Organs at Risk Delineation

13

Filipe Cidade de Moura and Mirjam Mast

13.1 Background

Accurate delineation of organs at risk (OARs) became crucial in the 3D planning era. With the implementation of CT simulation in the RT process, slowly volumetric delineation for both target volumes and OARs turned mandatory for improving treatment outcome and reducing toxicity. Quantitative analysis of normal tissue effects in the clinic (QUANTEC) is the latest reference for most of the OARs. 3D dose/volume/outcome data were reviewed and synthetized for better risk prediction and therapeutic ratio optimisation [1]. Concerning the delineation of target volumes and OARs, the American Association of Physicists in Medicine (AAPM) Task Group 263 (2018) [2] published a report for standardisation of nomenclatures in radiation oncology.

Recently, the RT Quality Assurance (RTQA) Global Harmonization Group (GHG) defined the consensus guidelines for OAR delineation for RT clinical trials, along with AAPM TG263 and the American Society for Radiation Oncology (ASTRO) [3]. Together with peer-reviewed, the anatomically defined contouring guidance, intent to be integrated into future clinical trial protocols independent of the RT delivery technique.

Standardised names for the treatment planning processes will allow for quality improvement of communication inside departments and within departments at national and international levels. Standardisation of terminology would facilitate scripting and automated processes and reports. It also enables better data collection and registries, which would be of benefit for the routine clinical care, population-based studies and clinical trials. Within the scope of this chapter, the adoption of AAPM TG263 and RTQA GHG OAR WG will be recommended when defining OARs for breast RT.

13.2 Treatment Planning: From 3DCRT to IMRT/VMAT

Targeting breast cancer tissues avoiding surrounding tissues is a major goal for EBRT. The radiation team should be aware that the OARs that might be exposed to RT dose can be significantly different if IMRT or VMAT (volumetric-modulated arc therapy or vIMRT) is used. Therefore, care should be given to delineate all

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F. C. de Moura (✉)
Escola Superior de Tecnologia da Saúde de Lisboa, Instituto Politécnico de Lisboa, Lisboa, Portugal
e-mail: Filipe.moura@estesl.ipl.pt

M. Mast
Haaglanden Medical Center, Leidschendam, The Netherlands
e-mail: m.mast@haaglandenmc.nl

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organs that might be exposed to radiation, otherwise treatment might result in increased or unexpected toxicity [4].

If IMRT/VMAT will be used for breast only and/or regional node irradiation, extra requirements should be adopted for volumes of interest (VOIs) definition, see chapter treatment planning. In this section all relevant OARs are described. Finally the adoption of OARs models, atlas based auto-segmentation, and artificial intelligence for planning are now being used to fasten the generation of a reliable structure set, but human visual inspection still needs to be done for structure validation and approval [3].

13.3 Visualisation of OARs on a CT Simulation Scan

Hounsfield number described as units (HU) or more commonly mentioned as CT numbers, is being used for planning purposes applied on Treatment Planning System (TPS) for an accurate conversion to electronic densities (ED). The so-called CT to ED curves allow for treatment beam dose attenuation at TPS for specific CT equipment under calibrated conditions. Displayed CT numbers will then result in different attenuations between tissues. Visualisation and organ recognition are possible under a specified window width (WW) and window level (WL). The transition of dark to light structures would require a narrow window width (<350 HU) and a wide window width (>1000 HU) would result in lower recognition between tissues, mainly soft tissues, which would become unclear. The WL, also referred as window centre, is the midpoint of the WW. When WL is increased, the CT image would become darker and vice versa.

13.4 Delineation of Organs at Risk

Heart (TG 263: Heart)
Modalities: 3DCRT/IMRT/VMAT

CT Contouring recommendation: WW:500, WL:50

Heart three-dimensional anatomy should be checked prior delineation. Coronal planes visualisation is essential to recognise and set the superior and inferior (CC) and lateral borders for discrimination of substructures such as the great vessels as well as the coronary arteries. For a global definition, the heart contour should encompass the outer surface of the pericardial sac [5]. The cranial border should be delineated from the point at which the pulmonary trunk and right pulmonary artery are seen as separate structures [3]. The contour should extend inferiorly to the apex of the heart, where the left ventricle touches the diaphragm [6].

Great vessels should be contoured separately from the heart namely the aorta, vena cava, and pulmonary vessels.

Left Anterior Descending Coronary Artery (LADCA)
(TG 263: A_LAD)

Modalities: 3DCRT/IMRT/VMAT

CT Contouring recommendation: WW:150, WL:50

The LADCA originates from the left main coronary artery (LMCA), on the top left of the heart, between the pulmonary trunk and the left auricle, and extends all way to the apex [7]. Additionally LAD become a small round structure descending in the anterior interventricular groove in close relation to the pericardium [6].

Where the LAD is not visible, the interventricular groove should be used as a surrogate.

Heart and LAD are shown in Fig. 13.1.

Great Vessels
(TG 263: GreatVes)

Modality: IMRT/VMAT

CT Contouring recommendation: WW:350, WL:40

Great vessels around the heart, for breast treatment planning, may encompass the superior vena cava, aorta, and the pulmonary arteries/veins. The delineation of great vessels can be contoured separately or as a single volume. The branches of the aortic arch: the brachiocephalic artery, the left common carotid artery, and the left subclavian

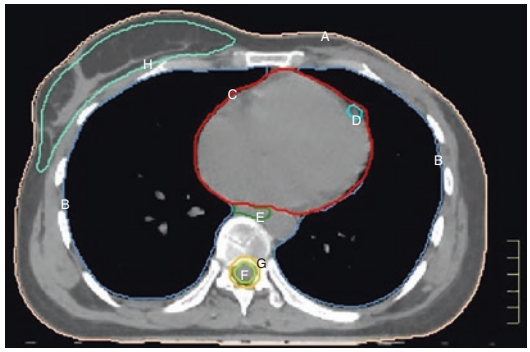


Fig. 13.1 *A* BODY, *B* Lungs, *C* Heart, *D* A_LAD, *E* Esophagus, *F* SpinalCord, *G* SpinalCord_PRV3, *H* Breast_R

artery may be included. Cranial great vessels extended from the top heart, inferiorly, to the superior aspect of aorta, approximately at the level of T2/T3 vertebra. Attention must be paid to avoid delineation of central structures such as trachea, main bronchus, and oesophagus.

Lung/Lungs (TG 263: Lung_L, Lung_R, Lungs)

Modalities: 3DCRT/IMRT/VMAT

CT Contouring recommendation: CT WW:1500 WL: −600|WW:1600 WL: −600

The right and left lungs should be contoured separately. One single structure (Lungs) should be generated from individual Lung_R and Lung_L summation, for evaluation and reporting purposes. Contour the whole lung from apex to diaphragm, including all air-inflated parenchyma, excluding trachea and the proximal bronchus, fluid and atelectasis [8].

Spinal Cord

(TG 263: SpinalCord/SpinalCord~ (partial organ))

Modalities: 3DCRT/IMRT/VMAT

CT Contouring recommendation: CT WW:350, WL:40

The spinal cord should be delineated as the true spinal cord, not the spinal canal. It has slightly higher density than the surrounding cerebrospinal fluid and ligaments. The spinal cord extends from the cranial cervical junction, after the brainstem, to the cauda equina at the inferior border of L2 vertebral body [8]. For planning purposes, the spinal cord should be contoured at least 5 cm extra lenght, in the longitudinal plane, from cranial and caudal PTV borders. For dosimetric evaluation and dose optimisation, a PRV margin applied to the spinal cord would be necessary (SpinalCord_PRV). When deemed necessary for standardisation reasons the PRV margin could be included in the nomenclature, according to AAPM TG 263, as SpinalCord_PRVxx.

Trachea

(TG 263: Trachea)

Modalities: 3DCRT/IMRT/VMAT

CT Contouring recommendation: CT WW:350, WL:40

The trachea should be fully contoured (including lumen) to the outer boundary of the cartilage and trachealis muscle, from the caudal edge of the cricoid cartilage to approximately 2 cm superior to the carina.

Oesophagus

(TG 263: Oesophagus/Oesophagus~ (partial organ))

Modalities: 3DCRT/IMRT/VMAT

CT Contouring recommendation: CT WW:350, WL:40

The oesophagus contour should include all muscle layers out to the fatty adventitia, superiorly at the level of the cricoid cartilage to the caudal edge of the gastroesophageal junction, usually at the level of the diaphragm [8]. Oesophagus lies close to the anterior border of vertebral bodies, behind heart and trachea, with a round/oval axial shape. Contour in visible slices and interpolate when possible.

Larynx

(TG 263: Larynx)

Modalities: 3DCRT/IMRT/VMAT

CT Contouring recommendation: CT WW:350, WL:40

The larynx should be contoured from the tip of epiglottis to the inferior aspect of the thyroid cartilage, near the caudal limit of the cricoid cartilage [9]. The anterior and lateral borders are the outer aspect of the thyroid cartilage. Posteriorly, the contour should include the arytenoid cartilages and extend to the edge of the pharyngeal constrictor muscles.

Thyroid

(TG 263: Glnd_Thyroid)

Modalities: 3DCRT/IMRT/VMAT

CT Contouring recommendation: CT WW:350, WL:100

The thyroid gland is located inferiorly to the thyroid cartilage. Thyroid has two lobes, connected in its anterior and lower portion. Thyroid is recognised by slightly high density than the adjacent soft tissues [10]. It extends and surrounds the thyroid and cricoid cartilages. Common carotid arteries border the lateral aspects.

Liver

(TG 263: Liver)

Modality: IMRT/VMAT

CT Contouring recommendation: CT WW:450, WL:40

The liver should be contoured as a single structure, excluding the gallbladder, and the inferior vena cava when clearly separated to the liver. It should be outlined from the diaphragm to the bottom of the right lobe.

Contralateral Breast

(TG 263: Breast_L, Breast_R)

Modality: IMRT/VMAT

CT Contouring recommendation: CT WW: 350, WL: 40

For evaluation purposes, the contralateral breast should be contoured for an accurate dose determination. When IMRT/VMAT is the chosen technique, the contralateral breast should be outlined as part of the inverse planning optimisation process. The cranial limit is at the upper border of visible breast tissue, normally up to the caudal edge of the sternoclavicular joint. The breast extends inferiorly to the intermammary sulcus, where breast shape is still visible. Medially the breast extends to the ipsilateral edge of the sternum, close to the medial mammary branches [11]. The lateral border may be defined using breast tissue lateral fold and, when visible, relate to the lateral thoracic artery as lateral/posterior anatomic reference.

Anteriorly the contralateral breast should be contoured 5 mm under the skin surface. Posteriorly should be delineated to the anterior border of the pectoralis major and where is not perceived, it should be contoured around the rib cage and intercostal muscles [12].

Humerus

(TG 263: Humerus_L, Humerus_R)

CT Contouring recommendation: CT WW:2000, WL:350

The ipsilateral humeral head is delineated for treatment optimisation and evaluation. It should be contoured from the top head to the full PTV extension plus margin, according to the technique field entrance and length.

To avoid inclusion of the glenohumeral joint and the connective tissues, a PRV of 1 cm around the humeral head may be generated [12].

Brachial Plexus

(TG 263: BrachialPlex_L, BrachialPlex_R)

Modality: IMRT/VMAT

CT Contouring recommendation: CT WW:350, WL:40

The brachial plexus (BP) is a neural network composed by 5 roots spinal nerves (SNs) started at the neural foramina:

1. Vertebral bodies C4-C5 (SN: C5)
2. Vertebral bodies C5-C6 (SN: C6)
3. Vertebral bodies C6-C7 (SN: C7)
4. Vertebral bodies C7-T1 (SN: C8)
5. Vertebral bodies T1-T2 (SN: T1)

For delineation purposes, identification of vertebral bodies and nerve roots from C4 to T2 are recommended.

According to Brouwer and Hall [10, 13], the use of a 5 mm diameter tool is recommended to contour the BP. Anterior and middle scalene muscles could be contoured from C5 to insertion onto the first rib, as guidance for BP segmentation. The BP should be contoured from the foramina to the space between the anterior and middle scalene muscles.

On slices where there is no visible neural foramina, contour the space or soft tissue between the anterior and middle scalene muscles. The scalene muscles will end at the level of the subclavian neurovascular bundle.

Contour the BP as the posterior aspect of the neurovascular bundle until the axial level below cla-

vicular head. If the BP is wrapped around the vascular bundle on the inferior slices, contour the brachial plexus divisions, cords, and terminal nerves by including the vascular structure into the axilla.

The first and second ribs would aid as the medial limit of the BP at subclavian space [8]. The BP contouring terminates at the medial limit of the second rib. The BP should be delineated inferiorly and laterally, to one or two CT slices below the clavicular head. Figures 13.2, 13.3, 13.4, and 13.5 show critical areas of the brachial plexus, for full view of the course of the

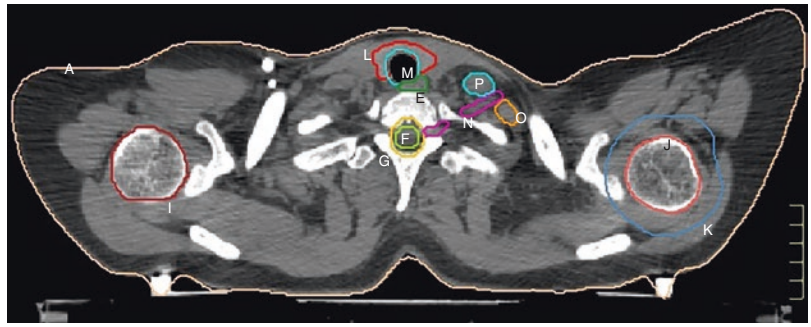


Fig. 13.2–13.5 *A* BODY, *B* Lungs, *E* Esophagus, *F* SpinalCord, *G* SpinalCord_PRV3, *I* Humerus_R, *J* Humerus_L, *K* Humerus_L_PRV10, *L* Thyroid, *M* Trachea, *N* BrachialPlex_L, *O* Scalene_M, *P* Scalene_A

Fig. 13.3

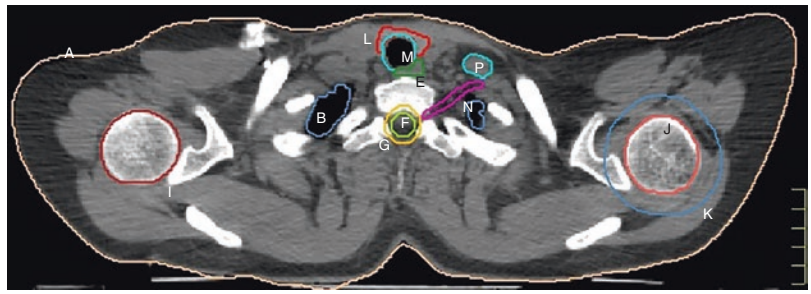


Fig. 13.4

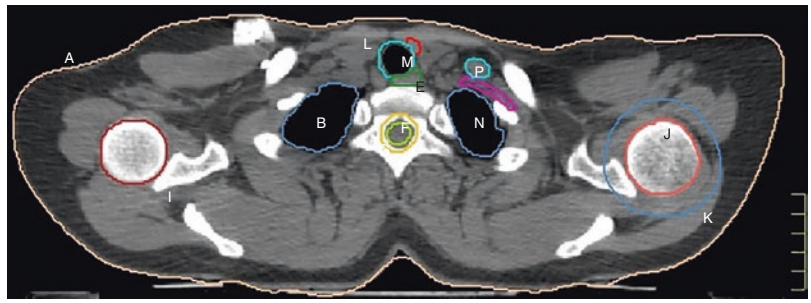
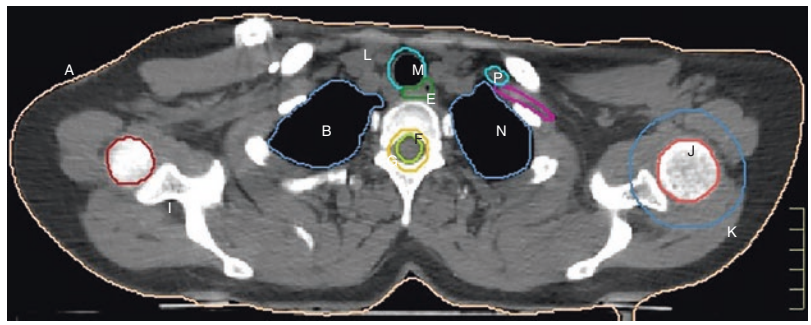


Fig. 13.5



brachial plexus, please view the electronic supplementary material.

13.5 Summary

Definition of volumes of interest has become one of the weakest links in contemporary Radiation Oncology. The contouring methods and treatment approaches have changed dramatically during the past decades, with the wide spread of technological advances and scientific network around the globe.

The quantitative analysis of normal tissues effects demanded for the improvement on organs and anatomical structures categorisation and standardisation, which became a priority of several working groups from RT community. The manual delineation of the Organs at Risk turns out to be an extensive time-consuming process, which could be eased with auto-segmentation tools available in most TPS and virtual simulator systems, nevertheless, human visual inspection remains the last checkpoint for contouring validation.

Unintended over- and/or under-contouring could lead to an unpredicted normal tissue complications with poor outcomes and patients QoL. Delineation skills and rationale are crucial for personalised RT, as it can contribute for better clinical care and promote evidence-based medicine.

In breast cancer RT, several guidance documents have been published towards standardisation and terminology of volumes of interest. Hereby, a compilation of the most relevant OARs were described and contoured, to guide and empower professionals for strengthening this crucial RT link.

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