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Critical Review

American Association of Physicists in Medicine Task Group 263: Standardizing Nomenclatures in Radiation Oncology

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A substantial barrier to the single- and multi-institutional aggregation of data to supporting clinical trials, practice quality improvement efforts, and development of big data analytics resource systems is the lack of standardized nomenclatures for expressing dosimetric data. To address this issue, the American Association of Physicists in Medicine (AAPM) Task Group 263 was charged with providing nomenclature guidelines and values in radiation oncology for use in clinical trials, data-pooling initiatives, population-based studies, and routine clinical care by standardizing: *(1)* structure names across image processing and treatment planning system platforms; *(2)* nomenclature for dosimetric data (eg, dose–volume histogram [DVH]-based metrics); *(3)* templates for clinical trial groups and users of an initial subset of software platforms to facilitate adoption of the standards; *(4)* formalism for nomenclature schema, which can accommodate the addition of other structures defined in the future; *(5)* a multisociety, multidisciplinary, multinational group of 57 members representing stake holders ranging from large academic centers to community clinics and vendors was assembled, including physicists, physicians, dosimetrists, and vendors; *(6)* the stakeholder groups represented in the membership included the AAPM, American Society for Radiation Oncology (ASTRO), NRG Oncology, European Society for Radiation Oncology (ESTRO), Radiation Therapy Oncology Group, Children's Oncology Group, Integrating Healthcare Enterprise in Radiation Oncology, and Digital Imaging and Communications in Medicine working group; and *(7)* a nomenclature system for target and organ at risk volumes and DVH nomenclature was developed and piloted to demonstrate viability across a range of clinics and within the framework of clinical trials. The final report was approved by

AAPM in October 2017. The approval process included review by 8 AAPM committees, with additional review by ASTRO, European Society for Radiation Oncology, and American Association of Medical Dosimetrists. This Executive Summary of the report highlights the key recommendations for clinical practice, research, and trials.

Introduction

The radiation oncology community can benefit from standardized nomenclatures applied to targets, normal tissue structures, and treatment planning concepts and metrics. Such conformity will enhance the safety and quality efforts within and between clinics for routine ongoing practice and enable data pooling for outcomes research, registries, and clinical trials. Standardization is a vital precursor to the development of scalable uses of scripting for quality assurance (QA) and treatment plan evaluation (1-3). Increased clarity and consistency through standardizing nomenclatures in these areas would provide broad benefits.

The charge of the American Association of Physicists in Medicine (AAPM) Task Group 263 (TG-263) was to provide guidelines of nomenclature in radiation oncology for use in clinical trials, data-pooling initiatives, population-based studies, and routine clinical care by standardizing the following:

1. Structure names across image processing and treatment planning system platforms.
2. Nomenclature for dosimetric data (eg, dose−volume histogram [DVH]-based metrics).
3. Templates for clinical trial groups and users of an initial subset of software platforms to facilitate adoption of the standards.
4. Formalism for nomenclature schema, which can accommodate the addition of other structures defined in the future.

Background

Much has been learned from the groups that have instituted standardized nomenclatures for structures and DVH metrics to facilitate development of outcomes databases, automated analysis of DVH metrics, and interinstitutional data exchanges. Although some standards for structures have been reported (4, 5), no single standard has been generally endorsed with multi-institutional and multivendor consensus. In addition, the standards that exist have generally not been comprehensive (eg, providing subsets but not the full set of dose−volume metrics, vendor system constraints, generalizability, or radiobiologic factors).

Data pooling

A key vision of the QUANTEC collaboration was promotion of a culture of data pooling among institutions to promote dose, volume, and outcomes research (8, 9). The QUANTEC papers highlighted the importance of standardizing which data elements are collected and how they are reported to reduce barriers to the development of shared wisdom through efficient use of combined data sets. At approximately the same time, the value of standardizations to improve QA in clinical trials was highlighted (10). The Imaging and Radiation Oncology Core group was established as part of the National Clinical Trials Network (NCTN) to perform clinical trial QA. The National Cancer Institute reorganized the clinical trials system in early 2014 by forming the NCTN to better promote large, multi-institutional trials. To promote participation of a broad range of institutions in clinical trials, it is critical to provide physicists, physicians, and other personnel with tools and methods within their clinics to efficiently support submission of high quality data to the clinical trial QA centers. The movement of professional organizations toward expectations for data sharing and similar requirements for publication in some journals has been growing stronger (11-14). Standardization is a crucial component in making shared data more accessible and usable to benefit patient care. AAPM TG-113 recommended standardizing nomenclature because it will facilitate interactions among all participants in clinical trials, ranging from the personnel at the institution performing the planning and quality steps to the QA centers and principal investigators responsible for reviewing the submitted data (15).

Facilitating communication during routine care

As part of routine patient care, establishing a common nomenclature to be used by clinics and vendors will enable an improved exchange of data for patients who visit multiple clinics (10). A common nomenclature will also improve safety by minimizing variability and ambiguity. The nomenclature is also an important enabling factor for construction of software solutions that can automate portions of the plan quality control process and improve safety (1, 16-18).

The National Patient Safety Agency and the Radiation Oncology Safety Information System (RO-SIS) reported adverse events (or incidents) in radiation therapy and stated that they were primarily due to wrong "communication of intent" (19, 20). Similarly, the Radiation Oncology −Incident Learning System, sponsored by American Society for Radiation Oncology (ASTRO) and AAPM, has identified miscommunication of the radiation therapy prescription as a problem (21). As a result, improved

communication in radiation therapy is a cornerstone of ASTRO's white paper on standardizing dose prescriptions (22). These reports have documented the deleterious effects of inaccurate or incomplete communication.

Standardizing structure names is 1 of the key factors that needs attention. Integration of standardized structure names into the Digital Imaging and Communications in Medicine (DICOM) standard or the Integrating the Healthcare Enterprise in Radiation Oncology (IHE-RO) Integration Profiles can allow for the safe transfer of information and, in turn, the automation of QA processes. For example, conformance of target names or verification of laterality designations could be built into automated QA checks.

Automatic data extraction and exchange

The use of standard nomenclature is an essential enabling step for the construction and use of tools to automatically extract pertinent data from the medical records in support of clinical trials, data-pooling initiatives, and clinical practice improvement. Even if natural language processing of free text fields might be a desirable vision for the future, a simple adoption of standards is the best choice for implementation in today's environment. The use of a common nomenclature will provide a foundation for development of common software tools to automate data extraction and analysis, data submission, data exchange, and QA.

Challenges despite some progress

The nomenclatures and ontologies relevant to structures have been developed that facilitate consistencies in communication, enhancing safety and quality for some clinical practices (1, 5) and trials (4). However, several barriers have prevented more general usage of the already proposed systems, including

- Vendor-based challenges
  - Intervendor variation on constraints for character strings used for structures, including length, special characters, and capitalization
  - Developing software using formats that are compatible with internal and common web-based data transmission formats (eg, XML, JSON, and DICOM databases and the upcoming HL7 FHIR standard) and with regular expression software tools
- Multi-institutional–based challenges
  - A lack of a clear multi-institutional oversight group to take charge of coordinating the standards
  - A lack of guidelines that extend across multiple languages even when the specific names cannot
  - A lack of a common language standard for definition of nomenclatures
  - Challenges with mapping previously used nomenclature to new standards
  - A lack of translation tables for mapping definitions from 1 language to another
  - A lack of participation in multi-institutional clinical trials
- Single institutional-based challenges
  - Incompatibility with requirements of data governance standards used at some institutions
  - Cost and effort to implement a new nomenclature
  - Compatibility with differing treatment modalities: external beam photons, electrons, particle therapy, and brachytherapy
  - Consistent use of standards by the range of staffing groups interacting with patient medical records (eg, physicians, physicists, therapists, dosimetrists)
- Clinical staff challenges
  - Inconsistent approaches to consider and/or define laterality and other structure qualifiers
  - A lack of detailed and site-specific guidelines for the definition of target structures to enable automated computer algorithms to extract relevant information
  - A lack of a schema allowing inclusion of anatomic structures and other structures (eg, buffers on organs at risk [OARs], such as spinal cord plus 5 mm, body planning target volume [PTV]) used for dose evaluation in clinical protocols
  - A lack of clear guidelines for clarifying or incorporating new elements of a standard nomenclature

TG Initiation and Membership

The AAPM formed TG-263 to develop a consensus position on nomenclature. This multi-institutional and multivendor collaboration involved physicists, physicians, and others engaged in the electronic transfer of information. The membership of this group was larger than that typical for an AAPM TG because the audience is broad. Wide representation, including members of the NRG Oncology (NRG) and other NCTN groups, was important to have the recommendations encompass a comprehensive set of viewpoints and enable wide adoption throughout the radiation oncology community.

TG-263 is composed of a diverse international group of 57 stake holders, including hospital-based physicists (n = 33) and physicians (n = 15), vendor representatives (n = 8), and dosimetrists (n = 1). The TG includes AAPM members (n = 39) and American Society for Radiation Oncology (ASTRO) members (n = 41), large academic centers (n = 16), community clinics (n = 6), vendors (n = 5), and leaders from NRG (n = 3), IHE-RO (n = 2), and the DICOM Working Group-7 (n = 2). Many TG members were also members of clinical trial groups, including the NRG, Radiation Therapy Oncology Group, Children's

Oncology Group, and Imaging and Radiation Oncology Core and had been involved in creating standardization templates within those groups. The group expanded from the original 20 members as the deliberations became more clearly defined and an enhanced perspective on particular topics was needed (eg, physician input on target naming, vendor input on technical constraints).

Initial Evaluation of Current Nomenclature Practices

The TG began its work with an initial assessment of published nomenclatures, unpublished nomenclatures used in commercially available systems, and unpublished nomenclatures at major academic centers. A survey of the initial 20 TG members collected information on nomenclature standards at their respective institutions for target and nontarget structures, DVH metrics, and dose (Gy vs cGy) and volume units (mL vs cc [cm^3]) used in naming and vendor constraints on character strings. The members were also surveyed on conventions for how overlapping structures were contoured for evaluation of DVH metrics.

The objective of the survey was not to define and embrace the most commonly used approaches. Our objective was to categorize the commonalities and variations in approaches at multiple institutions and provide examples to discuss later during the development of guiding principles and specific recommendations by the TG.

Dose and volume units

The most commonly used units to specify the dose to target structures was cGy. For example, when the dose was incorporated into naming a PTV structure that was prescribed to receive 5040 cGy, PTV5040 was more commonly selected than PTV50.4. Alternatively, the units used to specify the doses to normal tissues in DVH nomenclatures were most commonly Gy (eg, V20Gy[%] instead of V2000cGy[%]). The most frequent standard unit for reporting volume was cc (cm^3) rather than mL or ml.

Nontarget structure nomenclature

For normal structures, groups reported having nomenclatures in place for some (16 of 20) or most (12 of 20) of their disease sites. The number of structures defined by these groups ranged from 21 to 311, with only 5 reporting >100 items in their nomenclature. Several groups indicated referencing, but not strictly following, the nomenclature reported by Santanam et al (5). Yu et al (4) recently reported the nomenclatures used by the NRG as part of the Transfer of Images and Data system. Two of the nomenclatures linked specific structures to the Foundational Model of Anatomy (FMA). The FMA is an open source ontology for anatomic structures with a numeric coding scheme (23).

The respondents indicated that laterality as a prefix was used twice as often as a suffix on the root name for the structure. Selection of a prefix versus a suffix was generally based on prioritizing sorting to group structure types (eg, all optic nerve structures together, suffix) or guaranteed visibility of laterality (prefix) when the number of characters in the display was small. Most nomenclatures attempted to follow a uniform pattern, and differences are illustrated with a few examples in Table 1.

Convergence was greatest for simple structures requiring few characters (eg, heart or HEART). Variations increased as the number of characters required to represent the structure increased. Technical limitations on character strings displayed by the different vendors and local preferences for capitalization and separation of elements by spaces, underscores, or combinations of capital and lowercase characters were the main reasons for variations in nomenclature. Most groups had created nomenclatures for common structures (left lung) but had not developed a consistent naming strategy for a more comprehensive list of structures (right external iliac artery).

Nomenclature for target structures

The target structures showed wider variation in nomenclature approaches than did nontarget structures. Various combinations of prefixes and suffixes for International Commission on Radiation Units and Measurements (ICRU)−defined targets (gross tumor volume [GTV],

Table 1 Variations in standardized nomenclatures reported for nontarget structures by 16 institutions

Structure	Institutions (n)	Examples
Left optic nerve	12	Lt Optic Nerve, OPTICN_L, OPTNRV_L, optic_nrv_l, L_optic_nerve, OPTIC_NRV_L, OpticNerve_L, LOPTIC, OpticNerve_L(3), Lef Optic Nerve, ON_L
Left lung	12	Lt Lung, Lung_L(4), LUNG_L(3), lung_l, L_lung, LLUNG, L Lung
Both lungs	12	Lungs(2), LUNGs, LUNG_TOTAL, lung_total, combined_lung, LUNG, LUNGS(2), Lung, BilatLung, Lung_Both
8th Cranial nerve	7	CN_VIII(5), cn_viii(2), CN8, CN_8
Right external iliac artery	2	A_ILIAC_E_R, a_iliac_e_r

Data in parentheses indicate the number of respondents using the same value if > 1.

clinical target volume [CTV], internal target volume [ITV], PTV) and tumor bed volumes, internal gross target volumes, and internal CTVs were used to define the target location, target number, structure type, dose delivered, revision number, identity of person contouring, and so forth. Variations in capitalization and element separations were similar to those for normal structures. Thirteen institutions reported standardized nomenclatures for targets; examples of different nomenclatures are listed in Table 2.

Derived and planning structures

Derivative structures are formed from target and/or nontarget structures typically using Boolean operations (eg, intersection [x AND y], combination [x OR y], subtraction [x AND NOT y], margins [x+1.0]). Five institutions indicated that nomenclatures for derivative structures were used to define conditions for evaluating the dose distribution (eg, OAR contour excluding PTV). Variations in several structures were common (eg, body-ptv, PTV_EVAL, eval_PTV), but wide variation was noted for structures involving multiple concepts (eg, NS_Brain-PTVs, optCTV-N2R5L_MRT1_ex-3600-v12).

Institutions indicated that structures were frequently created as a tool for dose optimization instead of dose evaluation. For example, an optimization structure created from a copy of the PTV structure with a Boolean operation excluding critical OAR structures from it to reflect dose compromises in plan optimization is routinely created by multiple institutions. However, the naming conventions for such structures varied among members (eg, modPTV, opt PTV, PTV_OPT). Although clinical flow might improve with minimal constraints on the naming of dose-sculpting structures, members noted that these structures can present a safety issue if they are confused with the structures used for dose evaluation (eg, PTV, PTVHot, PTVCold, Ring, DLA). To minimize possible usage for the wrong purpose, several institutions selected a single character (eg, "z" or "_") that was uniformly applied as a prefix to those structures. This prefix ensured that in an alphabetical sort they would appear at the end or beginning of the list (eg, PTV, zPTVHot, zPTVCold, zRing, zDLA). The selection of "z" as a prefix is suggested.

Table 2 Variations in standardized nomenclatures reported for target structures by 12 institutions

Structure	Institutions (n)	Examples
PTV	13	
Dose information only	5	PTV5040
Dose plus primary or nodal volumes	2	PTVp_5040
Enumerations of target volumes (PTV1)	6	PTVp1_5040
Only enumerations of target volumes	2	PTV1
Relative dose indicators	2	PTV_high; PTV_intermediate; PTV_low
GTV	13	
Dose-based suffix	7	GTV5040, CTV_nodal_5040
Target-specifying suffixes	2	p.n.nodal, LNs, Lung

Abbreviations: CTV = clinical target volume; GTV = gross tumor volume; LNs = lymph nodes; PTV = planning target volume.

Vendor and DICOM limitations

Standardized nomenclature must be used for the widest possible range of systems in radiation oncology. This broad application requires consideration, not only of treatment planning systems and treatment management systems, but also formats used for transmission of data (eg, XML, JSON, DICOM) and standard software methods (eg, regular expression) used during automated computer extraction of data elements from character strings.

Examples of characters that are frequently incompatible with the restrictions of software systems for naming structures are listed in Table 3. Some treatment planning systems do not allow or might not be configured to use periods or might limit the number of periods in the name. Therefore, we sought to limit the nomenclature to strictly alphanumeric characters with only a few specifically allowed characters (eg, underscore, dash, caret, plus sign, equal sign, exclamation point) to be flexible across multiple platforms. Some commercially available systems do not allow capitalized characters. Although the nomenclature does make use of those characters for readability, the string identifiers need to remain unique when converted to all capital or lowercase letters to maximize utility on those restrictive systems. Vendor limits on the lengths of character strings for naming structures are a significant hurdle. Although some commercially available systems might allow storage of very long character strings for names, their displays have more restrictive constraints. This results in display of a truncated version of the full name in key areas or reports for the treatment plan. This can limit users from applying important annotations at the end of the structure and instead require that the important annotations, such as laterality, be placed at the beginning of the structure name.

Existing Standards

The TG investigated existing standardizations frequently discussed in the context of radiation oncology nomenclature. Among these are ontologies that provide a framework for defining concepts and interrelationships intended for use in machine learning applications. These are not sufficient for the needs of a clinical radiation oncology nomenclature because they do not accommodate many of the practical issues outlined in the section "Challenges Despite Some Progress." A better understanding of what

Table 3 Examples of compatible and incompatible special characters (unicode values corresponding to the universal coded character set standard UTF-8 hexadecimal values are listed)

Character	Description	Unicode
Compatible		
_	Underscore	U-005F
-	Dash or minus sign	U-002D
^	Caret	U-005E
+	Plus sign	U-002B
=	Equals sign	U-003D
!	Exclamation point	U+0021
~	Tilde	U-007E
Incompatible		
<	Less than	U+003C
>	Greater than	U+003E
:	Colon	U+003A
“	Double quote	U-0022
‘	Single quote	U+0027
/	Forward slash	U+002F
\	Backward slash	U+005C
|	Pipe	U-007C
?	Question mark	U-003F
*	Asterisk	U-002A
.	Period	U-002E
(	Left parenthesis	U+0028
)	Right parenthesis	U+0029
&	Ampersand	U+0026
#	Octothorpe	U+0023
$	Dollar sign	U+0024

these ontologies are will assist in understanding how linkage of the nomenclature to the ontologies, where possible, will improve interoperability and incorporation into the wider health care informatics community.

These and other standardized terminologies and ontologies relevant to the work of the TG can be accessed at the BioPortal web site maintained by the National Center for Biomedical Ontology (available at: http://bioportal.bioontology.org/ontologies).

Foundational model of anatomy

The FMA ontology compiles knowledge of human anatomy and is open-source, owned and maintained by the Structural Informatics Group at the University of Washington (Seattle, WA). FMA defines the anatomic structures and interrelationships necessary for a phenotypic representation of the human body. It provides extensive detail of structures; however, it has limitations for applicability as a nomenclature and comprehensive representation of radiation oncology-specific structures (eg, Bowel_Bag, SpinalCord_PRV, ICRU-based target specifications). Each structure is associated with a unique numerical identification code, the FMAID. Figure 1 provides an example of portions of the FMA class hierarchy related to the lungs (FMA identification codes [FMAIDs] not shown). In the TG's recommendation for nomenclature, the FMAID that most closely matched each item was also specified. The FMA can be accessed at the National Institutes of Health BioPortal (available at: http://bioportal.bioontology.org/ontologies/FMA) or the University of Washington (Seattle, WA) website (available at: http://xiphoid.biostr.washington.edu/fma/index.html).

Systematized Nomenclature of Medicine—Clinical Terms

The Systematized Nomenclature of Medicine—Clinical Terms (SNOMED-CT) is a standardized terminology owned and licensed by the International Health Terminology Standards Development Organization (London, UK). It provides a framework for defining health care concepts and interrelationships among them to improve usage of information across electronic records. Linkages can be very complicated and go well beyond physical anatomy. However, similar to the FMA, concepts can be incomplete for the purposes of radiation oncology, and the character strings for names are unable to meet the constraints of commercially available systems. Figure 2 illustrates a sample of a SNOMED-CT concept that relates to the lungs and lung cancer as a disease. Each concept is associated with a unique numerical code. In the TG's recommendation for nomenclature, the SNOMED-CT code that most closely matches each item was identified. A list of SNOMED-CT browsers is available online at http://ihtsdo.org/fileadmin/user_upload/doc/browsers/browsers.html and http://browser.ihtsdotools.org.

Equivalent SNOMED-CT codes were not supplied in the TG's recommendations for nomenclature. However, equivalent SNOMED-CT codes can be derived from thesauri that maintain mappings among terminologies. The US National Library of Medicine provides one such thesaurus. The Unified Medical Language System (UMLS) is available at https://www.nlm.nih.gov/research/umls/. Users can subscribe to the site at no cost to access a metathesaurus browser, which links concepts among ontologies, including SNOMED-CT and FMA. Users interested in ontologies for data sharing can find additional resources at UMLS, including the Logical Identifiers Names and Codes, and an ontology for generic and branded drugs termed “RxNorm.”

The SNOMED and FMA ontologies are important touch points for the nomenclature; however, they do not currently meet the needs addressed by the nomenclature presented in our report. The SNOMED and FMA ontologies do not meet the requirements for anatomic, nonanatomic, and target structure concepts and necessary compatibility with vended systems to enable practical clinical use. The nomenclature defined by the TG identified connections to the FMA, where applicable. We recommend the use of UMLS resources for establishing linkages between FMA and SNOMED concepts.

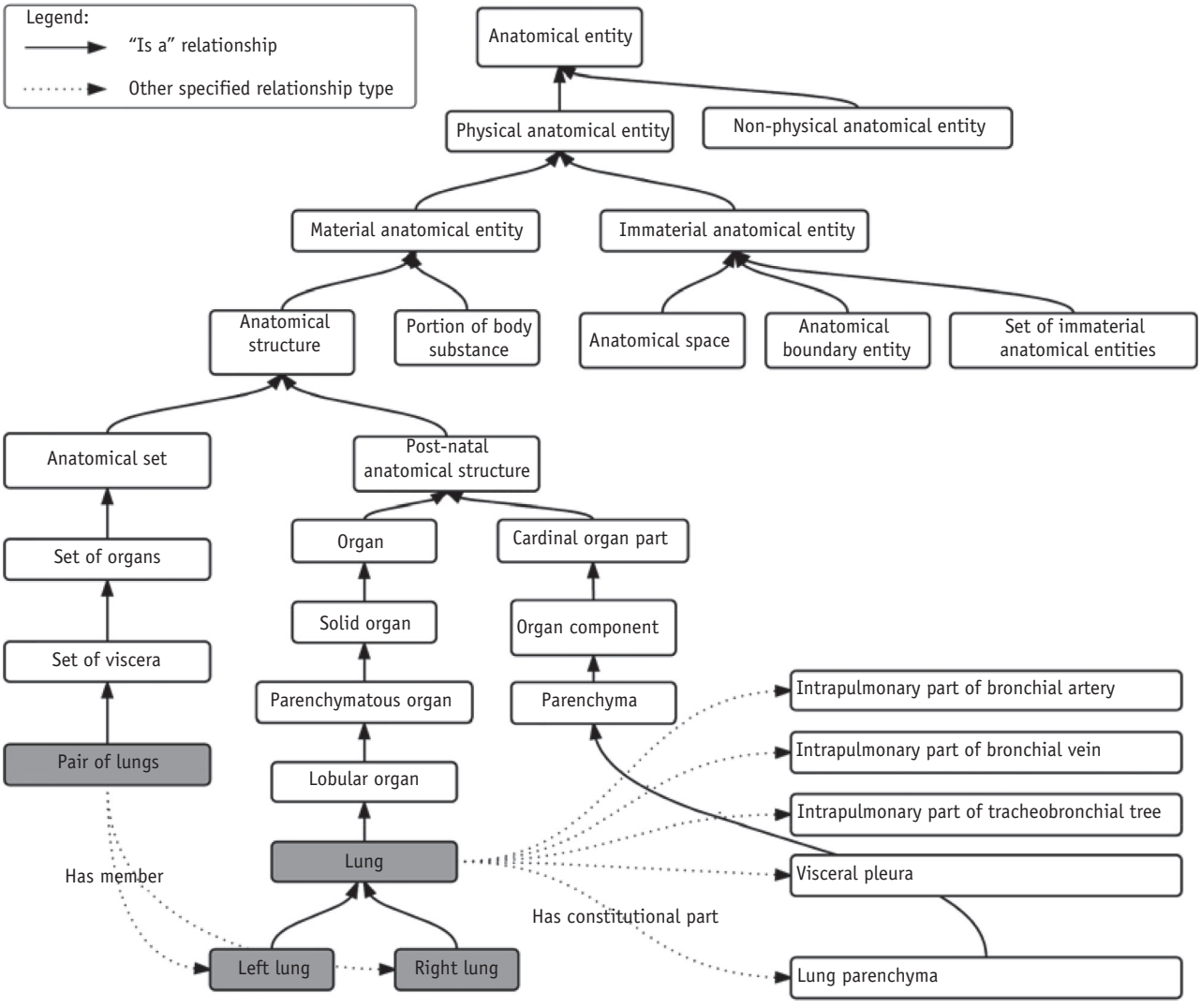

Fig. 1. Illustration of the Foundational Model of Anatomy ontology applied to lung volumes. The focus of the ontology is on defining concepts and relationships in a format consumable by programs used in machine learning. The ontology is widely used in informatics but omits some concepts used in routine clinical care and does not address practical clinical issues for target and nontarget structures addressed by the task group recommendations. For common structures, the task group nomenclature identifies the identification number of the corresponding Foundational Model of Anatomy structure.

DICOM standard

DICOM is a key technology standard in radiation oncology that enables data transfer for both clinical and research efforts. The length of structure names that can be represented by the region of interest (ROI) Name (3006,0026) attribute in the DICOM RT Structure Set information object is 64 characters. The number of characters maintained and displayed by applications is generally much fewer. Practical character limitations are not in the DICOM standard itself but, rather, in the implementation of the standard in clinical applications. The ability to track structure provenance and linkage to other concepts (eg, prescription) using ROI Names is limited. Although not yet generally implemented, code schemes and controlled terminology can be used in DICOM to identify and categorize structures. It should be mentioned that DICOM, unlike SNOMED and FMA, is not an ontology that tries to define, link, and enforce the semantics (meaning) of concepts but is a mostly syntactic standard to transfer and store information in a consistent manner.

DICOM structure interpreted types

DICOM-RT currently supports a well-defined ROI Interpreted Type (3006,00A4) attribute that adds granularity to ROI and point of interest for a given radiation treatment plan. These interpreted types can provide structured, standardized adjuvant information for a given ROI or point of interest that overcomes the shortfalls of free-text strings. An extensible set of defined terms for interpreted types is listed in Table 4.

In addition to the ROI interpreted type, the DICOM standard provides attributes that can be used to track the identity of the physician contouring (ROI Interpreter

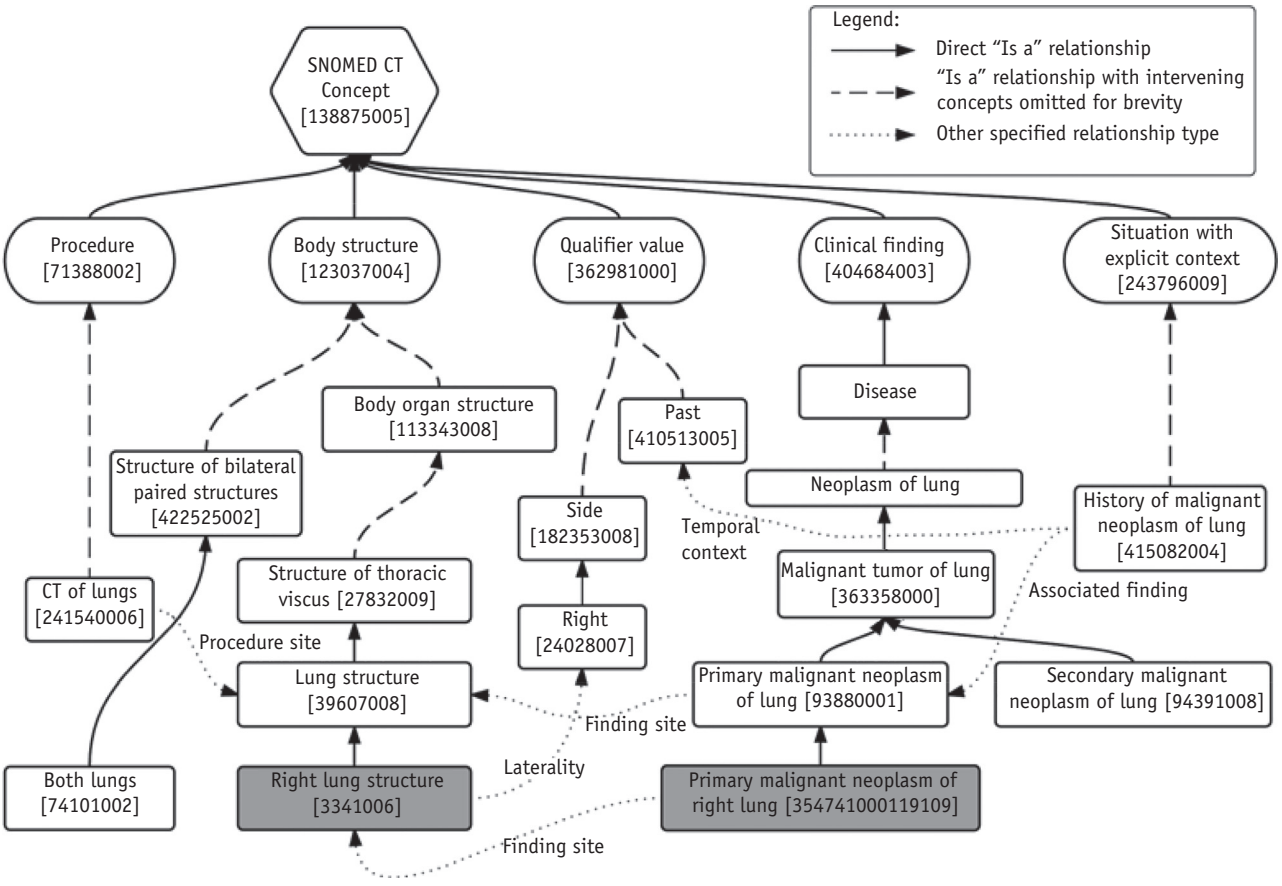

Fig. 2. Illustration of a Systematized Nomenclature of Medicine—Clinical Terms (SNOMED-CT) concepts applied to lung cancer. SNOMED-CT encompasses health care concepts beyond the purely anatomic goals of the Foundational Model of Anatomy (FMA). SNOMED is widely referenced in health care informatics. It has limitations similar to those of the FMA for direct use as a nomenclature.

[3006,00A6]) and record the reference images used for contouring such as magnetic resonance (MR) over layered on computed tomography (CT) and reference phase on 4-dimensional (4D) CT, and the image data sets used for contouring, which were coregistered to each other (ROI observation label [3006,0085]). Coordinated support for these attributes by vendors could provide important extensions to an integrated nomenclature system.

DICOM dose and imaging information specification

For all evaluated ROIs, often a specific dose of relevance exists relating to the prescribed dose and fractionation. The purpose of the ROI interpreted type in DICOM is to identify the class of an ROI, which can help to provide contextual information for the dose field. The DICOM RT Prescription IOD (Information Object Definition; part of Supplement 147, in preparation) conveys the dosimetric constraints for OARs and targets.

A reference to the images used to create ROIs is provided in the Contour Image Sequence within the RT Structure Set IOD. The Population of the Contour Image Sequence (ie, reference to the image [plane] used to create ROI contours) is required by the IHE-RO Basic RT Objects Integration Profile.

Other considerations for DICOM dose and imaging specifications

The radiation oncology community would benefit from distinct nomenclature for a wide range of attributes of structures but currently faces impractical character string representation or unworkable challenges with length constraints. Examples include details of

- Specific dose of relevance pertaining to the prescribed dose and fractionation
- Derivation of 1 structure from another, along with the associated Boolean operations and margins (eg, creation of ITV structures)
- Source image systems and considerations used in constructing the volumes (eg, combined CT and MR information for optic structures, combined used of MR, CT, and PET [positron emission tomography] to define target volumes)

Table 4 Defined terms for interpreted types from DICOM interpreted type

Interpreted Type	Term	Definition
Region of interest (ROI)	AVOIDANCE	Region in which dose is minimized
	BOLUS	Material layered onto patient to increase high dose provided by external beam therapy to patient's skin surface
	CAVITY	Patient anatomic cavity
	CONTRAST_AGENT	Volume into which a contrast agent has been injected
	CTV	Clinical target volume (as defined in ICRU 50/62)
	EXTERNAL	External patient contour
	GTV	Gross tumor volume (as defined in ICRU 50/62)
	IRRAD_VOLUME	Irradiated volume (as defined in ICRU 50/62)
	ORGAN	Patient organ
	PTV	Planning target volume (as defined in ICRU 50/62)
	REGISTRATION	Registration ROI
	TREATED_VOLUME	Treated volume (as defined in ICRU 50/62)
Point of interest (POI)	MARKER	Patient marker
	ISOCENTER	Treatment isocenter to be used for external beam therapy
Brachytherapy	BRACH_CHANNEL	Brachytherapy channel
	BRACHY_ACCESSORY	Brachytherapy accessory device
	BRACHY_SRC_APP	Brachytherapy source applicator
	BRACHY_CHNL_SHLD	Brachytherapy channel shield
Other type	SUPPORT	External patient support device
	FIXATION	External patient fixation or immobilization device
	DOSE_REGION	ROI to be used as a dose reference
	CONTROL	ROI to be used in control of dose optimization

Abbreviation: ICRU = International Commission on Radiation Units and Measurements.

- Specification of 4DCT used for treatment, including individual or averaged phases (eg, maximum intensity projection) used for delineating targets and OARs)
- Requirements defined by ICRU report 83 (p. 42) for reporting on a GTV:
    - The location and tumor extent according to TNM (GP)
    - The imaging type on which the GTV is delineated
    - The point in time (eg, during a series of RT sessions) at which the image on which the delineation was based was made

Color Specification

The TG survey investigated whether standard colors were used for structure templates and DVH curves. The selection of specific colors and display parameters (eg, filled-in, semitransparent, wire-contour) varied greatly among institutions. Standard coloration of structures at institutions facilitated plan QA and interpretation of plans for peer review and documentation. However, the standardization of the colors across institutions is not easily achievable because

1. Treatment planning and plan review systems have limited and variable color options.
2. The visibility of contours overlaid on tissues on CT images depends on the density of the contoured structure and the density of the surrounding structures. Even if the colors are appropriate for CT images, the transferred or displayed colors on a different modality might no longer be visible.
3. The visibility of contours also depends on the dose display (isodose lines or color wash). For example, different colors are needed to distinguish the 2—the target and the prescription isodose line. Note that color-blind people constitute 10% of a population. Thus, different formats (solid line vs dashed line) to improve visibility should also be considered.
4. The visual perception of reviewers differs.

The standardization of colors was seen as valuable; however, notions of the "right" color were highly variable. The TG elected not to provide specific recommendations for colors at this point because *(1)* specific color coding is not currently necessary to improve the ability to automate exchange of data among institutions; *(2)* challenges exist, as outlined above; and *(3)* uniformity is currently lacking among clinical trials for this parameter. In general, institutions can improve safety and consistency by defining and implementing simple rules for use of color to make plans more easily interpretable. However, using similar colors for isodose lines and structures when the dose abuts the structure is not recommended. As the nomenclature is adopted into clinical practice and trials, enabling sharing of standardized templates and scripts that reduce work, convergence on the expectations for color will begin to occur implicitly.

Recommendations for Nontarget Structure Nomenclature

Approach

TG-263 defined the following set of guiding principles for creating structure names. As new structures are added, following these principles will ensure names that are operable within the current vended systems and consistent in structure. This will enable the use of computer algorithms to parse names.

The primary objective in defining a nomenclature is to reduce variability in naming. Variation is the principle barrier to developing automated solutions for accurate extraction, exchange, and processing of data. Variation in naming occurs over time, between individuals and among institutions and vendors. The second objective for a nomenclature is straightforward adoption into current practice. For example, the use of just 3 hexadecimal characters would enable numeric coding of 4096 structures, leaving ample room to encode other details about the structures and also be language neutral. However, proposing that users label the brain as "06E" instead of "brain" would fail, utterly. To succeed in reducing data variability but be practical, a few situations were found for which it was necessary to sacrifice internal consistency or strict adherence to a set of ideals to define a pragmatic schema.

Guiding principles for nontarget nomenclature

1. All structure names are limited to $\leq$16 characters to ensure compatibility with most vended systems.
2. All structure names must resolve to unique values, independent of capitalization. This will ensure that systems with case-insensitive formats will not result in overlapping definitions.
3. Compound structures are identified using the plural (ie, the name ends with an "s" or "i" as appropriate to the root structure name [eg, lungs, kidneys, hippocampi, LNs (for all lymph nodes), Ribs_L]).
4. The first character of each structure category is capitalized (eg, Femur_Head, Ears_External).
5. No spaces are used.
6. An underscore character is used to separate categorizations (eg, Bowel_Bag).
7. Spatial categorizations for the primary name are always located at the end of the string following an underscore character (eg, Lung_L, Lung_LUL, Lung_RLL, OpticNrv_PRV03_L).
   a. L for left
   b. R for right
   c. A for anterior
   d. P for posterior
   e. I for inferior
   f. S for superior
   g. RUL, RLL, RML for right upper, lower, and middle lobe
   h. LUL, LLL for left upper and lower lobe
   i. NAdj for nonadjacent
   j. Dist for distal; Prox for proximal
8. A consistent root structure name is used for all substructures (eg, SeminalVes and SeminalVes_Dist have a consistent root structure name; SeminalVesicle and SemVes_Dist do not have a consistent root structure name).
9. Standard category roots are used for structures distributed throughout the body
   a. A for artery (eg, A_Aorta, A_Carotid)
   b. V for vein (eg, V_Portal, V_Pulmonary)
   c. LN for lymph node (eg, LN_Ax_L1, LN_IMN)
   d. CN for cranial nerve (eg, CN_IX_L, CN_XII_R)
   e. Glnd for glandular structure (eg, Glnd_Submand)
   f. Bone (eg, Bone_Hyoid, Bone_Pelvic)
   g. Musc for muscle (eg, Musc_Masseter, Musc_Sclmast_L)
   h. Spc for space (eg, Spc_Bowel, Spc_Retrophar_L)
   i. VB for vertebral body
   j. Sinus for sinus (eg, Sinus_Frontal, Sinus_Maxillary)
10. Planning OAR volumes (PRV) are indicated, with "PRV" following the main structure, separated by an underscore (eg, Brainstem_PRV). Optionally, the uniform expansion used to form the PRV from the main structure in millimeters is indicated with 2 numerals (eg, SpinalCord_PRV05, Brainstem_PRV03), unless the result exceeds the character limit. For example, OpticChiasm_PRV03 is 17 characters and can be truncated to OpticChiasm_PRV3.
11. Partial structures are designated by appending a tilde ("~") character to the root name (eg, Brain~, Lung~_L). This designator should be used to ensure a contoured structure is not misinterpreted as a whole organ when such a misinterpretation could have clinical implications (typically parallel organs). A use case example for a partial structure would be a CT scan not long enough to include the whole lung, for which "and Lungs~" could be used to designate the contoured pair of lungs.
12. If a custom qualifier string is to be used, it should be placed at the end after the caret ("^") character (eg, Lungs^Ex).
13. Establish a primary and a reverse order name for each structure.
   a. Primary name—reading left to right, the structure categorization proceeds from general to specific, with laterality on the end. Thus, an alphabetical sort of structure names will result in a list grouped by organ (eg, Kidney_R, Kidney_Cortex_L, Kidney_Hilum_R). The primary name is recommended as the standard choice.
   b. Reverse order name—reverse order naming reverses the order of the primary name. Some vended

systems allow longer strings but have displays that default to show <16 characters. The reverse order name increases the likelihood that sufficient information can be displayed to safely identify the correct structure. For example, R_Hilum_Kidney would display as R_Hilum_Ki if the vendor's report only showed the first 10 characters. Reverse order name should be limited to situations in which vendor system constraints prevent safe use of the primary name order.

14. Camel case (a compound word in which each word starts with a capital letter and no space is present between words such as CamelCase) is only used when a structure name implies 2 concepts but the concepts do not appear as distinct categories in common usage (eg, CaudaEquina instead of Cauda_Equina) because several examples of Cauda_xxxxx do not exist. Camel case names for primary and reverse order names are identical.
15. Structures that are not used for dose evaluation (eg, optimization structures, high- and low-dose regions) should be prefixed with a "z" or underscore ("_") character such that an alphabetical sort will group them away from structures used for dose evaluation (eg, zPTVopt). The selection of "z" to designate dose evaluation structures is suggested.

Very few vendor systems do not allow capital letters in the fields identifying structures. Because the vast majority do allow or require it, capitalization was used as part of the guiding principles (item 4). Item 2 ensures that if a system does not allow capitalization, the character string will still be unique and can be programmatically matched.

Potential conflicts exists for the use of "A" in indicating an arterial structure and for use in indicating an anterior portion of a structure (eg, A_Carotid_A) were noted and discussed. In practice, the need to identify an anterior surface is rare. For example, NRG currently does not use this descriptor in any of its trials. Alternative spatial designators either presented similar issues (eg, "D" for dorsal and "V" for ventral) or violated standard medical practice (eg, "F" for front and "B" for back). The use of alternative indicators for artery and vein were also discussed. The use of "A" and "V" to indicate artery and vein is in wide use, and no single character alternatives were evident. Because no examples existed with this potential conflict, the group elected to accept the potential conflict for the current version of the guidelines.

Permitting the use of camel case for a few specific structures was discussed. In primary name values, concepts are ordered from general to specific, proceeding from left to right. Reverse order name values inverts the ordering (eg, Bag_Bowel for primary name and Bowel_Bag for reverse order name). The usage of camel case would provide a method to not violate this principle and maintain compatibility with common usage for the relatively small number of structures involved (eg, CaudaEquina and OpticChiasm are rendered the same for both primary name and reverse order name systems). The potential safety effect of this usage of camel case was considered. No major risks were identified, and the TG believed that ensuring the same value for both name values for those few special cases would support patient safety.

Whether to allow for 2 naming values for each structure was considered from a practical perspective. The recommended standard is the primary name. Vendors are encouraged to modify their systems such that the full 16-character length of standard structure names are displayed in applications and reports. Reverse order name values should only be used for those systems unable to support the primary name values until further changes have been made in those systems. As these changes are made and the safety risks introduced by concatenating names are eliminated, usage should converge on the primary name.

In evaluating treatment plan dose distributions, tolerance levels are determined by the tissue or organ type. Using standard category root names, an alphabetic sort of the primary name structures will group those with similar tolerances. This is especially valuable when structure names might not be commonly used and could be at risk of misinterpreting the structure type (eg, Mesenteric vs A_Mesenteric, Illiac vs A_Illiac, or I vs CN_I). However, a few structures are in routine use for which forcing the use of the category root name could impede adoption (eg, Parotid vs Glnd_Parotid) of the nomenclature. In those few cases, the TG chose to accept the internal inconsistency of forgoing the root name (eg, Parotid) to maintain the overarching objectives of reducing variability in nomenclature and promoting high adoptability into clinical practice.

Structure nomenclature list

A spreadsheet was created to facilitate the search for structures. The structures were categorized, described, assigned official values, and linked to the corresponding FMAID. Currently, the nomenclature defines 713 structures. The complete list can be found at the AAPM website for TG-263 (available at: http://www.aapm.org/org/committees/committee/preview.asp?id=9768).

The list will be a living document with periodic updates. In addition, all guidelines for structure naming and for DVH metrics are included in the document.

The spreadsheet has 9 column headings used to aid in finding the names of the structures of interest.

1. Target type: anatomic, nonanatomic (eg, catheter), derived (eg, Body-PTV)
2. Major category: general organ category
3. Minor category: additional distinguishing category
4. Anatomic group: region of the body where the structure is located
5. "N" characters: number of characters in the name
6. TG-263—primary name: preferred naming system

7. TG-263—reverse order name: alternative naming system
8. Description: additional description of the structure
9. FMAID: identification number of the structure in the FMA most closely related

By clicking on the arrow to the right of each column heading (Fig. 3), a set of sorting and filtering options is presented. For example, structures that typically appear in the head and neck can be found by unchecking all but the "Head and Neck" item in the anatomic group heading.

Recommendations for Target Structure Nomenclature

Approach

Surveys of member responses for target naming strategies revealed that clinics use a very complex set of concepts: ICRU and other types, target classifiers for primary and nodal volumes, enumeration of volumes when several structures are present, dose, basis structures, imaging modality used to create, and so forth.

Clinics did not attempt to represent all concepts but selected those few most important to their process. Within an individual clinic, different naming strategies could be used for different treatment sites and/or physicians.

TG-263 determined that they could not come to a consensus to define a single standard for all use cases and clinics that spanned the numerous concepts for a target name and also met the character string constraints. However, TG-263 did establish a set of guiding principles to specify that if a concept is represented in the target name, where and how it should appear. Therefore, the TG-263 established a set of guiding principles for target nomenclature.

This approach enables construction of computer algorithms to parse the names and to automatically create names based on concepts selected by users. Users choose the supplemental information to incorporate into target names, and these guiding principles will ensure that computer programs can recognize these names for quality and research endeavors. Although these principles accommodate most encountered names, they cannot accommodate all. TG-263 recommends using the caret ("^") character to designate supplemental information not incorporated in the current guidelines.

Guiding principles for target nomenclature

1. The first set of characters must be 1 of the allowed target types:
   - GTV
   - CTV
   - ITV
   - IGTV (internal gross target volume—gross disease with margin for motion)
   - ICTV (internal clinical target volume—clinical disease with margin for motion)
   - PTV
   - PTV!—for low-dose PTVs that exclude overlapping high-dose volumes (see the section "Recommendations for Distinguishing Metrics of Segmented vs Nonsegmented Target Structures")
2. If a target classifier is used, place the target classifier after the target type with no spaces. Allowed target classifiers are as follows:
   - n: nodal (eg, PTVn)
   - p: primary (eg, GTVp)
   - sb: surgical bed (eg, CTVsb)
   - par: parenchyma (eg, GTVpar)
   - v: venous thrombosis (eg, CTVv)
   - vas: vascular (eg, CTVvas)
3. If multiple spatially distinct targets are indicated, Arabic numerals are used after the target type plus classifier (eg, PTV1, PTV2, GTVp1, GTVp2).
4. If designation of the imaging modality and sequential order in the image set require recording for adaptive therapy, the nomenclature follows the type/classifier/enumerator with an underscore and then the image modality type (CT, PT [positron emission tomography], MR, SP [XXX]) and number of the image in the sequence (eg, PTVp1_CT1PT1, GTV_CT2).
5. If structure indicators are used, they follow the type/classifier/enumerator/imaging with an underscore prefix and are the values from the approved structure nomenclature list (eg, CTV_A_Aorta, CTV_A_Celiac, GTV_Preop, PTV_Boost, PTV_Eval, PTV_MR2_Prostate).
6. If dose is indicated, the dose is placed at the end of the target string, prefixed with an underscore character.
   - The TG strongly recommends using relative dose levels instead of specifying the physical dose
     - High (eg, PTV_High, CTV_High, GTV_High)
     - Low (eg, PTV_Low, CTV_Low, GTV_Low)
     - Mid (eg, PTV_Mid, CTV_Mid, GTV_Mid)
     - Mid plus 2-digit enumerator: allows specification of >3 relative dose levels (eg, PTV_Low, PTV_Mid01, PTV_Mid02, PTV_Mid03, PTV_High); lower numbers correspond to lower dose values
   - If numeric values for the physical dose must be used, specification of the numeric value of the dose in units of cGy is strongly recommended (eg, PTV_5040).
   - If numeric values for the physical dose must be used and these must be specified in units of Gy, "Gy" should be appended to the numeric value of the dose (eg, PTV_50.4Gy). For systems that do not allow the use of a period, the "p" character should be substituted (eg, PTV_50p4Gy).
7. If the dose indicated must reflect the number of fractions used to reach the total dose, the numeric values of the dose per fraction in cGy, or in Gy with the unit specifier, and number of fractions separated by an "x" character

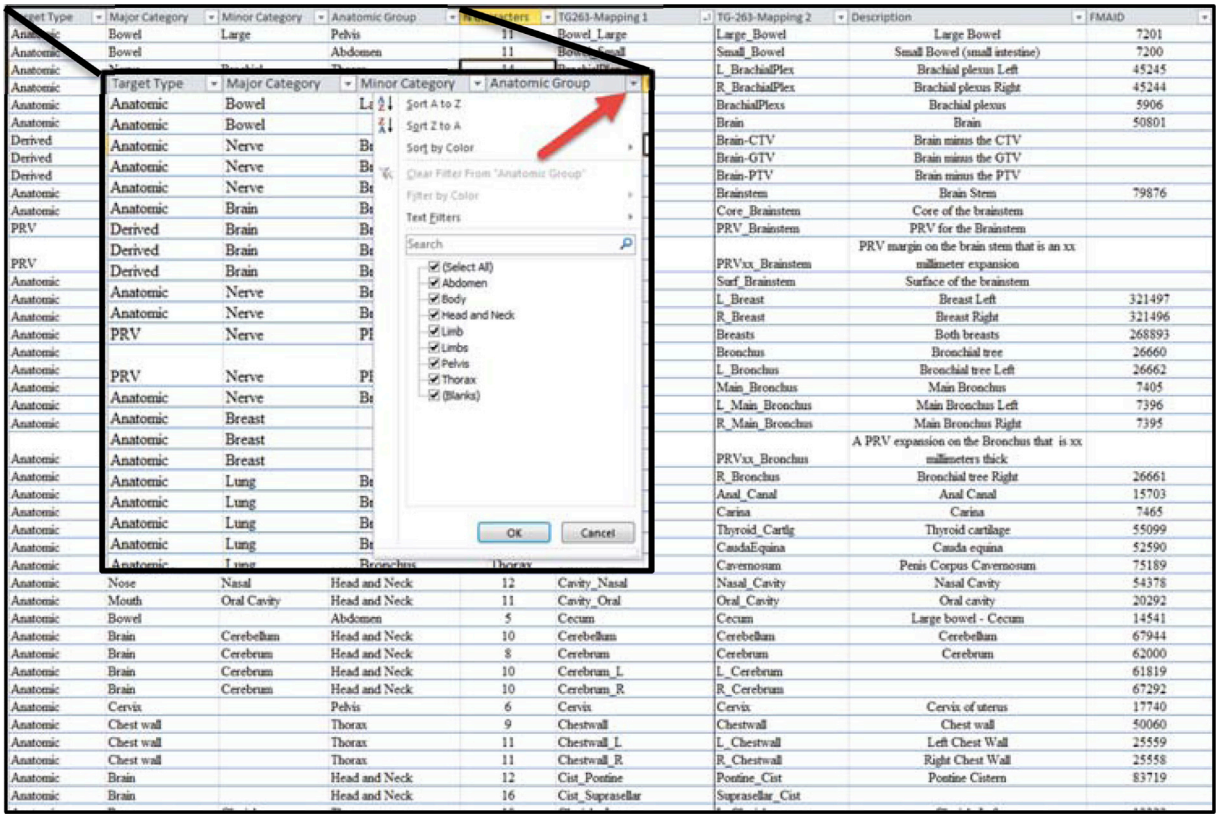

Fig. 3. Illustration of a section of the nomenclature list worksheet for nontarget structures. Each column allows for sorting and searching by clicking on the down arrow to the right of the heading, as shown in the zoomed region.

are added at the end (eg, PTV_Liver_2000x3 or PTV_Liver_20Gyx3).

8. If the structure is cropped back from the external contour for the patient, the quantity of cropping by "-xx" millimeters is placed at the end of the target string. The cropping length follows the dose indicator, with the amount of cropping indicated by xx millimeters (eg, PTV_Eval_7000-08, PTV-03, CTVp2-05).
9. If a custom qualifier string is used, the custom qualifier is placed at the end after a caret ("^") character (eg, PTVPhysician1, GTV_Liver^ICG).
10. If it is not possible to follow the guidelines and remain within the 16-character limit, preserve the relative ordering but remove the underscore characters, progressing from left to right as needed to meet the limit (eg, PTVLiverR_2000x3). However, this last resort scenario will undermine the use of automated tools.

Two distinct methods are used for sequential treatment of the same target volume (guiding principle 3). Some institutions used sequential numbers as the patient returns for future treatment courses for the same PTV (eg, PTV1 and PTV2 for the original course and PTV3 and PTV4 for lung metastasis treated in a later course). In contrast, other institutions have numbered sequentially for targets treated within the course, independently of historical treatment sessions (eg, PTV1 and PTV2 for the original course and PTV1 and PTV2 for lung metastasis treated in a later course) and used the same nomenclature for repeat irradiation of the same (not spatially distinct) target. TG-263 did not define a recommended sequential numbering method. Practices should ensure their method is self-consistent and guards against the incorrect summing of total doses.

The dose units used when categorizing target structures with dose information was extensively discussed. As stated, the primary objective for a nomenclature is to reduce variability. The secondary objective is to facilitate adaptability into clinical practice. The prescription of doses in units of cGy is common in the United States, is the current recommendation of the ASTRO working group on prescriptions, and is supported by analysis of Radiation Oncology Incident Learning System (RO-ILS) data (21). Prescription in units of Gy is more common in European countries and is also used in some large institutions in the United States. All groups advocating one over the other have cited safety as a primary factor. Although it is highly desirable to specify a single answer in the standard, the most important point for safety and data access is ensuring unambiguous communication. Because it was not possible to identify a single dose unit with wide global adoption, an approach compatible with each was identified.

The use of a relative dose (eg, PTV_High) was the primary recommendation if dose information is conveyed in the target name. This approach has several advantages.

First, it is independent of the physical dose units used at various institutions, eliminating the need to specify cGy (eg, PTV_6660) or Gy (eg, PTV_66.6Gy). Second, it is not uncommon for a prescription to be changed in the course of treating a patient. In that case, if physical dose units were used, the structure name would have to be renamed with the correct dose to convey the correct information (eg, a change from PTV_7560 to PTV_7380). Without this change, the name could convey conflicting information with respect to the current prescription, presenting both logistic and safety issues. Third, when mining dosimetric data, relative dose names greatly improve the speed, accuracy, and composability of queries to extract the needed information. For most disease sites, only 2 or 3 target structure names are needed (eg, PTV_High, PTV_Mid, PTV_Low); thus, extracting the median dose to these structures and number of fractions treated will provide a large amount of information on target structure doses with minimal effort. In contrast, needing to first identify all dose levels from the structure name and then reconstruct the relative dose levels within each plan from the physical doses specified in the name is much more difficult and prone to error.

If physical doses are used, the numeric value should be defined in units of cGy. The use of cGy is consistent with the recommendations from ASTRO and RO-ILS. Enabling unambiguous standardized communication of dose in the name promotes adaptability of the nomenclature in a broad range of national and international clinics. For clinics that currently use Gy for prescriptions, the physical doses in Gy should be communicated explicitly with the addition of "Gy" as a suffix for clarity in communication. This approach uses a similar number of characters for each dose unit, and, when Gy is used, it is consistent with the recommendations for DVH metrics, as described in the next section.

Recommendations for DVH Metrics

Approach

Very few examples of standardized nomenclatures exist for the full set of dose and volume metrics used in practice. Providing specificity on exactly what is measured, input parameters, units used for dose and volume, all in a format that can be parsed with regular expression operators, improves ability to use computer algorithms to automate calculation. The ability to incorporate radiobiologic metrics and units is also important. Figure 4 illustrates the recommended DVH nomenclature.

Guidelines for DVH metrics

- Units or a label for what is measured (output) are specified at the end of the string, enclosed in square brackets.
  - Dose: Gy or % where the percentage references the dose prescribed to PTV_High structure type
  - Volume: cc (cm^3) or % where the percentage references the volume of the structure
  - Equivalent 2 Gy: EQD2Gy
- Measurement type is specified at the beginning of the string. Units or a label for where on the curve the point is measured (input) are specified.
  - Vx: volume of the subvolume receiving dose x or greater, with the Dose units or label specified (eg, V20Gy[%], V95%[%], V20Gy[cc])
  - Dx: minimum dose received by the hottest subvolume x, with volume units or label specified (eg, D0.1cc[Gy], D95%[%])
  - CVx: volume of the subvolume receiving dose x or less, with dose units or label specified (eg, CV10.5Gy[cc], CV95%[cc])
  - DCx: maximum dose received by the coolest subvolume x, with volume units or label specified (eg, DC0.1cc[Gy], DC1%[Gy])
- If calculation parameters for the metric are required, they are enclosed in parentheses in front of the square brackets defining the output units or label (eg, V50EQD2Gy(2.5)[%]).

Conventional DVH metrics correspond to points receiving a certain dose or more. In the lung, V20Gy[%] is the percentage of the lung volume that receives $\geq$20 Gy. In contrast, details about the points receiving a certain dose or less use nomenclature with an inserted "C" for "complement" or "cold" to qualify the subvolume (1). Thus, for liver SBRT (stereotactic body radiation therapy), CV15Gy[cc] is the absolute volume that receives $\leq$15 Gy. For example, DC700cc[Gy] selects the 700cc subvolume that receives the lowest overall dose and reports the highest dose in that subvolume.

TG-263 discussed and acknowledged the differences in recommendation for the use of cGy dose units in defining target structure names (eg, PTV_4500) compared with the recommendation for the use of Gy for DVH metrics (eg, V20Gy[%] vs V2000cGy[%]). The nomenclature recommendations were in keeping with routine clinical practice for many clinics and represented minimal deviation from the less specific values commonly encountered in the reported data (eg, V20 vs V20Gy[%]). Furthermore, although the safety of minimizing the risk of miscommunication about target volumes and allowing for free text characters in vended systems was significant in the discussion of target structures (eg, PTV_5040 vs PTV_50.4), these safety issues were not found for the DVH metrics.

The nomenclature extends the use specification of input and output units with the addition of the EQD2Gy dose unit to specify the dose delivered in 2-Gy fractions calculated to have the same radiobiologic effect with the linear quadratic (LQ) model and a specified α/β value. The calculation parameter values, including α/β, are enclosed in parentheses before the output units. The nomenclature does not currently specify the ordering of parameter values for particular calculations. This approach minimizes the

naming constraints for the evolving types of radiobiologic calculations, or parameters used, preserving a consistent representation of the involved units and explicit indication parameter values. Designation of an algorithm could also be included as a parameter in the parentheses.

Examples of radiobiologic calculations using EQD2Gy follow:

- Maximum equivalent 2-Gy dose calculated with an α/β ratio of 4: Max(4)[EQD2Gy]
- Equivalent 2-Gy dose encompassing 90% of a target volume, calculated with an α/β ratio of 10: D90% (10)[EQD2Gy]
- Percentage of volume of a structure receiving 50 EQD2Gy using an α/β of 3 versus 10: V50EQD2Gy(3)[%] versus V50EQD2Gy(10)[%]
- Distinguishing the use of the LQ versus the LQ-linear (LQL) model in calculating the 2-Gy equivalent dose encompassing 95% of a structure when an α/β of 10 is used: D95%(10,LQ)[EQD2Gy] versus D95%(10,LQL)[EQD2Gy]

Research settings use a wide range of radiobiologic metrics. Examples include tumor control probability, normal tissue complication probability (NTCP), and biologically effective dose (BED). These are not typically encountered in clinical settings at present. Models continue to evolve, defining new types and parameters. Approaches currently in use at several member institutions were compatible with the guideline recommendations for enclosing calculation parameters in parentheses [eg, NTCP(LQL, $\alpha/\beta = 2.5$, TD50 = 40, n = 1.0, m = 0.13), NTCP(40, 1.0, 0.13), BED($\alpha/\beta = 10$), BED(10)]. The TG did not make specific nomenclature recommendations for these radiobiologic metric types and parameters.

Recommendations for Distinguishing Metrics of Segmented Versus Nonsegmented Target Structures

The reported DVH metrics for multiple PTVs treated to differing dose levels should define whether the lower dose PTVs exclude (segmented) or include (nonsegmented) the higher dose PTVs. For example, a low-dose nodal volume could be treated to 5000 cGy (PTV_5000) and a boost volume within that nodal volume could be treated to 7000 cGy (PTV_7000). The following discussion does not apply to structures created to achieve conformal dose distributions during intensity modulated radiation therapy/volumetric modulated arc therapy optimization.

Both segmented and nonsegmented volumes can be valuable for dose evaluation. The concern is that the clinical PTVs used to evaluate the plan might not be clearly delineated as segmented or nonsegmented PTVs in the

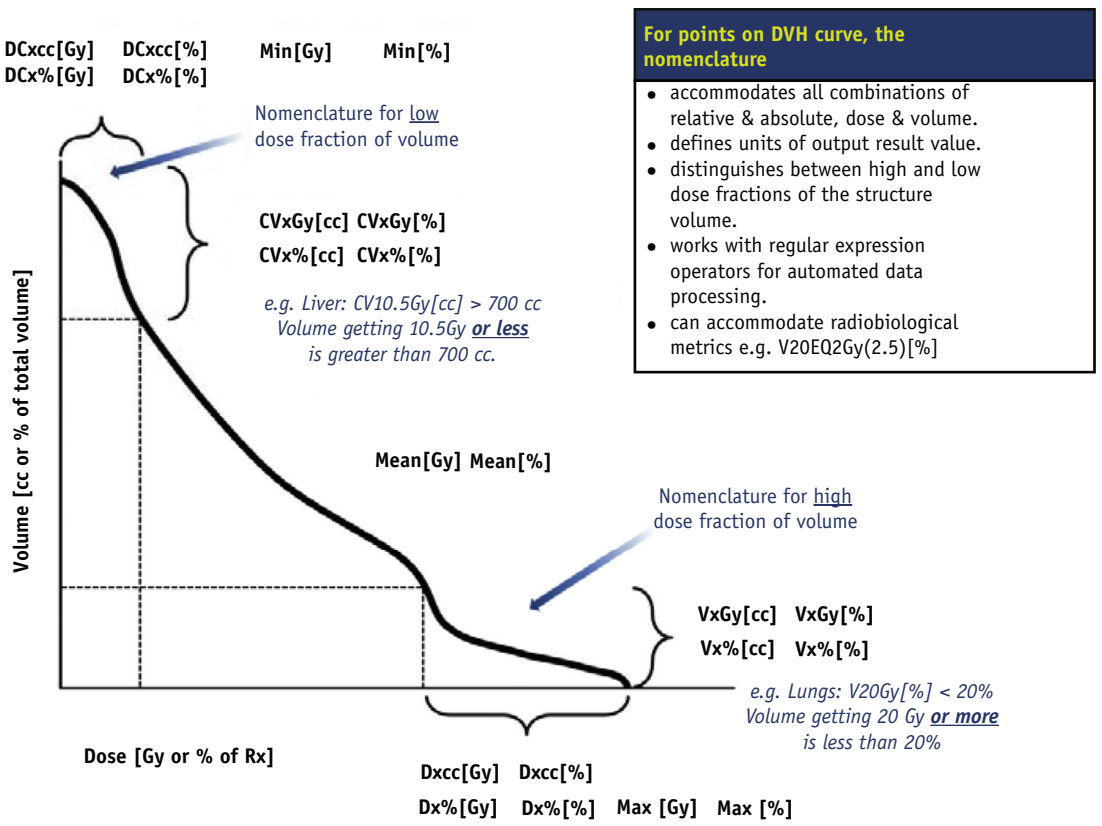

Fig. 4. Illustration of standardized dose–volume histogram (DVH) nomenclature specifying input and output units. The approach is compatible with the use of regular expressions.

nomenclature. This is illustrated in Figure 5. For nonsegmented low-dose PTVs, the DVH typically shows a "foot" of the overlap with the high-dose PTV. Segmented low-dose PTVs have a long high-dose tail. The nomenclature needs to clearly delineate between segmented and nonsegmented PTVs for pooling data. Either approach can work; however, if the standards vary among institutions, metrics such as PTV_5000: V115%[%] would be significantly different depending on the approach. For example, if the PTV_5000 is not segmented and contains PTV_7000, V115%[%] would necessarily be high, reflecting the ratio of the volumes. In contrast, for a segmented PTV_5000, the V115%[%] would be significantly lower.

Because nonsegmented PTVs retain information on overlaps relevant to dose evaluation but segmented PTVs do not, many institutions typically use nonsegmented volumes. To retain the ability to use both approaches, TG-263 recommended that the default assumption is nonsegmented target volumes. If a segmented volume is used (ie, exclusion of overlap with high-dose subvolumes), its target type should include an exclamation point ("!") character suffix to clarify (eg, GTV!, CTV!, PTV!). This should be exceedingly rare for GTV and CTV structures.

Recommendations to Vendors

Vendors have a critical role in facilitating safe and effective care of patients receiving radiation therapy. This role includes provision of platforms that allow for implementation of widely accepted nomenclature standards such as AAPM TG-263. The full range of information clinicians would like to convey about the structures used in plans exceeds the limited capabilities of a character string with the current identifiers. These limitations apply to a wide range of vended system categories (eg, treatment planning systems, record and verify systems, reporting systems, treatment machine consoles, QA devices). The deliberations of the TG considered 2 overall objectives: *(1)* a nomenclature that could be widely adopted in the vended systems as they currently exist; and *(2)* new definitions of data element representations for encapsulating a fuller representation of the data.

One important consideration for a standardized nomenclature is the adoptive ability across all available platforms. Currently, DICOM-RT is the standard for data communication across the radiation therapy process. Therefore, TG-263 recognizes that an updated nomenclature cannot exceed or violate any data limits imposed by DICOM. Some considerations could include the number of characters to define the ROI name string and the use of special characters (see the section "Vendor and DICOM Limitations"). In some cases, a planning system has stricter requirements than DICOM because of the effect of special characters on a vendor-specific database, data structure, user interface, or formatting of custom reports.

Two desirable features of a nomenclature system are

- The defined structure is human-readable.
- Sufficient information is available to avoid ambiguity between similar items in the system.

However, human readability must be resolved with the intent for the nomenclature to be logical from a data analysis standpoint, readily processed or deconstructed for analysis, and integrated with automated systems.

TG-263 summarizes the main challenges of designing a system:

- The information on structure identification, relationships to imaging modalities as use of adaptive therapy increases, motion assessments, and so forth currently exceed the capability of a single character string to encapsulate all parameters in a clinically usable fashion. Thus, the capabilities of vended systems need to be expanded to capture a wider set of properties to characterize structures and display the information.
- Clinical implementation of a standard nomenclature is hindered by the existing free-text naming of structures in most commercial systems.
- Multiple versions of the same anatomic structure for a specific patient can create a challenge. This scenario primarily occurs when multiple image sets define the same structure on each image set, representing the same anatomic entity (eg, image sets at different time points).
- Structure contour delineation on image sets is an important tool for treatment planning, appropriate treatment delivery, and adjustment of treatment plans. Contours define critical regions and target volumes for redefining and adapting our treatment plans. They are also used for tracking changes, assessing the meaning of the images within the regions, and determining the prognostic indications from multiple image modalities. Thus, accurate documentation of the intent and provenance of structures and their associated image sets with easy retrieval is a necessity.
- The system should be as intuitive and efficient as possible to maximize adoption by its clients and enhance comparative research analysis.
- Often, no option is available to add formal semantics or codes (eg, an FMAID) to a structure. Vendors should implement the use of DICOM coding attributes to identify and categorize structures.

The TG-263 nomenclature recommendations can be implemented using current vended systems and can improve the current situation. However, vendors need to develop or update their systems to capture a wider set of properties for characterizing structures and displaying the information. The following are general recommendations for vended system developments:

1. The user interface should incorporate tools to facilitate the inclusion of standard nomenclature and sufficient space for adding newly delineated ad hoc structures of interest. The tools for the standard nomenclature could

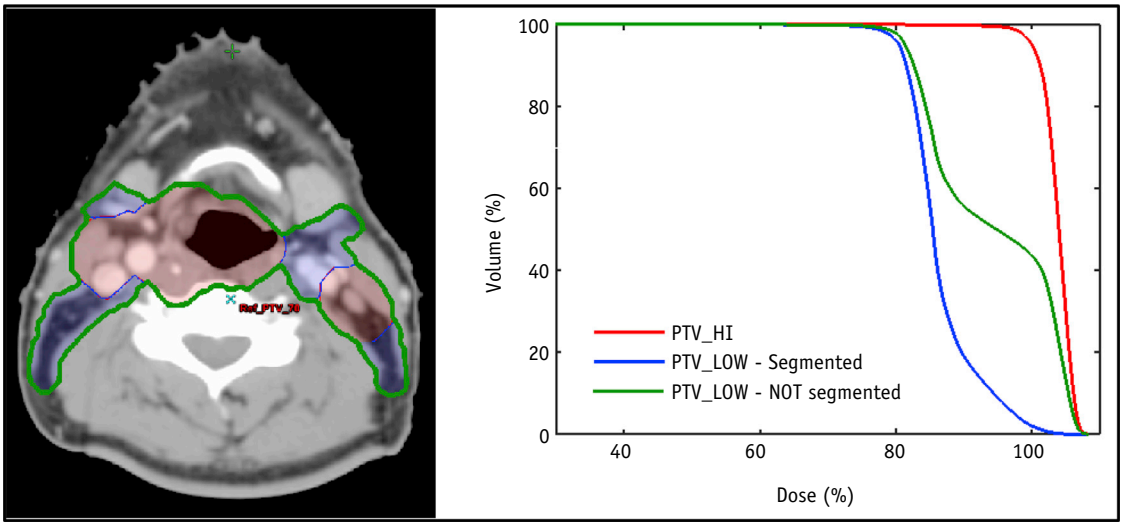

Fig. 5. Illustration of the dose–volume histogram (DVH) differences when using segmented planning target volume (PTV) definitions such that the high-dose PTV (PTV_High; red curve) is not included as part of a lower dose PTV (PTV_Low; blue curve) versus a nonsegmented approach, in which the high-dose PTV is included in the lower dose PTV (PTV_Low; green curve). In this example, the volume of PTV_High is 55% of the volume of the nonsegmented PTV_Low volume. (A color version of this figure is available at www.redjournal.org.)

range from suggestive auto-text to direct specification through selection lists of available names.

2. Systems should provide system administrators with latitude to restrict nomenclature choices to comply with external standards (eg, TG-263) and local standards as they evolve and as clinics are ready to implement them.
3. A wide range of attributes for structures are relevant for both research and clinical purposes. The system should allow standardization of attribute identifiers and capture of values to augment the single string name, including
   a. Versions
   b. Linkage of target structure volumes to prescription elements (dose and fractionation)
   c. Relationship of structures among data sets (eg, PTV_1 corresponds to the same target region in the structure set used for the first course and for a subsequent recurrence)
   d. Identification of the individual who created the structure
   e. Full or partial volume (eg, rectum near PTV vs full rectum)
   f. Image data set (including phase on 4DCT) used to create the structure (eg, created on registered MR scan and copied to a CT scan for planning)
   g. Motion status (eg, ITV created from 4DCT)
   h. Linkages to standardized codes (eg, diagnosis code [International Classification of Disease (ICD), 9th or 10th revision], oncology code [ICD-O], anatomic concept code [FMA])
   i. Dose tag (eg, name structure PTV_High and define dose tag = 7000 cGy)
   j. Margins used to create the structure
   k. Image modality characteristics
   l. Visualization characteristics (eg, window and level)
   m. Factors and operations used to define derived structures (eg, structure C is Boolean OR of structure A and structure B)
4. Systems should allow definition and linkage of multiple structures but maintain a requirement that only 1 structure can be definitive per image set. For example, an anatomic entity can be identified in multiple longitudinal image sets that track changes in volume or shape over time. Second, 1 structure is defined on multimodality image sets that link the image features such as PET affinity to density and perfusion to better characterize the anatomy and physiology comprehensively.
5. Systems should be designed to significantly improve the management of image segmentation for the multitude of uses in radiation therapy. For example, systems should preserve changes to contours over time, maintain flexibility to compare with different imaging modalities, and allow for links between image sets for a given patient over time. Such functionality will add value as multiple plans and imaging data sets are used with each patient, such as with adaptive radiation therapy.
6. Systems should be designed to allow for definition of algorithms or scripts to define the names of target structures to reflect the TG recommendations for target structures.
7. Systems should enable writable scripting that would enable the creation of plans and structures adhering to standardizations to improve consistency, safety, and interoperability for data sharing. Writeable scripts enable end users to create and share programs that design, edit, and optimize treatment plans consistent with standards

as they are introduced. For example, it should be easy to import and export and use tables that incorporate the desired nomenclature, attributes, and/or identifiers in the creation of treatment plans.
8. Investigation of the use of natural language processing mapping free-text input values to standard nomenclature values would improving the ease of use for end users.
9. Systems should match DICOM standards in determining the allowed characters and allowed storage and display string lengths. The current compromise of 16 characters for structure names is far shorter than the current DICOM standard of 64 characters.

Figure 6 shows an example of a general target structure concept with related attributes and associations between related structures. A conventionally fractionated right lung primary is the use case. Note that multiple attributes such as anatomic location, disease code, and dose tags are attached, along with the associated structures (ie, GTV, PTV) and their linking properties (eg, deformable transfer, margins, data set of origin) are also included in the potential design.

Implementing many of the naming concepts we have described will require significant effort by vendors. Furthermore, some concepts require development of standards that either do not exist or are not yet mature. However, implementing structure naming controls in treatment planning systems should require minimal changes to the software architecture.

A number of treatment planning systems have scripting capability. It is important that scripting allows for both read and write capabilities to allow users to build automated tools to reduce effort and improve QA of compliance with standardizations. In the near term, user groups can support nomenclature standardization through the development of validation scripts. These efforts will further support data integrity in clinical trials as described in AAPM TG-113 (15).

A standard format for communicating the set of structure names to be used for a clinical trial or clinical scenario is currently in development (DICOM Supplement 196). Broad implementation of this specification to create and distribute templates for structure identification in commercial image segmentation and treatment planning systems is expected to improve the consistency of structure names and provide a method to distribute codes for structure identification and categorization. Manufacturers are encouraged to support implementation of this standard as it becomes available.

TG-263 recommends that vendors place a priority on the development of systems that enable users to enforce compliance with specific nomenclatures (eg, TG-263 guidelines) and that the systems allow the nomenclature rules to be configured by the individual sites. The guidelines of TG-263 promote goals for safety, clinical efficiency, clinical trials, and usage of big data resource systems that are of common interest to users, vendors, and funding agencies to support advances in patient care. The group recommends that vended systems be made to follow the TG-263 guidelines within a 2-year period.

Nomenclature Pilot Study Design and Results

Pilot study design

Change is hard. Implementing the new standards in the clinic requires addressing learning curves and implications for existing documentation, additional work for staff, process changes, and so forth. It is important to know that new recommendations can be successfully implemented in clinical settings.

Before finalizing the recommendations, the preliminary nomenclature was piloted by a group of 5 institutions for head and neck patients. The pilot study was used to identify any hindrances to implementation, such as an overlooked anatomic site. Members also reported the ease or difficulty of adopting the nomenclature to allow improvements to be made before widespread adoption of the standards. The groups were asked to conform to the recommendations for nontarget structures and explore their willingness to adopt the guidelines for targets.

As a part of the pilot implementation, several institutions piloting the nomenclature developed scripts and xml files to facilitate adoption of the nomenclature.

Pilot study results

Five groups—NRG (Philadelphia, PA), MD Anderson Cancer Center (Houston, TX), University of Florida (Jacksonville, FL), Karmanos Cancer Center (Detroit, MI), and the University of Michigan (Ann Arbor, MI)—participated in the pilot study. A sixth group—Princess Margaret Cancer Centre (Toronto, Ontario, Canada)—piloted the nomenclature for breast patients. Several of the piloting institutions had conducted internal reviews of the naming variability in their current systems. The ability to converge on a single system that eliminated the variability and improved the data exchange with the NRG and other institutions was generally found to be more compelling than local preferences for naming syntax.

The pilot groups reported little difficulty in implementing the nomenclature. For example, although the pilot was targeted for a subgroup of patients with head and neck cancer, several of the institutions phased in adoption of the entire nomenclature for all disease sites. The nomenclature was readily adopted into the NRG standards as new trials were added. A common approach for easing the transition was the use of structure templates or scripting capabilities built into treatment planning systems to enable prepopulating the lists of structures seen by physicians and dosimetrists. Scripts that automated creation of plans and the naming of structures made using the standardized answer the easy choice. Three groups adopted the

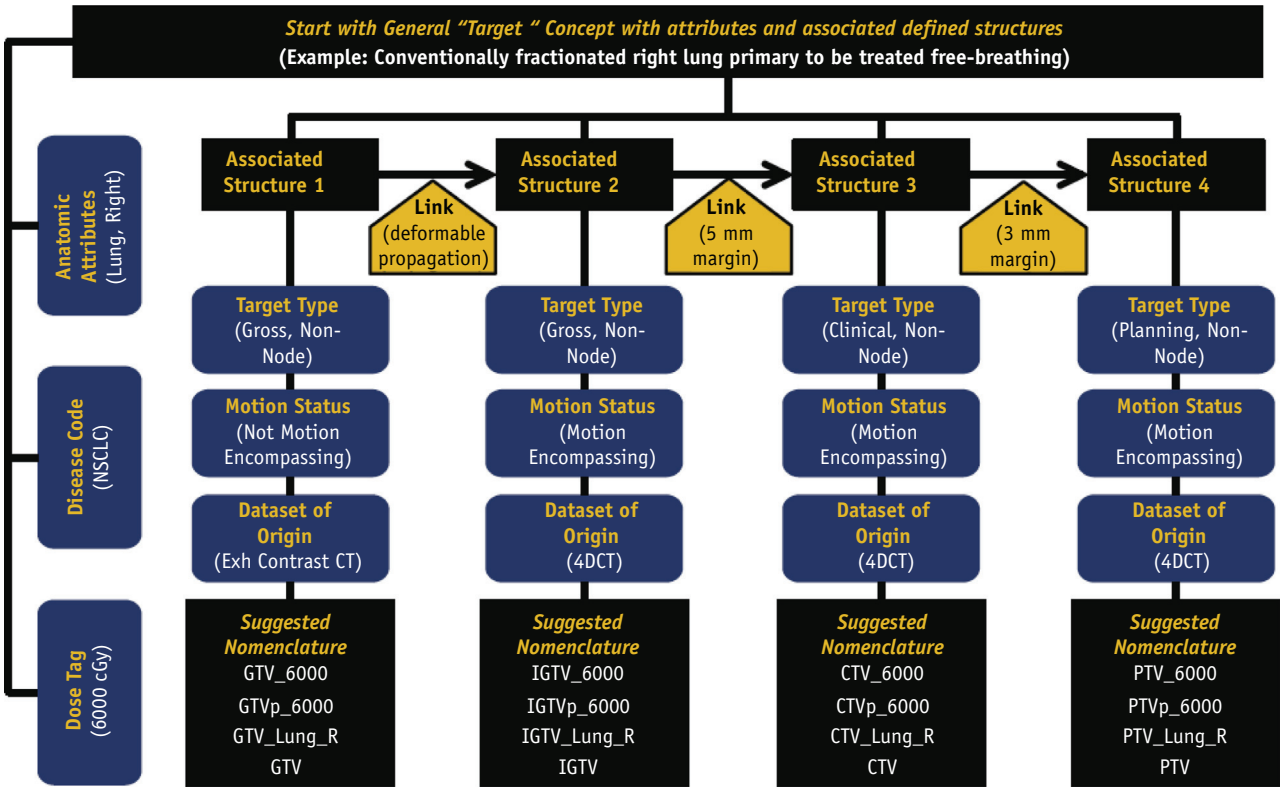

Fig. 6. Example of an enhanced target definition concept for vended systems to consider. Note the various attributes and linking properties that can be applied to describe a structure outside of the structure name itself. The specified margins are only for illustration of the concepts to capture and are not general recommendations for values.

nomenclature in conjunction with upgrades to their radiation oncology information systems.

Some vendors incorporated the developing consensus nomenclature from the TG into their products to facilitate the ability of users to standardize. Earlier versions of some vendor systems borrowed nomenclature from published and unpublished nomenclatures that had been previously developed by members. Incorporations of TG standards into vended systems was very helpful for the institutions piloting the nomenclature.

Some treatment planning systems include the ability to use templates and scripts to facilitate the introduction of standardizations into clinical practice. Among our pilot sites, 2 were in use. Examples of these systems are described below for practical illustration. This does not constitute an endorsement of either; better tools might or might not be available in other systems. Manufacturers are encouraged to support the adoption of the nomenclature by making it available in their systems for all users as systems are purchased or upgraded. They are further encouraged to create templates and scripts that facilitate implementation of this nomenclature when systems are purchased.

The use of nomenclature can be supported by different software versions such that it supports user adoption. For example, ARIA version 13.x provides a structure dictionary that includes FMAIDs, if available. Users edited labels, default identifiers, and synonyms for items most closely matching the nomenclature. Users can define specific treatment sites (eg, breast, lung prostate, head and neck), structure templates, and treatment plan protocols that use the nomenclature. Each structure requires the selection of a label from the structure dictionary to identify the structure category. The structure dictionary can be updated by the vendor to include the recommended nomenclature. Templates and protocols can be exported as XML files and imported by other users to facilitate adoption of the nomenclature. To automate inspection of the structure names for alignment with the recommendations, some users created scripts that can run from Eclipse and highlight structures that are not following the recommendations. The availability of writable scripting that would enable creation of plans and structures adhering to the standard nomenclature was highlighted as an important future advance.

A series of scripts were developed to aid structure naming in the Pinnacle Treatment Planning System. The first script loads a graphic interface that allows user-specified names to autopopulate the Pinnacle ROI list. This interface shows the master list of TG-263 approved structure names that can be used in Pinnacle. The user can select names from the master list or from a disease site-specific list containing a subset of the master name list. Target and nonstandard structures can be added using the TG-263 approved nomenclature.

Once the desired list of structure names has been chosen, the names are saved to disk. A secondary Pinnacle script

loads the new list of names into the active Pinnacle session and populates the ROI list. Duplicate names are not inserted.

In addition, each disease site has a script that can simply load all the TG-263—approved structure names that are deemed commonly used by a radiation oncologist for a given diagnosis. The final script removes all structures from the Pinnacle region of interest list if no contouring was done. This feature provides a quick method to remove unnecessary structures added by the site-specific bulk import.

Similar scripts can be developed for all commercially available treatment planning systems, thus encouraging the use of approved structure names widely in the community. Scripts and templates simplify the steps involved with adopting standard nomenclature and could help overcome some of the barriers to implementation. Staff should be trained in use of the tools, and leadership will need to affirm a long-term commitment to the standardization effort. Additional training should focus on using the correct nomenclature when the treatment site or organ is outside the department standards. The pilot study participants were academically affiliated and might have had less opposition to change than smaller clinics with limited staffing. Smaller clinics might therefore encounter additional obstacles not foreseen by this group. Hence, even greater importance has been placed on developing user-friendly scripts, which might greatly simplify the adoption of this nomenclature for such clinics.

The pilot study did not require participants to adopt the recommendations for target structures but did ask that they examine any barriers to the adoption of the recommendations. The guidelines had been carefully formulated in conjunction with NRG to facilitate adoption. Several clinics had already converged on the use of relative dose nomenclatures (eg, PTV_High, PTV_Intermediate or PTV_Mid01, PTV_Low) as a part of their routine practice. The relative dose nomenclatures made development of standardized templates possible without requiring conformance to particular dose prescriptions. It also enabled changing prescribed doses during treatment (eg, move from 68 to 72 Gy) without requiring a change in the associated target structure names (eg, PTV_High for both vs change from PTV_6800 to PTV_7200). A few clinics had previously standardized the dose units in their planning system on Gy versus cGy. Thus, the shift in dose representation in names (eg, PTV_5040 vs PTV_50.4Gy) was considered a substantial change and safety concern without a properly educated rollout plan. Switching to relative dose levels (eg, low, intermediate, and high) provided a method to bypass difficulties in changing.

Recommendations for Implementation

At the time of publication, >700 distinct structure names had been reported separately online in the complete list for the present report. In practice, individual clinics only use a small fraction (eg, 30) of these routinely. The TG recommends the use of the standard values for the small subset of structures relevant to their practice or participation in trials. Even a basic effort to change to standardized structure naming will be beneficial for the individual clinic and the radiation oncology community as a whole.

The TG recommendations facilitate the ability of clinics to best use their electronic records for safety, productivity, research, and regulatory reporting. The importance of standardizations should be emphasized in the training programs for clinical staff.

A range of staff will be affected by clinical implementation of the nomenclature (eg, physicians, dosimetrists, physicists, therapists, and information technology and administrative personnel). Gradual implementation to allow time to develop an understanding of the guidelines and specific string values and incorporation into the documentation is encouraged.

A suggested workflow for implementation is provided:

1. Identify common treatment sites (eg, prostate, breast, head and neck) and corresponding staffing groups (eg, physicians, dosimetrists, physicists, therapists) affected by changes in nomenclature.
2. Detail commonalities already in use for those treatment sites for target and nontarget structure naming and structure DVH metrics used in treatment plan evaluation.
3. Download the full list of nontarget structure names recommended by the present report.
4. Save the full list and create a separate copy for editing.
5. In that Excel sheet, delete rows from the spreadsheet containing structures that are not needed by your clinic (eg, delete all cranial nerve structures, delete all individual heart-vessel structures).
6. Discuss the final list, guidelines for target and nontarget structures, and DVH metrics with the disease site groups and other stakeholders in your clinic as required by your organizational structure.
7. Identify local documentation templates used in clinical practice that might need to be adjusted when changing to the nomenclature (eg, simulation and treatment directives, check lists used in plan review).
8. Develop a plan for gradual implementation of the nomenclature into clinical practice.
    a. For example, implement nontarget structure nomenclature and DVH metrics by disease site group during a defined period, followed by implementation of clinic-wide target naming for all disease site groups.
    b. Include all stake holders in the discussion (eg, physicians, dosimetry, therapists, physicists).
    c. Consider where optimal break points might be in your clinical process for checking that the correct values are used (eg, plan review, plan check, and QA rounds to review structures and doses).
    d. It might be easier for clinics that are large enough such that practices are divided by disease site to

implement the nontarget nomenclature first on a site-by-site basis and later implement the target nomenclature throughout the clinic.

9. Develop a short list and create templates in your treatment planning system containing your new standard structures.
   a. One template containing all your standard structures.
   b. Individual templates for each treatment type containing only structures needed for that treatment type.
10. Retain the full list of structures as a reference for adding new structures to your templates as needed in the future.

Recommendations for Clinical Trial Study Groups

The ability to automate, exchange, and combine data from multiple groups and studies is important for increasing participation in trials, reducing cost (financial costs and staff time), and maximizing the use of aggregated data over time. The definition of a common nomenclature and guidelines for new structures supports those objectives. Consistent usage of standardized nomenclature among trials is one of the best mechanisms for bringing this consistency into routine practice. We encourage clinical trial groups to adopt these standardizations when defining new studies.

Recommendations for a Working Group to Succeed the TG

As technologies and standards advance and data collection becomes more refined, further improvements of the proposed naming schemes could be required. TG-263 recommends that this group transition into a working group that will continue to advance and extend the proposed scheme and maintain an active list of the current nomenclature and guidelines. Standardization to improve communication, data sharing, and safety with focused needs for radiation oncology are important for a wide range of data elements. These include treatment plan names, toxicities, treatment course names, prescription elements, patient-reported outcome items, survival, and recurrence status. Coordination with groups working as part of other organizations is needed to ensure the emergence of standards that can be widely applied.

Another important difficulty to adopting one nomenclature in the worldwide RT community is the lack of 1 global native language. Although the many advantages of using only 1 language are widely recognized, unfamiliarity with English or legal reasons could hamper the use of English in many countries. Other obstacles could include character limits and differences in the interpretation of laterality and other abbreviations. A working group could help establish guidelines for translation of nomenclature and support such activities as needed. Similar to the TG, the working group should include broad representation of stakeholders, including the DICOM working group and the International Atomic Energy Agency, which has experience in working across many languages. The working group might consider creating a translation table from the native language to the English nomenclature that could be (automatically) applied when data need to be sent, stored, or mined in an international context.

The proposed working group could collaborate with the DICOM working group to construct a dictionary that treats the structure name as a unique identifier and provides a meaningful, human readable description to the user. Using the DICOM standard will require *(1)* some institutions with recognized authority to create, distribute, and maintain a code scheme; and *(2)* RT manufacturers that support the use of codes in their segmentation and treatment planning software.

The dictionary could be coupled with an algorithm to derive a human-readable description. Such an approach would allow for controlled growth of the dictionary system. Changes would affect fewer dictionaries and would allow the ability to create or modify several related structures formed through combinations of the elements in other component dictionaries with the changed elements in the affected dictionary. This allows for more efficient maintenance of the system of component dictionaries. The alternative approach of a single dictionary would involve entering 1 line of information for all affected combinations of components that are used to build the unique identifiers and the compiled dictionary.

The working group could start maintaining and extending the proposed scheme using the approach of efforts such as FMA, Radlex (radiology naming scheme), and ICD. These efforts report their schemes regularly at the Bioportal (available at: http://bioportal.bioontology.org/) as a formal ontology and between releases collect community feedback and suggested improvements using tools such as WebProtege (available at: http://protege.stanford.edu/). This could augment and incorporate existing efforts to develop radiation oncology-specific ontologies such as the Dependency Layered Ontology for Radiation Oncology (available at: http://bioportal.bioontology.org/ontologies/DLORO) and the Radiation Oncology Ontology (available at: http://bioportal.bioontology.org/ontologies/ROO).

This effort does not address the terms used to define clinical outcomes (eg, toxicity, local control, survival). The need for the establishment and promulgation of a standard nomenclature for structures and DVH metrics with sponsorship by a professional society, such as AAPM, is immediate for many research efforts and for vendor progress on implementation in their systems. The standardization of terms used to define clinical outcomes is important but not as immediate. These clinical outcome terms should be considered by the succeeding working group.

Summary of Key Take Home Points

- Standardized nomenclatures add value to the radiation oncology by providing a basis for improved communication and the ability to develop automated solutions for data extraction and QA to improve clinical workflow, safety, and research.
- The nomenclature was developed through the combined effort of many clinics, vendors, and clinical trial groups (eg, NRG, Radiation Therapy Oncology Group) to define a viable consensus recommendation. The nomenclature has already been put into routine use in many clinics, as a part of clinical trials, and in vendor software, demonstrating that it is a viable solution.
- The nomenclature was defined to work within the storage and display limits of a range of vended systems to convey information on structure types and laterality.
- Guidelines for target structure naming were created to allow a range of information to be conveyed using a standardized syntax and allowing automated parsing of the information from the name.
    - When dose is used as a part of target naming, relative dose levels are recommended (eg, PTV_High, PTV_Low). If the physical dose is required, units of cGy are preferred, aligning with the current recommendations of the ASTRO group-defined guidelines for prescriptions and RO-ILS.
- Guidelines for nontarget structures and specific values defined for >700 structures were created, including identification codes for corresponding FMA structures.
- A DVH nomenclature detailing the input and output units for high-dose and low-dose metrics and radiobiologic metrics was recommended that was designed to use regular expressions to automate the parsing parameters needed for automated calculations.
- Nonsegmented target structures were recommended for the default standard for contouring. However, target structure nomenclature guidelines define a method to identify segmented structures when preferred.
- The nomenclature was piloted in clinic, vendor, and trials groups to prove the viability of the recommendations before release.
- Vendor participation was important in nomenclature development and is beneficial to facilitate implementation in those vended systems.

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