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Critical Review

Dose-Volume Histogram Compendium of Dose Constraints for Treatment Planning: An ASTRO Consensus Paper

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Purpose: This dose-volume histogram (DVH) compendium shares the knowledge and resources compiled by disease-site experts during an immense undertaking by the Veterans Affairs (VA) and American Society for Radiation Oncology (ASTRO) to develop performance indicators for radiation therapy as part of quality surveillance. The guidance for breast, head and neck, liver, lung, prostate, and rectal cancers supports physician decision-making during dosimetric treatment planning, directs the reader to additional resources, and contributes to the evolution of DVH metrics for external beam radiation therapy.

Methods and Materials: DVH tables were developed for each disease site relating to the most common dose/fractionation regimens used in VA and non-VA radiation oncology centers nationwide. Dosimetric values with validation through prior clinical data and those used in ongoing multisite trials were prioritized, with references listed in the tables. In scenarios with a paucity of data for specific constraints, the disease-site panels discussed and agreed on appropriate clinical guidance. After panel discussion, each metric was voted on to obtain panel consensus. Panel consensus was evaluated with a modified Delphi approach using a prespecified threshold of ≥75% of raters who agree or strongly agree to establish consensus via a confidential survey. Where the content did not meet this threshold, it was removed or revised. Significant revisions went back to the full disease-site panel for review, approval, and a final consensus vote.

Results: The dose constraints are the result of quality measure development between the VA and ASTRO. They represent the body of work thus far, with the goal of expanding future resources to include other disease sites. There is still work to be done to optimize dose goals and constraints for target volumes and normal tissues. Different methodologies for calculating doses have produced varying data, and ongoing efforts will harmonize the lack of concordance where possible. Wide variation when reporting on toxicities and efforts to standardize provide an opportunity for future trial data to add to the depth of knowledge. This DVH compendium is pragmatic and reflective of general practice and established treatment regimens. Having accessible default constraints supports standardization and will help improve the quality of treatment planning and radiation delivery for all patients.

Preamble

Since 2016, the Veterans Affairs (VA) National Radiation Oncology Program (NROP) has contracted with the American Society of Radiation Oncology (ASTRO), under contract 36C24519C0242, as part of its Radiation Oncology Quality Surveillance (ROQS) Program to develop quality performance indicators for radiation therapy treatment of 6 primary disease sites: breast, head and neck, liver, lung, prostate, and rectum. For each disease site, a panel of experts convened by ASTRO developed a set of quality measures and dose-volume histogram (DVH) metrics.

Selection of Task Force Members — Over the course of this initiative with the VA, ASTRO identified subject matter experts to serve on each disease-site panel (Appendix E1). Each panel initially consisted of 7 radiation oncologists and a therapeutic medical physicist who were paid an honorarium as part of the VA contract. To provide unbiased guidance of VA processes and performance, these selected panelists did not provide care inside the VA system, and their decisions were independent of the NROP. Additionally, a radiation oncologist from within the VA was selected by VA leadership for each panel. The VA representatives were not paid. When creating a task force specifically for this initiative a cohort of prior panel members, including an ASTRO appointed expert medical physicist, ASTRO appointed expert radiation oncologist, and a VA radiation oncologist, from each disease site was selected.

Disclosure Policy — ASTRO has detailed policies and procedures related to disclosure and management of industry relationships to avoid actual, potential, or perceived conflicts of interest. All task force members are required to disclose industry relationships and personal interests from 1 year before the initiation of the writing effort, and these are reviewed for potential conflicts of interest. For the purposes of full transparency, task force members' comprehensive disclosure information is included in this publication.

Method and Consensus Development — DVH tables were developed for each disease site relating to the most common dose/fractionation regimens used in VA and non-VA radiation oncology centers nationwide at the time. Dosimetric values with validation through prior clinical data and those used in ongoing multisite trials were prioritized, and the references are listed in the tables. In scenarios where there was a paucity of data for specific constraints, the panel discussed and agreed on appropriate clinical guidance. After panel discussion, each metric was voted on to obtain panel consensus. Panel consensus was evaluated using a modified Delphi approach using a prespecified threshold of ≥75% of raters who agree or strongly agree to establish consensus throughout the ROQS project. Compendium task force members also indicated agreement with DVH content via a confidential survey. Where the content did not meet this threshold, it was removed or revised. Significant revisions went back to the full disease-site panel for review, approval, and a final consensus vote.

Evaluation and Updates — The DVH metrics were initially published in specific manuscripts for each of the 6 disease sites. These metrics were then compiled, reformatted, reviewed, and critically evaluated by the DVH compendium task force members. In cases where additional or revised metrics were suggested and agreed upon by task force members, these changes were shared with the disease-site-specific panels for consensus. The updated DVH metric tables were posted on the ASTRO website for public comment in August 2024 for 3 weeks. All feedback was

reviewed, and the metrics were then revised accordingly. Additionally, this paper and the DVHs were reviewed by 17 official peer reviewers (Appendix E2) in March 2025. The manuscript was also revised accordingly, and the modified document with all DVH metrics underwent another round of consensus voting by the task force. The final document was approved by the ASTRO Board of Directors in August 2025 and endorsed by the American Association of Physicists in Medicine and the American Association of Medicine Dosimetrists. The measures and DVH metrics are intended to be evaluated by the panels on a rotational basis and updated when new practice-changing information is available.

Introduction

There has been significant evolution in radiation therapy (RT) treatment planning and dose constraints since the well-known Emami publication in 1991.[1] Animal studies and case reports used in early iterations of dose constraints gave way to clinical and trial data that progressively incorporated increasingly complicated RT techniques. As the technology improved, dose constraints changed to reflect what was achievable. Although there is expanding evidence to inform dose constraints, there remains a tremendous amount of variation between countries, institutions, and even experts within the same practice. Part of this stems from dose-volume histogram (DVH) lists, constraint tables, or treatment directives being individual and institutional documents, with few publicly endorsed or available materials. Many clinical trial protocols are not widely available, and many published reports and resources lie behind paywalls.

Over the past 15 years, as increased dose per fraction treatments became more prevalent and new dosimetric guidance was needed to guide usage, Quantitative Analyses of Normal Tissue Effects in the Clinic,[2] the American Association of Physicists in Medicine's (AAPM) Task Group (TG)-101,[3] and Hypofractionated Treatment Effects in the Clinic[4] have served as modern and complex approaches to address radiation-related treatment toxicity. Despite this, in 2021, the question was asked, "What do people consider the gold standard for treatment planning for hypofractionated RT?" between AAPM TG-101, Hypofractionated Treatment Effects in the Clinic, Timmerman sheets,[5] and clinical trial protocols. In this case, the "Timmerman sheets" referred to an (at the time) unpublished, but electronically disseminated set of tables that Robert Timmerman, MD, had compiled based on clinical practice and limited modeling as foundations. The sheets were the purported poll winner and shortly thereafter were published for more widespread dissemination in the *International Journal of Radiation Oncology, Biology, Physics* as "A Story of Hypofractionation and the Table on the Wall."[5]

Contemporaneously, the Veterans Affairs (VA) National Radiation Oncology Program established the Radiation Oncology Quality Surveillance (ROQS) initiative to develop metrics assessing the quality of care for Veterans receiving RT for cancer. The VA contracted with ASTRO to commission disease-site expert panels for the purpose of developing disease site-specific quality measures, including collating dose constraints.[6-10] Each panel compiled tables of DVH metrics for common treatment regimens within the disease site using data from published literature and clinical trials, as well as the expert opinion of the panelists. The DVH tables were developed to be universally applicable and useful across practice settings and varying technologies. Afterward, it was recognized that these DVH tables collectively represent a collated resource that would be worth sharing more broadly to support treatment planning optimization. This compendium supports clinical decision-making to guide high-quality care but is not absolute and may not be achievable for every patient.

Scope

This DVH compendium (Appendix E3) shares the knowledge and resources compiled during the immense undertaking of the VA/ASTRO panels convened for breast, head and neck, liver, lung, prostate, and rectal cancers. This guidance is intended to support physician decision-making during dosimetric treatment planning, direct the reader to additional resources, and contribute to the evolution of DVH metrics for external beam RT. As such, the tables are intended to support common RT treatment regimens. There is a subset of treatment scenarios that may require additional organ at risk (OAR) contouring and/or modified dose constraints from those provided, and this was out of scope for this project. Specific considerations when using brachytherapy, heavy particles, or unsealed sources were outside the project's scope. The metrics are also intended for the definitive and adjuvant treatment settings; none of the included constraints pertain to traditional palliation, reirradiation, or concurrent treatment of multiple sites.

Additionally, outside of the scope of the project was discussion regarding specific clinical scenarios that impact selection of the optimal dose-fractionation (ie, clinical indications for various dose-fractionations) and patient-specific factors such as a solitary kidney (except for the liver tables, which include liver function parameters). Decision-making regarding the appropriate dose-fractionation regimen is determined on a case-by-case basis. Patient-specific considerations and physiological interventions, such as motion management techniques, devices (eg, rectal spacers and vaginal dilators) and other immobilization equipment to assist with treatment planning goals, were also outside the scope of this project.

Prioritization of specific volume structures and OARs within a disease-site protocol was also outside the scope of this project. Practices should determine their own priority preferences for metrics (eg, mean dose [Mean] vs volumetric dose [VxGy]) and when to prioritize treatment volumes over normal tissues and vice versa. Depending on patient-specific anatomy and disease, it may not be feasible to meet each metric; not meeting a metric(s) does not necessarily indicate poor plan quality. In assessing treatment decisions, clinicians must account for patient-specific considerations and the balance between tumor coverage for curative intent and dose to normal tissues.

Potential endpoint toxicities are not included in the tables. Although some constraints have specific expected toxicity rates supported by literature, many do not and even for those metrics that do, some of them may be oversimplified, ie, grade 3+. Additionally, there are a variety of factors that need consideration on a per-patient basis, including preexisting patient comorbidities, anatomic considerations, and whether to administer concurrent treatments. As a result, although toxicity was discussed during development, associated endpoint toxicities were outside the scope of this project.

Nomenclature

The DVH constraints are arranged in tables based on disease site and dose-fractionation regimen. Normal tissues are listed alphabetically (ie, not in priority order) in compliance with AAPM TG-263 terms[11] and are followed by target metrics. The dose limits are categorized into 3 levels:

1. Primary goal (green): Following treatment planning principles of keeping the dose to all normal tissues as low as reasonably achievable, ideally the calculated dose for each OAR should be below the primary goal threshold. However, meeting these goals for normal tissues and/or targets may be dependent on the size and location of treatment volumes, and this must be factored into any documented planning directive. Of note, metrics for the same OAR across different treatment regimens reflect what is felt to be achievable in a typical treatment case as supported by available literature and by consensus of the expert panels. For example, dose constraints for the lung are more restrictive when treating breast cancer than lung cancer because the target volume is anterior to and outside of the OAR, whereas the target is embedded in the OAR for lung RT. At times, different constraints are used for the spinal cord; this is not intended to reflect that the spinal cord has different tolerances, but merely that a lower dose may be more readily achievable for some disease sites, and it is reasonable to constrain it accordingly.
2. Secondary goal (yellow): Where planning target volume (PTV) prioritization and tumor coverage necessitates that dose to a normal tissue exceeds the primary dose constraint or where dose to target(s) is compromised by the proximity of an OAR, the secondary metrics offer an alternative set of constraints for appropriate consideration.
3. Deviation (red): Metrics in this category are based on reasoning that suggest exceeding these doses of radiation may result in an increased risk of severe treatment-related toxicity. The term deviation is used to reflect that the achieved value differs from standard practice and that it should be reviewed, not that it is inaccurate or should be changed with the intent of avoiding "red" dose metrics. In some cases, exceeding these dose constraints and/or goals may be clinically appropriate depending on specific clinical scenarios that balance the risk-benefit ratio. Discussion with the patient regarding risks and benefits is part of the informed consent process. In many cases, peer review and/or prospective plan review may be a useful process to support decision-making. As with all cases, the ultimate risk/benefit assessment should be according to the treating physician's judgment, in alignment with patient preferences, and these metrics are not intended to substitute for that judgment.

The fractionation regimens follow standard naming conventions:

- Conventional fractionation: daily treatment dose of typically 1.8 to <2.2 Gray (Gy) per fraction.
- Moderately hypofractionated: daily treatment dose of ≥2.2 to ≤5.0 Gy per fraction.
- Ultrahypofractionated: daily dose of >5.0 Gy per fraction, generally delivered in 5 fractions or fewer; this includes but is not limited to stereotactic radiosurgery and stereotactic body RT (SBRT)/stereotactic ablative RT.
- Other terms used for specific disease sites:
  - In rectal cancer, short-course treatment refers to the 5 Gy in 5 fractions (25 Gy total dose) regimen specifically delivered not using SBRT.
  - Lung cancer treatments with 10 fractions using conventional delivery techniques may be moderately hypofractionated or ultrahypofractionated depending on dose.

The panel considered proposed dose metrics from clinical trials and published literature. In some instances, metrics were sparingly created without a source, and these are listed as "panel consensus," based on the clinical experience and expertise of the disease-site panels.

The complementary (also referred to as cold) volume (CV) metric defines the volume of tissue receiving the stated dose or less (ie, volume spared). Because conventional DVH metrics define the volume of tissue receiving the stated dose or more, an alternative solution is needed to determine compliance with tolerance doses for critical volumes associated with parallel organs. The critical volume refers to the minimum volume of the parallel organ that must be spared below a threshold dose to preserve organ function. On a traditional, cumulative DVH, the CV can be computed by subtracting the volume noted at the tolerance dose from the total organ volume. If the CV exceeds the critical volume, then the constraint is met. Additional information can also be found in published literature.[11-13] Figure 1 provides an example computation of the CV acquired from a cumulative DVH.[12]

Disease Site-Specific Information

The 6 initial disease sites included in this project were selected by the VA ROQS program as the first priority group of malignancies to help assess the variation in practice and quality of care within radiation oncology centers in VA hospitals using quality metrics.[14,15] To maximize the impact of the ROQS program, commonly treated disease sites among VA patients were selected and for each disease site, metrics were divided into commonly used fractionation regimens.

The OARs included for each disease site were determined by the panel and align with recommendations from ASTRO's consensus statement on normal tissue contouring.[16] There may be normal tissues that are difficult to contour or inconsistently done (eg, bowel). This may be because of visualization on a planning image set (eg, no contrast and larger slice thickness), and efforts should be made to develop simulation protocols that support accurate and consistent contouring practices. For some normal tissues, there are notes on how the organ is contoured (eg, when the small bowel contours are individual loops or a bowel bag) and in limited cases, resources are provided to promote high-quality contouring. It is also important to note that the calculation of DVH metrics depends on factors such as the dose grid, voxel size, and algorithm used to define the contour boundary, particularly for small structures.[17] Clinicians should be aware of the impact of these factors when evaluating the dose and use the most appropriate settings for each disease site and treatment delivery approach (ie, stereotactic radiosurgery vs whole brain RT).

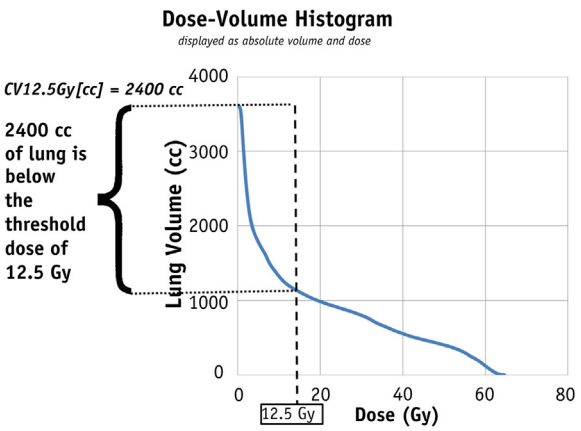

Figure 1 A cumulative dose-volume histogram for total lungs from a hypothetical 5-fraction stereotactic body radiation therapy treatment. In this example, the threshold dose is 12.5 Gy, the total lung volume is 3600 cc, and the volume receiving ≥12.5 Gy is 1200 cc. The complementary volume, CV12.5 Gy, is 2400 cc. Reproduced with permission from Ritter et al.[12]

The DVH tables include references for data sources using protocols from published clinical trial data or where otherwise openly available. However, some sources pertain to ongoing national clinical trials or protocols that are not published, in which case the latest version available was used. If one source matched the metric completely, then that source is listed; other sources that only partially align with the metric and were finalized by panel consensus are not listed. In some cases, multiple sources contribute to the entire metric (ie, different sources used for the primary goal and deviation).

Respecting OAR dose tolerance limits is a goal of all conformal treatment planning; however, whether to prioritize target coverage or respect normal tissues requires clinical judgment by the treating physician. Prioritizing target coverage over normal tissues to achieve curative intent or respecting OAR tolerance(s) with a compromised target dose is a trade-off based on patient-specific considerations. These trade-offs regarding quality of life and acceptable toxicity should be discussed with the patient as part of shared decision-making. When goals and constraints are met during the treatment planning process, no further action is required outside of normal peer review and approval/quality assurance processes. When dose goals and/or constraints cannot be met, additional review processes may be necessary as clinically indicated. In some circumstances, changing the prescription to adjust the dose-fractionation regimen or changing the technique of treatment delivery can be useful options.

Breast

Tables 1-5[18-24] include the DVH planning goals for breast cancer. Tables are separated by target (whole breast, breast/chest wall [CW] with regional lymph nodes, and partial breast) as well as dose/fractionation regimen. There is no table for a conventionally fractionated whole breast without lymph nodes because the panel recognized that this regimen is now rarely used in the absence of

Table 1 Breast/chest wall with regional lymph nodes: conventionally fractionated regimens (1.8-2.0 Gy per fraction to 50-50.4 Gy)

Organ/target	Laterality	Metric	Primary goal	Secondary goal	Deviation	Notes
Breast[18,19] (Contralateral)	Left/right	D10%	≤3 Gy	≤5 Gy	>5 Gy	
Heart[18]	Left	Mean	≤4 Gy	≤5 Gy	>5 Gy	
	Right	Mean	≤2 Gy*	≤3 Gy*	>3 Gy*	
Lung[18,19]						
(Contralateral)	Left/right	V5Gy	≤15%		>15%	
(Ipsilateral)	Left/right	V20Gy	≤35%	≤40%	>40%	
	Left/right	V10Gy	≤65%		>65%	
SpinalCord[2]	Left/right	D0.03cc	≤45 Gy*	≤50 Gy	>50 Gy	
Breast/Chestwall†[18]	Left/right	Rx dose	V95% ≥95%	V90% ≥90%	V90% <90%	Field volume may substitute for contoured PTV
	Left/right	D0.03cc	≤110%*	≤115%*	>115%*	
LN_Sclav[18]	Left/right	Rx dose	V95% ≥95%	V90% ≥90%	V90% <90%	
	Left/right	D0.03cc	≤110%*	≤115%*	>115%*	
LN_Ax[18]	Left/right	Rx dose	V95% ≥95%	V90% ≥90%	V90% <90%	
	Left/right	D0.03cc	≤110%*	≤115%*	>115%*	
LN_IMN[18]	Left/right	V90%	≥95%	≥80%	<80%	
	Left/right	D0.03cc	≤110%*	≤115%*	>115%*	

Abbreviations: D = dose; PTV = planning target volume; Rx = prescription; V = volume.
*Panel consensus.
†Goals do not include dose contribution from a boost (eg, lumpectomy cavity boost).

Table 2 Breast/chest wall without regional lymph nodes: moderately hypofractionated 15 or 16 fraction regimens (2.66-2.67 Gy per fraction to 40.05-42.56 Gy)

Organ/target	Laterality	Metric	Primary goal	Secondary goal	Deviation	Notes
Breast (Contralateral)	Left/right	D5%	≤1.44 Gy*	≤2.4 Gy*	>2.4 Gy*	
Heart[20]	Left	Mean	≤1.6 Gy	≤2.4 Gy	>2.4 Gy*	
	Right	Mean	≤0.8 Gy	≤1.6 Gy	>1.6 Gy	
Lung[20-22]						
(Contralateral)	Left/right	V4Gy	≤10%	≤15%	>15%	
(Ipsilateral)[20,22]	Left/right	V16Gy	≤15%	≤20%	>20%	
Breast/chestwall†[19]	Left/right	Rx dose	V95% ≥95%	V90% ≥90%	V90% <90%	Field volume may substitute for contoured PTV
	Left/right	D0.03cc	≤110%*	≤115%*	>115%*	
	Left/right	V107%	≤10 cc		>10 cc	

Abbreviations: D = dose; PTV = planning target volume; Rx = prescription; V = volume.
*Panel consensus.
†Goals do not include dose contribution from a boost (eg, lumpectomy cavity boost).

lymph node RT. There is variation in practice regarding contouring of breast tissue as a target. When contoured, the breast/CW PTV should be retracted from the skin surface (eg, by 0.5 cm) for evaluation purposes. Irrespective of the method for delineating the breast/CW, an evaluation of breast/CW tissue coverage and any hot spots should be performed.

DVH planning goals do not incorporate dose for a lumpectomy cavity boost and target evaluation assessment (ie, PTV coverage) does not include a boost dose. Generally, the lumpectomy cavity boost does not contribute significantly to OAR doses. However, an evaluation of the summative plan in all patients is recommended. For regional lymph node evaluation, nodal chains were

Table 3 Breast/chest wall with regional lymph nodes: moderately hypofractionated 15 or 16 fraction regimens (2.66-2.67 Gy per fraction to 40.05-42.56 Gy)

Organ/target	Laterality	Metric	Primary goal	Secondary goal	Deviation	Notes
Breast (Contralateral)[19]	Left/right	D10%	≤3 Gy	≤5 Gy	>5 Gy	
Heart[19]	Left	Mean	≤3 Gy	≤5 Gy	>5 Gy	
	Right	Mean	≤1.6 Gy*	≤2.4 Gy*	>2.4 Gy*	
Lung[19]						
(Contralateral)	Left/right	V4.3Gy	≤15%*		>15%*	
(Ipsilateral)	Left/right	V18Gy	≤35%	≤40%	>40%	
	Left/right	V10Gy	≤60%*		>60%*	
SpinalCord[5]	Left/right	D0.035cc	≤37.8 Gy*	≤42 Gy	>42 Gy	
Breast/Chestwall†[19]	Left/right	Rx dose	V95% ≥95%	V90% ≥90%	V90% <90%	Field volume may substitute for contoured PTV
	Left/right	D0.035cc	≤110%*	≤115%*	>115%*	
	Left/right	V107%	≤10 cc		>10 cc	
LN_Sclav[19]	Left/right	Rx dose	V95% ≥95%	V90% ≤90%	V90% <90%	
	Left/right	D0.035cc	≤110%*	≤115%*	>115%*	
LN_Ax[19]	Left/right	Rx dose	V95% ≥95%	V90% ≥90%	V90% <90%	
	Left/right	D0.035cc	≤110%*	≤115%*	>115%*	
LN_IMN[19]	Left/right	V90%	≥90%	≥80%	<80%	
	Left/right	D0.035cc	≤110%*	≤115%*	>115%*	

Abbreviations: D = dose; PTV = planning target volume; Rx = prescription; V = volume.
*Panel consensus.
†Goals do not include dose contribution from a boost (eg, lumpectomy cavity boost).

Table 4 Partial breast: ultrahypofractionated 5 fraction regimen (6 Gy per fraction to 30 Gy)

Organ/target	Laterality	Metric	Primary goal	Secondary goal	Deviation	Notes
Breast[23]						
(Contralateral)	Left/right	D0.03cc	≤3%	≤5%	>5%	
(Ipsilateral)	Left/right	V50%	≤50%	≤60%	>60%	
	Left/right	V95%	≤25%	≤40%	>40%	
Heart[23]	Left	V15%	≤5%	≤10%	>10%	
	Left	Mean	≤1.5 Gy	≤2 Gy	>2 Gy	
	Right	V5%	≤5%	≤10%	>10%	
	Right	Mean	≤0.7 Gy	≤1 Gy	>1 Gy	
Lung[23]						
(Contralateral)	Left/right	V10%	≤5%	≤15%	>15%*	
(Ipsilateral)	Left/right	V30%	≤10%	≤15%	>15%	
PTV[23] (Partial breast)	Left/right	V95%	≥95%	≥90%	<90%	PTV_EVAL: PTV cropped 3-5 mm inside patient surface; limited posteriorly by the pectoralis muscle.
	Left/right	V105%	≤5%	≤7%	>7%	
	Left/right	D0.03cc	≤110%		>110%	

Abbreviations: D = dose; PTV = planning target volume; PTV_EVAL = evaluation planning target volume; V = volume.
*Panel consensus.

Table 5 Whole breast/chest wall: ultrahypofractionated 5 fraction regimen (5.2 Gy per fraction to 26 Gy)

Organ/target	Laterality	Metric	Primary goal	Secondary goal	Deviation
Heart[24]	Left/right	V1.5Gy	<30%		≥30%
	Left/right	V7Gy	<5%		≥5%
Lung[24] (Ipsilateral)	Left/right	V8Gy	<15%		≥15%
Breast/Chestwall[†24]	Left/right	V95%	≥95%		<95%
	Left/right	V105%	≤5%		>5%
	Left/right	V107%	≤2%		>2%
	Left/right	D0.03cc	≤110%		>110%

Abbreviations: D = dose; V = volume.
[†]Goals do not include dose contribution from a boost (eg, lumpectomy cavity boost).

Table 6 Head and neck (excluding early-stage larynx): conventionally fractionated regimens (2.0-2.12 Gy per fraction to 70 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Inclusion/exclusion	Notes
Bone_Mandible[25,26]	D0.03cc	≤70 Gy	≤73.5 Gy	>73.5 Gy		
BrachialPlex_L/R[25,26]	D0.03cc	≤66 Gy	≤72 Gy	>72 Gy		
Brainstem[27]	D0.03cc	≤50 Gy	<52 Gy	≥52 Gy		
Cavity_Oral[27-29]					Excluding oral cavity cases	Uninvolved tissue
(Bilateral neck tx)	D0.03cc	≤60 Gy	>60 Gy			
	Mean	≤30 Gy		>30 Gy		
(Unilateral neck tx)	Mean	≤20 Gy		>20 Gy		
Cochlea_L/R[27]	D0.03cc	≤35 Gy		>35 Gy	Oropharynx only	Individual organ contouring
Esophagus[27]	Mean	≤45 Gy		>45 Gy	Larynx only	Bottom of pharynx to thoracic inlet
	Mean	≤35 Gy		>35 Gy	Oropharynx only	
Glnd_Submand_L/R[26,28,29] (contralateral)						
(Bilateral neck tx)	Mean	≤39 Gy	>39 Gy			
(Unilateral neck tx)	Mean	≤10 Gy	>10 Gy			
Larynx[27]	Mean	≤35 Gy		>35 Gy	Oropharynx only	
Musc_Constrict	Mean	≤50 Gy[*]	≤60 Gy[*]	>60 Gy[*]		Musc_Constrict − CTV
Parotid_L/R[26-30] (contralateral)						
(Bilateral neck tx)	Mean	≤26 Gy		>26 Gy		
(Unilateral neck tx)	Mean	≤7 Gy		>7 Gy		
SpinalCord[30]	D0.03cc	≤45 Gy[*]	≤50 Gy	>50 Gy		
PTV_high risk	D95%	100%[*]	≥95%[*]	<95%[*]		
	D99%	≥95%[*]	≥90%[*]	<90%[*]		
	D0.03cc	≤108%[*]	≤112%[*]	>112%[*]		
PTV_low risk	D95%	≥100%[*]	≥95%[*]	<95%[*]		
	D99%	≥95%[*]	≥90%[*]	<90%[*]		

Abbreviations: CTV = clinical target volume; D = dose; PTV = planning target volume; tx = treatment.
[*]Panel consensus.

Table 7 Head and neck: carotid sparing early-stage larynx (T1/2 glottic cancer) using IMRT/VMAT: moderately hypofractionated 28 or 29 fraction regimens (2.25 Gy per fraction to 63-65.25 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
A_Carotid_L/R[31]	D2%	≤35 Gy		>35 Gy	Entire length of PTV
	Mean	≤20 Gy*	≤50 Gy*	>50 Gy*	
Esophagus	D0.03cc	≤100%*		>100%*	
Glnd_Submand_L/R	Mean	≤15 Gy*	>15 Gy*		
Musc_Constrict[32]	D0.03cc	≤100%		>100%*	Musc_Constrict − CTV
SpinalCord[31]	D0.03cc	≤20 Gy	≤45 Gy	>45 Gy*	
PTV	D95%	100%*	≥95%*	<95%*	
	D99%	≥95%*	≥90%*	<90%*	
	D0.03cc	≤108%*	≤110%*	>110%*	

Abbreviations: CTV = clinical target volume; D = dose; IMRT = intensity modulated radiation therapy; PTV = planning target volume; VMAT = volumetric modulated arc therapy.
*Panel consensus.

Table 8 Liver: ultrahypofractionated 3 fraction regimens (12-20 Gy per fraction to 36-60 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bowel_Large[33]	D0.03cc	≤28 Gy		>28 Gy	
	D20cc	≤24 Gy		>24 Gy	
Bowel_Small[33]	D0.03cc	≤25 Gy		>25 Gy	
	D5cc	≤18 Gy		>18 Gy	
Chestwall[34,35]	D0.03cc	≤50 Gy		>50 Gy	
	D5cc	≤40 Gy		>40 Gy	
	D30cc	≤30 Gy		>30 Gy	
Duodenum[3,33]	D0.03cc	≤22 Gy		>22 Gy	
	D5cc	≤16.5 Gy		>16.5 Gy	
Esophagus[36]	D0.03cc	≤27 Gy		>27 Gy	
Heart[3,5]	D0.03cc	≤30 Gy		>30 Gy	
	D15cc	≤24 Gy		>24 Gy	
Kidneys	Mean	≤8 Gy*		>8 Gy*	
Liver[33]					Liver - GTV/iGTV
(Noncirrhotic)	CV19Gy†	≥700 cc		<700 cc	
	Mean	≤12 Gy	≤15 Gy	>15 Gy	
(CP class A)	Mean	≤10 Gy	≤12 Gy	>12 Gy	
SpinalCanal	D0.03cc	≤22.5 Gy*		>22.5 Gy*	
Stomach[3,33]	D0.03cc	≤22 Gy		>22 Gy	
	D10cc	≤16.5 Gy		>16.5 Gy	
PTV	V100%	≥95%*		<95%*	OAR has priority over PTV coverage when in close proximity
	V90%	≥100%*		<100%*	

Abbreviations: CP = Child-Pugh; CV = complementary volume; D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; OAR = organ at risk; PTV = planning target volume; V = volume.
*Panel consensus.
†CVxGy[cc] = total liver volume[cc] − VxGy[cc], representing the CV on a cumulative dose-volume histogram, which is the volume of tissue receiving the indicated dose or less.

Table 9 Liver: ultrahypofractionated 5 fraction regimens (8-12 Gy per fraction to 40-60 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bowel_Large[37,38]	D0.5cc	≤32 Gy	≤34 Gy	>34 Gy	
Bowel_Small[37,38]	D0.5cc	≤30 Gy		>30 Gy*	
	D5cc	<25 Gy		≥25 Gy	
Chestwall[35,39,40]	D0.03cc	≤57 Gy		>57 Gy	
	V30Gy	≤30 cc	≤70 cc	>70 cc	
Duodenum[37,38]	D0.5cc	≤30 Gy		>30 Gy*	
	D5cc	<25 Gy		≥25 Gy	
Esophagus[37]	D0.5cc	≤32 Gy		>32 Gy*	
Heart[37]	D0.03cc	≤52.5 Gy*		>52.5 Gy*	
	D30cc	≤30 Gy		>30 Gy	
Kidneys[37,38]	Mean	≤10 Gy		>10 Gy*	If one kidney Mean >10 Gy, other/only kidney V10Gy <10%
Liver[33]					Liver − GTV/iGTV
(CP class A)	CV15Gy†	≥700 cc		<700 cc	
	Mean	≤13 Gy	≤15 Gy	>15 Gy	
(CP class B)	CV10Gy†	≥500 cc		<500 cc	
	Mean	≤8 Gy	≤10 Gy	>10 Gy	
(non-cirrhotic)	CV21Gy†	≥700 cc		<700 cc	
	Mean	≤15 Gy	≤18 Gy	>18 Gy	
SpinalCanal‡[37,38]	D0.5cc	≤25 Gy		>25 Gy*	
Stomach[37,38]	D0.5cc	≤30 Gy		>30 Gy*	
	D5cc	<25 Gy		≥25 Gy	
PTV	V100%	≥95%*		<95%*	OAR has priority over PTV coverage when in close proximity
	V90%	≥100%*		<100%*	

Abbreviations: CP = Child-Pugh; CV = complementary volume; D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; OAR = organ at risk; PTV = planning target volume; V = volume.

*Panel consensus.

†CVxGy[cc] = total liver volume[cc] − VxGy[cc], representing the CV on a cumulative dose-volume histogram, which is the volume of tissue receiving the indicated dose or less.

‡Modified from spinal cord to spinal canal.

separated, however, the task force acknowledges that many physicians do not separate out the nodal chains but often will evaluate internal mammary nodal (IMN) coverage separately. The IMN constraints are appropriate for elective nodal irradiation; however, with the presence of gross disease in the IMN, coverage of at least 95% is recommended.

The spinal cord metrics for the breast regimens follow standard normal tissue constraints. However, it is recognized that in most instances doses well below this threshold are attainable. As with any plan, the concept of as low as reasonably achievable is applicable. Additional OAR inclusion was discussed among the panel members (eg, esophagus, brachial plexus, thyroid, and cardiac substructures), but these are not pertinent for all targets (ie, delivery of whole breast RT may/may not result in dose to the esophagus, brachial plexus, or thyroid) or techniques (arc therapy vs tangents). Consensus was not met (ie, ≥75% agreement) on DVH recommendations for these organs.

For each regimen, both right- and left-sided primary site heart constraints were included because this was thought to be critical to quality plan evaluation. Strong consideration for monitoring doses to these OARs should be considered. Interest in the cardiac substructures, primarily the left anterior descending artery and left ventricle, where emerging data are allowing for the formulation of DVH constraints, will be considered in future iterations.

Head and neck

Tables 6[25-30] and 7[31,32] include the DVH planning goals for head and neck cancers. During initial

Table 10 Liver: moderately hypofractionated 15 fraction regimens (3-4.5 Gy per fraction to 45-67.5 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bowel_Large[33]	D0.03cc	≤45 Gy		>45 Gy	
Bowel_Small[33]	D0.03cc	≤45 Gy		>45 Gy	
Chestwall[41,42]	D10cc	≤60 Gy		>60 Gy	
	D20cc	≤45 Gy		>45 Gy	
	D150cc	≤40 Gy		>40 Gy	
Duodenum[33]	D0.03cc	≤45 Gy		>45 Gy	
Esophagus[38]	D0.5cc	≤40 Gy	≤45 Gy	>45 Gy	
Heart	D30cc	≤45 Gy*		>45 Gy*	Equi effective dose conversion from 8 Gy × 5 fractions using $\alpha/\beta = 3$
Kidneys[38]	V18Gy	≤30%	≤32%	>32%	
Liver[33]					Liver − GTV/iGTV
(CP class A)	Mean	≤20 Gy		>20 Gy	
(CP class B)	Mean	≤16 Gy		>16 Gy	
(noncirrhotic)	Mean	≤24 Gy		>24 Gy	
SpinalCanal†[38]	D0.5cc	≤30 Gy	≤35 Gy	>35 Gy	
Stomach[33]	D0.03cc	≤42 Gy	≤45 Gy	>45 Gy	
PTV	V100%	≥95%*		<95%*	OAR has priority over PTV coverage when in close proximity
	V90%	≥100%*		<100%*	

Abbreviations: α/β = alpha/beta ratio; CP = Child-Pugh; D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; OAR = organ at risk; PTV = planning target volume; V = volume.
*Panel consensus.
†Modified from spinal cord to spinal canal.

Table 11 Lung: conventionally fractionated regimens (1.8-2 Gy per fraction to 60-70 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
BrachialPlex[43]	D0.03cc	≤66 Gy	≤70 Gy	>70 Gy	
Esophagus[2,44-47]	D0.03cc	≤105%	≤74 Gy	>74 Gy	
	V60Gy	≤15.3%*	≤17%	>17%	
	Mean	≤30.6 Gy*	≤34 Gy	>34 Gy	
Heart[2]	V45Gy	≤35%	≤40%	>40%	
Lung[48]	V20Gy	≤6.3%*	≤7%	>7%	Constraint applicable to patients with only one lung present. Lung − GTV/iGTV
	V5Gy	≤42%*	≤60%*	>60%*	
	Mean	≤7.7 Gy*	≤8.5 Gy	>8.5 Gy	
Lungs[44,47,49]	V20Gy	≤33%*	≤37%	>37%	Lungs − GTV/iGTV
	V5Gy	≤60%	≤70%	>70%	
	Mean	≤18 Gy*	≤22 Gy	>22 Gy	
SpinalCanal[44,47]	D0.03cc	≤50.5 Gy	≤52 Gy	>52 Gy	
PTV[44,47]	D95%	100%	≥95%	<95%	

Abbreviations: D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; PTV = planning target volume; V = volume.
*Panel consensus.

development, the focus was on RT to oropharyngeal and laryngeal primaries. In some instances, the metrics could be applied to other primary disease sites that use the same fractionation regimen. The 2.12 Gy per fraction regimen was incorporated into conventional fractionation for head and neck, rather than hypofractionated, and Table 6 provides dose constraints specific to head and neck cancers receiving conventionally fractionated RT (2.0-2.12 Gy per

fraction to a total dose of 70 Gy). These include treatment plans that may include a simultaneous integrated boost (SIB), with dose constraints derived from both definitive and postoperative RT protocols. The targets are listed as PTVs for high risk (ie, gross disease) and low risk (ie, elective nodes/regions), and it is recognized that there may be optional intermediate target volumes that would follow the same coverage metrics.

Table 6 does not apply to early-stage laryngeal cancers. Table 7 focuses on early-stage T1/T2 glottic cancers treated with moderate hypofractionation of 2.25 Gy per fraction to a total dose of 63 to 65.25 Gy.

Liver

Tables 8-10[3,5,33-42] include the DVH planning goals for 3- and 5-fraction SBRT, as well as moderately hypofractionated 15-fraction regimens. These were primarily derived from clinical data and protocols for treating primary liver cancers (hepatocellular carcinoma and intrahepatic cholangiocarcinoma) but may be applicable to the treatment of liver metastases. CW constraints were added in the current recommendations; however, there was variable implementation/prioritization of these in practice among the original panelists (eg, some elected to prioritize target coverage over meeting all CW metrics depending on the treatment goals and clinical context). The recommended planning goals for nonliver gastrointestinal OARs (eg, bowel) were established in clinical settings where comorbidities (eg, cirrhosis and portal hypertension) were more likely to be present. Because cirrhosis and/or portal hypertension may increase the risk of acute or late toxicities (eg, gastrointestinal bleeding), the proposed goals may be more restrictive than what might be permissible when these comorbidities are not present (eg, for limited liver metastases) in noncirrhotic livers.

Given the liver's parallel tissue architecture, many prior studies have reported critical volume constraints as key dosimetric parameters for the normal liver. Specifically, these constraints define the volume of normal liver that should receive a dose at or below a specified threshold.[3] For example, the ASTRO Liver Guideline recommends sparing at least 700 cc of the normal liver below a specified threshold dose, which varies based on the fractionation regimen and the patient's baseline liver

Table 12 Lung: ultrahypofractionated 1 fraction regimens (27-34 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
BrachialPlex[5]	D0.035cc	≤16.4 Gy		>16.4 Gy	
Bronchus[5]	D0.035cc	≤20.2 Gy		>20.2 Gy	Bronchial tree/smaller airways
	D0.5cc	≤17.4 Gy		>17.4 Gy	
Chestwall[50]	D1cc	≤30.2 Gy		>30.2 Gy	
	D5cc	≤27.2 Gy		>27.2 Gy	
Esophagus[3,45,51]	D0.035cc	≤15.4 Gy		>15.4 Gy	
	D5cc	≤11.9 Gy		>11.9 Gy	
GreatVes[3,5,45,51]	D0.035cc	≤37 Gy		>37 Gy	
Heart[3,5,45,51]	D0.035cc	≤22 Gy		>22 Gy	
	D15cc	≤16 Gy		>16 Gy	
Lungs[5]	V8Gy	≤37%		>37%	Lungs − GTV/iGTV
Ribs[3,45,51]	D0.035cc	≤30 Gy		>30 Gy	
	D1cc	≤22 Gy		>22 Gy	
Skin[3,45,51]	D0.035cc	≤26 Gy		>26 Gy	
	D10cc	≤23 Gy		>23 Gy	
SpinalCanal[4]	D0.035cc	≤12.4 Gy	≤14 Gy	>14 Gy	
Trachea/ Bronchus_Main[3,45,51]	D0.035cc	≤20.2 Gy		>20.2 Gy	
	D4cc	≤10.5 Gy		>10.5 Gy	
PTV	D95%	100%*	≥99%*	<99%*	Peripheral lesions only
	D99%	≥90%*	≥85%*	<85%*	

Abbreviations: D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; PTV = planning target volume; V = volume.
*Panel consensus.

function.[33] To simplify implementation of volumetric liver sparing, the use of CV, as described in the Nomenclature Section, was recommended.[12,13]

Lung

Tables 11-18[2-5,43-58] include the DVH planning goals for conventional, moderately hypofractionated, and ultrahypofractionated approaches for non-small cell lung cancer. These reflect the most commonly used fractionation regimens through literature and panel consensus, although other fractionation regimens outside the scope of this project may be considered in clinical practice (eg, small cell lung cancer twice daily treatment, SIB, postoperative treatment). For all lung regimens, the spinal canal is used rather than spinal cord, reflecting widespread practice and literature supporting the DVHs. In rare instances, published OAR constraints did not make logical sense when reviewing individual sources (eg, having a lower dose constraint for 10 fractions than for a 5-fraction regimen); therefore, "panel consensus" measures were created to account for this in several instances. The 8-fraction regimen was added to the original regimens previously reported[9] because of additional evidence from several trials using this fractionation regimen.[53,54]

For serial structures or critical mediastinal structures where there is a maximum dose constraint that cannot be met with 3 fractions, the selected regimen should change to 4 or 5 fractions. Moderately hypofractionated treatment is often pursued when an ultra-central location and/or burden of disease suggests a benefit with using more than 5 treatments. These tables include 8-, 10-, and 15-fraction regimens all to doses of ≥60 Gy. In general, tumor coverage should not be compromised, especially for parallel

Table 13 Lung: ultrahypofractionated 3 fraction regimen (18 Gy per fraction to 54 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
BrachialPlex[3,36,39,45]	D0.035cc	≤24 Gy		>24 Gy	
Bronchus[5]	D0.035cc	≤30 Gy		>30 Gy	Bronchial tree/smaller airways
	D0.5cc	≤25.8 Gy		>25.8 Gy	
Chestwall[35,39,52]	D0.035cc	≤50 Gy		>50 Gy	
	V30Gy	≤30 cc	≤35 cc	>35 cc*	
Esophagus[3,36,39,45]	D0.035cc	≤27 Gy		>27 Gy	
	D5cc	≤17.7 Gy		>17.7 Gy	
GreatVes[3,5,39]	D0.035cc	≤45 Gy		>45 Gy	
Heart[3,5,36,45]	D0.035cc	≤30 Gy		>30 Gy	
	D15cc	≤24 Gy		>24 Gy	
Lungs[3,4,36]	V20Gy	≤10%	≤15%	>15%	Lungs − GTV/iGTV
	CV11.6Gy†	≥1500 cc		<1500 cc	
	CV12.4Gy†	≥1000 cc		<1000 cc	
	Mean	≤8 Gy		>8 Gy	
Ribs[5]	D0.035cc	≤50 Gy		>50 Gy	
	D5cc	≤40 Gy		>40 Gy	
Skin[3,5,39]	D0.035cc	≤33 Gy		>33 Gy	
	D10cc	≤31 Gy		>31 Gy	
SpinalCanal[4]	D0.035cc	≤20.3 Gy		>20.3 Gy*	
Trachea/ Bronchus_Main[3,36,39]	D0.035cc	≤30 Gy		>30 Gy	
	D4cc	≤15 Gy		>15 Gy	
PTV	D95%	100%*	≥99%*	<99%*	Peripheral lesions only
	D99%	≥90%*	≥85%*	<85%*	

Abbreviations: CV = complementary volume; D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; PTV = planning target volume; V = volume.

*Panel consensus.

†CVxGy[cc] = total lung volume[cc] − VxGy[cc], representing the CV on a cumulative dose-volume histogram, which is the volume of tissue receiving the indicated dose or less.

Table 14 Lung: ultrahypofractionated 4 fraction regimens (12-12.5 Gy per fraction to 48-50 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
BrachialPlex[39,45,51]	D0.035cc	≤27.2 Gy		>27.2 Gy	
Bronchus[5]	D0.035cc	≤34.8 Gy		>34.8 Gy	Bronchial tree/smaller airways
	D0.5cc	≤28.8 Gy		>28.8 Gy	
Chestwall[35,39,52]	D0.035cc	≤50 Gy*	≤54 Gy	>54 Gy	
	V30Gy	≤30 cc	≤35 cc	>35 cc*	
Esophagus[39,53,43,45,51]	D0.035cc	≤30 Gy		>30 Gy	
	D5cc	≤18.8 Gy		>18.8 Gy	
GreatVes[5,39,43,45]	D0.035cc	≤43 Gy*	≤49 Gy	>49 Gy	
Heart[39,43,45,51]	D0.035cc	≤34 Gy		>34 Gy	
	D15cc	≤28 Gy		>28 Gy	
Lungs[4]	V20Gy	≤10%	≤15%	>15%	Lungs − GTV/iGTV
	Mean	≤8 Gy		>8 Gy	
Ribs[45,51]	D0.035cc	≤40 Gy		>40 Gy	
	D1cc	≤32 Gy		>32 Gy	
Skin[39,43,51]	D0.035cc	≤36 Gy		>36 Gy	
	D10cc	≤33.2 Gy		>33.2 Gy	
SpinalCanal[39]	D0.035cc	≤24 Gy		>24 Gy	
Trachea/ Bronchus_Main[39,45,51]	D0.035cc	≤34.8 Gy		>34.8 Gy	
	D4cc	≤15.6 Gy		>15.6 Gy	
PTV	D95%	100%*	≥99%*	<99%*	Peripheral or central lesions
	D99%	≥90%*	≥85%*	<85%*	

Abbreviations: D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; PTV = planning target volume; V = volume.
*Panel consensus.

structures where the constraint is volumetric. This also applies when unable to meet rib or CW constraints, as exceeding these constraints does not generally carry the same grade 4 and 5 toxicity risks as other organs, and coverage should be optimized to avoid underdosing the target while seeking to minimize toxicity. In some circumstances, selecting another dose/fractionation regimen is an option. There are situations where lower doses (eg, 45 Gy in 15 fractions, 50 Gy in 10 fractions) may be clinically appropriate, but those were not directly addressed by these DVH constraints (eg, a constraint of 60 Gy to the trachea is not relevant if prescribing 45 Gy to the PTV) and are not included in the tables' fractionations. If using alternate doses, reviewing evidence specific to that dosing schema is recommended. Although SBRT lung constraints are sometimes applied for treating lung metastases, this was outside the panel's consensus for listed DVH constraints intended for primary lung cancer treatment.

While conventional lung treatment is most typically delivered to 60 to 70 Gy in 2 Gy daily fractions,[59] the constraints listed in Table 11 can also be applied when treating in 1.8 Gy fractions. For adjuvant RT cases treating in 1.8 Gy fractions to doses <60 Gy, more conservative constraints should generally be applied, especially for cardiopulmonary organs.

Prostate

Tables 19-23[2,4,60-76] include the DVH planning goals for prostate cancer. These goals are intended to be applied when treating prostate/seminal vesicle only, prostate/seminal vesicle with elective pelvic nodal RT, prostate bed only, and prostate bed with elective pelvic nodal RT. Importantly, these goals were developed for use in settings that do not include a primary tumor boost (ie, "FLAME" microboost). However, when a primary tumor boost is used, it is typically planned to deliver the closest dose to the planned boost dose that is possible while meeting OAR constraints. Thus, these OAR constraints can be used to inform such treatments, although constraints specific to the urethra in the setting of the primary tumor boost would be necessary. Refer to the literature for further details regarding planning for a primary tumor boost.[77-79] Additionally, the panel acknowledges that some rectal and bowel planning goals can be challenging

Table 15 Lung: ultrahypofractionated 5 fraction regimens (10-12 Gy per fraction to 50-60 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
BrachialPlex[39,45,54,55]	D0.035cc	≤32 Gy		>32 Gy	
Bronchus[3,5,39]	D0.035cc	≤40 Gy	≤105%	>105%	Bronchial tree/smaller airways
	D0.5cc	≤21 Gy		>21 Gy	
Chestwall[35,39,40,52]	D0.035cc	≤50 Gy*	≤57 Gy	>57 Gy	
	V30Gy	≤30 cc	≤70 cc	>70 cc	
Esophagus[3,5,39]	D0.035cc	≤38 Gy	≤105%	>105%	
	D5cc	≤19.5 Gy		>19.5 Gy	
GreatVes[39,45,55]	D0.035cc	≤105%		>105%	
Heart[3,5,39,55]	D0.035cc	≤38 Gy	≤105%	>105%	
	D15cc	≤32 Gy		>32 Gy	
Lungs[3,4,55]	V20Gy	≤10%	≤15%	>15%	Lungs − GTV/iGTV
	CV12.5Gy†	≥1500 cc		<1500 cc	
	CV13.5Gy†	≥1000 cc		<1000 cc	
	Mean	≤8 Gy		>8 Gy	
Ribs[3]	D0.035cc	≤43 Gy		>43 Gy	
	D1cc	≤35 Gy		>35 Gy	
Skin[45,55]	D0.035cc	≤32Gy		>32 Gy	
	D10cc	≤30 Gy		>30 Gy	
SpinalCanal[5,39]	D0.035cc	≤28 Gy		>28 Gy	
Trachea/ Bronchus_Main[3,39,55]	D0.035cc	≤40 Gy	≤105%	>105%	
	D4cc	≤18 Gy		>18 Gy	
PTV	D95%	100%*	≥99%*	<99%*	Peripheral or central lesions
	D99%	≥90% *	≥85%*	<85%*	

Abbreviations: CV = complementary volume; D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; PTV = planning target volume; V = volume.
*Panel consensus.
†CVxGy[cc] = total lung volume[cc] − VxGy[cc], representing the CV on a cumulative dose-volume histogram, which is the volume of tissue receiving the indicated dose or less.

to meet. In these situations, a larger secondary planning goal range was created to avoid underdosing of the PTV in an attempt to meet unattainable primary rectal DVH goals. Finally, it is general practice not to reduce target coverage to meet penile bulb planning goals, and thus a deviation in these goals may not warrant the same response as other critical OARs.

Rectal

The target and normal tissue dose constraints are listed for both conventional and short-course regimens in Tables 24[80−84] and 25,[85-87] respectively, for rectal cancer. Treatment planning of pelvic RT for rectal cancer is complex, particularly since pelvic treatment plans can be achieved using 3-dimensional conformal RT or intensity modulated RT. Rectal treatments may involve a whole pelvis field followed by a cone-down boost or using an SIB approach. In addition, short-course RT (25 Gy in 5 fractions) is an option for preoperative therapy in select patients. Given the lack of consensus on contouring the small bowel, the panel provided options for when it is contoured as individual bowel loops or as a bowel bag. Several resources are available to help identify OARs and improve uniformity in defining normal tissues.[80,88] The D0.03 cc primary/secondary goal boundary for small bowel is 55 Gy to 56 Gy, reflecting that 56 Gy is used as a prescription dose for SIB and sequential boosts. DVH objectives for the genitals and vagina are given for conventional fractionation but not for short course because there is a paucity of data for their use in this setting and a lower total dose. These OARs are most relevant when the inguinal and external iliac nodes are included in the target volume, and this scenario is most often treated with conventional fractionation.

Table 16 Lung: ultrahypofractionated 8 fraction regimen (7.5 Gy per fraction to 60 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
BrachialPlex[39,53]	D0.035cc	<38 Gy		≥38 Gy	
Chestwall[39,56]	D0.035cc	≤63 Gy	>63 Gy		
	V45Gy	<30 cc		>30 cc	
Esophagus[53,56]	D0.035cc	<40 Gy	<52.5 Gy	≥52.5 Gy*	
	D5cc	<22 Gy		≥22 Gy	
GreatVes[5]	D0.035cc	<62 Gy		≥62 Gy	
Heart[5,56]	D0.035cc	<46 Gy	<60 Gy	≥60 Gy*	
	D15cc	<34.4 Gy		≥34.4 Gy	
Lungs[56]	V26Gy	<10%		≥10%	Lungs − GTV/iGTV
	Mean	<10 Gy*		≥10 Gy*	
Ribs[5,53]	D0.035cc	≤63 Gy	>63 Gy		
	D5cc	≤50 Gy		>50 Gy	
SpinalCanal[39,53,54]	D0.035cc	<32 Gy		≥32 Gy	
Trachea/	D0.035cc	<46.3 Gy	<56 Gy	≥56 Gy	
Bronchus_Main[5,56]	D5cc	<50 Gy		≥50 Gy	
PTV	D95%	100%*	≥99%*	<99%*	
	D99%	≥90%*	≥85%*	<85%*	

Abbreviations: D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; PTV = planning target volume; V = volume.
*Panel consensus.

Table 17 Lung: moderately/ultrahypofractionated 10 fraction regimens (7 Gy per fraction to 70 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
BrachialPlex[5]	D0.035cc	≤43 Gy		>43 Gy	
Chestwall[57]	V50Gy	≤60 cc		>60 cc	
Esophagus[5]	D0.035cc	≤48 Gy	≤52.5 Gy	>52.5 Gy*	
	D5cc	≤24 Gy*		>24 Gy*	
GreatVes[5]	D0.035cc	≤62.9 Gy		>62.9 Gy	
	D10cc	≤55.7 Gy		>55.7 Gy	
Heart[5,57,58]	D0.035cc	≤42.5 Gy	≤60 Gy	>60 Gy	
	D15cc	≤36.6 Gy		>36.6 Gy	
Lungs[54]	V16Gy	≤30%*	≤32%*	>32%*	Lungs − GTV/iGTV
	Mean	<12 Gy		≥12 Gy	
SpinalCanal[5]	D0.035cc	≤33.3 Gy*	≤36 Gy	>36 Gy	
Trachea/	D0.035cc	≤59 Gy		>59 Gy	
Bronchus_Main[5]	D5cc	≤52 Gy		>52 Gy	
PTV	D95%	100%*	≥99%*	<99%*	
	D99%	≥90%*	≥85%*	<85%*	

Abbreviations: D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; PTV = planning target volume; V = volume.
*Panel consensus.

Table 18 Lung: moderately hypofractionated 15 fraction regimen (4 Gy per fraction to 60 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
BrachialPlex[49]	D0.03cc	≤49.8 Gy	≤52 Gy	>52 Gy	
Chestwall[42]	V40Gy	≤150 cc		>150 cc	
Esophagus[49]	D0.03cc	≤58.9 Gy	≤61.3 Gy	>61.3 Gy	
	Mean	≤25 Gy*	≤32 Gy	>32 Gy	
GreatVes[53]	D0.03cc	≤60 Gy*	≤66 Gy	>66 Gy	
Heart[49,53,54]	D0.03cc	≤60 Gy*	≤66 Gy	>66 Gy	
	Mean	≤16.5 Gy	≤18.5 Gy	>18.5 Gy	
Lungs[49]	V16.5Gy	≤37%	≤40%	>40%	Lungs − GTV/iGTV
	V5Gy	≤65%	≤70%	>70%	
	Mean	≤16.5 Gy	≤18.5 Gy	>18.5 Gy	
SpinalCanal[49]	D0.03cc	≤36.5 Gy	≤40.2 Gy	>40.2 Gy	
Trachea/ Bronchus_Main[53,54]	D0.03cc	≤60 Gy*	≤66 Gy	>66 Gy	
PTV[49]	D95%	60 Gy	≥50 Gy ≤61.2 Gy	<50 Gy; >61.2 Gy	
	D99%	≥52.5 Gy	≥45 Gy	<45 Gy	
	D0.03cc	≤66 Gy	≤69 Gy	>69 Gy	

Abbreviations: D = dose; GTV = gross tumor volume; iGTV = internal gross target volume; PTV = planning target volume; V = volume.
*Panel consensus.

Table 19 Prostate: conventionally fractionated regimens (1.8-2 Gy per fraction to 74-81 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[2,60-64]	V75Gy	≤25%		>25%	
	V70Gy	≤35%		>35%	
	V50Gy	≤50%		>50%	
Bowel_Large[65]	D0.035cc	≤62.5 Gy		>62.5 Gy	
	V60Gy	≤1%*		>1%*	
Bowel_Small[66,67]	D0.035cc	≤52.5 Gy	≤54 Gy	>54 Gy	
	V45Gy	≤150 cc	≤200 cc	>200 cc	
Femur_Head[66]	V50Gy	≤10%		>10%	
PenileBulb[60-63,67-69]	Mean	≤52.5 Gy		>52.5 Gy	PTV coverage should not be compromised
Rectum[64,67]	V75Gy	≤10%	≤15%	>15%	
	V70Gy	≤15%	≤25%	>25%	
	V40Gy	≤40% *	≤65%	>65%	
PTV	V100%	≥95%*	≥90%*	<90%*	
	D2%	≤110%*	≤115%*	>115%*	

Abbreviations: D = dose; PTV = planning target volume; V = volume.
*Panel consensus.

Discussion

The dose constraints provided are the result of quality measure development between the VA and ASTRO to date. They represent the body of work thus far, with the goal of expanding future resources to include other disease sites. Updates to the tables will occur when new data is presented and as technologies evolve.

Table 20 Prostate: moderately hypofractionated 20 fraction regimen (3 Gy per fraction to 60 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[64,65,69]	V60Gy	≤5%	≤15%	>15%	
	V48Gy	≤25%		>25%	
	V40Gy	≤50%		>50%	
Bowel_Large[65]	D0.03cc	≤50 Gy		>50 Gy	
Bowel_Small[64,68]	D0.03cc	≤50 Gy*		>50 Gy*	
	V40Gy	≤17 cc	≤195 cc	>195 cc	
Femur_Head[64]	V40Gy	≤5%	≤50%	>50%	
PenileBulb[64]	V48Gy	≤10%		>10%	PTV coverage should not be compromised
Rectum[67,69,70]	V60Gy	≤0.01%	≤8%	>8%	
	V50Gy	≤22%		>22%	
	V30Gy	≤57%		>57%	
PTV	V100%	≥95%*	≥90%*	<90%*	
	D2%	≤110%*	≤115%*	>115%*	

Abbreviations: D = dose; PTV = planning target volume; V = volume.
*Panel consensus.

Table 21 Prostate: moderately hypofractionated 28 fraction regimen (2.5 Gy per fraction to 70 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[65,67-69,71]	V70Gy	≤10%	≤15%	>15%	
	V65Gy	≤15%	≤25%	>25%	
	V40Gy	≤35%	≤65%	>65%	
Bowel_Large[65,68]	D0.035cc	≤55 Gy	≤60 Gy	>60 Gy	
	V50Gy	≤1%*	>1%*		
Bowel_Small[67,71]	D0.035cc	≤52.5 Gy	≤54 Gy	>54 Gy	
	V40Gy	≤1%	>1%		
Femur_Head[71]	V40Gy	0%		>0%	
PenileBulb[71]	Mean	<50 Gy		≥50 Gy	PTV coverage should not be compromised
Rectum[67-69,71]	V70Gy	≤5%	≤10%	>10%	
	V65Gy	≤10%		>10%	
	V40Gy	≤35%		>35%	
PTV	V100%	≥95%*	≥90%*	<90%*	
	D2%	≤110%*	≤115%*	>115%*	

Abbreviations: D = dose; PTV = planning target volume; V = volume.
*Panel consensus.

As RT treatment planning and delivery techniques improve, anticipated goals of treatment may evolve as well. For example, increasing use of daily online adaptive therapy has led to an increased focus on gross target volume coverage in those cases and increasing/decreasing the daily fraction dose based on achievable planning goals or further refinement of OAR dose constraints. Increasing the precision of RT has made ultrahypofractionated regimens feasible for more disease sites, and as evidence becomes available for more of these regimens, they may be included in this guidance. It is also anticipated that previously overlooked structures may be identified as receiving clinically meaningful incidental doses, and more structures could be recognized as at risk, necessitating new planning considerations. Many

Table 22 Postoperative prostate: conventionally fractionated regimens (1.8-2 Gy per fraction to 64-72 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[72]	V65Gy	<50%	≤57.5%	>57.5%*	Bladder − CTVp
	V40Gy	≤70%	≤77%	>77%	
Bowel_Large	D0.03cc	≤62.5 Gy*		>62.5 Gy*	
	V60Gy	≤1%*		>1%*	
Bowel_Small[66,73]	V60Gy	≤0.1 cc		>0.1 cc	
	V45Gy	≤150 cc	≤200 cc	>200 cc	
Femur_Head[66]	V50Gy	≤10%	≤15%	>15%	
PenileBulb[73]	Mean	≤52.5 Gy		>52.5 Gy	
Rectum[72]	V65Gy	≤35%	≤45%	>45%*	
	V40Gy	≤55%	≤65%	>65%*	
PTV (Prostate bed)	V100%	≥95%*	≥90%*	<90%*	
	D2%	≤110%*	≤115%*	>115%*	

Abbreviations: CTVp = primary clinical target volume; D = dose; PTV = planning target volume; V = volume.
*Panel consensus.

Table 23 Prostate: ultrahypofractionated 5 fraction regimens (7.25-8 Gy per fraction to 36.25-40 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[64,68]	V37Gy	<5 cc	<20 cc	≥20 cc	
	V18.1Gy	<40%		≥40%	
Bowel_Large[68]	D0.03cc	≤30 Gy		>30 Gy*	
Bowel_Small[64,68,74]	V30Gy	≤0.03 cc	≤1 cc	>1 cc*	
	V18.1Gy	<5 cc		≥5 cc	
Femur_Head[64]	V14.5Gy	<5%		≥5%	
PenileBulb[64,74,75]	D0.03cc	≤36.25 Gy	>36.25 Gy		PTV coverage should not be compromised
	V29.5Gy	<50%	≥50%		
Rectum[64,68,76]	V36Gy	<1 cc	<3 cc	≥3 cc	
	V29Gy	<20%		≥20%	
	V18.1Gy	<50%		≥50%	
Urethra[64]	V42Gy	<50%		≥50%	
PTV[4,74,75]	V100%	≥95%*		<95%*	
	D0.03cc	≤120%*		>120%*	Robotic/ablative
	D0.03cc	≤107%		>107%	Linac based

Abbreviations: D = dose; Linac = linear accelerator; PTV = planning target volume; V = volume.
*Panel consensus.

panelists thought that the existing data supported using a mean dose for serial functioning organs or large organs, but this metric may be less meaningful when the organ is only partially irradiated. As work on normal tissue effects from modern RT continues, future iterations of this compendium will critically assess the value of this metric. Additionally, existing studies have frequently used percentage constraints, which can be affected by overcontouring or incomplete contouring of an OAR. New studies are shifting toward replacing these with volumetric constraints, and future updates to the compendium will likely incorporate these evolving measures.

There is still work to be done to optimize dose goals and constraints for target volumes and normal tissues, within radiation oncology. Different methodologies for calculating doses have produced varying data, and ongoing efforts will harmonize the lack of concordance where possible. Wide variation when reporting on toxicities and efforts to standardize provide an opportunity for future

Table 24 Rectal: conventionally fractionated regimens (1.8-2.0 Gy per fraction to 50-56 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[80-83]	V45Gy	≤15%	≤30%	>30%*	
	Mean	≤40 Gy	≤44 Gy	>44 Gy	
Bowel_Small	D0.03cc	≤56 Gy*	≤60 Gy*	>60 Gy*	Contoured as Bag_Bowel
	D100cc	≤45 Gy*	≤49.5 Gy*	>49.5 Gy*	
	D180cc	≤35 Gy*	≤38.5 Gy*	>38.5 Gy*	
Bowel_Small[84]	D0.03cc	≤56 Gy*	≤60 Gy	>60 Gy	Contoured as individual loops
	V50Gy	≤30 cc	>30 cc		
	V45Gy	≤150 cc	>150 cc		
Femur_Head[81]	D5%	≤45 Gy	≤49.5 Gy	>49.5 Gy	
	D50%	≤30 Gy	≤33 Gy	>33 Gy	
Genitals[84]	V40Gy	≤5%	≤10%	>10%	Vulva or testis/penis
	V30Gy	≤35%	>35%		
	V20Gy	≤50%	>50%		
Vagina	V45Gy	≤50%	>50%		Vaginal canal
PTV[81,82]	D95%	≥95%	≥90%	<90%	
	D10%	≤110%	≤120%	>120%	

Abbreviations: D = dose; PTV = planning target volume; V = volume.
*Panel consensus.

Table 25 Rectal: short-course regimen (5 Gy per fraction to 25 Gy)

Organ/target	Metric	Primary goal	Secondary goal	Deviation	Notes
Bladder[85]	V25Gy	≤20%*	>20%*		
	V15Gy	≤50%	>50%		
	Mean	≤20 Gy*	>20 Gy*		
Bowel_Small[80]	D0.03cc	≤26.5 Gy*	≤28.75 Gy*	>28.75 Gy*	Contoured as Bag_Bowel
	V20Gy	≤200 cc	>200 cc		
Bowel_Small[86,87]	D0.03cc	≤26.5 Gy*	≤28.75 Gy*	>28.75 Gy*	Contoured as individual loops
	V20Gy	≤50 cc	>50 cc		
Femur_Head	D5%	≤25 Gy*	>25 Gy*		
PTV[87]	D95%	≥95%		<95%	
	D0.03cc	≤115%		>115%	

Abbreviations: D = dose; PTV = planning target volume; V = volume.
*Panel consensus.

trial data to add to the depth of knowledge. The development of automated tools to support contouring is ongoing and, where possible, vendors should incorporate these tools into the oncology information systems and treatment planning systems to promote this standard of care.

This DVH compendium is pragmatic and reflective of general practice and established treatment regimens. The VA plans to assess the consistency of these metrics within clinical practice to evaluate adherence and quality following their adoption. Having accessible default constraints supports standardization and will help improve the quality of treatment planning and radiation delivery for all patients.

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Leslie Ballas is consultant for UpToDate, reports institutional research funding from Merck and Seagen/Astellas,

and is an editor of UroToday. Bhisham Chera owns stocks and serves on the advisory board of Naveris, is an editor of *Practical Radiation Oncology*, and journal editor of *American College of Radiology*. Indrin Chetty is board member of Indian American Society of Medical Physics and Medical Physics Institute, and received travel expenses from Varian. Dustin Jacqmin is work group chair of American Association of Physicists in Medicine. Christine Eyler received institutional research funding from National Cancer Institute (NCI)/National Institutes of Health, V Foundation, American Gastroenterological Association, and is committee member on American Board of Radiologic. Karyn Goodman serves on advisory board of RenovoRx, received travel expenses from Agenus, is steering committee co-chair of NCI. Evangelia Katsoulakis is consultant for 3D Communications and owns stocks of AbbVie, Bristol-Myers Squibb, and Pfizer. Lindsay Puckett received honoraria from OncLive (faculty honoraria-ended 10/8/2024). Jennifer Pursley is a subcommittee chair of American Association of Physicists in Medicine. Charles Simone is president and committee chair of Proton Collaborative Group, work group chair of NRG Oncology, committee chair of American Radium Society, and editor-in-chief of *Annals of Palliative Medicine*. Abhishek Solanki is councilor and executive committee member of American College of Radiology. Smith Apisarnthanarax, Samantha Dawes, John DeMarco, Dustin Jacqmin, Christine Ko Bang, Ksenija Kujundzic, Elizabeth Nichols, Mihaela Rosu, and Ping Xia reported no disclosures.

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Supplementary materials

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