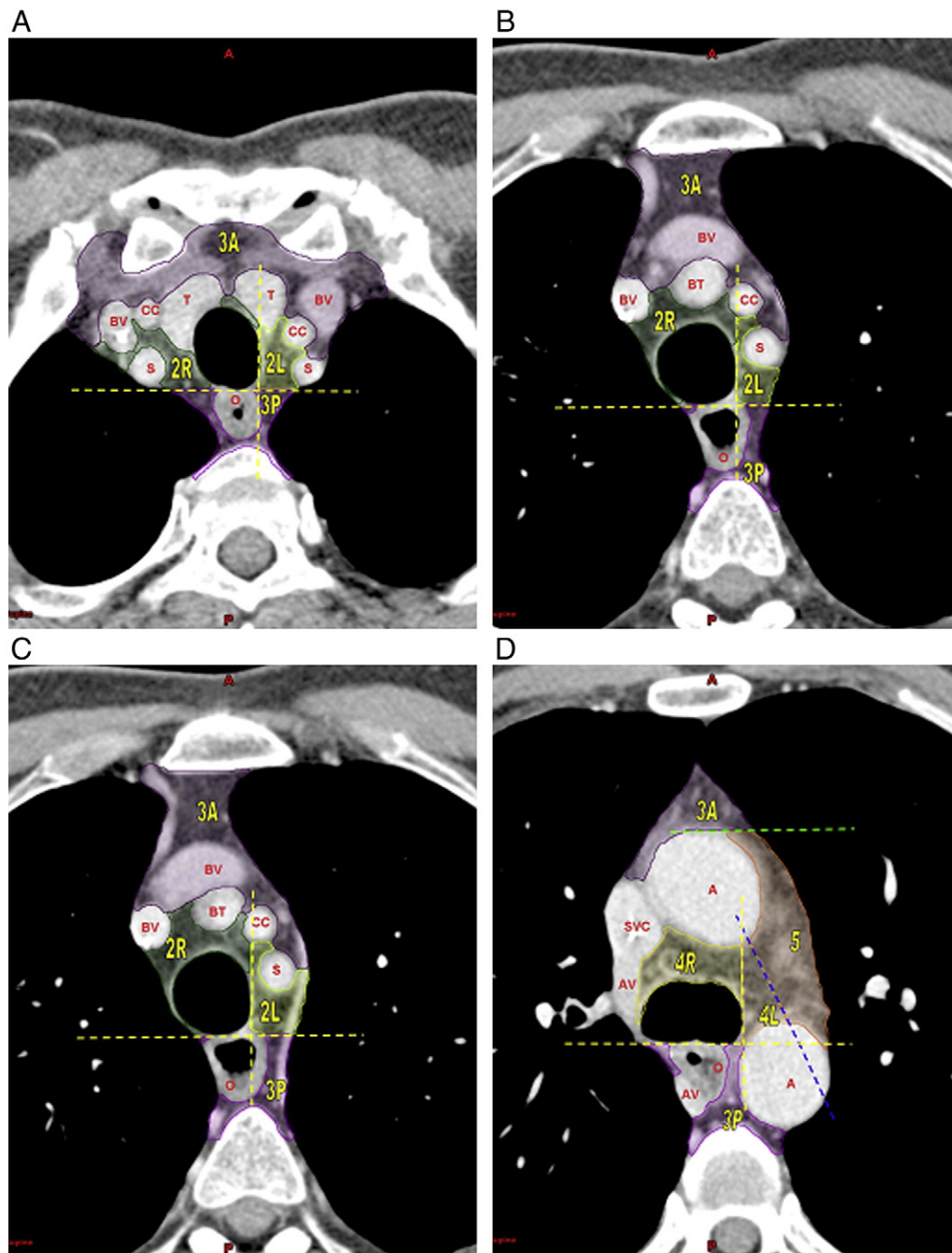


Figure 3 Station 3a. (A) Superior border of station 3a at the upper manubrium. (B) and (C) The left brachiocephalic vein is included in station 3A. Posterior border of 3A is an imaginary line drawn between the midpoint of the vessels separating 3A from 2R and 2L. (D) Below the aortic arch, the posterior border is a green dotted line running horizontally from the anterior border of the ascending aorta separating 3A from 5. Abbreviations: A, aorta; AV, azygos vein; BT, brachiocephalic trunk; BV, brachiocephalic vein; CC, common carotid artery; O, esophagus; S, subclavian artery; SVC, superior vena cava; T, thyroid gland.

of the thorax, the superior border of station 3p can extend above the superior border of station 3a. Often, on axial CT images of the thorax, the apex of the lung on the right and left side are not on the same slice. For the purposes of this atlas, where this is the case, the superior border becomes the more inferior of the 2 apices (Fig 1B).

The inferior border is the carina and it is at this point that station 3p abuts station 7. The anterior border is an imaginary horizontal line extending along the posterior wall of the trachea (Fig 4A). The delineation of station 3p is limited to the soft tissues surrounding the esophagus with the esophagus being excluded from this nodal station.

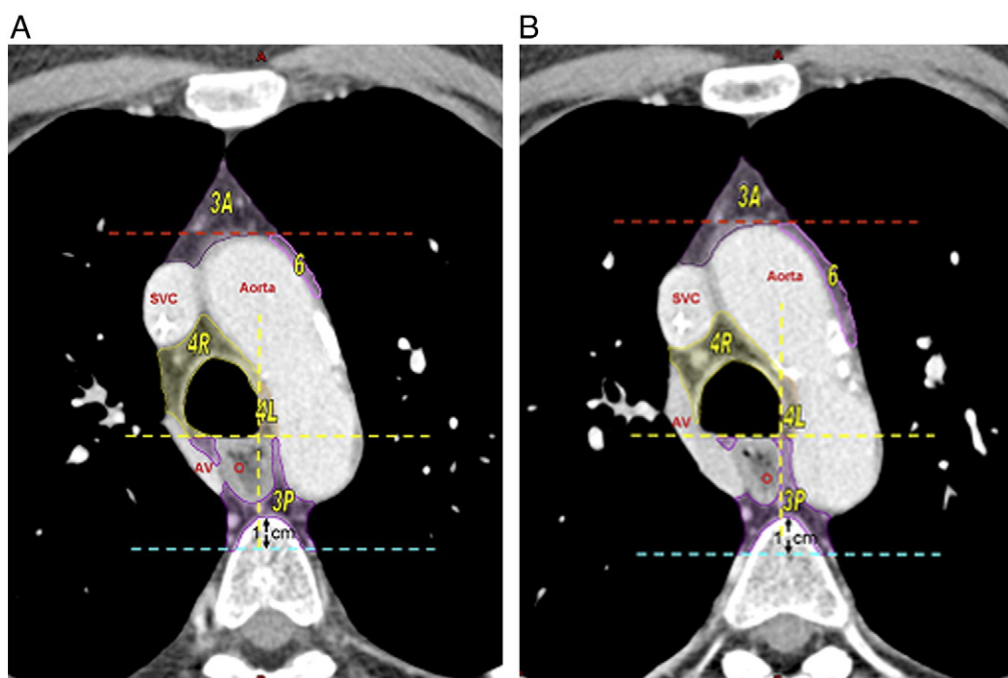


Figure 4 Station 3p. (A) and (B) The anterior border is represented by a horizontal yellow dotted line running along the posterior wall of the trachea separating 4R and 4L from 3P. The posterior border extends 1 cm posteriorly from the anterior aspect of the vertebral body shown by a horizontal blue line. Abbreviations: AV, azygos vein; O, esophagus; SVC, superior vena cava.

On the right lateral side of 3p, the azygos vein as it moves anteriorly is also excluded from the nodal station, as it is for station 4R. The lateral border at these levels should be the medial border of the azygos vein. Elsewhere, the lateral border is the pleural envelope (Fig 4B).

The posterior border is delineated along the anterior and lateral borders of the vertebral body, as described by Chapet et al,⁵ until it reaches an imaginary horizontal line running 1 cm posterior to the anterior aspect of the vertebral body (Fig 4A, B).

Station 4R: Right lower paratracheal nodes

The superior border is at the intersection of the caudal margin of the brachiocephalic vein with the trachea. This can be difficult to identify on axial CT images. Essentially station 4R continues on from station 2R. The inferior border is the lower border of the azygos vein. This anatomic point is best identified on a sagittal image at this level (Fig 5A). The medial border of station 4R is defined as an imaginary line running vertically from the left lateral tracheal border. This is the same medial border as was described for station 2R. On the right side, superiorly it is within the pleural envelope and more inferiorly medial to the arch of the azygos vein. The posterior border is the same as for station 2R, an imaginary horizontal line extending from the posterior wall of the trachea.

The anterior border is the superior vena cava (SVC) and aorta. Between the SVC and aorta station 4R has been

delineated for this atlas as extending halfway between the 2 vessels (Fig 5B).

Station 4L: Left lower paratracheal nodes

Station 4L includes nodes to the left lateral border of the trachea and is medial to the ligamentum arteriosum. The upper border is from the superior border of the aortic arch, being a direct continuation from station 2L (Fig 6A). The lower border is the upper margin of the left main pulmonary artery. The posterior border is an imaginary horizontal line extending from the posterior wall of the trachea. The anterior border, superiorly, is the aorta arch and below this the ascending aorta. For the lateral margin it is the medial aspect of the aortic arch initially and below the arch, the ligamentum arteriosum. This is represented as an imaginary line from the most posterior part of the ascending aorta to the most anterior part of the descending aorta. It is here that station 4L is in contact with station 5 (Fig 6B).

Station 5: Aortopulmonary window nodes

Superiorly, station 5 begins at the lower border of the aortic arch. The IASLC has defined the inferior border as the upper rim of the left main pulmonary artery. There are not a large number of nodes located in the region designated as station 5. There is, however, an area below this

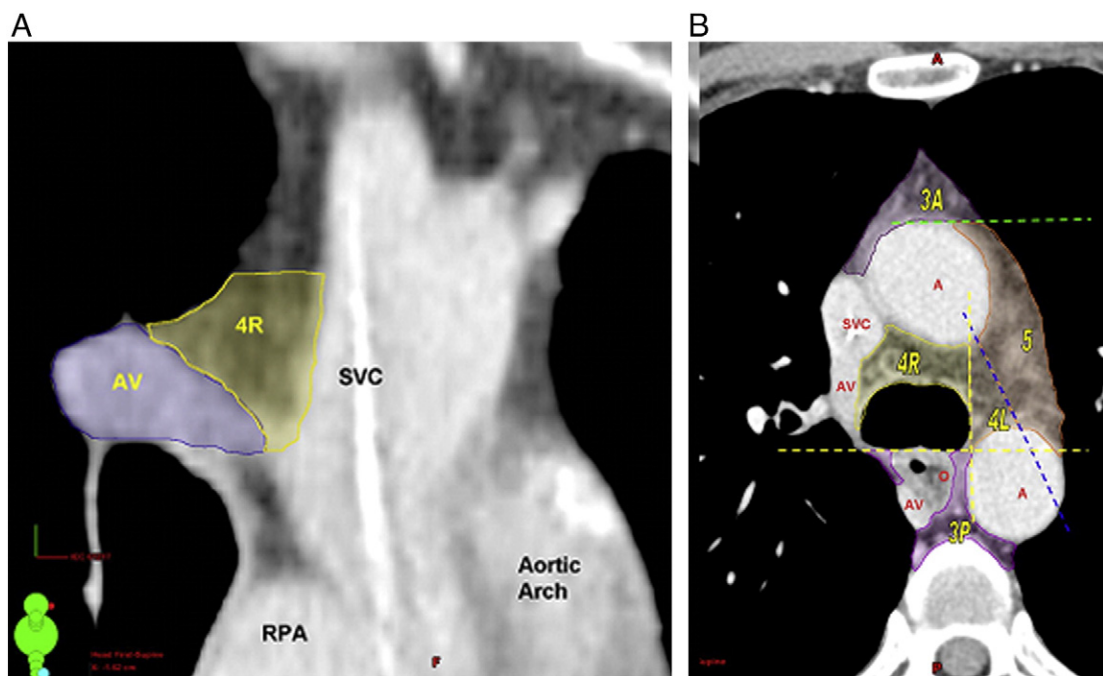


Figure 5 Station 4R. (A) Sagittal image of station 4R. The inferior border is the lower border of the azygos vein. (B) Anterior border below the arch of the aorta is the superior vena cava and the ascending aorta. The vertical yellow dotted line runs along left lateral border of trachea separating 4R from 4L. Abbreviations: A, aorta; AV, azygos vein; O, esophagus; RPA, right pulmonary artery; SVC, superior vena cava.

IASLC-defined inferior border, lateral to the ascending aorta and left pulmonary artery, also at low risk of nodal involvement. The atlas proposes extending the inferior border of station 5 to the level of the carina. This point is

readily reproducible on CT imaging and corresponds with the lower level for station 3a (Fig 7B).

The medial border of station 5 is the ligamentum arteriosum. This structure is difficult to visualize on CT

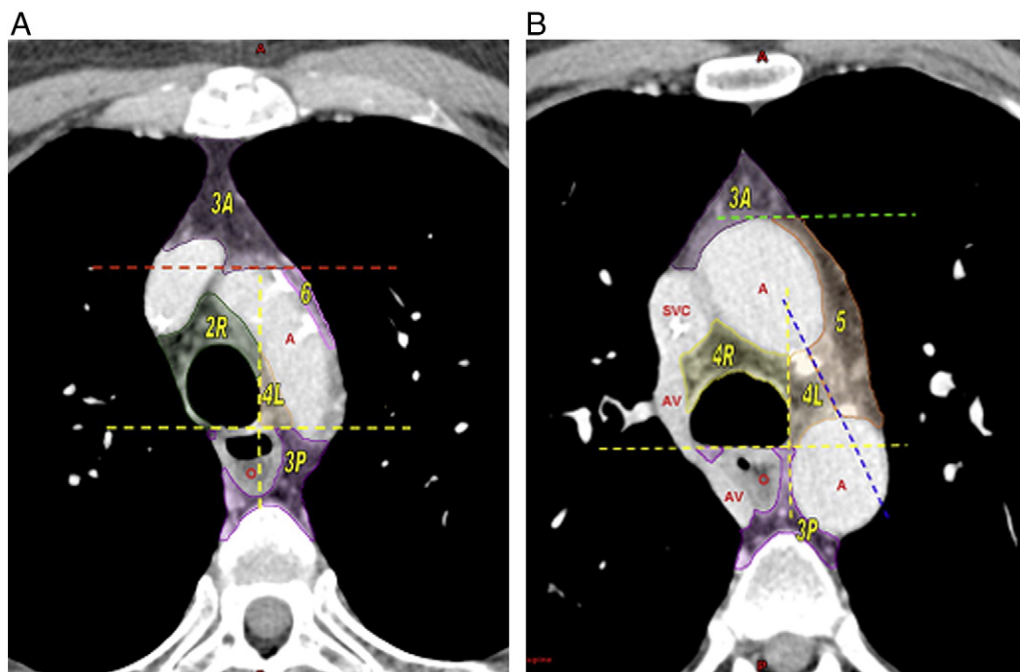


Figure 6 Station 4L. (A) The vertical yellow dotted line running along the left lateral border of the trachea separates 2R from 4L. Superiorly the lateral border of station 4L is the aortic arch. (B) Below the aortic arch, the lateral border of station 4L is represented by the blue dotted line running from the most posterior point of the ascending aorta to the most anterior point of the descending aorta separating 4L from 5. Abbreviations: A, aorta; AV, azygos vein; O, esophagus; SVC, superior vena cava.

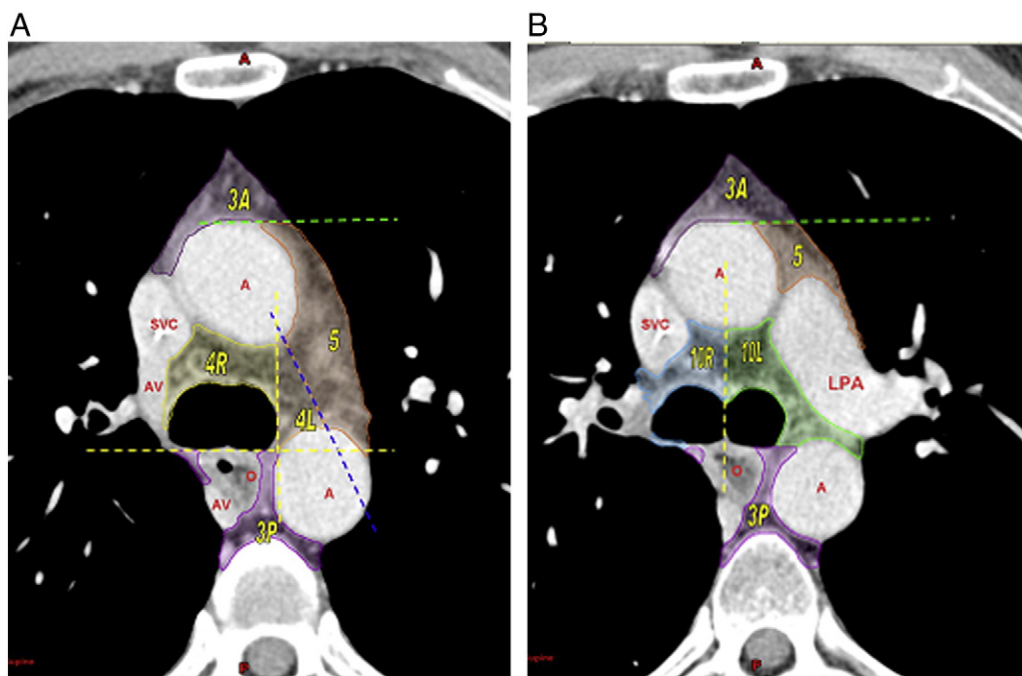


Figure 7 Station 5. (A) The medial border of station 5 is the ligamentum arteriosum represented by the blue dotted line running from the most posterior point of the ascending aorta to the most anterior point of the descending aorta and separates 4L from 5. (B) The anterior border is shown by the green dotted line running horizontally from the anterior border of the ascending aorta separating 3A from 5. Abbreviations: A, aorta; AV, azygos vein; LPA, left pulmonary artery; O, esophagus; SVC, superior vena cava.

imaging. On magnetic resonance imaging (MRI), the ligamentum arteriosum can be seen in up to 87% of patients according to Sans et al⁸; however, MRI scanning is not routinely used in radiotherapy planning. The

ligamentum arteriosum, if it is calcified, can be identified on a diagnostic CT scan and this increases in prevalence with age. The ligamentum arteriosum is, however, not reliable for delineating this nodal station on a CT scan.

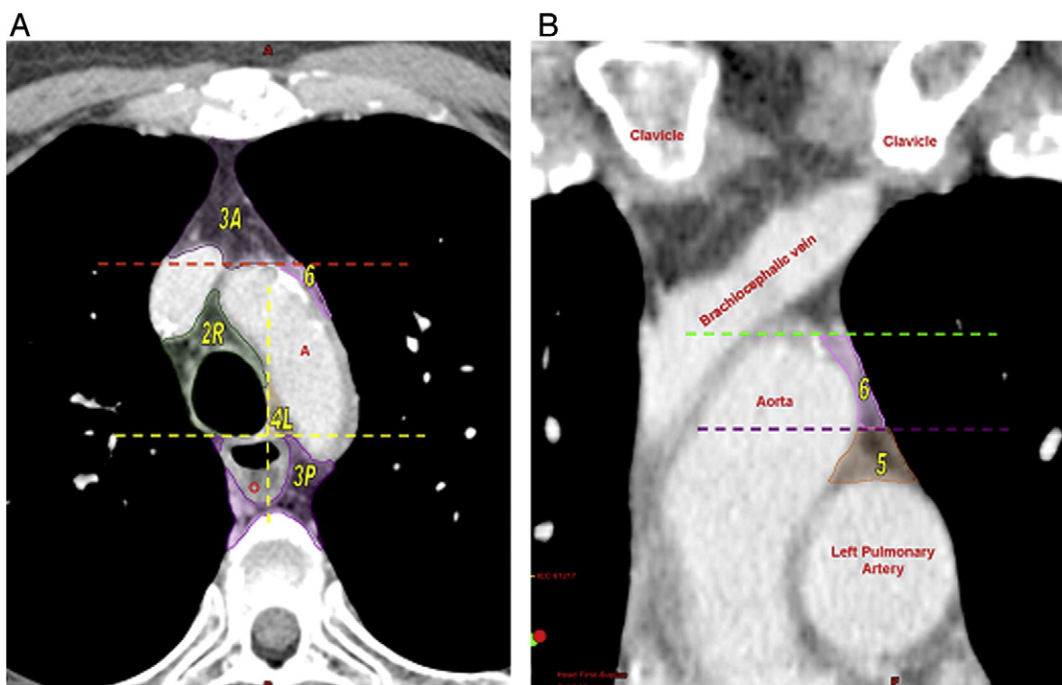


Figure 8 Station 6. (A) The anterior border is shown by the red dotted line running horizontally from the anterior border of the arch of aorta separating 3A from 6. (B) Coronal view showing station 6. The superior border is shown by the green dotted line running horizontally from the upper border of the aortic arch. The inferior border is shown by the purple dotted line running horizontally from the lower border of the aortic arch where station 6 abuts station 5. Abbreviations: A, aorta; O, esophagus.

For the purpose of this atlas the medial border has been defined as an imaginary line drawn from the most posterior part of the ascending aorta to the most anterior part of the descending aorta (Fig 7A). This definition is readily reproducible on CT imaging.

The anterior border of station 5 is an imaginary horizontal line extending from the anterior wall of the aorta. Station 3a abuts this anterior border of station 5 (Fig 7A). Station 6 abuts station 5 at its superior border

(Fig 8B) and maintains essentially the same anterior border as for station 6. Laterally, the region is contained within the pleural envelope.

Station 6: Para-aortic nodes (ascending aorta or phrenic)

Station 6 encompasses the lymph nodes anterior and lateral to the ascending aorta and aortic arch. The IASLC

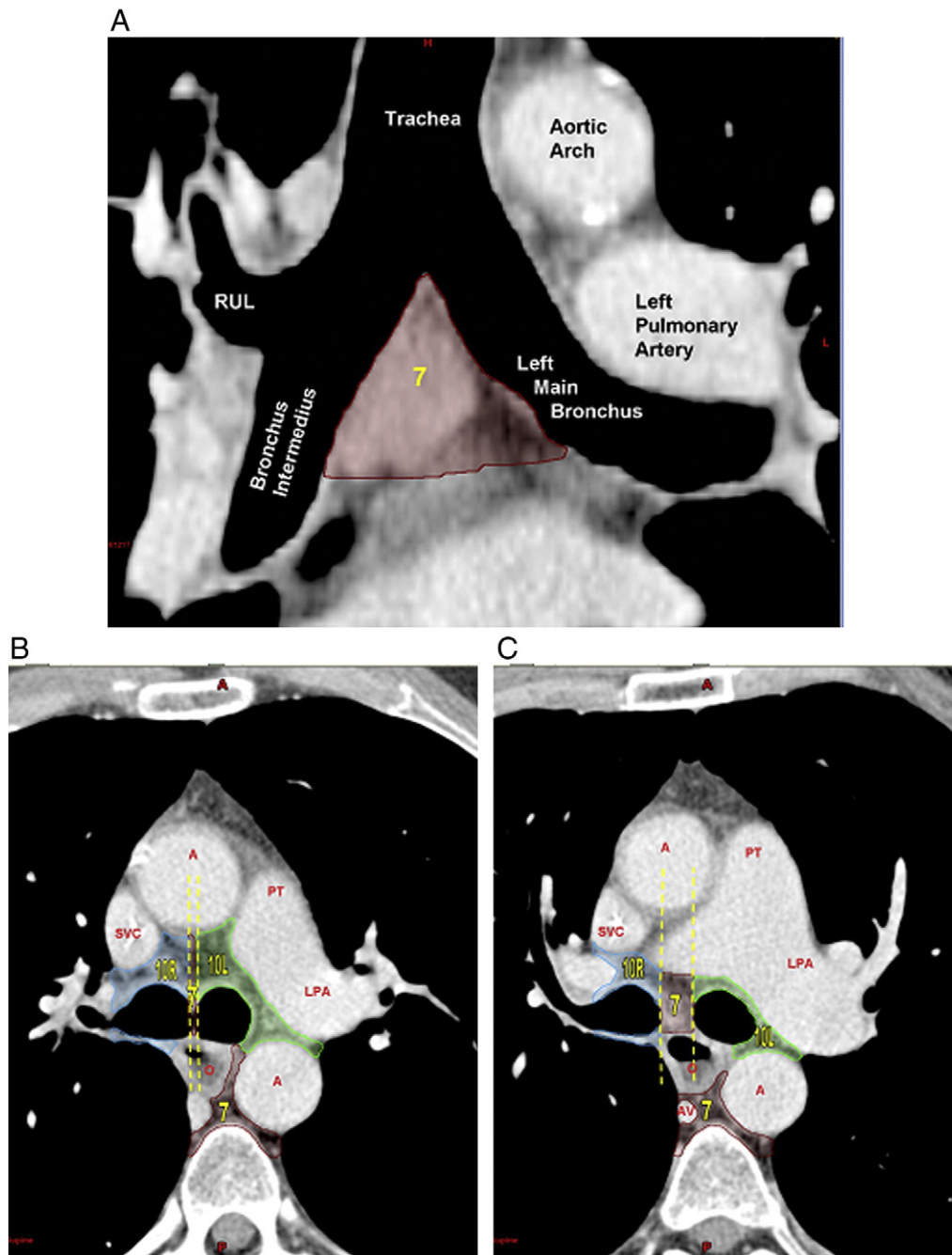


Figure 9 Station 7. (A) Coronal view showing station 7 with the lateral borders being the space between the left main bronchus and right main bronchus and bronchus intermedius. (B) and (C) The lateral border is shown by the yellow dotted lines along the medial border of the main bronchus and separates 7 from 10R and 10L. Abbreviations: A, aorta; AV, azygos vein; LPA, left pulmonary artery; O, esophagus; PT, pulmonary trunk; RUL, right upper lobe; SVC, superior vena cava.

definition of the superior border is the upper border of the aortic arch, while the inferior border is the lower border of the aortic arch. These anatomic points are best identified on a sagittal slice using the defined mediastinal window settings.

The anterior border of station 6 is an imaginary horizontal line extending from the anterior wall of the arch of the aorta. It is here that station 6 abuts station 3a (Fig 8A). Posterolaterally, the station is bound between the aortic

arch and the pleural space. Inferiorly, station 6 abuts station 5 best demonstrated on a coronal view (Fig 8B).

Station 7: Subcarinal nodes

In the IASLC lymph node map, station 7 has been enlarged. The upper border of station 7 remains the carina of the trachea. The lower border on the left is the upper border of the lower lobe bronchus, while the lower

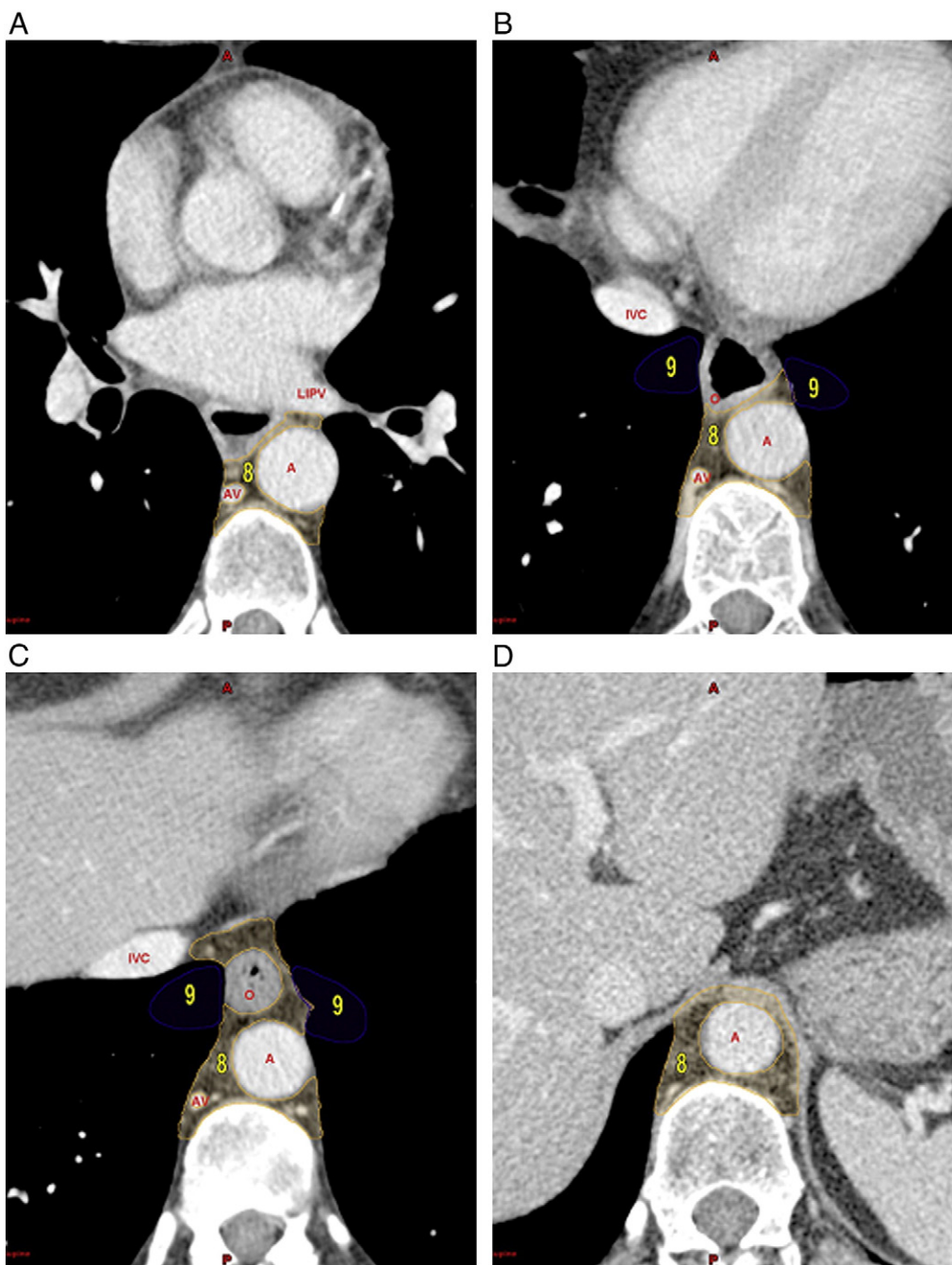


Figure 10 Station 8. (A to D) Images showing station 8 at a number of levels. The azygos vein, aorta and esophagus are excluded from this station. Abbreviations: A, aorta; AV, azygos vein; IVC, inferior vena cava; LIPV, left inferior pulmonary vein; O, esophagus.

border on the right is the lower border of the bronchus intermedius. These points are best identified on the coronal images using the recommended pulmonary window settings.

The lateral border of station 7 is the space between the right main and left main bronchi (Fig 9A). For this atlas the lateral border has been defined as an imaginary vertical line running along the medial border of the right and left main bronchi (Fig 9B, C).

With the new lymph node map definition, station 8 does not commence until the inferior border of station 7 has been reached and consequently station 7 has been extended posteriorly. We have used the definition of Chapet et al⁵ to define the outlined posterior limit of stations 7 and 8 as an imaginary horizontal line that runs 1 cm posterior to the anterior border of the vertebral body (Fig 9B, C).

Station 8: Paraesophageal nodes (below carina)

This station incorporates the nodes lying adjacent to the wall of the esophagus and to the right or left of midline, excluding the subcarinal nodes (Fig 10A-D).

The superior border on the left is the upper border of the left lower lobe bronchus and on the right it is the lower border of the bronchus intermedius. These anatomic boundaries are readily defined on a coronal image using the recommended lung window settings. The inferior border of station 8 is the diaphragm. The anterior border is in contact with the heart and inferior pulmonary vein and the lateral border is the pleural envelope. The esophagus, descending aorta, and azygos vein are excluded from the nodal station.

Again, the posterior border, as previously defined by Chapet et al,⁵ is the vertebral body and extends to an

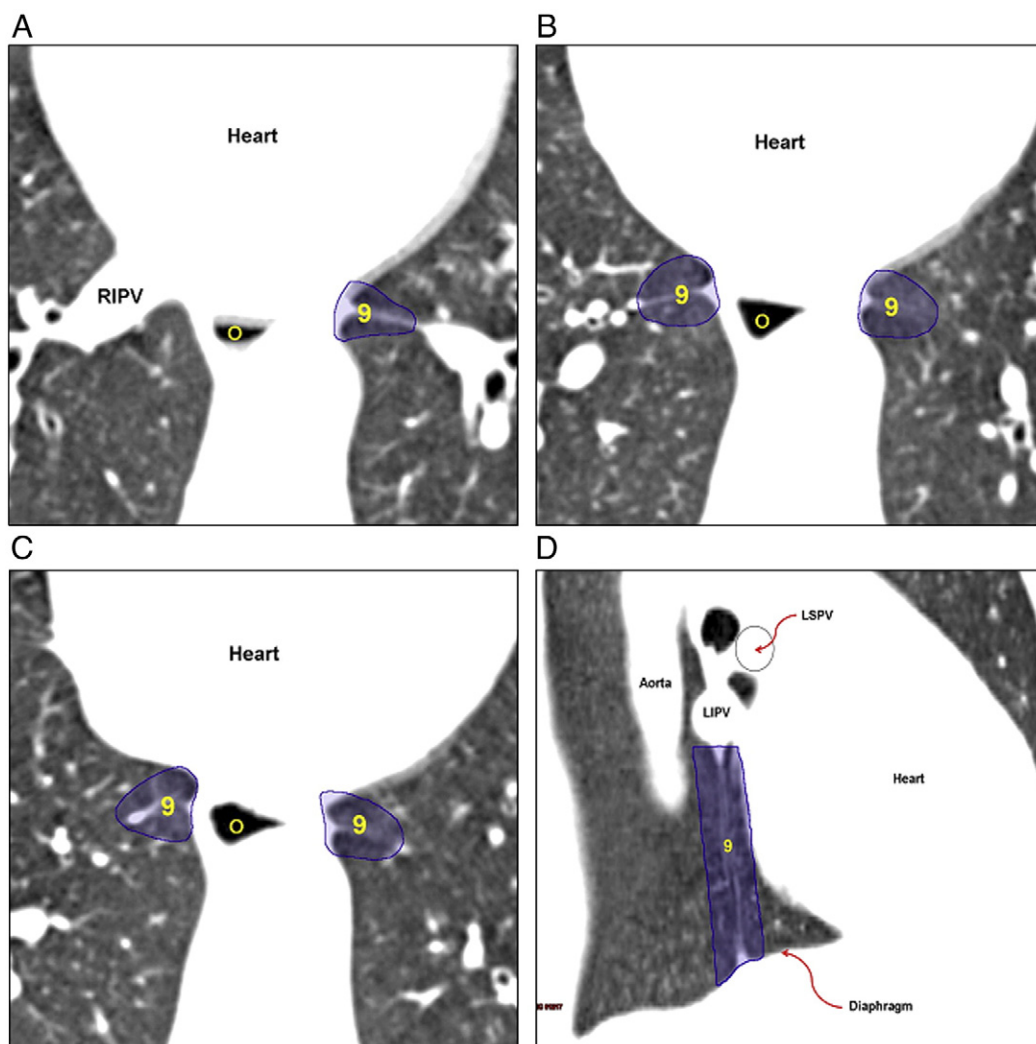


Figure 11 Station 9. (A to C) Station 9 has been marked at a number of levels using lung window settings. The nodal station is marked around the pulmonary ligament, as described. (D) Shows station 9 on a sagittal view extending from the left inferior pulmonary vein to the diaphragm. Abbreviations: LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; O, esophagus; RIPV, right inferior pulmonary vein.

imaginary horizontal line running 1 cm posterior to the anterior border of the vertebral body.

Station 9: Pulmonary ligament nodes

The pulmonary ligament is the downward extension of the pleural sleeve that surrounds the hilum. The inferior extent of the pulmonary ligament is variable and can terminate above the diaphragm. The length of this ligament can also vary in the same individual from side to side.

The upper border of station 9 is the inferior pulmonary vein, which is easily identified on a CT image with intravenous contrast, with the pulmonary ligament beginning just below this vessel (Fig 11A).⁹ Utilizing the recommended pulmonary window settings, the ligament is identified as a soft tissue beak extending laterally from the posterior mediastinum. The pulmonary ligament is located lateral to the esophagus (Fig 11B, C). For the purpose of this atlas the nodal station has been marked as a half ellipse. At its base, the point where station 9 commences at the mediastinum, it measures 1.5 cm centered on the pulmonary ligament. The nodal station then extends laterally 1.5 cm into the lung parenchyma. A sagittal view of station 9 is shown in Fig 11D, which demonstrates this station extending from the inferior pulmonary artery to the diaphragm.

Station 10: Hilar nodes

Station 10 includes the nodes immediately adjacent to the mainstem bronchus and hilar vessels, including the proximal portions of the pulmonary veins and main pulmonary artery. Under the new IASLC node map definitions, station 10 can extend more centrally than previously.

The upper border on the right is the lower rim of the azygos vein, while on the left it is the upper rim of the left main pulmonary artery.

Above the carina, station 10L and 10R are separated by the midline of the trachea (Fig 7B). Below the carina, the medial border is defined as a vertical line drawn from the medial aspect of the main bronchus. It is at this point that station 10 abuts station 7 (Fig 9C). On the right side, the lateral border of station 10R is represented as a vertical line drawn from the lateral aspect of the right main bronchus. On the left side, the lateral border superiorly, before station 11 commences, is the left pulmonary artery and pleural envelope. From the commencement of the upper lobe bronchus, the lateral border is represented by a vertical line running along the lateral aspect of the left main bronchus.

Station 11: Interlobar nodes

The interlobar nodes are located between the origin of the lobar bronchi. The medial border is junctional with

station 10 and is a vertical line running along the lateral aspect of the main bronchus. Lung window settings are best used to define the lateral borders. For station 11R laterally, the border is the lung-soft tissue interface. Station 11R includes the lobar bronchi and vessels in the hilum (Fig 12A, B). For station 11L laterally, the lung soft tissue interface is again used but the segmented bronchi are excluded (Fig 12C, D).

Discussion

Although conformal radiotherapy planning requires target volumes to be accurately delineated, variation in outlining target volumes is a known issue in radiotherapy for lung cancer.¹⁰⁻¹² The IASLC node map has incorporated a large body of clinical data in creating revised definitions for the nodal stations involved in lung cancer staging and aims to improve on the prior definitions.

This paper has attempted to incorporate the new IASLC node map into a set of reproducible definitions for CT-based datasets of each nodal station to assist clinicians who deal with lung cancer staging and treatment.

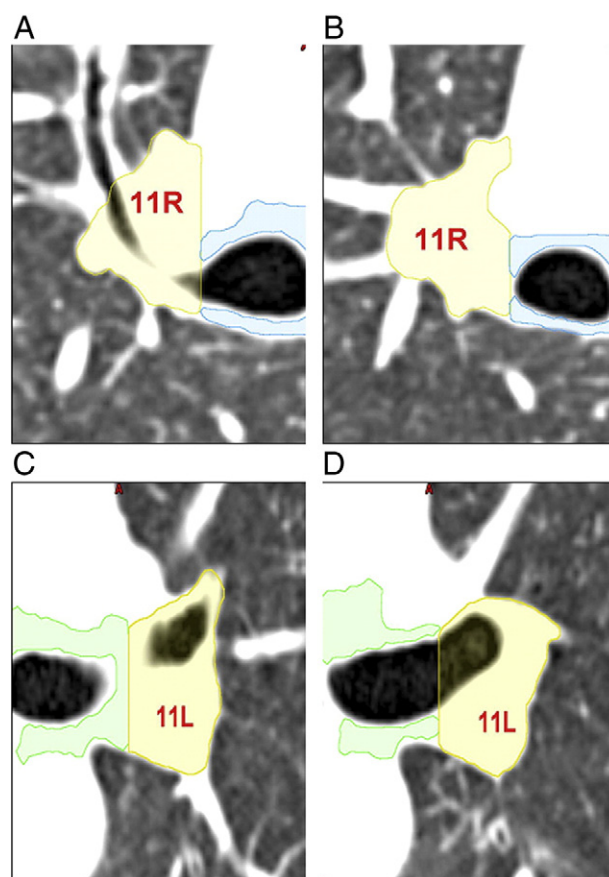


Figure 12 Station 11. (A) and (B) Station 11R. (C) and (D) Station 11L. The lateral border is defined using lung window settings. The medial border of station 11 is the lateral border of the main bronchus where it abuts station 10.

Outlining of nodal stations in radiotherapy is based on delineating anatomic regions in continuity that entails a slightly different approach compared with surgical staging, and we feel there are some ambiguities in the new definitions from the point of view of CT-based outlining. In particular, we have concerns regarding the use of the clavicle (a mobile landmark) as the border of stations 1 and 2 and the medial extent of station 10 in the new definition. These items are particularly important given that they are boundaries between N2 and N3 disease and N1 and N2 disease, respectively. We have discussed potential issues with the updated definitions elsewhere¹³; however, this atlas has attempted to follow the new definitions as stated rather than to create variations.

It is hoped that this atlas can provide guidance for clinicians when incorporating the new IASLC node map into their daily practice.

Acknowledgments

The authors would like to thank Dr Cheng-Hon Yap, Cardiothoracic Surgeon, FRACS, MS, for his thoughtful discussion and review of this manuscript. The authors also wish to thank Kathy Ball, PA to the Director Radiation Oncology for her assistance with this manuscript.

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