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Standardizing Naming Conventions in Radiation Oncology

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Abstract

Purpose—The aim here is to report on the development of a standardized target and organ at risk naming convention for use in Radiation Therapy and to present the nomenclature for structure naming for inter-institutional data sharing, clinical trial repositories, integrated multi-institutional collaborative databases and quality control centers. This taxonomy should also enable improved plan benchmarking between clinical institutions and vendors and facilitation of automated treatment plan quality control.

Materials and Methods—The Advanced Technology Consortium (ATC), Washington University in St.Louis, Radiation Therapy Oncology Group (RTOG), Dutch Radiation Oncology Society (NVRO) and the Clinical Trials RT QA Harmonization Group collaborated in creating this new naming convention. The ICRU guidelines have been used to create standardized nomenclature for target volumes (CTV, ITV, PTV etc.), organs at risk (OAR), and planning organ at risk volumes (PRVs) in radiation therapy. The nomenclature also includes rules for specifying laterality and margins for various structures. The naming rules distinguish tumor and nodal PTVs, with correspondence to their respective tumor/nodal CTVs. It also provides rules for basic structure naming, as well as an option for more detailed names. Names of non-standard structures used mainly for plan optimization or evaluation (rings, islands of dose avoidance, islands where additional dose is needed (dose painting)) are identified separately.

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Conflicts of Interest Notification

Results—In addition to its use in 16 ongoing RTOG advanced technology clinical trial protocols and several new EORTC protocols, a pilot version of this naming convention has been evaluated using patient data sets with varying treatment sites. All structures in these data sets were satisfactorily identified using this nomenclature.

Conclusions—Use of standardized naming conventions is important to facilitate comparison of dosimetry across patient datasets. The guidelines presented here will facilitate international acceptance across a wide range of efforts, including groups organizing clinical trials, ROI, NVRO, IHE-RO, and DICOM.

Keywords

Standardizing; Naming conventions; Structures; Target Volumes

I. Introduction

Like much of health care, Radiation Oncology (RO) is expanding its definition of quality to include not only avoidance of gross errors but also consistent delivery of the full potential of the currently available technology and evidence. In support of this effort, RO is increasingly relying on normalized, well-established approaches to process management and process improvement (1). A key component of an effective process improvement and workflow management infrastructure is consistent language and terminology (2). The topic of this paper is a standard scheme for naming RO structures. It is an important topic, both for management of “routine” clinical practice as well as collective pursuit of new standards of care.

Several recent reports document the deleterious effects that inaccurate, incomplete communication can have in RO. An article published by the Pennsylvania Patient Safety Advisory in September 2009 found that 46% (17/37) of reported errors involved treatment to an incorrect site and 21% (8/37) to the wrong dosage (3). A similar error and near-miss reporting and learning system was implemented by Washington University (4). Based on the data collected from April 2008 to February 2010, 500 events due to miscommunication of intent were reported based on the treatment planning and simulation orders request. Of these 17% (84) were due to wrong contours or modifying or renaming (5). While these events reported at Washington University did not result in patient mistreatments, each represents a process inefficiency that adds no value to the planning process. In Europe, a radiation oncology safety information system (ROSIS) was established in 2001(6) that published profiles of participants and the first 1074 incident reports. They observed that out of the 1074 incident reports many incidents arose during pre-treatment phase but were not detected until later in the treatment process. Improved communication in RT is also highlighted in the ASTRO’s six point action plan (7) on safety and quality assurance. There are numerous other examples in the literature of work that will benefit from a standardized structure naming convention, including the following:

a. Support of electronic prescription requests and treatment planning orders (5).

b. Improvement of communication between electronic medical records and RT treatment planning systems (8).

c. Facilitation of automated treatment plan quality control (9–11).

d. Improvement in data mining in individual clinics (12,13).

e. Improvement in communication between individual clinics and national clinical trial repositories, integrated multi-institutional collaborative databases and quality control centers (14).

f. Improved plan communication and plan benchmarking between clinical institutions and vendors (10,11).

g. Facilitation of automated treatment planning and report generation (15).

One alternative for consistent identification of treatment planning structure volumes is to use translators to map “ad hoc” structure names to a standardized nomenclature. For analyses that use data generated before the adoption of a standard nomenclature this is the only option. However, the variability of free-text structure names limits the reliability of such heuristic methods for mapping structure names, thus requiring a great deal of manual quality assurance. As the field moves forward to more inter-institutional data sharing and analyses it is prudent to identify, adopt, and maintain a list of standardized structure names. Equally important is the introduction of a schema for standardizing structure names that can be used in the Digital Imaging and Communication in Medicine (DICOM) standard or Integrating the Healthcare Enterprise, Radiation Oncology domain (IHE-RO) Integration Profiles.

The aim of this paper is to report on the development of such a standardized target and organ at risk naming convention for use in RT and to present the list of structures for inter-institutional data sharing.

The Advanced Technology Consortium (ATC), Washington University in St. Louis, Radiation Therapy Oncology Group (RTOG), Dutch Radiation Oncology Society (NVRO) and the Clinical Trials RT QA Harmonization Group, in which major trial groups from all over the world are represented, collaborated in creating this new naming convention. This approach for naming target volumes, organ at risk volumes (18–19) and derived structures (user defined) can be used for planning, quality assurance, data sharing and data collection for multi-institutional clinical trials. It is hoped that this scheme will be adopted by clinical or clinical trials organizations, which will maintain and further develop this resource. It is further hoped that this naming scheme will be adopted by individual clinics and treatment planning vendors.

II. Materials and Methods

The ATC schema, available on the ATC website (atc.wustl.edu), has been used to create a standardized list of target volumes, organs at risk, and planning organ at risk volumes. This list incorporates structures published by Emami *et al.*(16) and Marks *et al.* in the QUANTEC review (17). Structure names are divided into two categories: (A) Target Volumes (TV), (B) Organs at Risk (OAR) and Planning Organ at Risk Volumes (PRV) according to ICRU guidelines (18–19). All radiation dose levels are specified in units of cGy with a maximum of 5 characters. All margins around structures are specified in units of millimeters with a maximum of 2 characters.

Base names for OAR are constructed with “camel case”, i.e, by capitalizing each word in a name and removing all spaces between words, and are abbreviated to a maximum number of characters less than 16. Underscore (_) is used to delimit modifiers indicating margin size, prescription dose, laterality, etc.

A) Target Volumes(TV)

In order to distinguish multiple target volumes with distinct treatment planning dose objectives, the naming convention incorporates treatment planning dose objectives in the target volume name. The tumor bed volume is identified as TBV. The target volume name consists of an alphanumeric combination consisting of an ICRU target descriptor (18–19) and treatment dose objective. For example, a planning target volume (PTV) with a prescription dose of 5000 cGy would be named PTV_5000. In order to avoid ambiguity resulting from differences in precision of dose values represented using fractional Gy values with decimal points, prescription doses are expressed as integers with units of cGy. With this approach a treatment prescription of 50.4 Gy would be listed as 5040 cGy.

For 4D treatment planning, a Gross Tumor Volume (GTV) (18–19) at End Exhale, End Inhale or Maximum Intensity Projection (MIP) would be labeled as GTV_EE, GTV_EI or GTV_MIP respectively. For targets defined in a specific breathing phase, irrespective of whether phase or amplitude binning has been used, the percentage value is specified with an underscore followed by the number and pct for eg. GTV at phase or amplitude 30% is defined as GTV_30pct.

To distinguish between primary and nodal targets, the target volumes are appended with p or n for example PTVp_5000 or PTVn_5000. If needed to distinguish multiple clinical primary and nodal volumes, an integer may be added after the p or n (e.g. PTVp1_5000, PTVn1_5000). This integer should then also be added to the corresponding TBV, GTV and/or CTV structures to identify them consistently. Table 1 provides further examples of TV names generated using this scheme.

If deemed useful, the uniform margin used to generate the target volume may be specified in mm using 2 characters(XX) preceding the dose prescription(YYYY) using underscores as separator as PTV_XX_YYYY. For example, The PTV with a prescription dose of 5000 cGy generated by expanding the corresponding CTV by 7 mm uniformly, may be described as PTV_07_5000. Likewise, a CTV generated by expanding the GTV uniformly by 15 mm may be described as CTV_15_5000.

B) Organs at Risk(OAR) and Planning Organs at Risk Volume(PRV)

1. Organs at Risk—The proposed OAR naming convention is based on organ name and, where applicable, structure laterality. Laterality is indicated by appending an underscore character (“_”), followed by L or R, respectively. For example, the left femur is named Femur_L, and right femur is Femur_R. This convention leads to a compact notation for laterality.

Cranial nerves are named using CN_, followed by upper-case Roman numeral and L or R to indicate laterality, as appropriate. Thus, CN_VIII_R indicates the right, eighth cranial

(auditory) nerve. Vertebral bodies, are named using VB with extensions _C, _T, _L, _S (cervical, thoracic, lumbar, sacral) followed by an Arabic numeral like 1,2 etc. Thus, the second (cervical) vertebral body is VB_C1, and the twelfth (thoracic) is VB_T12. The Ribs are named as Rib1_L for the left, first rib.

Bilateral structures, e.g., lung, kidneys, parotid, etc., can be combined to create a structure containing both organs. Such combined structures are commonly used in treatment plan evaluation (20). Names for organs created from bilateral structures are defined as the name of the structure with _L or _R. The combined structure (pair) is named with the plural of the base name. For example, the total lung will be defined as Lungs, a structure created by combining left and right lungs, Lung_L + Lung_R. Arteries and veins are specified with an A followed by an underscore and V followed by underscore respectively. For e.g., A_Pulmonary, V_Pulmonary represents, pulmonary artery and vein respectively.

2. Planning Organ at Risk Volumes—PRVs are created with specific margins around organs at risk. Names for such structures are based on the base OAR and the geometric margin. All expansion margins are in units of millimeters. Therefore, a planning risk volume around the spinal cord with a 5mm expansion would be named SpinalCord_05. When the PRV has non-uniform margins they are specified as "_PRV" and the expansion margin is omitted. Table 2 provides further examples of PRV names generated using this scheme.

c) Clinical Evaluation of the Schema

The naming scheme has been evaluated for clinical practice in the Department of Radiation Oncology at the Washington University School of Medicine and is currently tested at the Netherlands Cancer Institute/Antoni van Leeuwenhoek Hospital (NKI/AvL) in Amsterdam and the Catharina Hospital in Eindhoven, the Netherlands. The scheme was used to derive names for all structures used in treatment planning, extending the list provided by the ATC, and has been used for treatment planning.

A preliminary version of the naming scheme has been used since April 2009 to specify standard names for structures in treatment planning data sets submitted for several RTOG and EORTC clinical trial protocols. Future trial protocols within the trial organizations represented within the Clinical Trials QA Harmonisation Group will use this scheme and extend the list of standardized OAR names as needed.

III. Results

Table 3 contains a list of newly proposed standardized OAR names. On the whole, the scheme was found to be sufficiently flexible to accommodate the variety of structure names and planning techniques considered in the pilot clinical study. However, several opportunities for improving the scheme were noted.

First, in certain situations where multiple nodal targets are defined where laterality is needed, one could specify the laterality in the target definition as in CTVn1_R for a right sided node 1. These definitions would yield a better understanding of the laterality when defining target volumes. The second observation has to do with special structures that are

used for shaping dose distributions. These structures include rings, islands of dose avoidance, or islands where additional dose is needed (dose painting). A proposed solution for these structures is displayed in Table 4. Note that this schema is optional, but could help in giving clear definitions for structure names and target volumes. Since the proposed schema in Table 4 is complex, clinics could adopt this schema if detailed descriptions are preferred. This schema will result in a common nomenclature for easy adoption in the future when detailed descriptions become necessary. Certain structures created with Boolean operators fall in this category as well. Since such structures are largely idiosyncratic to individual patient plans or individual institutions and typically do not have a purpose outside the plan generation and dose shaping, these structures are not addressed explicitly in the naming convention and could be prefixed with NS(Non_Standard). These could also include structures like prosthesis, rectal balloons, fiducials etc.

Notwithstanding these opportunities for improvement, the naming scheme has been adopted and serves as the basis for institution-wide standardization of structure names in our departments. Structure name mapping files have been created at the Washington University for historical data, so that all future analyses will rely on the now standard nomenclature. Furthermore, standard structure names have been incorporated into clinical workflow communications (e.g. radiation oncologists treatment plan orders) and planning scripts. In the NKI/AvL and Catharina Hospital the institution specific scripts for their treatment planning system have been adapted to accommodate this new convention.

In addition to specifying structure names, the scheme described in this report can be readily applied as a Coding Scheme for structures within DICOM RT Structure Set objects. The use of DICOM ROI Identification Codes would provide consistent identification of structures while permitting local languages and character sets to be used in displaying their names. This approach is being used in the development of an IHE-RO Integration Profile for the exchange of Structure Templates.

IV. Conclusions and Future Work

In this paper a scheme for naming RT structures was presented along with an update of standard structures names in use at the ATC. The list and the scheme have been adopted and tested in clinical practice by the Department of Radiation Oncology at the Washington University School of Medicine and NKI/AvL and Catharina Hospital in the Netherlands as part of our efforts to improve the efficiency, consistency and reliability of communications. Furthermore, the naming scheme was found to be useful for creating and standardizing structure names that do not currently belong to the ATC list. The result of clinical implementation of the naming scheme noted several opportunities for improvement, namely in how it deals with margins and laterality specifications in target volume definitions and how it accommodates the use of “dose shaping” structures. In certain situations for dose volume evaluation, combinations of structures are created using inclusion (union) and exclusion (subtraction) operators. This approach is used to specify composite regions of interest for dose-volume histograms in the DICOM RT Dose information object. Such structures may be used, for example, in evaluating the dose delivered to the portion of an organ that does not overlap with the target volume. In principle, one could identify such

composite structures as combinations of base structures using Boolean operators. However, a complete syntax for expressing these combinations is beyond the scope of this report.

It is expected that continued use will result in the identification of new opportunities to update and enhance the naming scheme. From a purely clinical perspective these needs will likely emerge from the adoption of new technologies for planning and delivery or efforts at more automated or standardized workflow.

The list will expand in concert with the needs and consensus emerging from its support of ongoing and future clinical trials. In the past, maintenance of the list and the scheme was administered by the ATC. Presently, the new scheme and structure list has been developed as a joint effort of the ATC, the NVRO and the Clinical Trials QA Harmonisation Group. This broader approach will hopefully result in an even wider acceptance in the RT community. Given the importance of standardized communication terminology it is hoped that this effort will receive continued interest and support, both in terms of adoption by clinics and clinical trials organizations as well as contributions to elaborations on the scheme and list. For example, with the increasing need to conduct intergroup trials, global acceptance by clinical trial organisations becomes more and more important. The guidelines presented here will facilitate international acceptance across a wide range of efforts and will stimulate incorporation in standards like IHE-RO and DICOM and vendor specific software.

Acknowledgments

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Table 1

The table above shows examples of Target Volume (TV) names.

Target Volume ICRU Name	Primary/ Node	Single/ Multiple	Number	Prescription Dose (cGy)	Proposed Name
PTV	Primary	Single	N/A	5000	PTV_5000
PTV	Node	Multiple	1	5000	PTVn1_5000
CTV	Node	Multiple	2	4000	CTVn2_4000
PTV	Node	Multiple	2	4000	PTVn2_4000
PTV	Primary	Multiple	1	5000	PTVp1_5000

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Table 2

Table above shows the Planning organs at risk volumes (PRV).

Organ at risk name	Left/Right	Margin (mm)	Proposed Name
SpinalCord	N/A	non-uniform	SpinalCord_PRV
SpinalCord PRV	N/A	5	SpinalCord _05
Parotid	Left	0	Parotid_L
Parotid	Right	0	Parotid_R
Total Parotid	Left+Right	0	Parotids
Kidney	Left	10	Kidney_L_10

Table 3

Table above shows Standardized OAR names. Highlighted names are new and have been added to the existing ATC list of structure names.

Standard Name	Description
AnalCanal	Anal Canal
A_Pulmonary	Pulmonary Artery
A_Carotid	Carotid Artery
A_Brachiocephali	Brachiocephalic Artery
A_Coronary	Coronary Artery
A_Subclavicular	Subclavicular Artery
A_Hypophyseal	Hypophyseal Artery
Aorta	Aorta
AnalSphincter	Anal Sphincter
Atrium	Atrium
Bladder	Bladder
BladderWall	Bladder Wall
BrachialPlexus	Brachial Plexus
Brain	Brain
BrainStem	Brain Stem
Breast	Breast
BronchialTree	Bronchial Tree
BaseOfTongue	Base of Tongue
Carina	Carina
CaudaEquina	Cauda Equina
Cerebellum	Cerebellum
Cerebrum	Cerebrum
Chiasm	Optic Chiasm
CN_VII	Seventh Cranial Nerve
CN_VIII	Eighth Cranial Nerve
Cervix	Cervix
Cochlea	Cochlea
Colon	Colon
ConstrMuscle	Constrictor Muscle
Cornea	Cornea
Duodenum	Duodenum
Ear_Middle	Middle Ear
Ear_External	External Ear
Esophagus	Esophagus
Esophagus_Upper	Upper Esophagus
Esophagus_Lower	Lower Esophagus

Standard Name	Description
Esophagus_Middle	Middle Esophagus
External	Skin
Eye	Eye
Femur	Femur
FemoralJoint	Femoral Joint
FrontalLobe	Frontal Lobe
GHJoint	Glenohumeral Joint
Globe	Eye Globe
Glottis	Glottis
GreatVessel	Great Vessel
Heart	Heart
Hippocampus	Hippocampus
Hypothalamus	Hypothalamus
Kidney	Kidney
LargeBowel	Large Bowel
Larynx	Larynx
LacrimalGland	Lacrimal Gland
Lens	Eye Lens
Lips	Lips
Liver	Liver
Lung	Lung
Mandible	Mandible
MassMuscle	Masseter Muscle
Mediastinum	Mediastinum
MainBronchus	Main Bronchus
OccipitalLobe	Occipital Lobe
OpticNerve	Optic Nerve
OralCavity	Oral Cavity\
Ovary	Ovary
Parametrium	Parametrium
ParietalLobe	Parietal Lobe
Pancreas	Pancreas
Parotid	Parotid
PelvicBones	Pelvic Bones
PenileBulb	Penile Bulb
Penis	Penis
Perineum	Perineum
Pericardium	Pericardium
Pharynx	Pharynx

Standard Name	Description
PharynxConst	Pharyngeal Constrictor
Pituitary	Pituitary
Prostate	Prostate
PubicSymphysis	Pubic Symphysis
Rectum	Rectum
RectalWall	Rectal Wall
Retina	Retina
Rib	Rib
Sacrum	Sacrum
SalivaryGland	Salivary Glands
SeminalVesicle	Seminal Vescile
SmallBowel	Small Bowel
SpinalCord	Spinal Cord
Spleen	Spleen
Stomach	Stomach
Submandibular	Submandibular Gland
Supertentorial	Supertentorial
TemporalLobe	Temporal Lobe
Testis	Testis
Thyroid	Thyroid
TMjoint	Temperomandibular Joint
Trachea	Trachea
Tongue	Tongue
Urethra	Urethra
Uterus	Uterus
V_Azygos	Azygos Vein
V_CavaInferior	Inferior vena cava
V_CavaSuperior	Superior vena cava
V_Pulmonary	Pulmonary Vein
V_SubClav	SubClavicular Vein
Vagina	Vagina
VB_Cervical	Cervical Vertebrae
VB_Thoracic	Thoracic Vertebrae
VB_Lumbar	Lumbar Vertebrae
VB_Sacrum	Sacrum Vertebrae
Ventricle	Ventricle
Vessels	Vessels
Vulva	Vulva

Table 4

Table above shows the target volumes and structures not mentioned in the ATC website generated using the aforementioned schema. NS: Non Standard.

Volume Name	Prescription Dose (cGy) / & Margin (mm)	Prescription Target /Laterality	Proposed Name
3mmRing	3mm around PTV	N/A	NS_Ring_3
3mmRing	3mm thick ring at 10 mm from PTV	N/A	NS_10_Ring_3
Fiducials			NS_FIDUCIALS
CTV	0 mm around GTV		CTV_00_2000
CTV	15 mm around GTV 2000 cGy		CTV_15_2000
PTV	20 mm around Nodal CTV, 5000 cGy		PTVn1_20_5000
GTV	Nodal level 3	Left side	GTVn3_L