# Open RT Structures: A Scalable Solution for TG-263 Accessibility

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# Abstract

**Purpose:** Consistency of nomenclature within radiation oncology is increasingly important as big data efforts and data sharing become more prevalent. Automation of radiation oncology workflows depends on standardized contour nomenclature which enables toxicity and outcomes research, while also reducing medical errors and facilitating quality improvement activities. Recommendations for standardized nomenclature have been published in the American Association of Physicists in Medicine (AAPM) report from Task Group 263. Transitioning to TG-263 requires creation and management of structure template libraries, and retraining of staff, which can be a considerable burden on clinical resources. Our aim is to develop a program that allows users to create TG-263 compliant structure templates in English, Spanish, or French to facilitate data sharing.

**Methods and Results**: 53 pre-made structure templates were arranged by treated organ based on an American Society for Radiation Oncology (ASTRO) consensus paper. Templates were further customized with common target structures, relevant OARs (e.g., Spleen for anatomically relevant sites such as gastroesophageal junction or stomach), sub-site specific templates (e.g. partial breast, whole breast, intact prostate, postoperative prostate, etc.) and the addition of brachytherapy templates from the AAPM brachytherapy working group. An informal consensus on OAR and target coloration was also achieved, though color selections are fully customizable within the program. The resulting C# program is usable on any Windows system and generates template files in practice-specific DICOM or XML formats, extracting standardized structure nomenclature from an online database maintained by members of the TG-263U1 Task Group which ensures continuous access to up-to-date templates.

**Conclusions:** We have developed a tool which runs on any Windows system to easily create TG-263-compliant structure template libraries for all planning systems utilizing the DICOM standard. The program and source code are publicly available via GitHub. Feedback from community users is encouraged to identify opportunities for improvement and guide further development.

# Introduction

The creation of treatment plans in radiation oncology requires the delineation of regions of interest (ROIs), which primarily represent structures such as volumes and organs at risk (OARs). While Digital Imaging and Communications in Medicine (DICOM) standards specify data formats required to electronically communicate information about these structures, users are individually responsible for creating and naming sets of structures for each treatment plan in their treatment planning system (TPS). Labeling structures manually is tedious, error-prone (e.g., ‘Brian’ instead of ‘Brain’), and variable (e.g., ‘Lung\_R’ vs ‘Right Lung’), with greater than 10 variants reported for many OARs1.

While many TPS provide the option of maintaining template libraries to let users load a specific set of ROIs for a particular treatment, these libraries are often manually created, making the process relatively time-intensive, both for their initial creation and subsequent updates, and remain vulnerable to the issues listed above.

The American Association of Physicists in Medicine (AAPM) published ‘Standardizing Nomenclatures in Radiation Oncology’1, a report from Task Group 263 (TG-263) in order to create a standard nomenclature for ROIs and dosimetric data. While adoption of the standard nomenclature has popular support, its implementation is time-consuming and resource-intensive. In a recent survey2 conducted by the TG-263U1 Task Group, the majority of respondents had not yet adopted the standardized nomenclature, indicating that the largest hurdles were lack of time/resources to create new templates and difficulty with retraining staff.

Our aim in this work was to lower the barrier to adoption of TG-263 nomenclature in English, Spanish, or French by disseminating standardization that may facilitate data sharing. We have developed a tool which runs on any Windows system to easily create TG-263-compliant structure template libraries. **Our program can monitor folders and automatically add patient-specific structure sets, or create loadable RT structure/.xml templates. It presents a scalable solution focused on compatibility with all Treatment Planning Systems (TPS) utilizing the DICOM standard.**

# Methods and Results

The 53 pre-made structure templates are arranged by treated organ and include treatment sites based on an American Society for Radiation Oncology (ASTRO) consensus paper3.

An attempt was made to standardize coloration across treatment planning systems (e.g., Pinnacle v16.2.1, Raystationv 12.14, and Eclipse v15.6). Twenty-four colors were utilized in total, due to coloration limitations in Pinnacle. Default target color selection was based on institutional preference at UCSF (Dr. Sue Yom), MDACC (Dr. Anna Lee), and Michigan (Dr. Charles Mayo), reflecting the Clifford Chao’s IMRT book5.

An online spreadsheet, Airtable6, was utilized to house all templates in an evergreen fashion. The online spreadsheet containing the raw data for all templates may be found at the following link: [bit.ly/StructureNaming](https://airtable.com/shrojSoXyfnHHKzJV). A static version of these templates at the time of publication is displayed in Table S1. Congruent with the ASTRO consensus paper3, there are two types of structures: Recommend, which should be contoured in all adult definitive cases and may assist with organ selection for palliative cases; and Consider, for structures considered on a case-by-case basis. The program selects Recommended structures by default, with Consider structures initially unchecked and can be imported based upon user selection. Changes to the online spreadsheet are updated and viewable in the program in real time.

The program was written (BMA) using C#7, ensuring it’s computability with windows systems. Its workflow is broken down into three major steps, as illustrated in Figure 1: (1) the creation of a template, (2) manipulation of ROIs, and (3) setting DICOM paths and requirements, and/or creating loadable DICOM/XML files. Resulting output is compatible with all treatment planning systems which utilize the DICOM standard. DICOM files are manipulated via the publicly available FellowOakDicom package8, and a C# wrapper for the ITK coding package, SimpleITK9. The framework for creating RT Structure files in Python has been previously reported10. Videos for the installation and running of the program can be found linked at the bottom of the publicly available GitHub page: <https://github.com/brianmanderson/DicomTemplateMakerCSharp>, and are continually updated to demonstrate current features and performance of the program. Individual ROIs are linked across treatment sites, so changes in nomenclature are easily transferred to all structure set templates via a single change when a clinic-specific online spreadsheet is used.

Template language can be selected as English, Spanish, or French. Structures default to English if Spanish or French translations are not available. By default, the program orders the structures using a combination of primary and reverse orders, as reverse order reflects natural language more clearly for certain structures (e.g., Reverse order of Anal\_Canal, Bowel\_Bag reflects natural language more than Primary order of Canal\_Anal, Bag\_Bowel). Users can choose to import all structures by Primary or Reverse TG-263 nomenclature.

The program was piloted at multiple sites with Eclipse (JR, KW, DH), Pinnacle (RZ) and Raystation (CE) to ensure compatibility with multiple treatment planning systems (TPS). We wanted to make the model output compatible with as many TPS as possible, and so ensured the model output follows the DICOM standard.

The subsequent sections expand on each step of the program’s workflow.

Figure 1: General workflow of the program

## Step 1: Creation of Template

The program comes with a library of 53 premade structure set templates designed for specific anatomical sites and clinical indications which can be loaded from our online spreadsheet as described above.

A user can create their own template in several ways; 1) Copying a pre-made structure templates, 2) creating a new template from a previous RT structure file or Varian xml file or 3) Manual creation. We wanted to ensure that users could benefit from the previously created templates that follow TG-263 nomenclature, but also have the ability to create their own templates as desired within their clinic.

Loading of premade structure sets are demonstrated in **Video 1**. All default templates load in ABC order, arranged by the name of the template (Table S1). If the user has pre-existing templates in Varian .xml file format, they can be easily added to allow for template modification within our program. This plugin was created to remove any headache of exporting templates from the Varian system to our program. Lastly, the user may create a new template, by adding ROIs and selecting new colors manually.

## Step 2: Manipulation of ROIs

After a template has been created, ROIs are listed alphabetically grouped within their Interpreted Type11 (PTV, CTV, Organ, etc.). This means any ROI with a type of PTV will be listed above CTV, then GTV, and then all other types, as shown in Figure 2. The list of ROI Interpreter Types can be found in the DICOM Standard Browser.11 If utilizing the premade structure sets, Recommend structures (which should be contoured in all adult definitive cases and may assist with organ selection for palliative cases) will populate first in alphabetical order as default-checked, while all Consider structures (structures considered on a case-by-case basis) will populate below in alphabetical order as default-unchecked (Figure 2) according to the ASTRO consensus paper.3 Therefore, the program is structured to allow for users to add Consider structures on an as-needed basis.

Additional ROIs can be added via the program interface or selection of an existing RT Structure file. This allows the user to easily combine structures from several RT structure files into a single template. Furthermore, adding RT structures automatically populates the ontologies list.

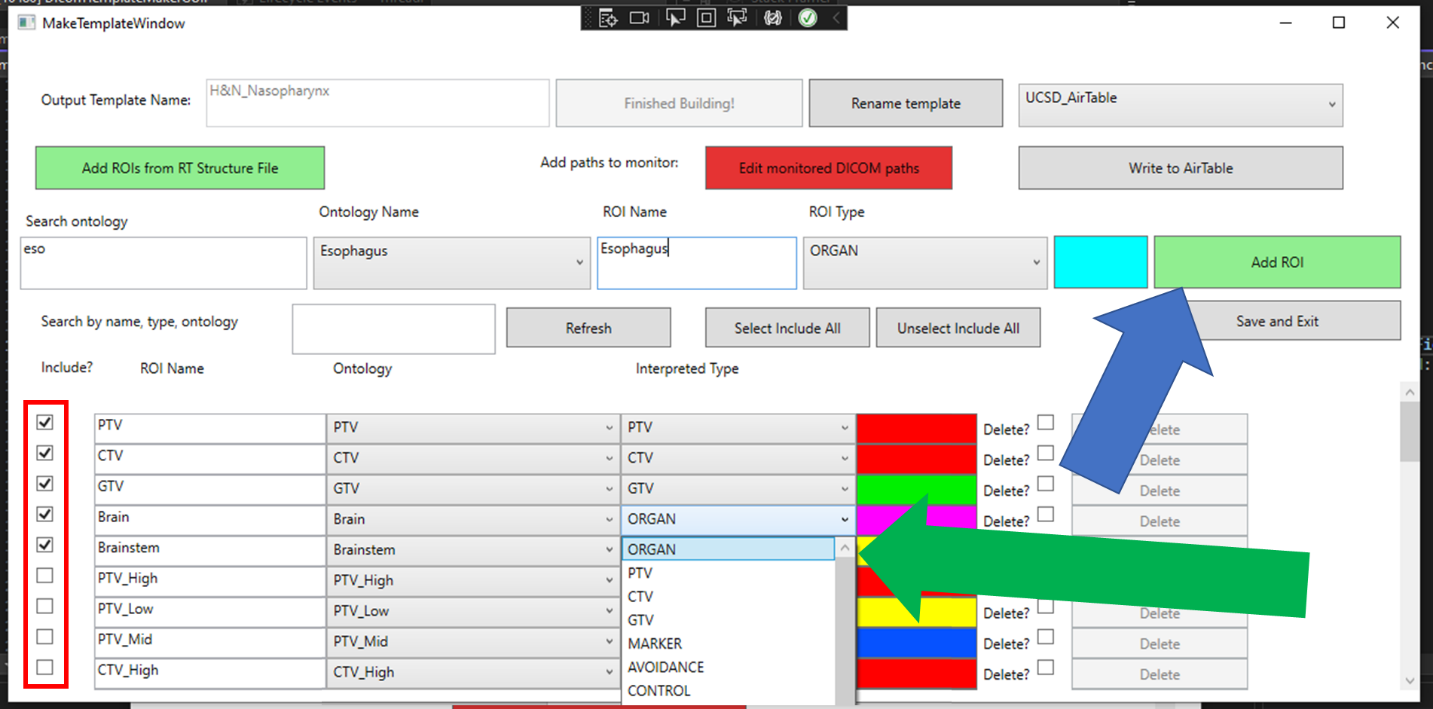


Figure : Edit within the template ‘H&N\_Nasopharynx’. The red box on the bottom left shows that only PTV, CTV, GTV, Brain, and Brainstem have been checked as ‘Include?’ for the RT Structure file. The ‘Incuded?’ ROIs are listed above the non-included ROIs. The ROIs are grouped PTV -> CTV -> GTV -> ORGAN, and alphabetically within each group. The blue arrow shows where the user is manually adding a new ROI, ‘Esophagus’. The green arrow shows where the user can change the interpreted type.

## Step 3: Setting DICOM paths and requirements, and/or creating loadable DICOM/XML files

The program can function as a server with which to create a structure set for each patient image that appears in a monitored folder designated by the user. The program also may create structure templates to be assigned to patients within the TPS.

If set up as a server, the program will loop through each of the monitored paths defined within each template. A file system watcher monitors for file changes at each path, waiting a period of time between each change to ensure all files are uploaded before the process begins. This is performed since DICOM images are often uploaded to a server after acquisition on the CT. The upload process can take time, depending on the size of the scan and latency of the network. This file system watcher ensures the entire DICOM dataset is present before an RT structure is generated.

If the DICOM images are consistently placed within the same folder (server location post acquisition where all acquired images are deposited), the users can define values within the Series Description or Study Description to indicate which template should be run automatically. For example, including the tag ‘Breast\_CW’ in the Series Description during acquisition could ping the program to automatically create the ‘Breast\_CW’ template.

DICOM files are internally separated based on the series instance UID. This ensures that a unique RT structure file will be made, even if multiple scans are placed within the same folder. For each unique series instance UID, a new RT-Structure file is created with the form ‘{Structure template name}\_{UID}.dcm’. The generated structure file will correctly update the necessary frame of reference UID and SOP Instance UID for the associated images, as well as study time, study date, accession number, referring physician name, study description, patient name, patient ID, patient birthdate, patient sex, study instance UID, and study description.

If the user instead wishes to create a dummy patient and load RT Structure files to save as templates they can select the ‘Create folder with loadable RTs’. This will create a folder with a previously anonymized four-slice CT and generate the available structure templates as described above. The user may also create a series of loadable XML files by selecting the ‘Create folder with loadable Varian Xmls’. Generated .xml files follow the 2001 xmlscheme instance version 1.2. The default .xml file is present within our GitHub page named ‘Structure Template.xml’. By default the program will attempt to find the current Varian directory of .xml files, allowing for easy uploading.

## Behind the scenes

This section is written to help the reader understand how the program writes and maintains the information present. It is not recommended for the user to manually alter the files created without a high level of confidence. However, should issues arise, the program can be re-downloaded from the site.

### Creation of ROIs

Each ROI is saved as an individual text file, consisting of three lines. The first line is the RGB color which will be presented for the ROI in the treatment planning system/within the generated RT Structure file. The second line is the associated ontology, detailed below. The third line is the ROI Interpreted Type, as listed in the DICOM Standard Browser11. The Interpreted Type can be changed at any time within the template software, as shown in Figure 3.

### Creation of Ontologies

DICOM RT Structures have Identification Code Sequences that relate a ROI with a name defined by the coding scheme. The code value is typically unambiguous code rather than natural language, e.g., ‘12738006’. The code meaning is text that is human interpretable. Detailed descriptions of each of these can be found in the DICOM Standard Browser for identication code12.

The sequence is defined by several items, including a code value, coding scheme designator, and code meaning. The coding scheme designator is a short string that relates the code value to a human interpretable value. A list of available code schemes can be found online13.

Any newly created ROI must have an associated ontology. These ROIs can be uploaded manually by including a Common Name, associated Code, and Code Scheme. For example, the ‘Brain’ in the Foundation Model of Anatomy (FMA)14 is defined as having a code value of 5080115.

While all DICOM approved coding schemes will function within the program, the online templates are built around the Systemized Nomenclature of Medicine – Clinical Terms (SNOMED-CT) scheme, as is the recommended coding scheme of TG-263U1. The value for ‘Brain’ in SNOMED-CT is 12738006, as seen in Figure 3.

Graphical user interface

Description automatically generated

Figure : Demonstration of ontology for ‘Brain’. Based on the SNOMED-CT, the ‘Brain’ structure has a code value of 12738006.

When ontologies are not present, a newly created ROI will default to ‘Undefined Normal Tissue’, which is not an FMA ontology but instead a Varian Medical Systems code.

# Discussion

In this paper, we describe the first reported effort to create open-source software to create and maintain libraries of patient-specific treatment planning structure templates to lower the barrier to adoption of TG-263 standardized nomenclature and facilitate data sharing for toxicity and outcomes research. All outputs are compatible with TG-263 and TG-263U1 guidelines for nomenclature of structures, which is endorsed by multiple professional societies (AAPM, AAMD, ASTRO, ESTRO). This software was tested at multiple sites and ensured to be compatible with Pinnacle v16.2.1, Raystation v12.1, and Eclipse v15.6, although output should be compatible with all TPS utilizing the DICOM standard. There have been previous reports of software tools used to homologate sets of previously treated structures to support retrospective data analysis16. There have also been tools created within the TPS to verify that structures names comply with TG-26317. With Open RT Structures, clinics can ensure that clinical standards are met, enable automated workflows, and facilitate data pooling and outcomes research. Furthermore, we hope that this tool can help reduce medical errors and facilitating quality improvement activities.

The DICOM Template Maker reduces the burden of manual creation of structure templates by providing TG-263 designed templates and allowing users multiple pathways to ease the creation of user-defined templates. Templates can be easily edited in case of future changes, and a reasonable set of default TG-263 templates can be refreshed using the ‘Load Online Templates’ feature.

The largest risk that we could foresee is that the program continually updates it’s own previously generated RT Structure files. To ensure this does not happen, the program internally tracks which images have been previously viewed (via Series Instance UID), and creates each RT Structure file with that same Series Instance UID. The program never opens or edits an already existing RT Structure file, and so presents no risk to work flows already present by the user.

To support large-scale, multi-institutional, and international data sharing, the DICOM Template Maker enables users to create templates in English, French, or Spanish. French and Spanish language versions also follow TG-263 guidelines to enable easy mapping of structures between languages. The framework of DICOM Template Maker using AirTable enables the quick integration of TG-263 updates and new languages. The inclusion of other languages will be an ongoing effort within both TG-263 and DICOM Template Maker, along with field testing at several clinical sites.

# Conclusion

We have created open-source software that may drastically reduce the burden of creating and maintaining TPS structure templates and facilitates the adoption of TG-263 standardized nomenclature. This program allows clinics to quickly create templates in English, Spanish, or French and allows for customization of laterality and color schemes. Both patient-specific DICOM RT Structure files and Varian XML template files can be easily created.

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