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The Japan Lung Cancer Society–Japanese Society for Radiation Oncology consensus-based computed tomographic atlas for defining regional lymph node stations in radiotherapy for lung cancer

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ABSTRACT

The purpose of this study was to develop a consensus-based computed tomographic (CT) atlas that defines lymph node stations in radiotherapy for lung cancer based on the lymph node map of the International Association for the Study of Lung Cancer (IASLC). A project group in the Japanese Radiation Oncology Study Group (JROSG) initially prepared a draft of the atlas in which lymph node Stations 1–11 were illustrated on axial CT images. Subsequently, a joint committee of the Japan Lung Cancer Society (JLCS) and the Japanese Society for Radiation Oncology (JASTRO) was formulated to revise this draft. The committee consisted of four radiation oncologists, four thoracic surgeons and three thoracic radiologists. The draft prepared by the JROSG project group was intensively reviewed and discussed at four meetings of the committee over several months. Finally, we proposed definitions for the regional lymph node stations and the consensus-based CT atlas. This atlas was approved by the Board of Directors of JLCS and JASTRO. This resulted in the first official CT atlas for defining regional lymph node stations in radiotherapy for lung cancer authorized by the JLCS and JASTRO. In conclusion, the JLCS–JASTRO consensus-based CT atlas, which conforms to the IASLC lymph node map, was established.

KEYWORDS: CT atlas, lung cancer, lymph nodes, radiotherapy

INTRODUCTION

Based on advances in treatment devices and planning systems, treatment planning in radiotherapy has transitioned from a 2D approach based on plain radiography to a 3D technique. In 3D radiotherapy treatment planning, the clinical target volume (CTV) must be delineated on axial CT images. In the case of elective nodal irradiation (ENI) for lung cancer, the CTV contains some regional lymph node stations. We referred to the International Association for the Study of Lung Cancer (IASLC) map [1] to outline regional lymph node stations. However, in the IASLC map, there are some ambiguous boundaries between neighboring lymph node stations and between lymph node stations and structures. The purpose of this study was to establish a consensus-based CT atlas that describes lymph node stations in radiotherapy for lung cancer, based on the IASLC lymph node map, through a collaboration between the Japan Lung Cancer Society (JLCS) and the Japanese Society for Radiation Oncology (JASTRO). The final consensus-based CT atlas has been published in the *Japanese Journal of Lung Cancer* [2]. This English-language report is based on the previous Japanese publication.

MATERIALS AND METHODS

Contrast-enhanced CT images were obtained for one healthy 42-year-old male volunteer in treatment position with inspiration breath-holding in July 2014. CT imaging was performed using a multidetector CT scanner (Aquilion LB; Toshiba Medical Systems, Otawara, Japan) with 16 detector rows. The volunteer received 110 ml of iohexol (Omnipaque, 300 mgI/ml, Daiichi-Sankyo, Tokyo, Japan) intravenously by means of power injector; the injection duration was 50 s. The scan duration was 80 s after the start of the injection. The parameters used in CT imaging were as follows: the field of view was 55 cm, the tube-current was 300 mA, and the tube-voltage was 120 kVp. The beam pitch was 0.8, and auto-exposure control was not used.

The images were imported into a 3D radiotherapy treatment planning system (RTPS) (Eclipse™ Treatment Planning System ver. 10.0; Varian Medical Systems, Palo Alto, CA). The lymph node stations were initially contoured on CT images in the RTPS as regions of interest (based on IASLC definitions) by a radiation oncologist who belongs to the Japanese Radiation Oncology Study Group (JROSG). Subsequently, a project group was established by JROSG in October 2014. This group consisted of six additional radiation oncologists, a thoracic radiologist and a thoracic surgeon. All of the contoured CT images were revised, and tentative definitions for the boundaries of lymph node Stations 1–11 in six directions (cranial, caudal, left, right, anterior and posterior) were assigned by the JROSG project group as a draft of the atlas.

Finally, a JLCS–JASTRO joint committee, which consisted of four radiation oncologists, four thoracic surgeons and three thoracic radiologists, was established to revise the draft. The committee held four conferences (in December 2014, and February, April and June 2015) and proposed a consensus-based CT atlas for defining the regional lymph node stations in radiotherapy for lung cancer. This atlas was approved by the Board of Directors of JASTRO in June 2015 and by the Board of Directors of JLCS in July 2015.

RESULTS

The boundary definitions for each of the lymph node stations are shown in Table 1. Figures 1–12 illustrate the lymph node stations on CT images in the coronal (Fig. 1), axial (Figs 2–6 and 9–12) and sagittal (Figs 7 and 8) views. Figure 13 shows the atlas in serial axial CT images.

Station 1R/1L: low cervical, supraclavicular and sternal notch nodes

The cranial border is the lower margin of the cricoid cartilage. According to the IASLC definition, the caudal border is 'clavicles bilaterally and, in the middle, the upper border of the manubrium'. However, it is difficult to express the diagonal region on axial CT images. Therefore, the caudal border was defined as the 'apex of the lung', which was also defined as the cranial border for Station 2R and Station 2L. The apex of the lung in axial CT images was defined as the upper marginal slice of the lung. When the level of the apex of the lung differs between the right and the left, this border should be aligned to the upper side. At this border, Station 1 abuts on Stations 2R, 2L and 3p (Fig. 1). The medial border is the midline of the trachea. The lateral border is the clavicle and anterior scalene muscle, including the fat tissue surrounding the anterior scalene muscle. The anterior border is the posterior aspect of the clavicles. The posterior border is muscles and bones (Fig. 2).

Station 2R: right upper paratracheal nodes

The cranial border is the apex of the lung, which is the same as the caudal border of Station 1, while the IASLC definition is 'apex of the right lung and pleural space, and in the midline, upper border of the manubrium'. It is here that Station 2R is in contact with Station 1R (Fig. 1). The caudal border is the intersection of the caudal margin of the left brachiocephalic vein with the midline of the trachea. The level of the intersection point includes Station 4R. The left border is the left lateral border of the trachea. At this border, Station 2R shares the boundary with Station 2L (Fig. 3). The right border is the pleura. The anterior border is muscles and blood vessels in the region above the upper border of the manubrium, and an imaginary line that smoothly connects the anterior aspects of the right brachiocephalic vein, the brachiocephalic artery, the left common carotid artery, and the left subclavian artery (Line A) in the region below the upper border of the manubrium. At Line A, Station 2R contacts Station 3a. Furthermore, Line A was set to traverse the anterior space of the trachea (Fig. 3). The posterior border is the membranous wall of the trachea. At this border, Station 2R abuts on Station 3p (Fig. 3).

Station 2L: left upper paratracheal nodes

The cranial border is the apex of the lung, which is the same as the caudal border of Station 1, while the IASLC definition is 'apex of the left lung and pleural space, and in the midline, upper border of the manubrium'. It is here that Station 2L is in contact with Station 1L (Fig. 1). The caudal border is the upper margin of the aortic arch. At this border, Station 2L abuts on Station 4L (Fig. 1). The left border is the pleura. The right border is the left lateral border of the trachea. At this border, Station 2L shares the boundary with Station 2R (Fig. 3). The anterior border is muscles and blood vessels in the region above the upper border of the manubrium, and Line A in the region below the upper border of the manubrium. At Line A, Station 2L contacts Station 3a (Fig. 3). The posterior border is the membranous wall of the trachea and a virtual horizontal line extending along the posterior wall of the

Table 1. Consensus guidelines for the boundaries of lymph node stations in radiotherapy for lung cancer

Station	Name	Cranial	Caudal	Left	Right	Anterior	Posterior
1R	Right low cervical, supraclavicular, and sternal notch nodes	Lower margin of the cricoid cartilage	Apex of the lung[a]	Midline of the trachea	Clavicle and anterior scalene muscle	Posterior aspect of the clavicles	Muscles and bones
1L	Left low cervical, supraclavicular, and sternal notch nodes			Clavicle and anterior scalene muscle	Midline of the trachea		
2R	Right upper paratracheal nodes	Apex of the lung[a]	Intersection of the caudal margin of left brachiocephalic vein with the midline of the trachea[b]	Left lateral border of the trachea	Pleura	Above the upper border of the manubrium: muscles and blood vessels Below the upper border of the manubrium: Line A†	Membranous wall of the trachea
2L	Left upper paratracheal nodes		Upper margin of the aortic arch	Pleura	Left lateral border of the trachea		Membranous wall of the trachea Lateral side of the esophagus: virtual horizontal line extending along the posterior wall of the trachea
3a	Prevascular nodes	Upper border of the manubrium	Level of the carina	Pleura	Pleura	Posterior aspect of the sternum	Above the upper margin of the aortic arch: Line A† Below the upper margin of the aortic arch: virtual horizontal line extending from the anterior wall of the ascending aorta and the anterior aspect

							of the superior vena cava
3p	Retrotracheal nodes	Apex of the lung[a]	Level of the carina	Pleura and descending aorta	Pleura and azygos vein	Membranous wall of the trachea Lateral side of the esophagus: virtual horizontal line extending along the posterior wall of the trachea	Anterior aspect of the vertebral body[c]
4R	Right lower paratracheal nodes	Intersection of the caudal margin of the left brachiocephalic vein with the midline of the trachea[b]	Lower margin of the azygos arch[d]	Left lateral border of the trachea Caudal portion (near the carina): a caudally extended virtual line that passes along the left tracheal border	Pleura and azygos vein	Superior vena cava and aorta	Membranous wall of the trachea
4L	Left lower paratracheal nodes	Upper margin of the aortic arch	Upper margin of the left main pulmonary artery	Line B[‡]	Left lateral border of the trachea Caudal portion (near the carina): a caudally extended virtual line that passes along the left tracheal border	Aortic arch and ascending aorta	Membranous wall of the tracheaLateral side of the esophagus: virtual horizontal line extending along the posterior wall of the trachea
5	Subaortic nodes (aortopulmonary window)	Lower margin of the aortic arch	Upper margin of the left main pulmonary artery	Pleura	Line B[‡]	Line C[§]	Descending aorta
6	Paraaortic nodes (ascending aorta or phrenic)	Upper margin of the aortic arch	Level of the carina	Pleura	Aortic arch and ascending aorta	Virtual horizontal line extending from the anterior wall of the ascending aorta	Aortic arch level: intersection of the aortic arch and pleura Below the aortic arch: Line C[§] Below the upper

Continued

Table 1. Continued

Station	Name	Cranial	Caudal	Left	Right	Anterior	Posterior
							margin of the left main pulmonary artery: Line C'[¶]
7	Subcarinal nodes	Carina	Left: upper border of the lower lobe bronchus Right: lower border of the bronchus intermedius	Above the upper margin of the left lower lobe bronchus: left main bronchus Below the upper margin of the left lower lobe bronchus: right lateral border of the esophagus	Right main bronchus and truncus intermedius	Virtual line that connects the anterior aspects of the main bronchi bilaterally Below the level of the main bronchi: heart and great vessels	Virtual line that connects the posterior aspects of the main bronchi bilaterally
8	Paraesophageal nodes (below the carina)	Level of the carina	Diaphragm	Pleura and descending aorta	Pleura Between the level of the left upper border of the lower lobe bronchus and the level of the lower border of the bronchus intermedius: the right lateral border of the esophagus.	Virtual line that connects the posterior aspects of the main bronchi bilaterally Below the level of the main bronchi: heart and great vessels	Anterior aspect of the vertebral body[c]
9	Pulmonary ligament nodes	Inferior pulmonary vein	Diaphragm (up to the level at which the pulmonary ligament can be detected)	Pleura (up to the area at which the pulmonary ligament can be detected)			
10R	Right hilar nodes			Midline of the trachea			Pleura and azygos vein

		Lower margin of the azygos arch	Lower margin of the right upper lobe bronchus		Lateral border of the right main bronchus	Ascending aorta, superior vena cava, and pulmonary artery	
10L	Left hilar nodes	Upper margin of the left main pulmonary artery	Upper margin of the left lower lobe bronchus	Pulmonary artery, pleura, and lateral border of the left main bronchus	Midline of the trachea[e]	Ascending aorta and left pulmonary artery	Descending aorta, esophagus and pleura
10L*	Left hilar nodes*	Upper margin of the left main pulmonary artery	Lower margin of the left superior pulmonary vein	Pleura, left pulmonary artery, and left superior pulmonary vein	Left main pulmonary artery	Line C'[¶]	Left pulmonary artery and left superior pulmonary vein
11s	Superior interlobar nodes	Lower margin of the right upper lobe bronchus	Lower margin of the truncus intermedius	Lateral border of the right main bronchus		Lung	
11i	Inferior interlobar nodes	Lower margin of the truncus intermedius	Upper margin of the right lower lobe bronchus	Middle lobe bronchus and right lower lobe bronchus	Lung	Lung and middle lobe bronchus	Lung and right lower lobe bronchus
11	Left interlobar nodes	Lower margin of the left upper lobe bronchus	Upper margin of the left lower lobe bronchus	Lung	Lateral border of the left main bronchus Caudal area: left upper and lower lobe bronchi	Lung and left upper lobe bronchus	Lung and left lower lobe bronchus

Line A[†] = an imaginary line that smoothly connects the anterior aspects of four vessels (the right brachiocephalic vein, the brachiocephalic artery, the left common carotid artery and the left subclavian artery), Line B[‡] = an imaginary line that connects the ascending and descending aorta at the shortest distance, Line C[§] = an imaginary line that is tangential to the posterior aspect of the ascending aorta and is at a right angle to Line B, Line C'[¶] = an imaginary line in which Line C is moved parallel to the anterior border of the left main pulmonary artery. [a]When the apex of the lung differs between the right and the left, this border should be aligned to the upper side. [b]The level of the intersection point includes Station 4R. [c]Fat tissue adjacent to the esophagus and the descending aorta is included. [d]Since there are individual differences in the relative positions of the azygos arch and carina, this border could be extended caudally. [e]If Station 10L shares a boundary with Station 4R, alignment should be performed with Station 4R.

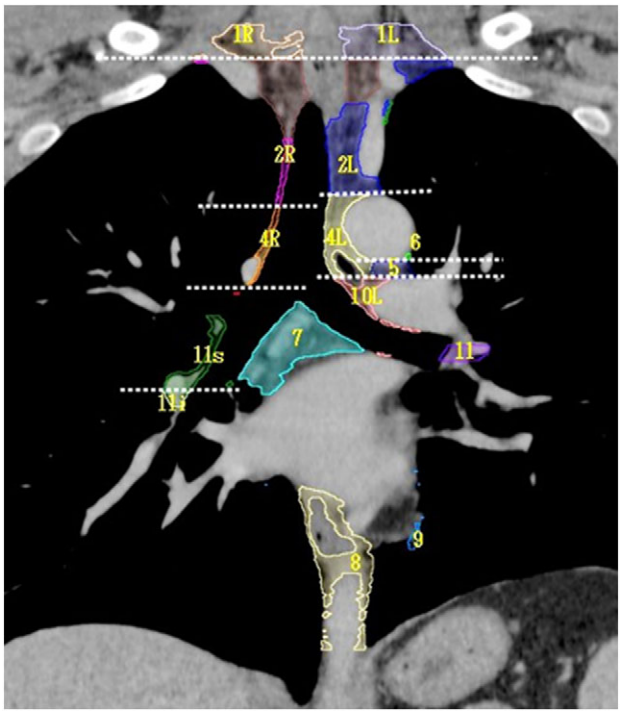


Fig. 1. Coronal view including the carina.

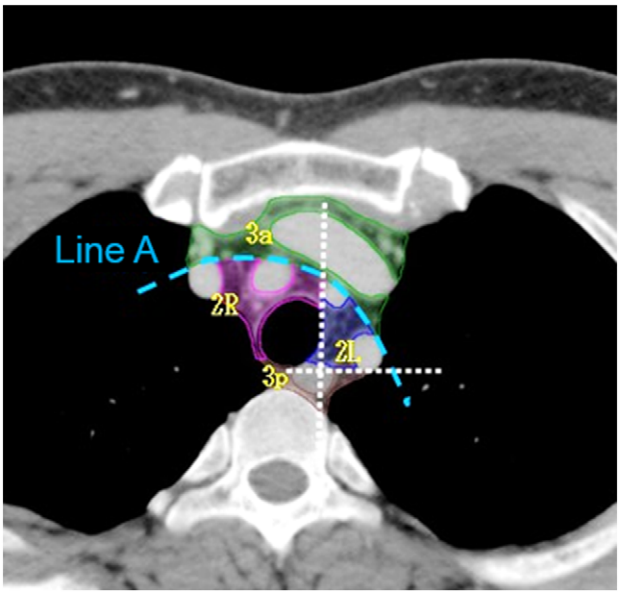


Fig. 3. Upper mediastinal cross-section. Line A (light blue dotted line): an imaginary line that smoothly connects the anterior aspects of four vessels (the right brachiocephalic vein, the brachiocephalic artery, the left common carotid artery and the left subclavian artery).

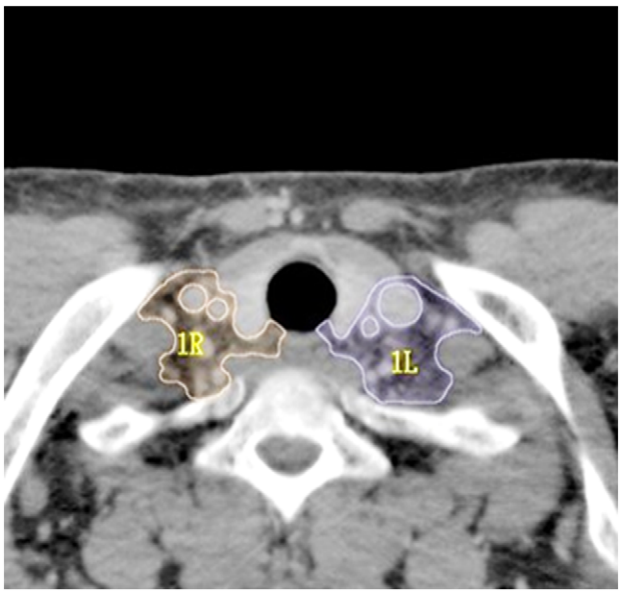


Fig. 2. Supraclavicular-level cross-section.

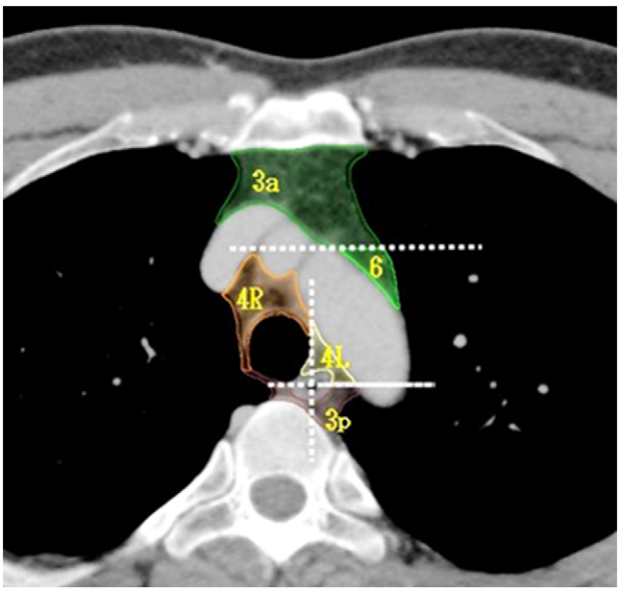


Fig. 4. Aortic arch-level cross-section.

trachea on the lateral side of the esophagus. At this border, Station 2L abuts on Station 3p (Fig. 3).

Station 3a: prevascular nodes

The cranial border is the upper border of the manubrium (the IASLC definition is the apex of the chest). The caudal border is the level of the carina. The lateral border is the pleura. The anterior border is the posterior aspect of the sternum (Fig. 3). The posterior border is Line A in the region above the upper margin of the aortic arch, at which Station 3a shares the boundary with Stations 2R and 2L (Fig. 3). In the region below the upper margin of the aortic arch, the posterior border is a virtual horizontal line extending from the anterior wall of the ascending aorta and the anterior aspect of the

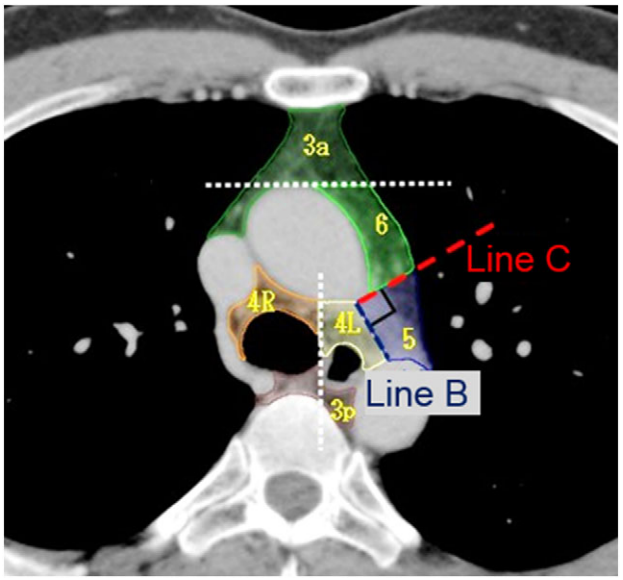


Fig. 5. Azygos arch-level cross-section. Line B (dark blue dotted line): an imaginary line that connects the ascending and descending aorta at the shortest distance. Line C (red dotted line): an imaginary line that is tangential to the posterior aspect of the ascending aorta and is at a right angle to Line B.

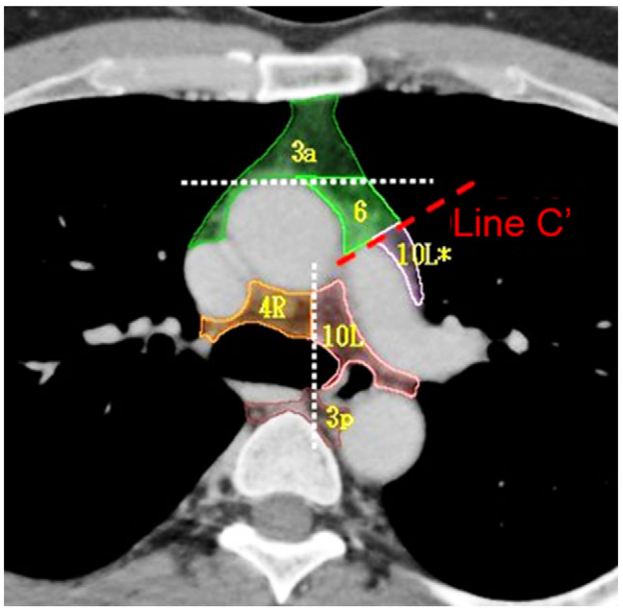


Fig. 6. Carina-level cross-section. Line C' (red dotted line): an imaginary line in which Line C is moved parallel to the anterior border of the left main pulmonary artery.

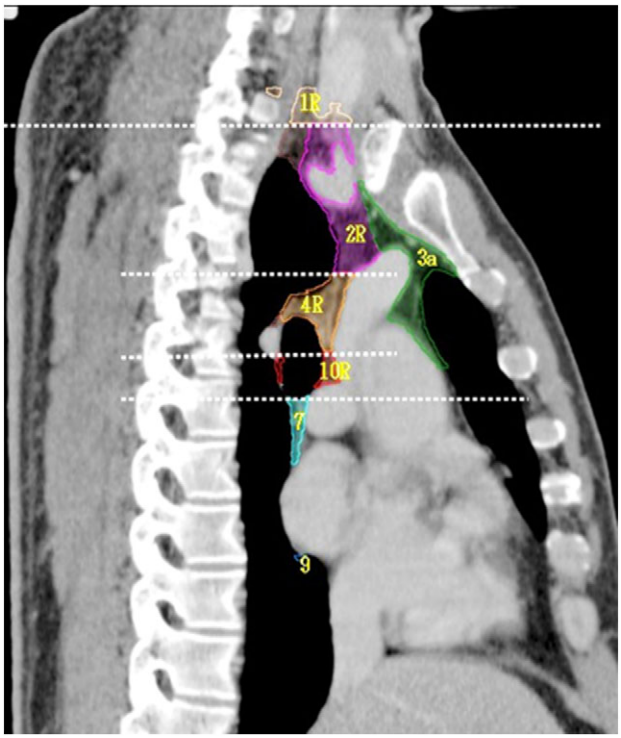


Fig. 7. Sagittal view including the right main bronchus.

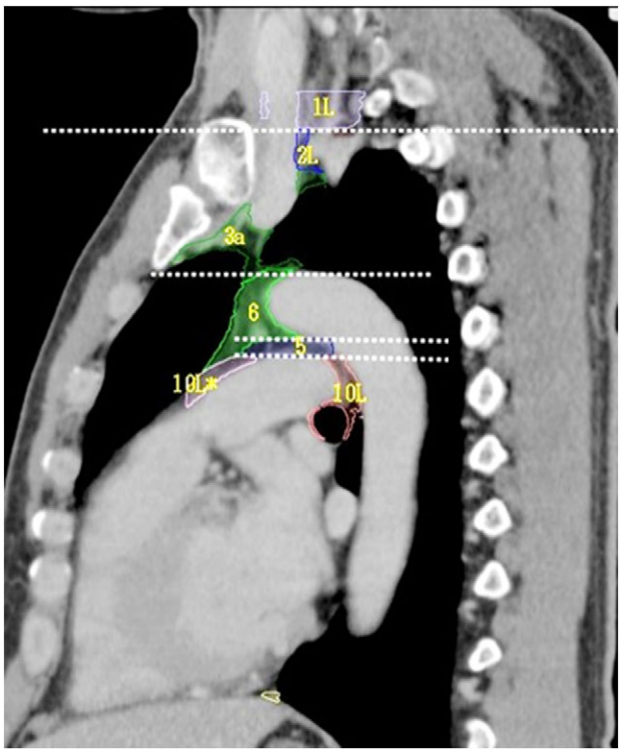


Fig. 8. Sagittal view including the left main bronchus.

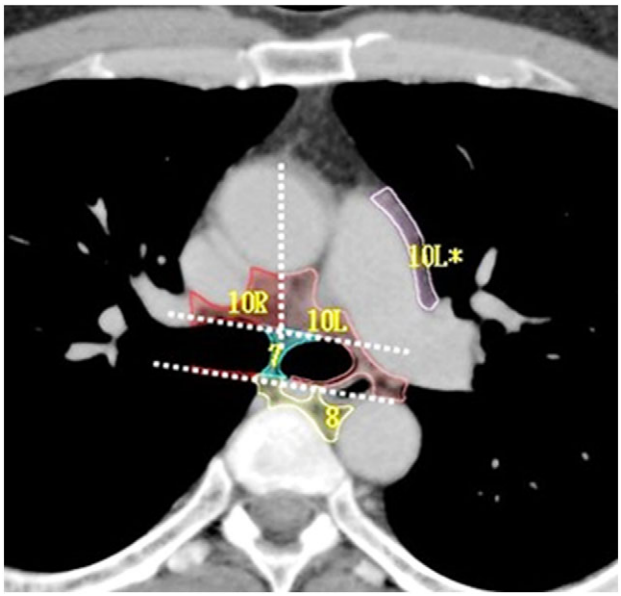


Fig. 9. Inferior border-level of carina cross-section.

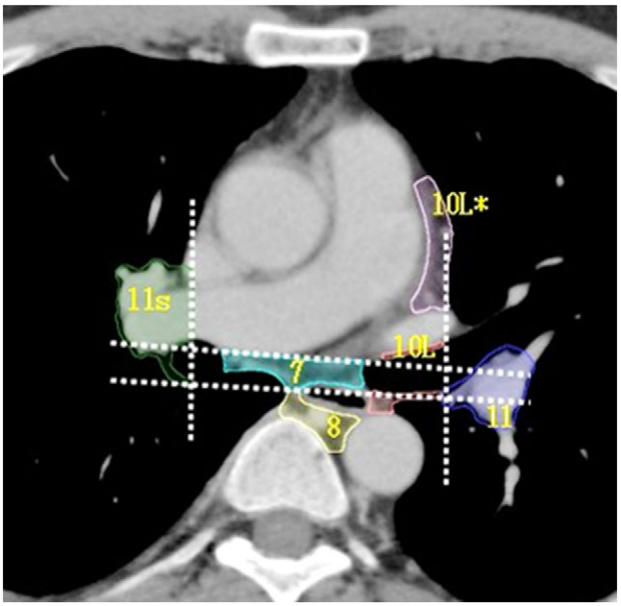


Fig. 11. Left superior lobar bronchial bifurcation-level cross-section.

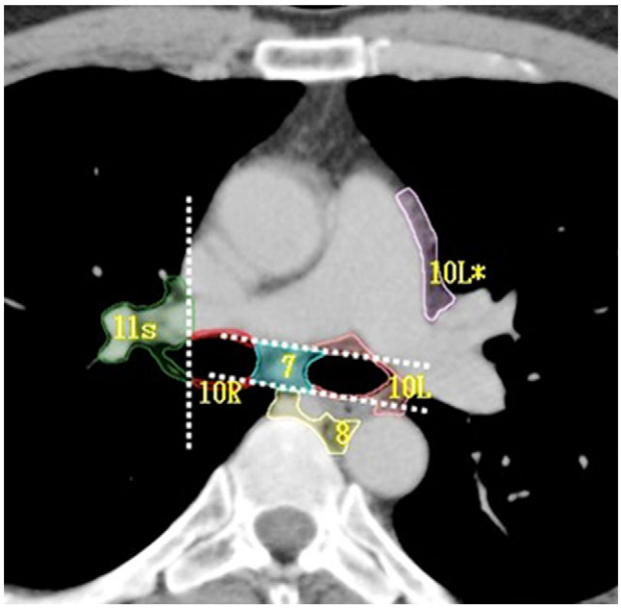


Fig. 10. Subcarinal-level cross-section.

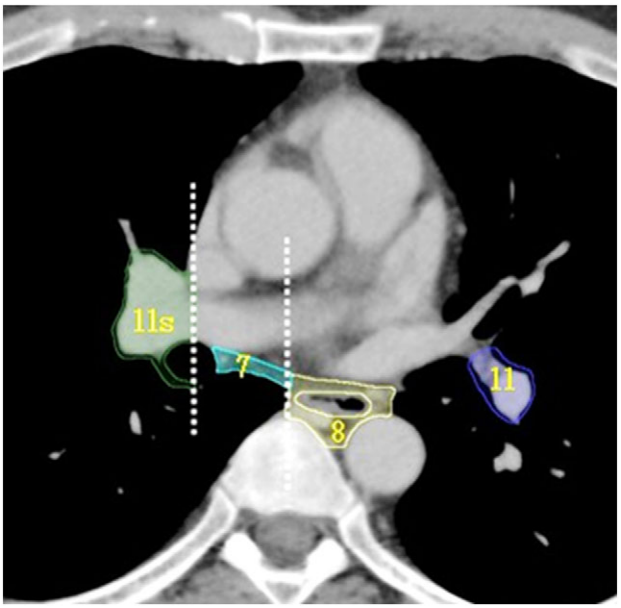


Fig. 12. Truncus intermedius-level cross-section.

superior vena cava (SVC). At this border, Station 3a abuts on Station 6 (Figs 4–6). The IASLC definition is 'anterior border of SVC on the right, and the left carotid artery on the left'.

Station 3p: retrotracheal nodes

The cranial border is the apex of the lung. It is here that Station 3p is in contact with Station 1. The caudal border is the level of the carina. At this border, Station 3p abuts on Station 8. The left border is the pleura and descending aorta. The right border is the pleura and azygos vein. The anterior border is the membranous wall of the trachea and a virtual horizontal line extending along the posterior wall of the trachea on the lateral side of the esophagus. At this border, Station 3p shares the boundary with Stations 2R, 2L, 4R and 4L (Figs 3–5). The posterior border is the anterior aspect of the vertebral body. Due to individual differences in the relative positions

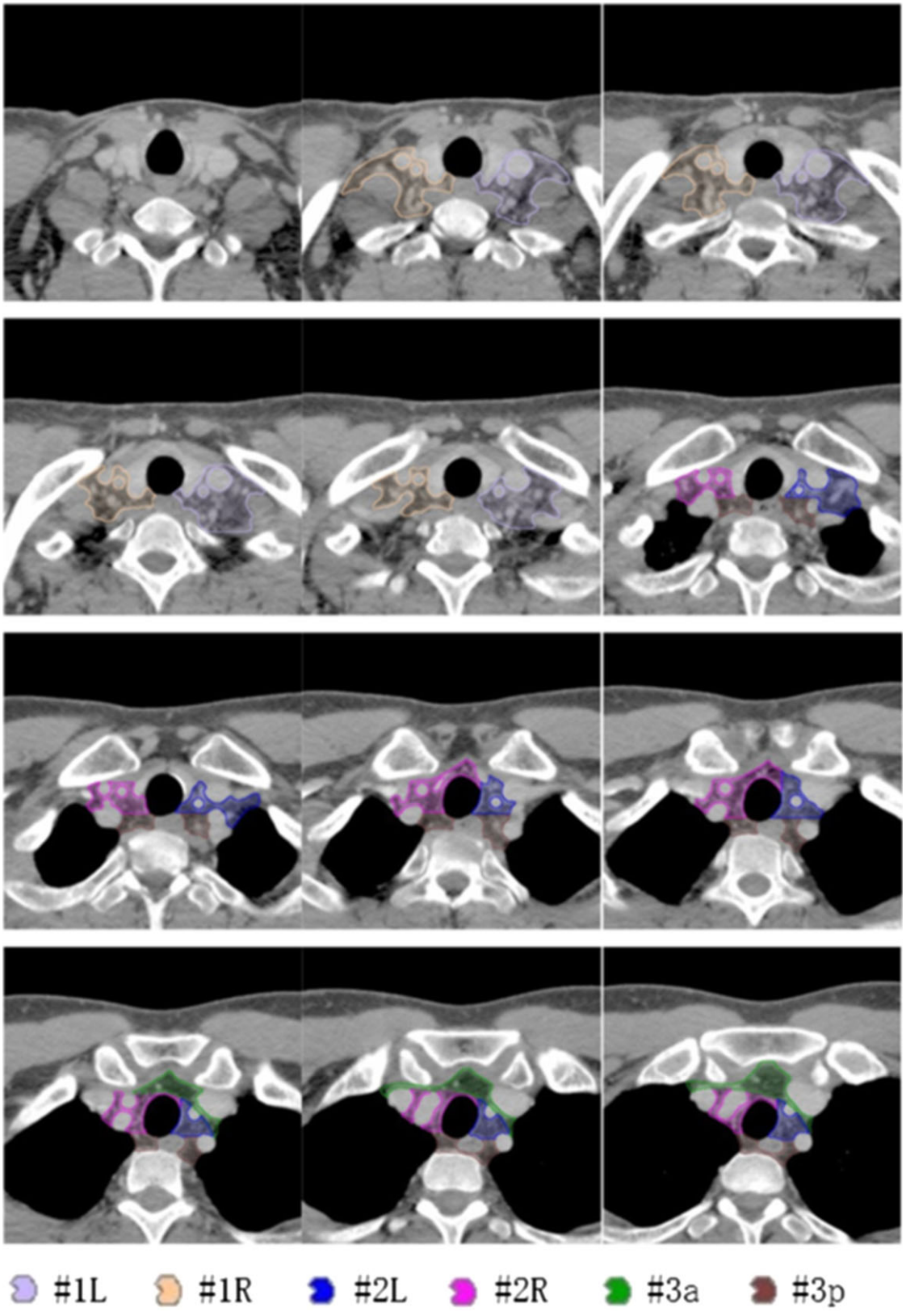
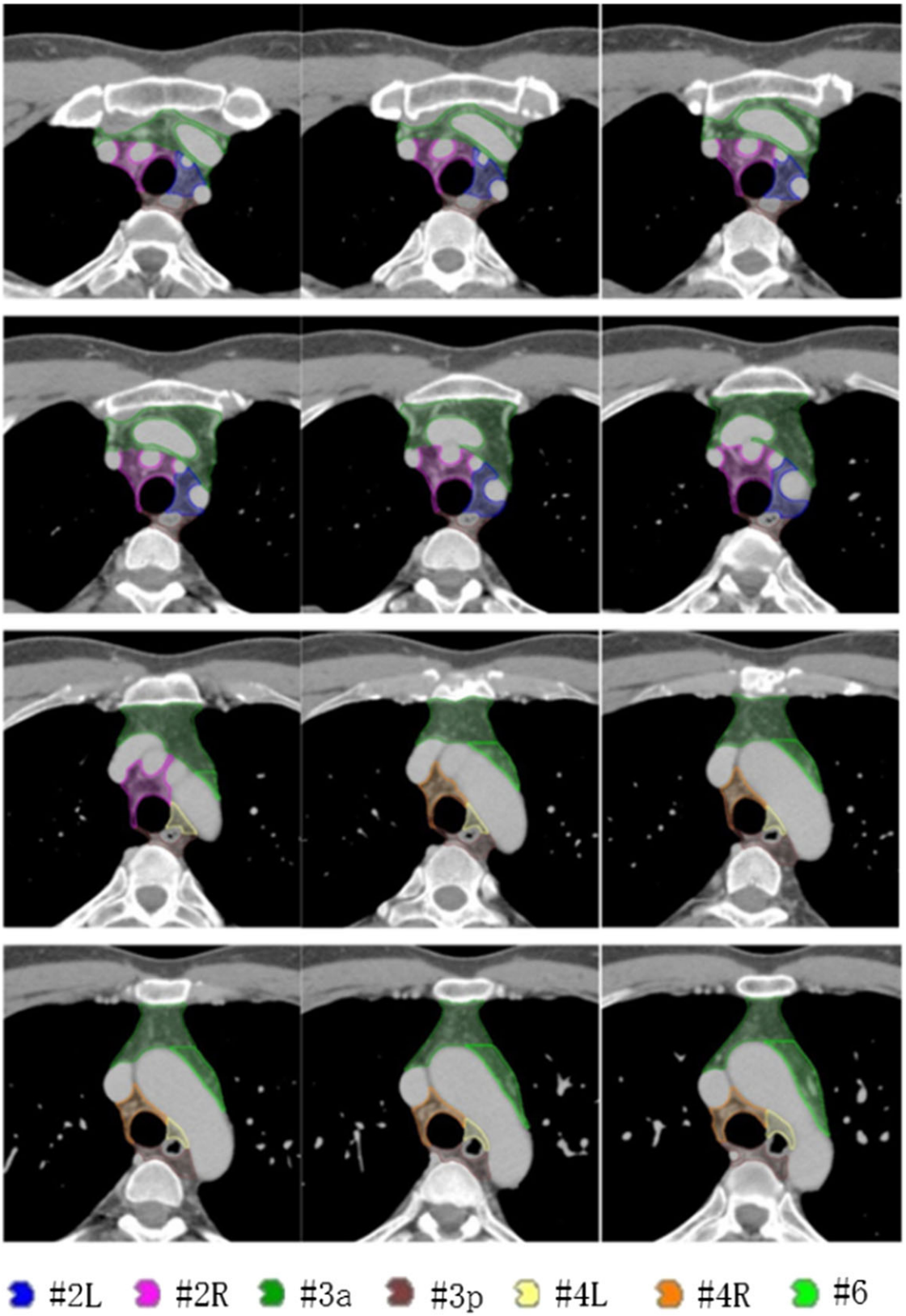


Fig. 13. Atlas of the regional lymph node stations in radiotherapy for lung cancer (serial axial images).



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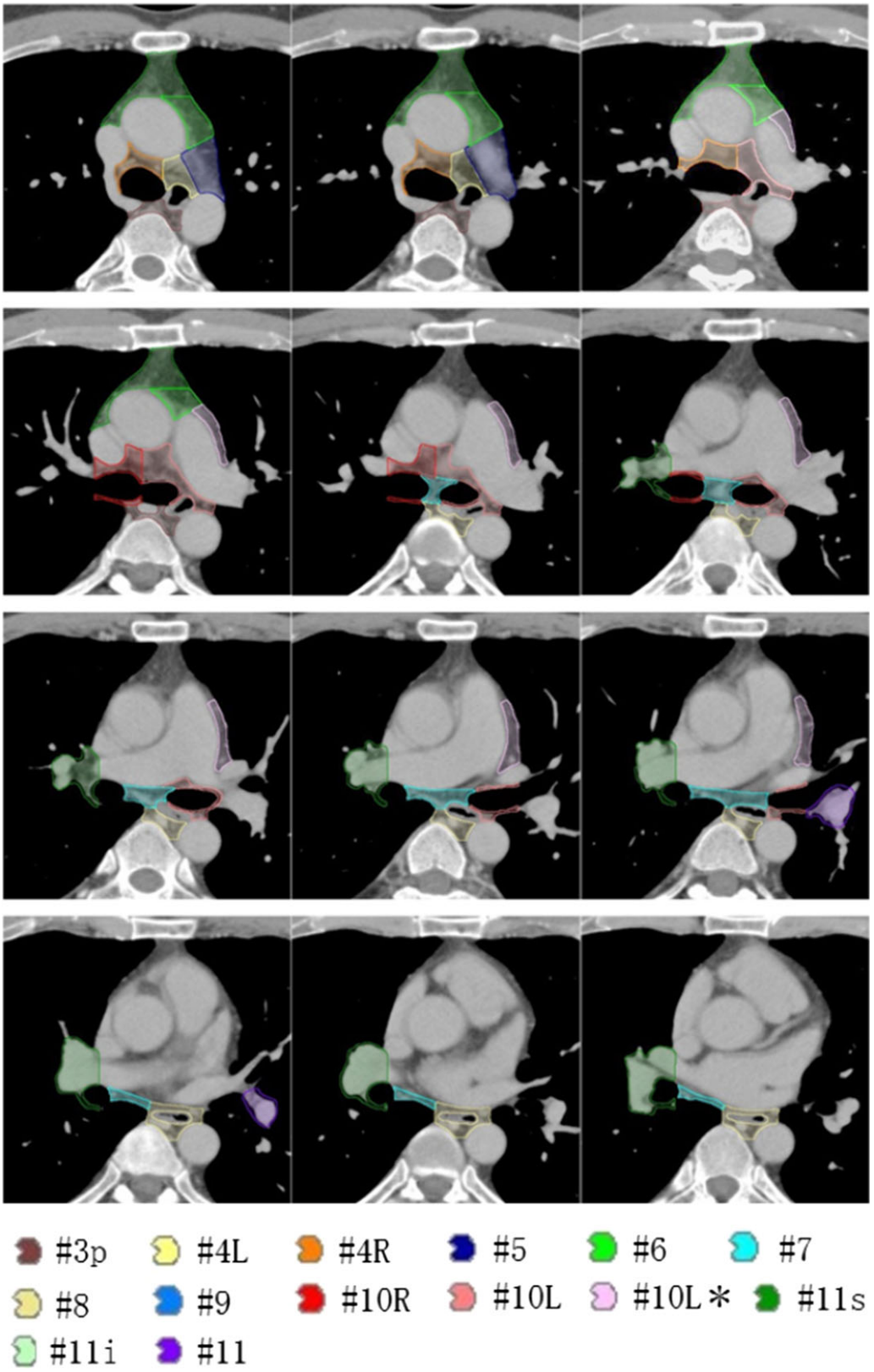

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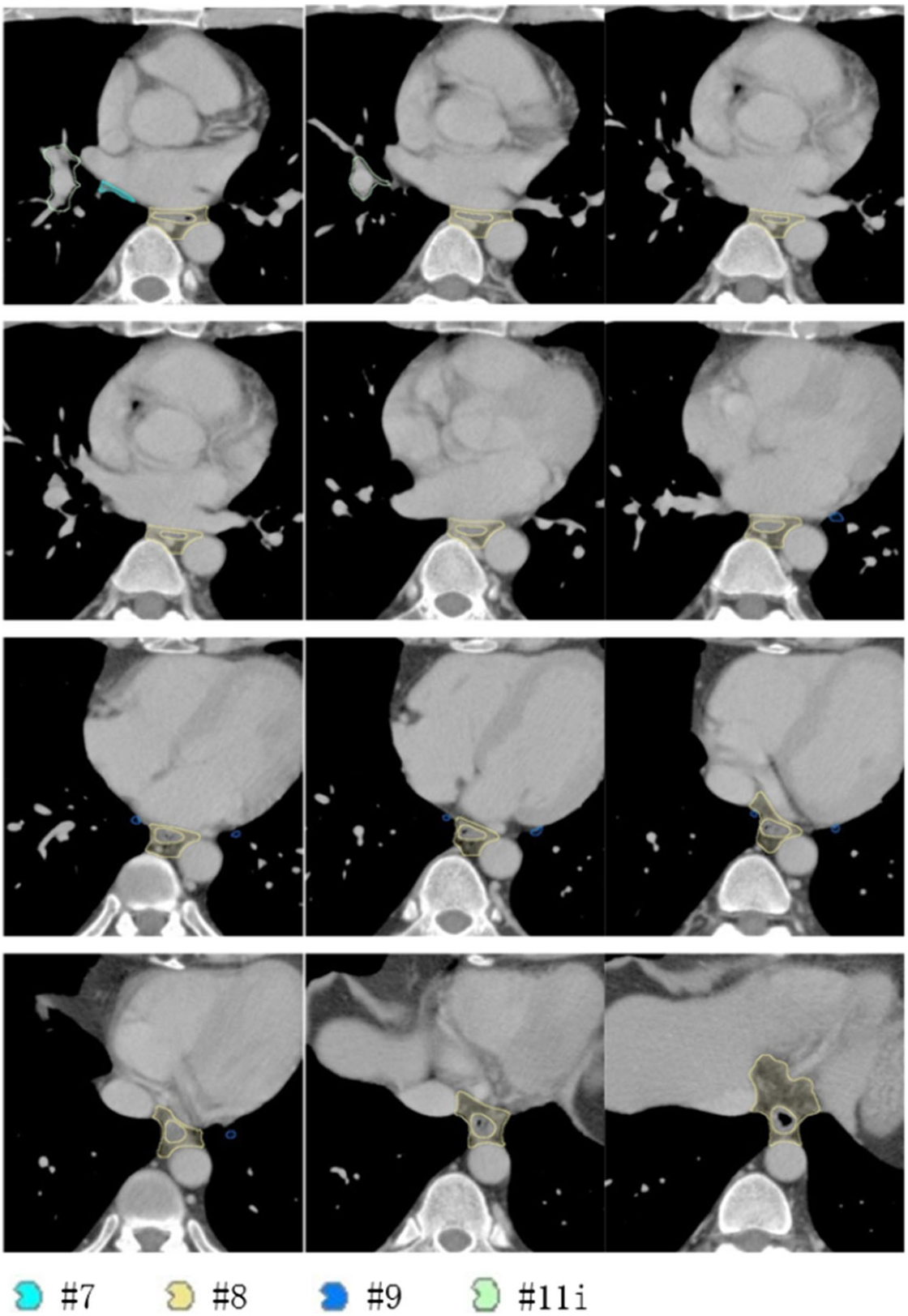

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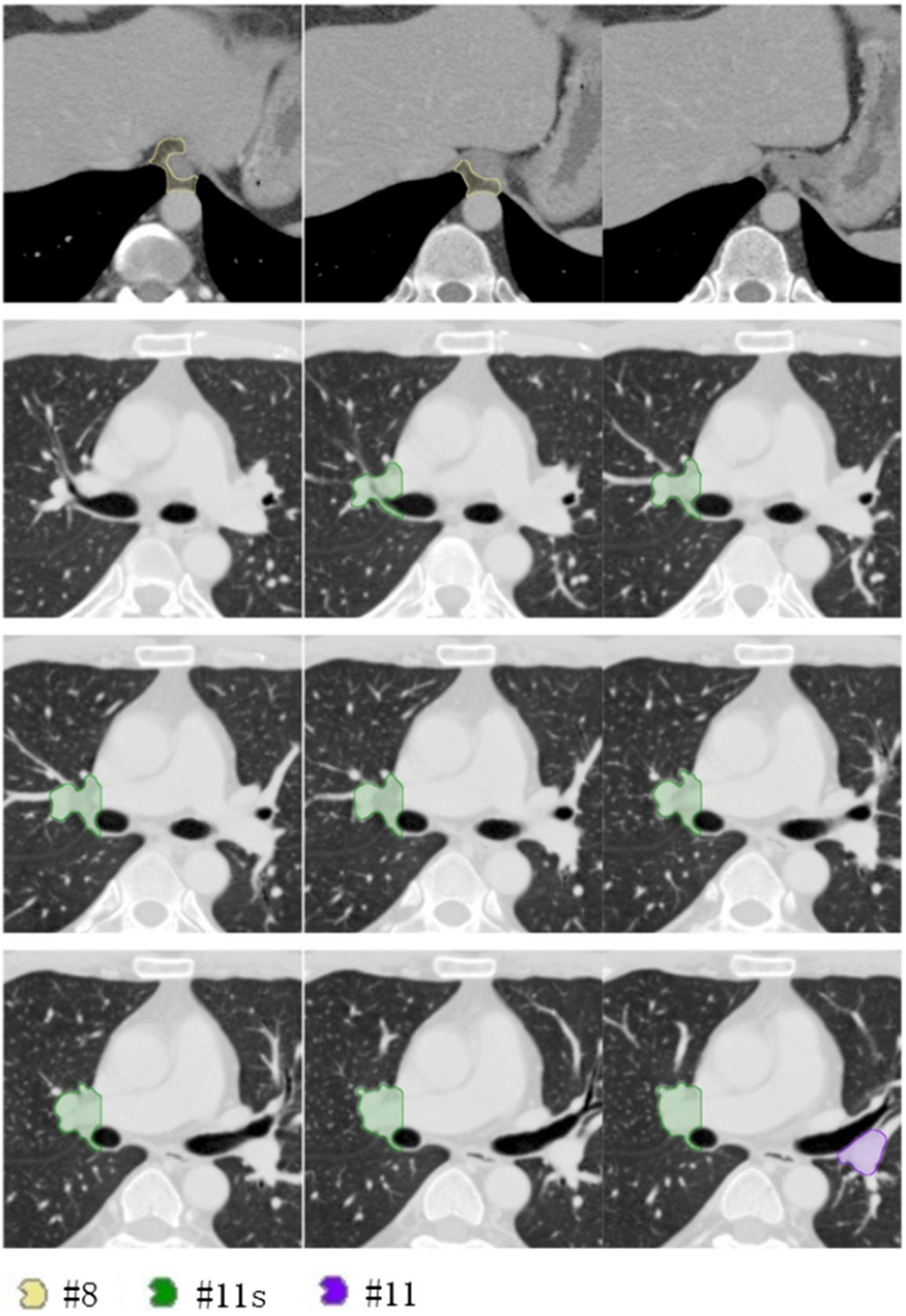

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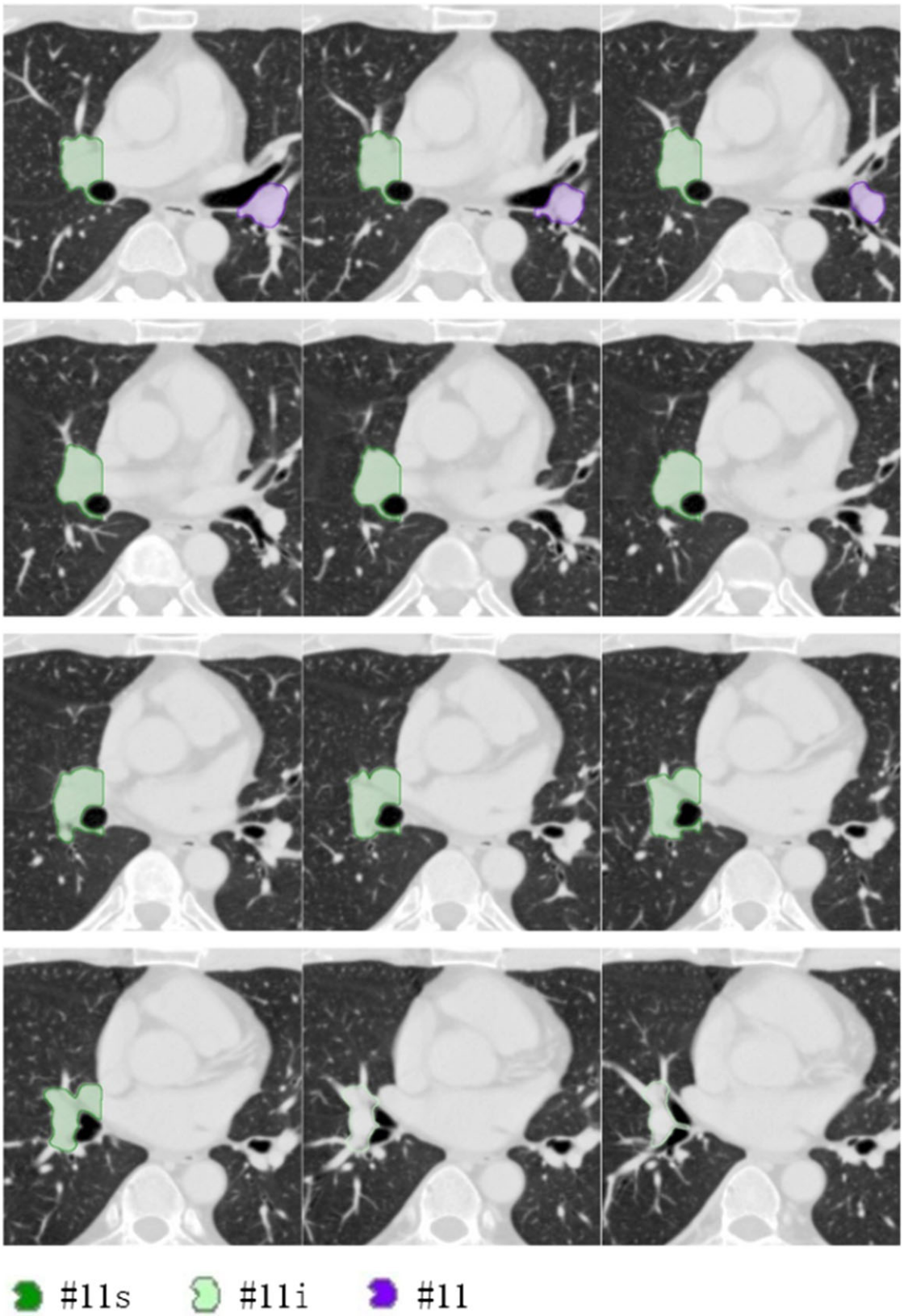

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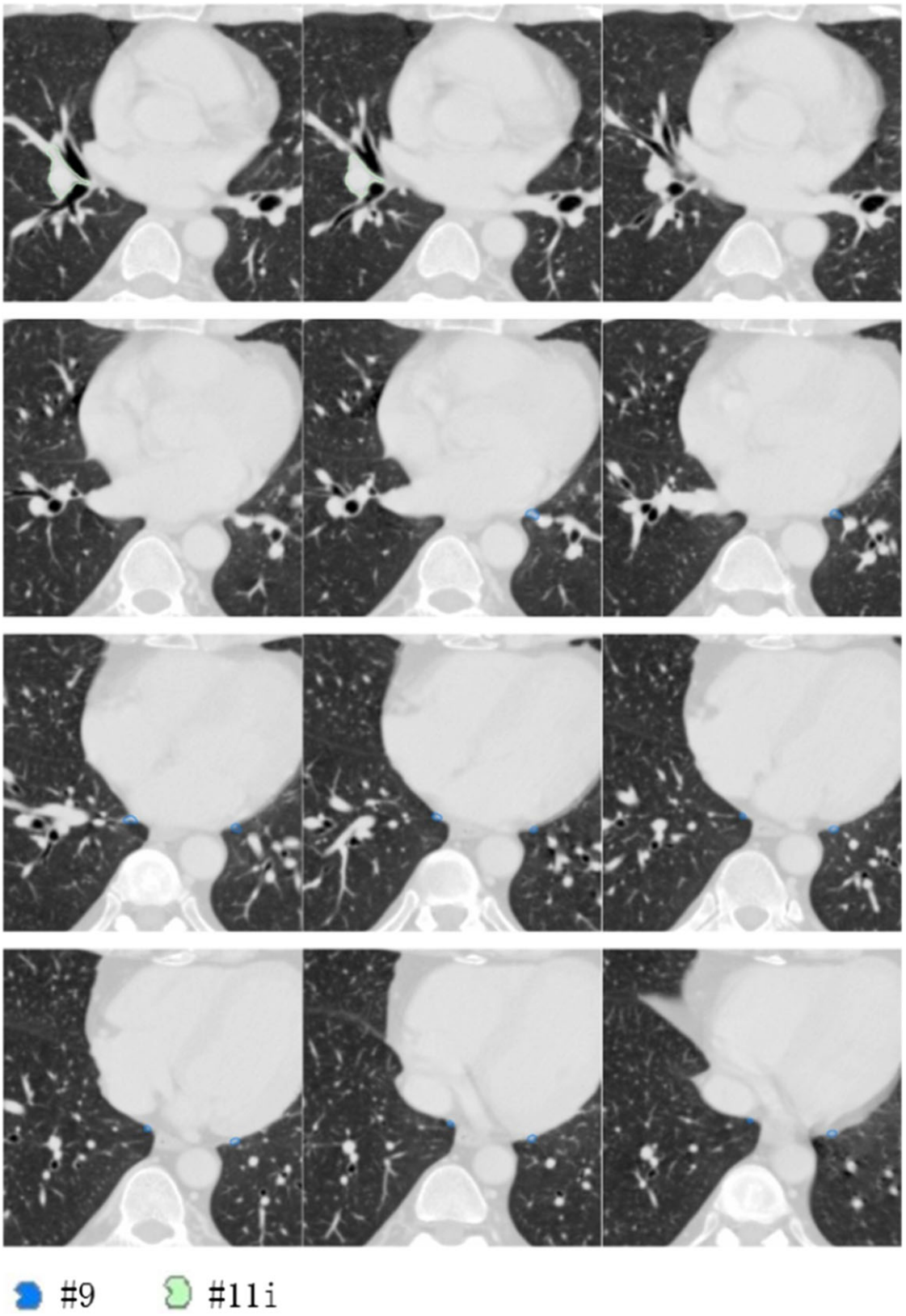

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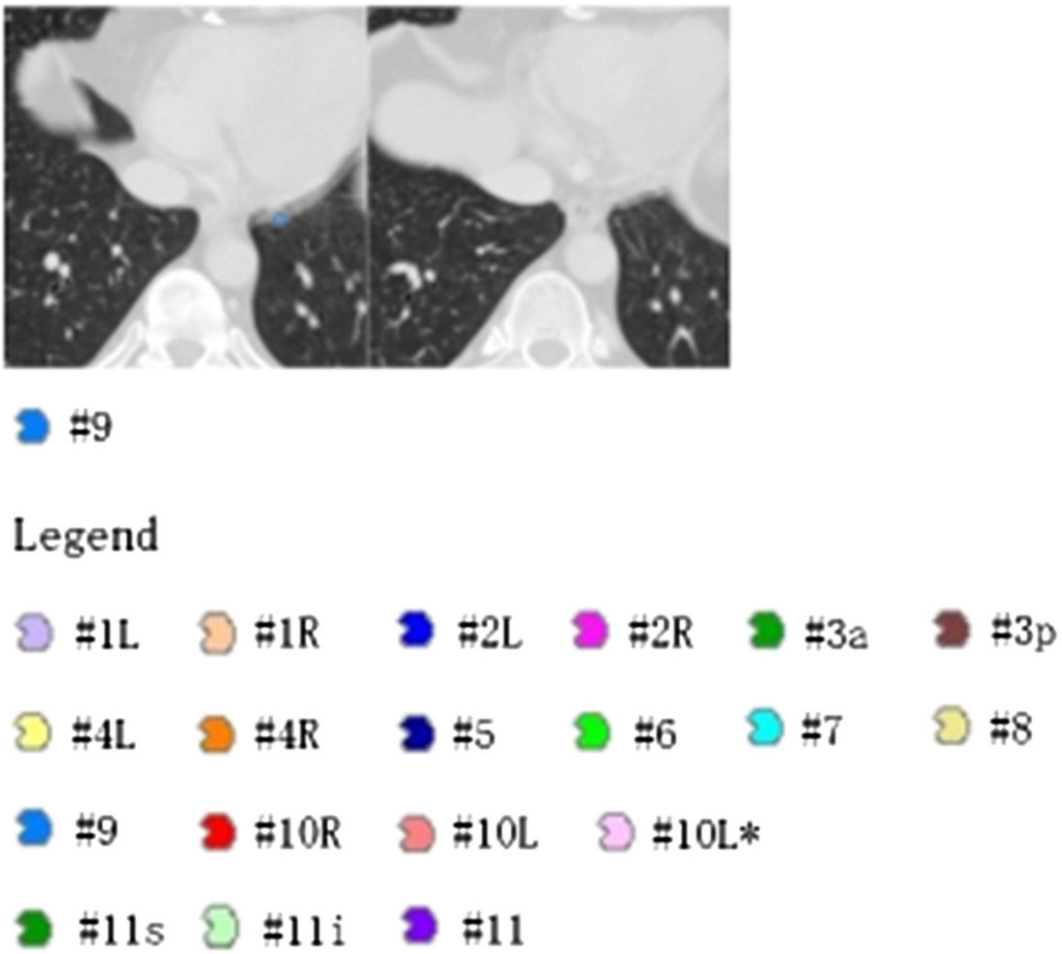

Fig. 13. Continued

of the vertebral body and the esophagus, fat tissue adjacent to the esophagus and the descending aorta is included (Figs 3–6).

Station 4R: right lower paratracheal nodes

The IASLC definition is 'right paratracheal nodes and peritracheal nodes extending to the left lateral border of trachea'. The cranial border is the intersection of the caudal margin of the left brachiocephalic vein with the midline of the trachea. The level of the intersection point was included in Station 4R. The caudal border is the lower margin of the azygos arch. At this border, Station 4R abuts on Station 10R. Since there are individual differences in the relative positions of the azygos arch and carina, this border could be extended caudally (Figs 1 and 7). The left border is the left lateral border of the trachea and a caudally extended virtual line that passes along the left tracheal border in the caudal portion (near the carina). At this border, Station 4R shares the boundary with Station 4L and can contact Station 10L in the caudal position (Figs 4–6). The right border is the pleura and azygos vein. The fat tissue between the trachea and azygos vein should be included in this station. The anterior border is the SVC and aorta. The fat tissue between the SVC and aorta should be included in this station (Figs 4–6). The posterior border is the membranous wall of the trachea. At this border, Station 4R abuts on Station 3p (Figs 4 and 5).

Station 4L: left lower paratracheal nodes

The IASLC definition is 'lymph nodes to the left lateral border of the trachea, medial to the ligamentum arteriosum'. The cranial border is the upper margin of the aortic arch. At this border, Station 4L contacts Station 2L (Fig. 1). The caudal border is defined as the upper margin of the left main pulmonary artery, since the IASLC definition, 'upper rim of the left main pulmonary artery', is ambiguous. At this border, Station 4L abuts on Station 10L (Fig. 1). The left border is an imaginary line that connects the ascending and descending aorta at the shortest distance (Line B) as a surrogate for the ligamentum arteriosum, which is difficult to detect on CT images. At Line B, Station 4L shares the boundary with Station 5 (Fig. 5). The right border is the left lateral border of the trachea and a caudally extended virtual line that passes along the left tracheal border in the caudal portion (near the carina). At this border, Station 4L contacts Station 4R. Fat tissue surrounded by the

esophagus, membranous wall of the trachea, and left lateral border of the trachea should be included in Station 4L (Figs 4 and 5). The anterior border is the aortic arch and ascending aorta. The posterior border is the membranous wall of the trachea and a virtual horizontal line extending along the posterior wall of the trachea on the lateral side of the esophagus. At this border, Station 4L abuts on Station 3p (Figs 4 and 5).

Station 5: subaortic nodes (aortopulmonary window)

The IASLC definition is 'subaortic lymph nodes lateral to the ligamentum arteriosum'. The cranial border is the lower margin of the aortic arch. It is here that Station 5 is in contact with Station 6 (Figs 1 and 6). The caudal border is the upper margin of the left main pulmonary artery, since the IASLC definition, 'upper rim of the left main pulmonary artery', is ambiguous. At this border, Station 5 abuts on Station 10L (Figs 1 and 8). The left border is the pleura. The right border is Line B. At this border, Station 5 shares the boundary with Station 4L (Fig. 5). The anterior border is an imaginary line that is tangential to the posterior aspect of the ascending aorta and is at a right angle to Line B (Line C). At this border, Station 5 contacts Station 6 (Fig. 5). The posterior border is the descending aorta.

Station 6: paraaortic nodes (ascending aorta or phrenic)

The IASLC definition is 'lymph nodes anterior and lateral to the ascending aorta and aortic arch'. The cranial border is the upper margin of the aortic arch (Fig. 8). The caudal border is defined as the level of the carina, while the IASLC definition is 'the lower border of the aortic arch' because it was considered that the paraaortic area which lies along the ascending aorta should be included in this station. The lateral border is the pleura on the left, the aortic arch and ascending aorta on the right. The anterior border is a virtual horizontal line extending from the anterior wall of the ascending aorta. At this border, Station 6 contacts Station 3a (Figs 4–6). In the aortic arch level, the posterior border is the intersection of the aortic arch and pleura, up to where fat tissue is detected (Fig. 4). In the region below the aortic arch, the posterior border is Line C. In the region below the upper margin of the left main pulmonary artery, the posterior border is an imaginary line in which Line C is moved parallel to the anterior border of the left main pulmonary artery (Line C'). At this border, Station 6 abuts on Stations 5 and 10L* (Figs 5 and 6).

Station 7: subcarinal nodes

The IASLC definition is 'lymph nodes surrounded by the carina and the main bronchi bilaterally'. The cranial border is the carina (Fig. 1). The caudal border is the upper border of the lower lobe bronchus on the left, and the lower border of the bronchus intermedius on the right. In the region above the upper margin of the left lower lobe bronchus, the left border is the left main bronchus. In the region below the upper margin of the left lower lobe bronchus, the left border is the right lateral border of the esophagus. At this border, Station 7 shares the boundary with Station 8 (Figs 9–12). The right border is the right main bronchus and truncus intermedius (Figs 1 and 9–12). The anterior border is a virtual line that connects the anterior aspects of the main bronchi bilaterally. At this border, Station 7 contacts Stations 10R and 10L. Below the level of the main bronchi, the anterior border is the heart and great vessels (Figs 9–12). The posterior border is a virtual line that connects the posterior aspects of the main bronchi bilaterally. At this border, Station 7 abuts on Station 8 (Figs 9–12).

Station 8: paraesophageal nodes (below the carina)

The IASLC definition is 'lymph nodes lying adjacent to the wall of the esophagus and to the right or left of the midline, excluding subcarinal nodes'. The cranial border is defined as the level of the carina, while the IASLC definition is 'the upper border of the lower lobe bronchus on the left, the lower border of the bronchus intermedius on the right', because it was considered that the paraesophageal area between the level of the carina and this IASLC-defined border should not be included in Station 7. It is here that Station 8 is in contact with Station 3p. The caudal border is the diaphragm. The left border is the pleura and descending aorta. The right border is the pleura. Between the level of the left upper border of the lower lobe bronchus and the level of the lower border of the bronchus intermedius, the right border is the right lateral border of the esophagus. At this border, Station 8 shares the boundary with Station 7 (Figs 9–12). The anterior border is the virtual line that connects the posterior aspects of the main bronchi bilaterally. At this border, Station 8 contacts Station 7. In the region below the level of the main bronchus, the anterior border is the heart and great vessels (Figs 9–12). The posterior border is the anterior aspect of the vertebral body. Due to individual differences in the relative positions of the vertebral body and the esophagus, fat tissue adjacent to the esophagus and descending aorta was included (Figs 9–12).

Station 9: pulmonary ligament nodes

The IASLC definition is 'lymph nodes lying within the pulmonary ligament'. The cranial border is the inferior pulmonary vein. The caudal border is the diaphragm (up to the level at which the pulmonary ligament can be detected). The lateral, anterior and posterior border is up to the area at which the pulmonary ligament can be detected.

Station 10: hilar lymph nodes

The IASLC definition is the lymph nodes immediately adjacent to the mainstem bronchus and hilar vessels, including the proximal portions of the pulmonary veins and main pulmonary artery. Station 10 was divided into three substations due to the requirements of radiotherapy treatment planning: Station 10R (right hilar nodes), Station 10L (left hilar nodes adjacent to the left main bronchus), and Station 10L* (left hilar nodes adjacent to the hilar vessels, including the proximal portions of the pulmonary veins and the main pulmonary artery).

Station 10R: right hilar nodes

The cranial border is the lower margin of the azygos arch. It is here that Station 10R is in contact with Station 4R (Figs 1 and 7). The

caudal border is the lower margin of the right upper lobe bronchus, which is a surrogate for the right interlobar regions that are difficult to detect in axial CT images. The left border is the midline of the trachea. At this border, Station 10R shares the boundary with Station 10L (Fig. 9). The right border is the lateral border of the right main bronchus, which is represented as a vertical line drawn from the lateral aspect of the right main bronchus. At this border, Station 10R contacts Station 11s (Fig. 10). The anterior border is the ascending aorta, SVC and pulmonary artery. The posterior border is the pleura and azygos vein (Figs 9 and 10).

Station 10L: left hilar nodes

The cranial border is defined as the upper margin of the left main pulmonary artery, since the IASLC definition, 'upper rim of the left main pulmonary artery', is ambiguous. It is here that Station 10L is in contact with Station 4L (Fig. 1). The caudal border is the upper margin of the left lower lobe bronchus, which is a surrogate for the left interlobar regions that are difficult to detect in axial CT images. The left border is the pulmonary artery, pleura and lateral border of the left main bronchus that is represented as a vertical line drawn from the lateral aspect of the left main bronchus. At this border, Station 10L shares the boundary with Station 11 (Fig. 11). The right border is the midline of the trachea. In cases where Station 10L shares a boundary with Station 4R, this station should be aligned with Station 4R (Figs 6 and 9). The anterior border is the ascending aorta and left pulmonary artery. The posterior border is the descending aorta, esophagus and pleura (Figs 9–11).

Station 10L*: left hilar nodes*

The cranial border is the upper margin of the left main pulmonary artery. It is here that Station 10L* is in contact with Station 5 (Fig. 8). The caudal border is the lower margin of the left superior pulmonary vein. The left border is the pleura, left pulmonary artery and left superior pulmonary vein. The right border is the left main pulmonary artery. The anterior border is Line C'. At this border, Station 10L* shares the boundary with Station 6 (Fig. 6). The posterior border is the left pulmonary artery and left superior pulmonary vein.

Station 11s: superior interlobar nodes

The IASLC definition is 'lymph nodes between the upper lobe bronchus and the bronchus intermedius on the right'. The cranial border is the lower margin of the right upper lobe bronchus that is represented in the caudal slice where the right B3 branches off. The caudal border is the lower margin of the truncus intermedius (just above the cranial slice where the middle lobe bronchus and the right lower lobe bronchus branch off completely). At this border, Station 11s abuts on Station 11i. The left border is the lateral border of the right main bronchus, which is represented as a vertical line drawn from the lateral aspect of the right main bronchus. At this border, Station 11s shares the boundary with Station 10R (Figs 10–12). The right, anterior and posterior border is the lung.

Station 11i: inferior interlobar nodes

The IASLC definition is 'lymph nodes between the middle and lower lobe bronchi on the right'. The cranial border is the lower margin of the truncus intermedius that is represented as the level where the middle lobe bronchus and the right lower lobe bronchus branch off completely. At this border, Station 11i contacts Station 11s. The caudal border is the upper margin of the right lower lobe bronchus that is represented as the level where the right B6 branches off completely. The left border is the middle lobe bronchus and the right lower lobe bronchus. The right border is the lung. The anterior border is the lung and middle lobe bronchus. The posterior border is the lung and right lower lobe bronchus.

Station 11: left interlobar nodes

The IASLC definition is 'lymph nodes between the origins of the left lobar bronchi'. The cranial border is the lower margin of the left upper lobe bronchus that is represented as the level where the left B4+5 branches off. The caudal border is the upper margin of the left lower lobe bronchus that is represented as the level where the left B6 branches off. The left border is the lung. The right border is the lateral border of the left main bronchus, which is represented as a vertical line drawn from the lateral aspect of the left main bronchus in the cranial area of Station 11. At this border, this station shares the boundary with Station 10L. In the caudal area of this station, the right border is the left upper and lower lobe bronchi (Fig. 11). The anterior border is the lung and left upper lobe bronchus. The posterior border is the lung and left lower lobe bronchus.

DISCUSSION

The IASLC map was established to reconcile the differences between the Naruke map [3] and the Mountain–Dresler modification of the American Thoracic Society (MD-ATS) map [4]. While we refer to the IASLC map to decide upon the boundaries of lymph node stations in radiotherapy for lung cancer, the IASLC map contains some ambiguous boundaries for each of the lymph node stations. Several contouring guidelines for regional lymph nodes have been established to standardize treatment planning in head and neck cancers [5, 6] and uterine cervical cancers [7]. Lynch *et al.* [8] published an original CT atlas of lymph nodes for lung cancer based on the IASLC map. However, it was based on the perspective of radiation oncologists, and there is no standardized regional lymph node CT atlas in radiotherapy for lung cancer that has been authorized by multidisciplinary experts. The lack of a standardized CT atlas may result in considerable variation in the contouring of lymph node stations, and a global consensus is required to standardize treatment planning in radiotherapy for lung cancer. Therefore, we created the JLCS–JASTRO consensus-based CT atlas to define regional lymph node stations based on the IASLC map.

This consensus-based CT atlas includes five changes from the IASLC map, since some boundaries are either ambiguous or not defined in the IASLC map.

The first change is the presence of four imaginary lines that represent the boundaries between several lymph node stations. Line A is an imaginary line that directly connects the anterior aspects of the right brachiocephalic vein, the brachiocephalic artery, the left common

carotid artery and the left subclavian artery. It lies between Stations 2R, 2L and 3a (Fig. 3). Line B is an imaginary line that connects the ascending and descending aorta at the shortest distance; it serves as a surrogate for the ligamentum arteriosum, which is difficult to detect on CT images. It lies between Stations 4L and 5 (Fig. 5). Line C is an imaginary line that is tangential to the posterior aspect of the ascending aorta, and at a right angle to Line B. It lies between Stations 5 and 6 (Fig. 5). Line C' is an imaginary line in which Line C is moved parallel to the anterior border of the left main pulmonary artery. It lies between Stations 6 and 10L* (Fig. 6).

The second change is the boundary between Stations 1 and 2, which is ambiguous in the IASLC definition. The caudal border of Station 1 (clavicles bilaterally and the upper border of the manubrium centrally) and the cranial border of Station 2 (apex of the lung and pleural space, and in the midline, upper border of the manubrium) are not necessarily identical. To resolve this ambiguity, we defined this boundary as the 'apex of the lung', thus giving priority to Station 2.

The third change is the caudal border of Station 6. We considered that the paraaortic area that lies along the ascending aorta should be included in Station 6. Therefore, the caudal border of Station 6, which is defined as 'the lower border of the aortic arch' according to the IASLC, is extended caudally to the level of the carina.

The fourth change is the cranial border of Station 8. We considered that the paraesophageal area below the level of the carina should be included in Station 8. Therefore, the cranial border of Station 8 (defined as 'the upper border of the lower lobe bronchus on the left, the lower border of the bronchus intermedius on the right' according to the IASLC) is extended cranially to the level of the carina.

The fifth change concerns Station 10. The IASLC definition is 'lymph nodes immediately adjacent to the mainstem bronchus and hilar vessels, including the proximal portions of the pulmonary veins and main pulmonary artery'. However, due to the requirements of radiotherapy treatment planning, Station 10 is here divided into three substations: Station 10R (right hilar nodes), Station 10L (left hilar nodes adjacent to the left main bronchus) and Station 10L* (left hilar nodes adjacent to the hilar vessels, including the proximal portions of the pulmonary veins and main pulmonary artery).

This atlas was established for contouring of lymph node stations in radiotherapy treatment planning for lung cancer. Therefore, it should not be used for image diagnosis or surgery because several definitions are different from those of the IASLC. Additionally, the irradiation field according to this atlas might be larger than conventional field settings; the cranial part of Station 2 and the lateral part of Station 7 should be excluded from the CTV in treatment planning as needed. Moreover, individual differences should be considered. Further revision and modification may be required with the accrual of new clinical findings and opinions.

In conclusion, the JLCS–JASTRO consensus-based CT atlas, which conforms to the IASLC lymph node map, was established. This atlas should assist radiation oncologists in accurately contouring lymph node stations for the treatment of lung cancer. In the future, we will establish guidelines for contouring the CTV in radiotherapy for lung cancer with this atlas.

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CONFLICT OF INTEREST

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