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CONSIDERATION OF DOSE LIMITS FOR ORGANS AT RISK OF THORACIC RADIOTHERAPY: ATLAS FOR LUNG, PROXIMAL BRONCHIAL TREE, ESOPHAGUS, SPINAL CORD, RIBS, AND BRACHIAL PLEXUS

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Abstract

Purpose—To review the dose limits and standardize the three-dimensional (3D) radiographic definition for the organs at risk (OARs) for thoracic radiotherapy (RT), including the lung, proximal bronchial tree, esophagus, spinal cord, ribs, and brachial plexus.

Methods and Materials—The present study was performed by representatives from the Radiation Therapy Oncology Group, European Organization for Research and Treatment of Cancer, and Southwestern Oncology Group lung cancer committees. The dosimetric constraints of major multicenter trials of 3D-conformal RT and stereotactic body RT were reviewed and the challenges of 3D delineation of these OARs described. Using knowledge of the human anatomy and 3D radiographic correlation, draft atlases were generated by a radiation oncologist, medical physicist, dosimetrist, and radiologist from the United States and reviewed by a radiation oncologist and medical physicist from Europe. The atlases were then critically reviewed, discussed, and edited by another 10 radiation oncologists.

Results—Three-dimensional descriptions of the lung, proximal bronchial tree, esophagus, spinal cord, ribs, and brachial plexus are presented. Two computed tomography atlases were developed:

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one for the middle and lower thoracic OARs (except for the heart) and one focusing on the brachial plexus for a patient positioned supine with their arms up for thoracic RT. The dosimetric limits of the key OARs are discussed.

Conclusions—We believe these atlases will allow us to define OARs with less variation and generate dosimetric data in a more consistent manner. This could help us study the effect of radiation on these OARs and guide high-quality clinical trials and individualized practice in 3D-conformal RT and stereotactic body RT.

Keywords

Atlas; Lung; Esophagus; Spinal cord; Brachial plexus

INTRODUCTION

In the United States, >400,000 people were diagnosed with breast, lung, and esophageal cancers in 2009 (1), and approximately 50–60% of these will undergo radiotherapy (RT) (2). The normal tissues within the thorax, including the lungs, main bronchi, esophagus, ribs/chest wall, heart, brachial plexus, and spinal cord, are organs at risk (OARs) and often dose limiting during thoracic RT.

The dosimetric limits of these OARs guide the daily RT practice and have been used in institutional and multicenter trials in cooperative groups such as the Radiation Therapy Oncology Group (RTOG), European Organization for Research and Treatment of Cancer, and Southwest Oncology Group (SWOG). However, to date, the anatomic delineation of these structures has not been standardized. As an example of the potential error, a previous report by Collier *et al.* (3), indicated the magnitude of intra- and interdosimetrist variations in delineating the contours reached 6 cm and 8.1 cm for esophagus and 0.7 cm and 0.9 cm for spinal cord, respectively. The magnitude of discrepancies did not appear to correlate with the experience of the dosimetrists and can be attributed to a lack of consensus in delineating these anatomic structures.

The effect of OAR delineations on the dosimetric parameters can be significant and will influence the treatment decision and outcome in both clinical trials and daily practice. The present report aimed to (1) review the dose limits of thoracic OARs currently used in multicenter trials, (2) demonstrate examples of variations in delineating the thoracic OARs and their effect on the dosimetric constraints, and (3) provide an atlas to delineate the OARs in a reproducible fashion for patients undergoing thoracic RT.

METHODS AND MATERIALS

Consideration of dosimetric limits

In the two-dimensional (nonconformal) treatment era, Emami *et al.* (4) published the widely used TD 5/5 and TD 50/5 (5% risk at 5 years and 50% risk at 5 years, respectively) dose limits for the whole, two-thirds, and one-third organ volumes for many tissues, assuming a conventional fractionation scheme of 1.8–2.0-Gy fractions. With modern 3D-conformal RT (3D-CRT), more sophisticated dosimetric parameters have been used to guide our daily practice and clinical trials (5). Although a uniformly accepted and published guideline has not been published for thoracic RT, the RTOG and European Organization for Research and Treatment of Cancer constraints are in widespread use and normally accepted by multiple participating institutions. Table 1 lists the dose limits from the ongoing protocols of fractionated RT, RTOG 0617 and RTOG 972/Cancer and Leukemia Group B 36050, and the dose limits from the ongoing protocol of stereotactic RT, RTOG 0618.

Challenges in OAR delineation

As expected, any of the OARs can be outlined differently by different dosimetrists or treating physicians. The reasons for these variations in delineations are discussed. For lung contours, no guideline or atlas is available, and the lung contours can often be defined by autosegmentation, a common feature of all modern treatment planning systems. However, the normal lung shows a great deal of variation in electron density and the corresponding computed tomography (CT) number. Depending on the threshold limits and the defined region of interest, it is possible to capture unwanted areas (nonlung), such as the airways, regions of atelectasis, bronchiectasis, scarring, and large vessels. Compounding factors that can affect the final contour include the threshold setting; editing of the trachea, bronchus, and small size vessels; the respiratory motion phase; and the exclusion/inclusion of target volumes such as the planning target volume (PTV), clinical target volume, and gross tumor volume (GTV). Figure 1 shows an example of autosegmentation failures and contour variants that can affect the lung dose–volume histograms (DVHs).

For the trachea and proximal bronchial tree, the differences result from the proximal extent, distal end, circumferential thickness, and inclusion or exclusion of air.

Variations in the esophagus can result from CT windowing and the use of oral contrast, inclusion of the muscular wall, the length of esophagus (*e.g.*, from cricoid cartilage to the gastroesophageal junction or 5 cm superior and inferior to the end of the PTV), and motion considerations. Examples of such variations have been previously reported (Fig. 2) (3, 6).

For the spinal cord, the contours can vary from the superior and inferior extents or the circumferential extent, which can include the true spinal cord only or all the spaces within the bony canal.

For the brachial plexus, the variations can result from inclusion of nerve roots; inclusion of the vascular bundles; the level of the distal ends; the arm position (up vs. down); and motion consideration. An atlas has been published for brachial plexus for head-and-neck RT (7), but it has limited value for thoracic RT as the arm position is remarkably different from that for head-and-neck RT.

For the heart, the variants result from inclusion of the large vessels, the pericardium, and separation of the heart chambers. The details of the heart contours will be discussed in a separate report.

For the ribs and chest walls, the considerations should include inclusion of the intercostal muscles, inclusion of the external chest wall muscles, and the extent of the superior, inferior, lateral, and medial dimensions (8, 9).

Consideration of organ motion for OARs

For any of the OAR structures, organ motion affects both the proper delineation of the anatomy, as well as the characterization of dose deposition. Respiratory motion is typically the greatest contributor to overall organ motion. In particular, both the lung (10) and esophagus (6) can move significantly during the breathing cycle (Fig. 2B). Four-dimensional CT is a valuable imaging tool used in motion consideration of the lung and other OARs. Although the influence of lung density on treatment planning and DVH calculations has been shown to be very limited, the volume variation has not been adequately studied. In patients with a large tumor motion (median amplitude, 1.9 cm), the mean dose to the lungs varied from −5% (inhale phase) to +3% (exhale phase) compared with a full four-dimensional dose calculation (averaged for 10 breathing phases) (11). For dose calculations, one can select a reconstruction that includes the data from the complete breathing cycle

(*e.g.*, an average scan) or a breathing phase that represents the average position (*e.g.*, the 20% or 80% phase or mid-ventilation phase) if RT delivery is also performed for multiple breathing cycles. If RT is performed using respiratory gating, the phase representing the center of the gating window can be used for dose calculation. RT planning can also be executed using a natural exhale scan for a worst case estimate of the lung dose. Although variations exist regarding this, current evidence has not always been enough to establish a consensus among investigators. We recommend that the approach used be clearly specified in all protocols and publications.

OAR atlas generation

The present study was a project of the combined efforts of radiation oncologists working within the RTOG, European Organization for Research and Treatment of Cancer, and SWOG lung cancer committees. Using our anatomic knowledge and 3D radiographic correlation, a draft atlas was first generated by a radiation oncologist (F.M.K.), medical physicist (T.R.), dosimetrist (L.M.), and radiologist (D.Q.) from the United States and reviewed by a radiation oncologist (S.S.) and medical physicist (C.W.H.) from Europe. The atlas was then critically reviewed, discussed, and edited by another 10 radiation oncologists. The final atlas resulted from a consensus of all the investigators.

RESULTS

An atlas for the lung, main bronchus tree, ribs/chest wall, esophagus, and cord is shown in Fig. 3. The atlas for the brachial plexus applicable to RT for thoracic malignancies (arm-up position) is shown in Fig. 4. Considering the complexity of the pericardium/recesses, various cardiac chambers, and vascular supplies, contouring the heart and great vessels will be the subject of future report.

Lung

We recommend that the lung contours be limited to the air-inflated lung parenchyma without inclusion of the fluid and atelectasis visible on the CT image. Automated contouring tools can be used; however, appropriate thresholds, specific to each CT scan, should be chosen. Reviewing and editing the autocontoured structures is always required. The proximal bronchial tree should be excluded, and small sized vessels (<1 cm or vessels beyond the hilar region) should be included. The right and left lungs can be contoured as one structure or as separate structures. Normally, the lung dose limits are based on the DVHs of both lungs, with exclusion of the target volume. However, controversies exist regarding which target volume to subtract—the GTV, CTV or PTV. The RTOG recommendations have ranged from the PTV in RTOG 9311 (closed) (12), the clinical target volume in RTOG 0617 (ongoing), to the GTV in RTOG 0117 (closed)/RTOG 0618 (ongoing)/RTOG 0813 (ongoing)/ RTOG 0915 (ongoing) (13). Because no evidence is available to support one method vs. another, we have recommended adopting the one used by most of the ongoing RTOG trials (*i.e.*, to subtract the GTV, which can be defined on an average scan, free helical scan, maximal intensity projection scan, or as a composite volume from the GTVs of multiphase four-dimensional scans or inhale and exhale scans). Special attention should ensure that only the GTV overlapping the normal lungs is subtracted (*i.e.*, only the component of the GTV existing within the Boolean intersection of the lung) and that the GTVs outside the lung, such as the mediastinal nodal GTVs, are not subtracted. All inflated lung should be contoured; the trachea/bronchus (as defined in the next section) should not be included in this structure. When collapsed lung is present, the use of intravenous contrast and/or positron emission tomography can may be very helpful in distinguishing the GTV from the collapsed lung.

To plan stereotactic body RT (SBRT), the lung is often divided into central and peripheral regions. The green dashed line in Fig. 3 shows the border between the central and peripheral lungs defined by a 2-cm uniform expansion in all directions, except the superior direction, from the edge of the proximal bronchial tree.

Proximal bronchial tree

The RTOG stereotactic protocols for lung cancer have used the proximal bronchial tree both as an avoidance structure and to help differentiate central from peripheral tumors. The proximal bronchial tree can be contoured using mediastinal windows on the CT scan to correspond to the mucosal, submucosa, and cartilage rings and airway channels associated with these structures. It can be contoured as one structure, including the most inferior 2 cm of distal trachea and the proximal airways of both sides. The proximal bronchial tree includes the following structures, according to the standard anatomic relationships: the distal 2 cm of the trachea, the carina, the right and left mainstem bronchi, the right and left upper lobe bronchi, the intermedius bronchus, the right middle lobe bronchus, the lingular bronchus, and the right and left lower lobe bronchi. Contouring the lobar bronchi should end immediately at the site of a segmental bifurcation, as recommended by RTOG 0618.

Esophagus

Our findings have shown that the esophagus should be contoured using mediastinal windowing on CT to correspond to the mucosa, submucosa, and all muscular layers out to the fatty adventitia. We have recommended that the esophagus contour should begin at the level of cricoid cartilage and continue on every CT image to include the gastroesophageal junction until it ends at the stomach (Fig. 3). Unless gross tumors are located around the esophagus, we would not routinely recommend oral contrast, because it could affect the dose computation and change the anatomic shape of the esophagus. When oral contrast is used, the esophagus can be given the density of soft tissue to minimize any influence of the contrast material on the DVHs of the target and esophagus.

Spinal cord

For the purpose of treating lung tumors, we would recommend that the spinal cord be contoured according to the bony limits of the spinal canal. The contour of the spinal cord can start at the same cranial level as the esophagus to the bottom of L2, or the level at which the cord ends. This differs from the ongoing RTOG studies, which have uniformly included 10 cm above the superior extent of the PTV and continuing on every CT slice to 10 cm below the inferior extent of the PTV. The reason for not using the 10-cm expansion is that it often goes beyond the range of the CT scan for the lung cancer plan. It can go below the point at which the true cord ends inferiorly for tumors of the lower lungs and above the range of the CT scan superiorly. Using the body limit could improve the reproducibility, because cord itself is often not visible on the CT scan. For patients undergoing SBRT for tumors adjacent to the spinal cord, magnetic resonance imaging can be used to identify the true spinal cord.

Ribs and chest wall

The ribs and chest wall can be autosegmented from the corrected lung edges with a 2-cm expansion in the lateral, anterior, and posterior directions. The intercostal muscles should be included and other muscles and skin excluded. This recommendation was derived from the combined consideration of previously reported methods, which varied from only the bony ribs to a comprehensive inclusion of the entire chest wall (8, 9). To avoid cumbersome contouring of the entire rib/chest wall, one can define the rib contours arbitrarily within a 3-cm limit from the PTV. When collapsed lung is present within, or close to, the PTV, the rib

contour should be individualized on a case-by-case basis. Manual editing can be applied to exclude the collapsed lung.

Brachial plexus

The brachial plexus originate from the spinal nerves exiting the spinal canal through the neural foramina from the C4-C5 (C5 nerve roots) to the T1-T2 (T1 nerve roots) level (Fig. 4A). RTOG 618 required delineation of the major trunks of the brachial plexus, using the subclavian and axillary vessels as a surrogate. Using high-quality CT scanning with intravenous contrast, it is possible to identify the actual roots and trunks of the brachial plexus directly without the need for a surrogate. We recommend outlining this structure starting from the C5 root (within the C4-C5 neural foramen) and ending at the subclavian neurovascular bundle, without including the vessels (Fig. 4B,C). The key step is to identify the anterior and middle scalene muscles, subclavian and axillary arteries and veins, and relevant cervical and thoracic vertebrae on the axial CT scan (7). The following steps were modified from the atlas for the head-and-neck guidelines from Hall *et al.* (7):

1. Locate the neural foramina at the C4-C5 and T1-T2 levels to identify the C5 and T1 roots, respectively
2. Locate the subclavian and axillary neurovascular bundle to identify the lateral aspect of the brachial plexus inferiorly
3. Locate the anterior and middle scalene muscles from the C5 vertebral level to their respective insertions on the first rib
4. Start at the neural foramina at the C4-C5 level and moving caudally; contour the region from the lateral aspect of the spinal canal laterally to the small space between the anterior and middle scalene muscles. At levels at which no neural foramina are present, contour the space or soft tissue between the anterior and middle scalene muscles
5. Continue to contour the space between the anterior and middle scalene muscles; eventually, the middle scalene muscle will terminate in the region of the subclavian neurovascular bundle
6. Contour the brachial plexus structures inferiorly until the region of the subclavian vascular bundle is identified, the second rib should serve as the medial limit

To delineate the brachial plexus, the use of intravenous contrast can help to distinguish nerves from vessels. In situations in which the exact location of the brachial plexus is required, magnetic resonance imaging fusion with the CT scan is recommended.

DISCUSSION

The present effort was intended to bring to the attention of our colleagues the potential variations of contouring OARs during RT planning and to provide atlases to guide clinical trials and daily radiation oncology practice.

The lung is one of the major dose volume-limiting organs for thoracic RT. Many dosimetric parameters such as the percentage of volume that received 20 Gy (V_{20}), V_5 , V_{30} , and the mean lung dose have been reported to be associated with radiation lung toxicity (12–18). Although no standardization has occurred for delineating the normal lung used for dose computation and the dosimetric cutoff is controversial, clinical trials and the National Comprehensive Cancer Network practice guideline have limited lung dosimetry using V_{20} and the mean lung dose. Underestimating the normal lung volumes from inappropriate delineation can have two effects: excluding a patient from participating in a clinical trial

they would otherwise be eligible for or overestimating lung toxicity and, consequently, unnecessarily limiting the prescription dose. Using a uniform guideline to contour the OARs, we hope to (1) generate more reproducible data under both clinical trials and practice for more accurate future models; (2) improve the external validity of each clinical trial, allowing the results from one trial to guide another; and, ultimately (3) optimize the dose prescription in each patient for thoracic 3D-CRT and SBRT.

The esophagus is a critical structure for thoracic RT that is sometimes dose limiting. Many volumetric factors, including the V_{15} , V_{35} , V_{50} , V_{65} , V_{80} , and the maximal and mean dose have been reported to be significantly associated with esophagitis (19–21). Some have reported the circumference or axial area in relationship to RT esophagitis (20). All these parameters depend highly on the absolute volume and anatomic location of the esophagus, as well as the DVH computation. However, no consensus has been reached on delineating the esophagus, particularly in the caudal (gastroesophageal junction) and cephalic (inclusion of the cervical esophagus) extents (22, 23). The current data failed to identify a single factor that can threshold the risk of esophagitis. Although many factors, such as tissue heterogeneity, organ motion, and the use of oral contrast, are important, the heterogeneity of esophagus delineation has definitely contributed to the variations in the significance of volumetric factors. Using an atlas with clear guidelines of delineation, the standardized dosimetric data might allow the generation of a meaningful threshold for both clinical trials and the daily practice of 3D-CRT and SBRT.

The consistency of contouring the spinal cord is critical for both conventionally fractionated 3D-CRT and oligofractionated SBRT. Although limited evidence is available on the exact limits of the spinal cord tolerance, 50 Gy with a <2-Gy fraction size is an extremely safe limit, normally associated with a <1% risk of severe myelopathy (24–27). For hypofractionated treatment regimens, recent clinical protocols such as the RTOG trial 0631 have described a single-fraction spinal cord dose constraint of 10 Gy to a limited volume. Although the maximal dose is clearly relevant for spinal cord toxicity, it is likely that a volume effect also exists for spinal cord tolerance (28–30). Our atlas of including all of the spinal canal for the cord contour is relatively safe for consideration of the maximal dose but might underestimate the volume effect. Nevertheless, a consistent delineation of the spinal cord contour is critical for clinical trials and the daily care of patients undergoing 3D-CRT and SBRT.

Contouring the brachial plexus on CT scans is challenging. Although an atlas is available for patients with head-and-neck cancer (7), guidelines on the structure definition are not available for thoracic RT when the patient's arms are placed over the head. The tolerance dose for the brachial plexus is also largely unknown for treatment of thoracic cancer. The consensus recommendations on the brachial plexus dose tolerance by Emami *et al.* (4) suggested a value for a 5% risk at 5 years of 62, 61, and 60 Gy and a value for a 50% risk at 5 years of 77, 76, and 75 Gy for one third, two thirds, and the whole organ, respectively. The tolerance dose for the brachial plexus has been reported as 66 Gy in 2-Gy fractions for head-and-neck cases (7). Dosimetric tolerance data on the brachial plexus is lacking in the treatment of lung cancer, and recommendations have varied from one trial to another. It is reasonable to believe that the tolerance dose of brachial plexus depends on the total dose, fraction size, α/β ratio, and the use of chemotherapy (7, 31–33). Assuming an α/β ratio of 2 and a tolerance of 66 Gy in 2-Gy fractions, the tolerance dose for the brachial plexus can be estimated accordingly for various fractionation regimens.

When using the atlas, one should note that great individual differences exist among patients, and the delineation of individual variants should be addressed by the treating physicians using the same principles described in previous sections. One should recognize that this atlas

did not take normal anatomic variations into consideration. Taking the brachial plexus as an example, variants of the brachial plexus with inclusion of the fourth cervical nerve or T2 thoracic nerve roots were not considered. For DVH computation, tissue heterogeneity should be applied appropriately to consider both attenuation and scattering contributions. The effects of respiratory motion cannot be overstated. The correction of fraction size is another important topic of consideration; thus, the dose limits for 3D-CRT and SBRT should be individualized. Additionally, this atlas is purely CT anatomy based, with no considerations of the functionality of the lungs that appear normal on CT. The atlas has yet to be validated by global users for its utility and reproducibility.

CONCLUSIONS

Standardizing the delineations of OARs is critical for clinical trials and daily practice. The presented atlases may guide us to define the OARs with less variation and thus generate more reliable dosimetric data in a consistent manner. This will help us learn the effects of radiation on these OARS, guide our high-quality clinical trials for wider external validity, and, ultimately, direct RT for each individual patient with greater confidence.

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Fig. 1.

Variance in normal lung definition and its effect on lung dose-volume histograms (DVH). Autosegmentation often leads to inaccurate lung volume, with (A) arrows showing autotracked lung structure going into lung parenchyma causing exclusion of some normal lungs and (B) with misses of lung parenchyma between tumors and small vessels) that causes notable differences in lung DVHs (C). Calculation of lung DVH in consideration of target and treatment volumes also affects lung DVH (D). Unless otherwise specified, lung refers to both lungs with subtraction of gross tumor volume (GTV). CTV = clinical target volume; PTV = planning target volume; AA = ascending aorta; DA = descending aorta; SVC = superior venous cava; PA = pulmonary artery.

Fig. 2.

Example variations of esophagus definition. (A) Collier *et al.* (3) demonstrated completely different esophagus contours by 2 dosimetrists. (B) Dieleman *et al.* (6) demonstrated motion of esophagus (green during exhale phase, purple during inhale phase).

Fig. 3.

Atlas of lung, proximal bronchial tree, esophagus, and spinal cord. Brachial plexus, brown; spinal cord, thick red; lung, yellow; proximal bronchus tree, green; primary tumor GTV and nodal GTV, thin red; esophagus, dark blue; ascending aorta, aortic arch, and descending aorta, purple; superior vena cava, light blue; pulmonary artery, white. GTV = gross tumor volume; AA = ascending aorta; DA = descending aorta; SVC = superior vena cava; PA = pulmonary artery; IVC = inferior vena cava.

Fig. 4.

Atlas of brachial plexus. (A) Brachial plexus anatomy. (B) Digital reconstructed radiograph. Brown used to indicate brachial plexus; red, carotid artery; light blue, jugular vein; and green, middle scalene muscle. (C) Axial computed tomography sections through brachial plexus. Red indicates internal carotid arteries, subclavian arteries, and innominate artery; light blue, internal jugular veins, subclavian veins; red within spine, spinal cord; dark blue, esophagus; pink, anterior scalene muscle; green, middle scalene muscle; light orange, brachial plexus structures (*i.e.*, nerves, roots, trunks). VB = vertebral body level (*e.g.*, C4 indicates C4 vertebral body level); CA = carotid artery; JV = jugular vein; AS = anterior scalene muscle; MS = middle scalene muscle.

Table 1

Dosimetric limits for thoracic organs at risk

Dose limits for OARs	3D-CRT (RTOG 0617)	3D-CRT (RTOG 0972/CALGB 36050)	SBRT (RTOG 0618, 3 fx)	SBRT (ROSEL European trial, 3 or 5 fx)
Spinal cord (point dose)	Point dose 50.5 Gy	Any portion 50 Gy	18 Gy (6 Gy/fx)	18 Gy (3 fx) 25 Gy (5fx)
Lung	Mean lung dose 20 Gy, V ₂₀ 37%	V ₂₀ 35%	V ₂₀ 10%*	V ₂₀ <5–10% [†]
Esophagus	Mean dose 34 Gy	Not limited	27 Gy (9 Gy/fx)	24 Gy (3 fx) 27 Gy (5 fx)
Brachial plexus (point dose)	66 Gy	Not limited	24 Gy (8 Gy/fx)	24 Gy (3 fx) 27 Gy (5 fx)
Heart [‡]	60, 45, 40 Gy for 1/3, 2/3, 3/3 of heart	60, 45, 40 Gy for 1/3, 2/3, 3/3 of heart	30 Gy (10 Gy/fx)	24 Gy (3 fx) 27 Gy (5 fx)
Trachea, bronchus	Not limited	Not limited	30 Gy (10 Gy/fx)	30 Gy (3 fx) 32 Gy (5 fx)
Ribs	Not limited	Not limited	Not limited [§]	Not limited
Skin	Not limited	Not limited	24 Gy (8 Gy/fx)	Not limited

Abbreviations: OARs = organs at risk; 3D-CRT =three-dimensional conformal radiotherapy; RTOG = Radiation Therapy Oncology Group; CALGB = Cancer and Leukemia Group B; SBRT = stereotactic body radiotherapy; ROSEL = *Radiosurgery Or Surgery for Early Lung Cancer*; fx = fraction; V₂₀ = percentage of both lungs (without inclusion of gross tumor volume) receiving 20 Gy.

* Other constraints limited dose within 2 cm of target.

[†] V₂₀ 5% for tumor 2 cm, V₂₀ 5% for tumor 2–5 cm.

[‡] Atlas for heart discussed in separate report in this issue of the Journal.

[§] Intended to limit dose to ribs, no specific number provided.