

CT-BASED DEFINITION OF THORACIC LYMPH NODE STATIONS: AN ATLAS FROM THE UNIVERSITY OF MICHIGAN

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Purpose: Accurate delineation of the mediastinal and hilar lymph node regions is essential for a reproducible definition of target volumes used in conformal irradiation of non-small-cell lung cancer. The goal of this work was to generate a consensus to delineate these nodal regions based on definitions from the American Joint Committee on Cancer.

Methods and Materials: A dedicated thoracic radiologist, thoracic surgeon, medical physicist, and three radiation oncologists were gathered to generate a three-dimensional radiologic description for the mediastinal and hilar nodal regions on axial CT scans. This paper proposes an atlas of most of the lymph node stations described by Mountain and Dresler.

Results: The CT boundaries of lymph node stations 1–2, 3, 4, 5, 6, 7, 8, 10–11 were defined on axial CT, along with image illustrations.

Conclusion: These CT-based illustrative definitions will provide guidelines for clinical practice and studies evaluating incidental radiation in radiotherapy. Studies are ongoing at the University of Michigan to measure quantitatively the incidental nodal radiation received by patients with non-small-cell lung cancer. © 2005 Elsevier Inc.

Lung, Nodes, Delineation, Reproducibility, CT scan, Radiotherapy.

INTRODUCTION

Lung cancer often presents with mediastinal and/or hilar lymph node involvement. Accurate definition of lymph node location is essential for appropriate staging and treatment of the disease. In 1997, Mountain and Dresler (1) proposed a classification system for regional lymph node stations for lung cancer that has since been adopted by the American Joint Committee on Cancer and the Union International Contre le Cancer. This classification system is widely used by physicians involved in the treatment of patients with lung cancer. The principal aim is to aid surgeons and pathologists in interpreting and defining the extent of regional tumor spread.

For patients undergoing radiotherapy, either alone or in combination with chemotherapy, the issue of which lymph node regions to include in the target volume is controversial (2). Some have proposed selective radiation of only the mediastinal and/or hilar lymph nodes believed to be involved on the basis of CT, bronchoscopy, and/or mediastinoscopy (3–8). Others would also prefer to irradiate electively the uninvolved mediastinum and ipsilateral hilum (9).

However, the lymph node stations have not been clearly defined on CT scans.

The results of surgical series need to be correlated with clinical staging for patients undergoing nonsurgical therapy. Radiation oncologists who plan to irradiate lymph nodes that are known to be at risk according to surgical series need to know how to delineate the nodes on planning CT scans. At the University of Michigan, physicians from the Departments of Radiology, Thoracic Surgery, and Radiation Oncology collaborated to define the radiologic boundaries of the Mountain and Dresler lymph node stations on axial CT images. The aim of this paper was to generate a consensus on their definitions to provide reliable anatomic markers that will facilitate the delineation of lymph nodal stations in a reproducible manner.

METHODS AND MATERIALS

CT scan selection

A patient without lung cancer was randomly selected from those who had common CT scan anatomic characteristics without unusual deformation or translation of structures and without evidence

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of mediastinal nodal involvement. The lymph node stations were initially defined on the chest CT scans of a patient treated in the Department of Radiation Oncology at the University of Michigan. The CT scan was performed with intravenous contrast, and the axial CT slices were 5 mm thick.

Volumes delineated

The surgical-based lymph node station classification is detailed in Table 1 and Fig. 1. Hilar and mediastinal lymph node stations were delineated using the Mountain and Dresler classification system (11). The volumes of interest were 1R (right) and 1L (left), 2R and 2L, 3A (anterior) and 3P (posterior), 4R and 4L, 5, 6, 7, 8, 10–11R, and 10–11L. Station 9 was not delineated because its location is defined in part by the inferior pulmonary ligament, which is typically not visible on CT. Stations 1 and 2 typically cover a very short vertical distance and are often limited to one or two axial CT images, thereby making three-dimensional delineation of each station quite challenging. More specifically, the 2R station is below the innominate vein and above the aortic arch. However, for some patients, the innominate vein crosses the mediastinum where the aortic arch appears on the CT scan, and 2R becomes completely virtual. Therefore, Stations 1 and 2 were combined on the right and left side and termed 1–2R and 1–2L.

Delineation procedure

A dedicated thoracic radiologist, thoracic surgeon, medical physicist, and three radiation oncologists worked together to elab-

orate a consensus for delineation of the lymph node regions. This procedure had to fulfill the following requirements:

1. Be as close as possible to the definitions put forth by Mountain and Dresler (1)
2. Be based on clinical, surgical, and radiologic experience
3. Allow for reproducible delineation of the different areas on CT
4. Provide a reasonable delineation of the volumes to be used in thoracic irradiation

All designated lymph node stations (except for 10–11R and 10–11L) were delineated using a soft-tissue CT scan window width of 400 and a CT scan level at +20, as recommended by Harris *et al.* (10) for the study of anatomic structures in the mediastinum.

RESULTS

Stations 1–2R and 1–2L: highest mediastinal and upper paratracheal nodes

The upper limit of Stations 1R and 1L was not clearly defined in the Mountain and Dresler classification (1). Thus, we arbitrarily defined an upper limit corresponding to the upper limit of the sternal notch (Fig. 2A). This limit seemed reasonable and allowed for consistency. The lower limit of Station 1–2 corresponds to the lower limit of 2R and 2L, just superior to the aortic arch (Fig. 2C). Medially, 1–2R and

Table 1. Mountain and Dresler classification system

Station	Description
1R: highest mediastinal nodes	Nodes lying above horizontal line at upper rim of brachiocephalic (left innominate) vein where it ascends to left, crossing in front of trachea at its midline
2R and 2L: upper paratracheal nodes	Nodes lying above horizontal line drawn tangential to upper margin of aortic arch and below inferior boundary of station 1 nodes
3: prevascular nodes and retrotracheal nodes	Prevascular and retrotracheal nodes may be designed 3A and 3P; midline nodes are considered to be ipsilateral
4R and 4L: right and left lower paratracheal nodes	Lower paratracheal nodes on right lie to right of midline of trachea between horizontal line drawn tangential to upper margin of aortic arch and line extending across right main bronchus, and contained within mediastinal pleural envelope; lower paratracheal nodes on left lie to left of midline of trachea between horizontal line drawn tangential to upper margin of aortic arch and line extending across left main bronchus at level of upper margin of left upper lobe bronchus, medial to ligamentum arteriosum and contained within mediastinal pleural envelope
5: subaortic (aortic–pulmonary window)	Subaortic nodes are lateral to ligamentum arteriosum or aorta or left pulmonary artery and proximal to first branch of left pulmonary artery and lie within mediastinum pleural envelope
6: paraaortic nodes	Nodes lying anterior and lateral to ascending aorta and aortic arch or innominate artery beneath line tangential to upper margin of aortic arch
7: subcarinal nodes	Nodes lying caudal to carina of trachea but not associated with lower lobe bronchi or arteries within lung
8: paraesophageal nodes	Nodes lying adjacent to wall of esophagus and to right or left of midline, excluding subcarinal nodes
10: hilar nodes	Proximal lobar nodes, distal to mediastinal pleural reflection and nodes adjacent to bronchus intermedius on right; radiographically, hilar shadow may be created by enlargement of both hilar and interlobar nodes
11: interlobar nodes	Nodes lying between lobar bronchi

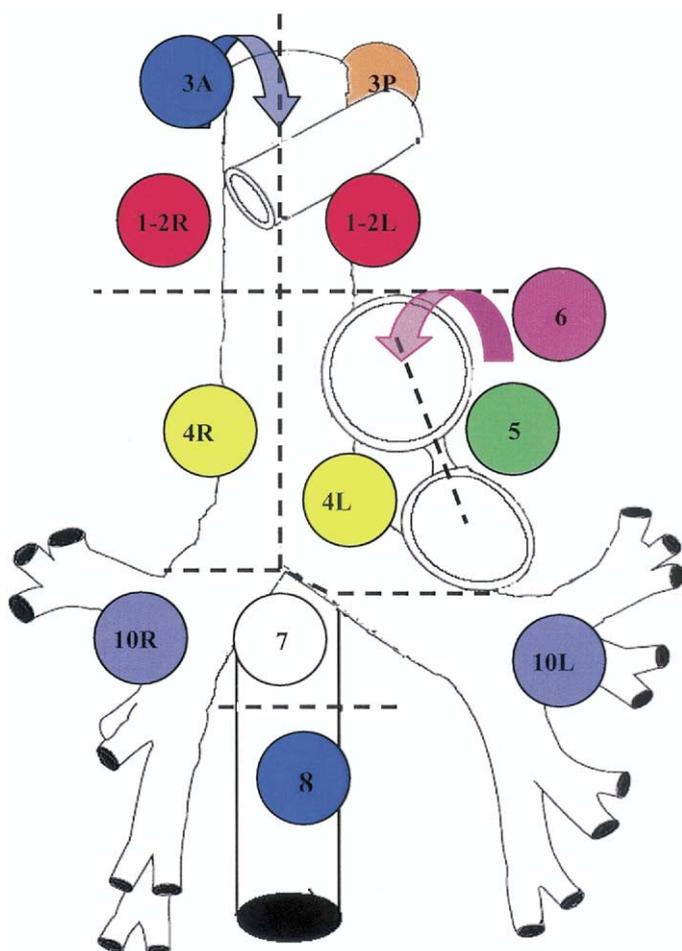


Fig. 1. Schema of Mountain and Dresler classification system, after Mountain and Dresler (1). Station 3A is anterior to Stations 1–2R and L and Stations 4R and L (blue arrow). Station 3P is posterior to trachea. Station 6 is anterior and lateral to aortic arch and ascending aorta (purple arrow).

1–2L are separated by the midline of the trachea (Fig. 2A, yellow line). Both on the right and the left sides laterally, Stations 1–2R and 1–2L remain within the pleural envelope. Anteriorly, this volume is posterior to the vessels (right subclavian vein, left brachiocephalic vein, right brachiocephalic vein, left subclavian artery, left common carotid artery, and brachiocephalic trunk; (Fig. 2A–C). Posteriorly, Stations 1–2R and 1–2L are delineated until reaching an imaginary horizontal line extending along the posterior wall of the trachea (Fig. 2B, yellow line).

Station 3: prevascular nodes and retrotracheal nodes

Station 3A: prevascular nodes or retrosternal nodes. The superior limit of Station 3A is the same as for Stations 1–2. Inferiorly, it stops at the level of the carina. Laterally, it is limited by the pleural envelope. Anteriorly, it is limited by the sternum, clavicular heads, and ribs (Fig. 2A–I and 3A,B). Posteriorly, it is limited, superiorly, by the anterior border of Stations 1–2 but excludes the great arteries (left subclavian artery, left common carotid artery, and brachio-

cephalic trunk). Inferiorly, it is in contact with Station 6 on the left and the anterior border of the superior vena cava on the right. Station 3A includes the left brachiocephalic vein in its mediastinal section until the superior vena cava (Figs. 2I and 3A).

Station 3P: retrotracheal nodes. Station 3P includes the retrotracheal nodes above the carina. Superiorly, this region begins, as do Stations 1–2, at the upper limit of the sternum (Fig. 2A). Inferiorly, delineation of Station 3P stops at the carina (Fig. 3B,C). On the right side, the limit is defined by the air–soft-tissue interface. On the left side, it is defined by the air–tissue interface superiorly (Fig. 2A–C) and the aorta inferiorly (Figs. 2D–I and 3A–C). Anteriorly, it is in contact with the posterior aspect of Stations 1–2 superiorly (Fig. 2A–C) and with Stations 4R and 4L inferiorly (Fig. 2D–I and 3A–C). The anterior limit of Station 3P is kept posterior to the trachea, which is defined by an imaginary horizontal line running along the posterior wall of the trachea (Fig. 2B,E, red line). Posteriorly, it is delineated along the anterior and lateral borders of the vertebral body until an imaginary horizontal line running 1 cm posteriorly to the anterior border of the vertebral body (Fig. 2D).

Station 4R: right lower paratracheal nodes

From superior to inferior, the delineation of Station 4R starts at the top of the aortic arch (Fig. 2D) and ends at the upper lobe bronchus or where the right pulmonary artery crosses the midline of the mediastinum (Fig. 3E,F). On the left side, Station 4R is defined by the midline of the trachea (Fig. 2D). On the right side, it is contained within the pleural envelope in the upper part, medial to the superior vena cava and the arch of the azygos vein in the intermediate section (Fig. 2I and 3A,B) and the right upper lobe pulmonary vein in its very caudal part. Anteriorly, it is limited most superiorly by the right brachiocephalic vein (Fig. 2D–H), followed by the superior vena cava and the arch or ascending section of the aorta (Figs. 2I and 3A–E). In between the superior vena cava and the aorta, we recommend delineating Station 4R so that it extends halfway between the two vessels where it will contact Station 3A or 6 (Figs. 2H,I and 3A–D). Posteriorly, Station 4R is defined at its superior extent by an imaginary horizontal line running along the posterior wall of the trachea (Fig. 2E). Inferiorly, it remains anterior to the right main stem bronchus, filling the soft-tissue space between the vessels.

Station 4L?: left lower paratracheal nodes

Superiorly, Station 4L is defined by the top of the aortic arch similar to Station 4R. Inferiorly, its limit is determined by the left upper lobe bronchus (Fig. 3G). Commonly, this limit corresponds to the disappearance of the space bordered by the left main bronchus, and the left and right pulmonary arteries (Fig. 3G,H). On the right side, the medial limit of Station 4L is primarily defined by a vertical line through the middle of the trachea, except more inferiorly, where it is limited by the right pulmonary artery and Station 7 (Fig. 3F, G). On the left side, three sections have to be differentiated.

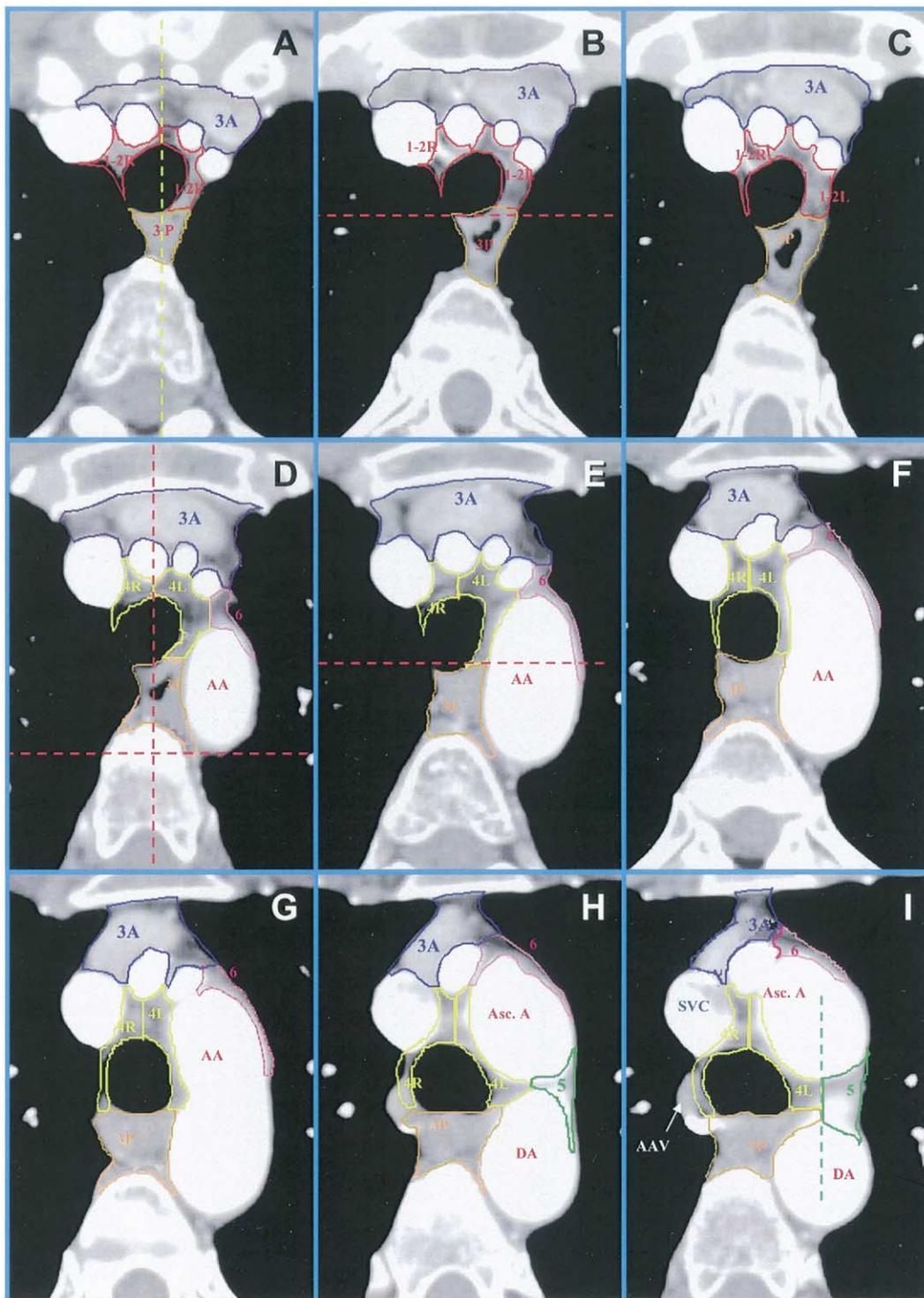


Fig. 2. (A) Sternal notch is beginning of delineation of stations 1–2R and L and 3A and 3P. Yellow dotted line separates 1–2R from 1–2L. (B) Posterior limit of 1–2R and L defined by red dotted line. (C) Inferior limit of 1–2R and L. (D) Top of aortic arch (AA). First slice with Stations 4R, 4L, and 6. Vertical red dotted line, midline of trachea separating 4R from 4L. Horizontal red dotted line 1 cm posterior to anterior border of vertebral body delimiting posterior limit of 3P. (E) Posterior limit of 4R and L (red dotted line). (F,G) Left brachiocephalic vein still included in Station 3A. (H) Most inferior aspect of AA. Superior limit of Station 5. Asc. A = ascending aorta; DA = descending aorta. (I) Midline between Asc. A and DA separating Stations 4L and 5. SVC = superior vena cava.

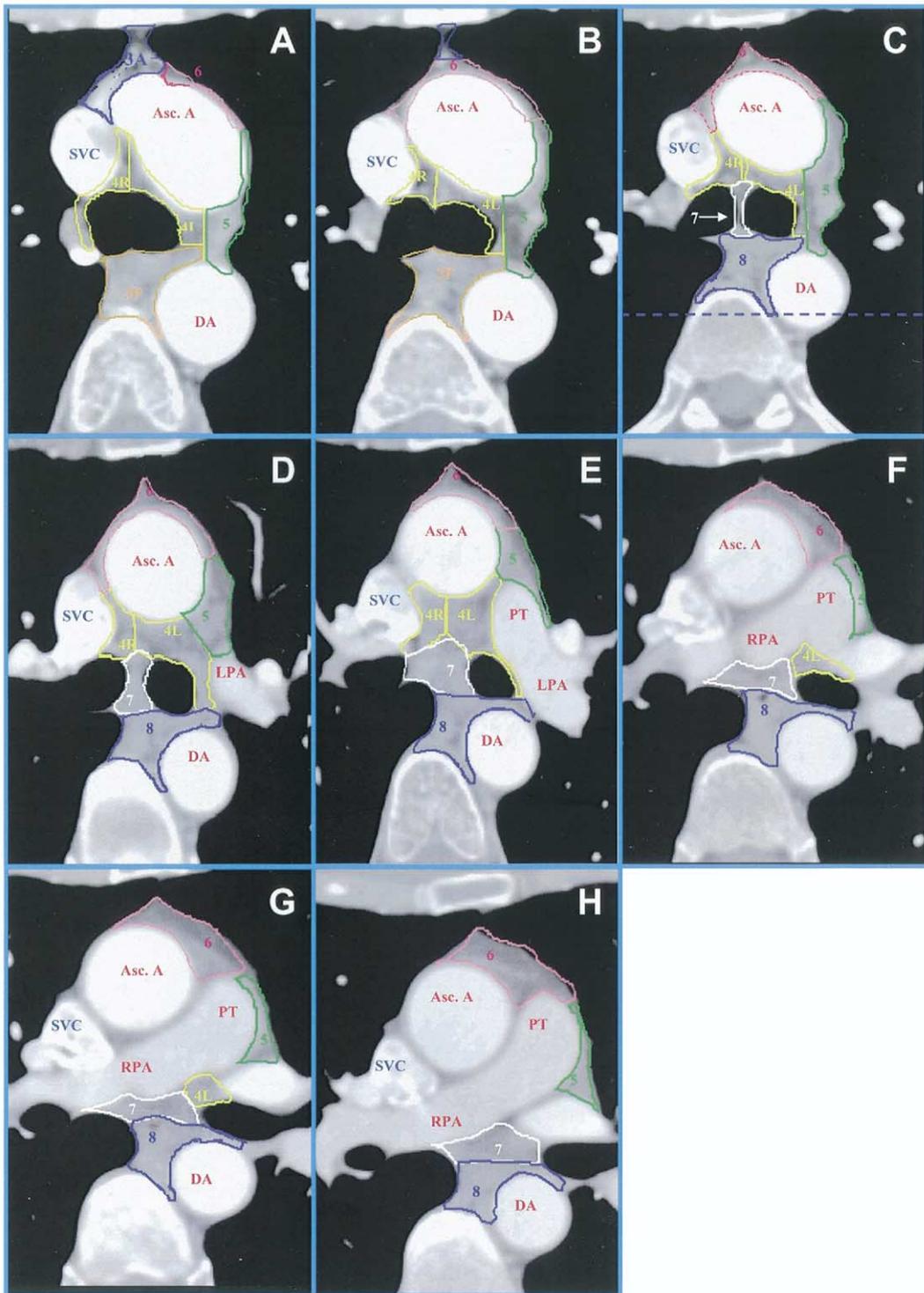


Fig. 3. (A) Station 5 extending at midpoint of ascending aorta. (Asc. A). SVC = superior vena cava; DA = descending aorta. (B) Inferior limit of Stations 3A and 3P. (C) Carina. Superior limit of Stations 7 and 8. Blue dotted line 1 cm posterior to anterior border of vertebral body defines posterior limit of Station 8. (D) Midline between left pulmonary artery and ascending aorta defining limit between Stations 4L and 5. LPA = left pulmonary artery. (E) Station 8 covering anterior border of DA. PT = pulmonary trunk. (F) Right pulmonary artery (RPA) crossing mediastinum. Inferior limit of Station 4R. (G) Inferior limit of 4L. (H) Lowest image in which RPA is maximally visualized.

The upper portion is in contact with the aortic arch (Fig. 2E–G). In the intermediate section between the pulmonary trunk and the aortic arch, the lateral limit of Station 4L is the midline between the ascending and descending aorta (Figs. 2H,I and 3A–C). The lateral aspect of the lower section of Station 4L is defined by the pulmonary trunk and/or the left pulmonary artery (Fig. 3D–G). Anteriorly, it is delimited by the great vessels or the aorta (Figs. 2D–I and 3A–E). Posteriorly, it is also defined by an imaginary horizontal line running along the posterior wall of the trachea or the anterior aspect of the left main bronchus.

Station 5: subaortic (aortic–pulmonary window) nodes

Superiorly, the original definition was not specified by Mountain and Dresler (1). We propose using the most inferior aspect of the aortic arch when delineating the superior aspect of this region (Fig. 2G,H). Inferiorly, Station 5 is defined as the lowest image in which the right pulmonary artery is maximally visualized (Fig. 3H). This limit ensures that this volume stays above the heart. On the right side, this area is limited by the boundary of Station 4L (Fig. 2H,I and 3A–E), the pulmonary trunk (Fig. 3E–H), and the left pulmonary artery (Fig. 3F–G). On the left side, this area remains within the pleural envelope. Anteriorly, we defined Station 5 as extending to the midpoint of the ascending aorta (Fig. 3A–E) or visible soft tissue (Fig. 2H,I). Posteriorly, the limits of this region are the anterior aspect of the descending aorta, the left lateral aspect of the pulmonary trunk, and the upper lobe pulmonary veins and/or left pulmonary artery.

Station 6: paraaortic nodes or anterior aortic nodes

Superiorly, Station 6 is defined by the top of the aortic arch (Fig. 2D). Inferiorly, Station 6 ends at the same level as Station 5 (Fig. 3H). Anteriorly and laterally the border extends 1 cm around the ascending aorta and the aortic arch. Posteriorly, Station 6 is delimited by the anterior and lateral walls of the ascending aorta, aortic arch (Figs. 2D–I and 3A–G) and the anterior aspect of the medial wall of the pulmonary trunk until Station 5 (Fig. 3F–H).

Station 7: subcarinal nodes

Superiorly, Station 7 is at the carina. The lower limit of this region, according to the Mountain and Dresler classification (1), is not associated with the lower lobe bronchi or arteries within the lung. The inferior limit of this Station is defined at the origin of the right middle lobe bronchus. Laterally, this level is limited to the space between the right main and left main bronchi (Fig. 3C–H). Anteriorly, it is bounded by Station 4R, Station 4L, the right pulmonary artery, and/or the left superior pulmonary vein. Posteriorly, it is bounded by Station 8 and does not extend past the posterior wall of the main bronchi.

Station 8: paraesophageal nodes

Superiorly, Station 8 begins at the level of the carina and, therefore, abuts Station 3P (Fig. 3C). Inferiorly, the lower limit of Station 8 was not specified in the Mountain and

Dresler classification (1). We delineate this volume until it reaches the gastroesophageal junction. Laterally, it is within the pleural envelope and again abuts the descending aorta on the left. Reasonably, the delineation of Station 8 is limited to the soft tissue surrounding the esophagus (Fig. 3C–H). Anteriorly, it is in contact with Station 7 and the left main stem bronchus in its superior aspect (Fig. 3C–H) and with the heart more inferiorly. Posteriorly, Station 8 abuts the descending aorta and the anterior aspect of the vertebral body until an imaginary horizontal line running 1 cm posterior to the anterior border of the vertebral body (Fig. 3C).

Stations 10 and 11

Stations 10 and 11 were grouped together, because these nodes are included in the radiographic hilar shadow, and it is difficult to differentiate them on axial CT images.

We recommend the use of a lung window width of 850 and a level of -750^{10} to identify the segmental bronchus as the anterior, posterior, and lateral limits of Stations 10–11. Mediastinal CT settings were used to define the medial border of the hilum.

Station 10–11R: right hilar nodes. Superiorly, Station 10R is delimited by the point of division of the right upper lobe bronchus into segmental branches (Figure 4A1,2). Inferiorly, Station 10–11R ends at the origin of the superior segmental bronchus of the right lower lobe (Fig. 4B1,2). Laterally, the limit is defined by the air–tissue interface when the CT slice is displayed in mediastinal windows (Fig. 4C,D). Medially, the region remains outside of an imaginary line drawn between the lateral border of the superior vena cava and the middle of the vertebral body (Fig. 4A1,2, C,D). Anteriorly and posteriorly, the limit is defined by the air–tissue interface when the CT slice is displayed in mediastinal window, with inclusion of the main bronchus, lobar bronchi, and vessels in the hilum (Fig. 4C,D).

Station 10–11L: left hilar nodes. Superiorly, Station 10–11L begins at the bifurcation of the upper lobar bronchus into the segmental bronchi (Fig. 4E1,2). Inferiorly, Station 10–11L ends at the point at which the left lower lobe bronchus branches into segments (Fig. 5A1,2). Medially, this region is delimited by an imaginary line drawn between the lateral border of the pulmonary trunk and the lateral border of the descending aorta (Figs. 4E2, 5A2,B). This line is easy to identify and reproduce and is very close to the anatomic limit pleural envelope defined by Mountain and Dresler (1). On the left side, the air–tissue interface should be used, similar to on the right side. However, the segmental bronchi must not be included in this volume (Fig. 5A1,2). Anteriorly, Station 10–11L is limited by the posterior border of the left pulmonary artery (Figs. 4E1,2 and 5B). Posteriorly, it is limited by the posterior border of the left lower pulmonary artery (Figs. 4E2, and 5B).

DISCUSSION

The aim of this article was to relate our experience in defining the radiologic boundaries of the lymph node sta-

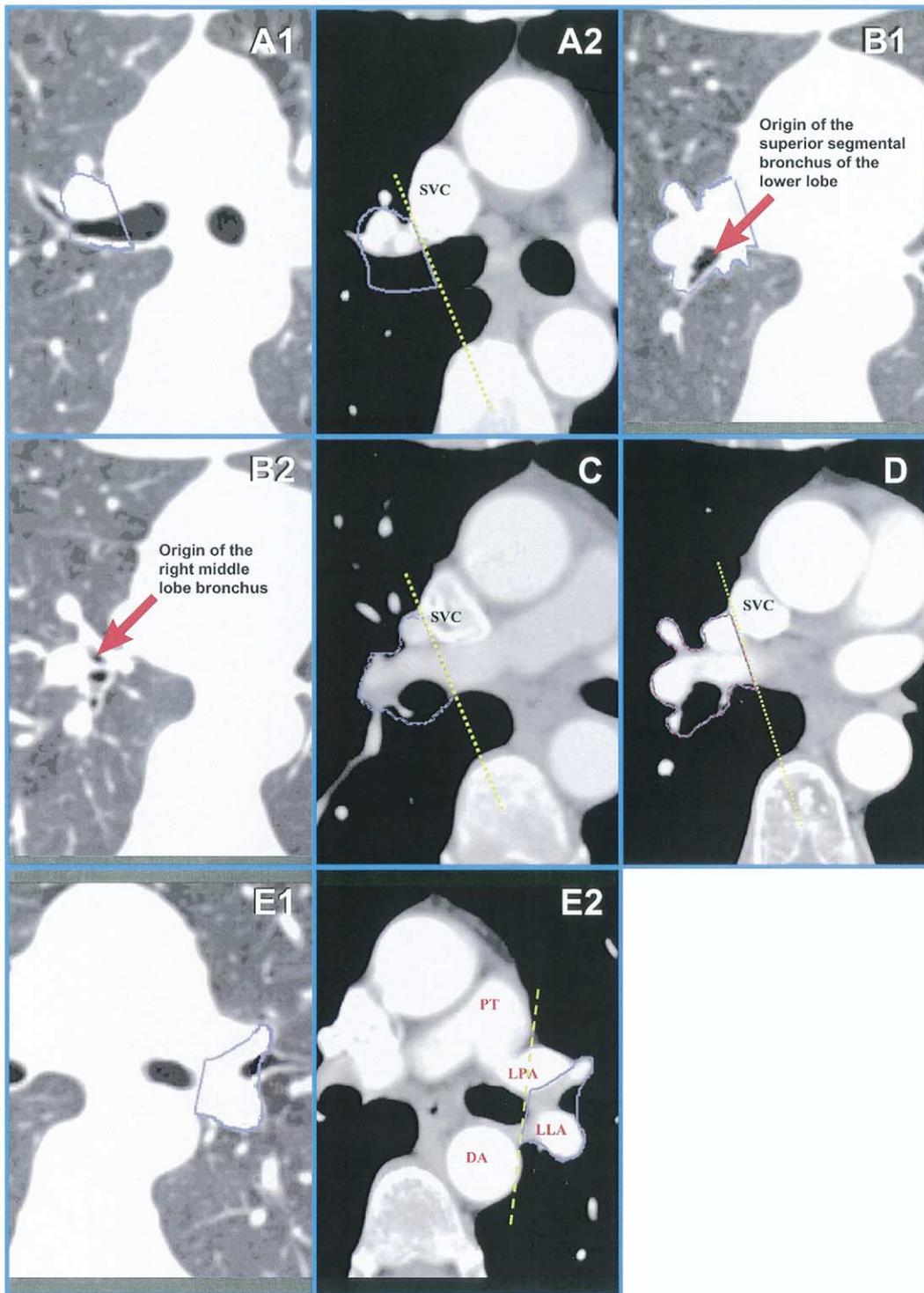


Fig. 4. (A1) Lung window to identify upper limit of Stations 10–11R. Point of division of right upper bronchus into segmental branches. (A2) Mediastinal CT windows. Yellow dotted line between superior vena cava (SVC) and middle of vertebral body defines medial limit of Stations 10–11R. (B1,2) Inferior limit of Stations 10–11R defined with lung CT windows. (C,D) Definition of medial limit of Stations 10–11R. (E1) Lung CT window. Superior limit of Stations 10–11L at bifurcation of upper lobar into segmental bronchi. (E2) Yellow dotted line between left border of pulmonary trunk (PT) and left border of descending aorta (DA) defining medial limit of Stations 10–11L. LPA = left pulmonary artery; LLA = left lower artery.

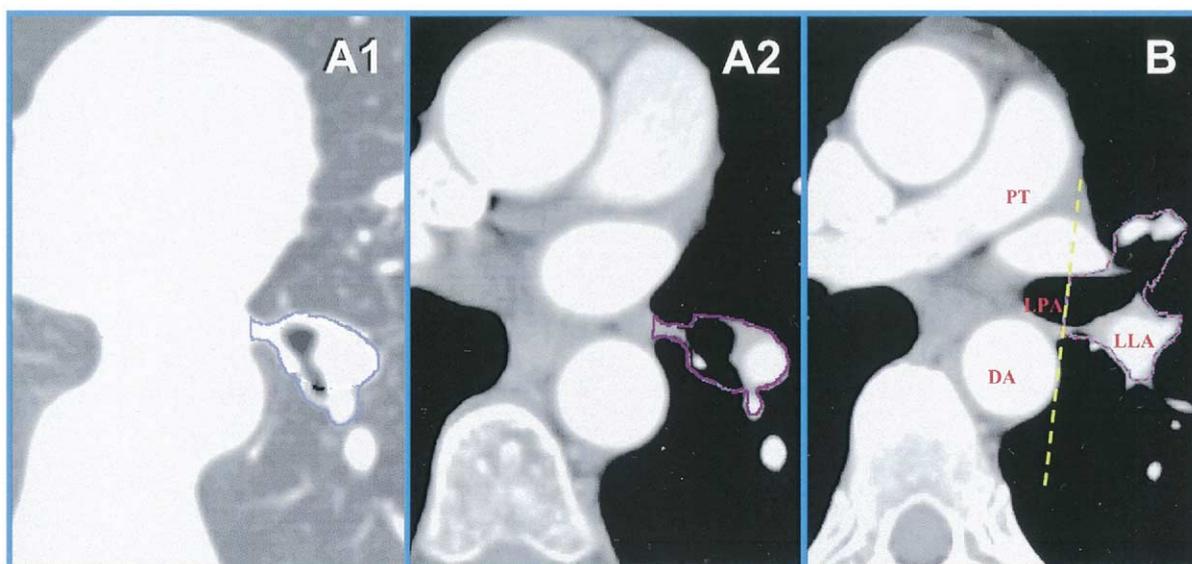


Fig. 5. (A1,2) Inferior limit of Stations 10–11R and L defined by point of left lower lobe bronchus branching into segments. (B) Anterior and posterior limit of Stations 10–11R and L. PT = pulmonary trunk; LPA = left pulmonary trunk; LLA = left lower artery; DA = descending aorta.

tions initially described by Mountain and Dresler (1) and to provide guidelines to aid clinicians and researchers in the reproducible delineation of them. To our knowledge, this is the first article to propose a CT scan definition of the mediastinal and hilar lymph node stations.

In a recent retrospective study of 557 patients who underwent surgery for non-small-cell lung cancer (11), the authors found that the lymph node levels involved depended on the location of the primary tumor. Tumors in the right upper lobe mainly metastasized to Station 4 lymph nodes and tumors of the right middle and right lower lobe mainly spread to Stations 4 and 7, respectively. On the left, tumors of the upper lobe metastasized predominantly to Station 5 and tumors of the lower lobe mainly spread to Stations 7 and 9. These results were in accordance with other studies showing that Stations 4, 5, and 7 are the most commonly involved (12, 13). In this study, we propose a description of

the radiologic boundaries of all stations, except for Station 9. In the Mountain and Dresler classification (1) Station 9 is defined by the inferior pulmonary ligament, which is typically not visible on CT. That definition is mainly surgical and, therefore, not easily adapted to CT-based anatomy.

An accurate delineation of the mediastinal and hilar nodal regions is essential for a reproducible definition of target volumes used in conformal irradiation of non-small-cell lung cancer. This paper proposes a three-dimensional radiologic description of most of the lymph node stations described by Mountain and Dresler (1). We intend to use these volumes in an ongoing study evaluating the incidental irradiation of the mediastinum and hilum in which only the involved nodal diseases are irradiated. Guided by this consensus, studies are ongoing to measure quantitatively the incidental nodal radiation in patients with Stage I–III NSCLC.

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