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

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# Abstract

Consistency of nomenclature within radiation oncology is becoming increasingly important as big data efforts and data sharing become more prevalent. Automation of radiation oncology workflows depends on standardized contour nomenclature which enables retrospective data analysis and outcomes research. Recommendations for standardized nomenclature of structure and dosimetric data have been published in the American Association of Physicists in Medicine (AAPM) report from Task Group 263 titled ‘Standardizing Nomenclatures in Radiation Oncology’. 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. To reduce practice expense and facilitate TG-263 implementation, we developed a program that allows users to create TG-263-compliant structure templates in English, Spanish, or French. This 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; this ensures users have continuous access to up-to-date structures. This tool has been evaluated for ease of use and designed to allow users multiple pathways for the creation of user-defined templates. 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 (‘Brian’ instead of ‘Brain’), and variable (i.e. ‘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 survey 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 study was to lower the barrier to adoption of TG-263 nomenclature and disseminate 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 using the DICOM standard. Our tool can monitor folders and automatically add patient-specific structure sets, or create loadable RT structure/.xml templates.

# Methods and Results

The 53 pre-made structure templates are arranged by treated organ and include all sites based on an American Society for Radiation Oncology (ASTRO) consensus paper2. Templates were further customized with common target structures for each site.

An attempt was made to standardize coloration across treatment planning systems (e.g., Pinnacle, Raystation and Eclipse). 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 book3.

The program was written (BMA) using C#3 and 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. DICOM files are manipulated via the publicly available FellowOakDicom package4, and a C# wrapper for the ITK coding package, SimpleITK5. The framework for creating RT Structure files in Python has been previously reported6. 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.

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

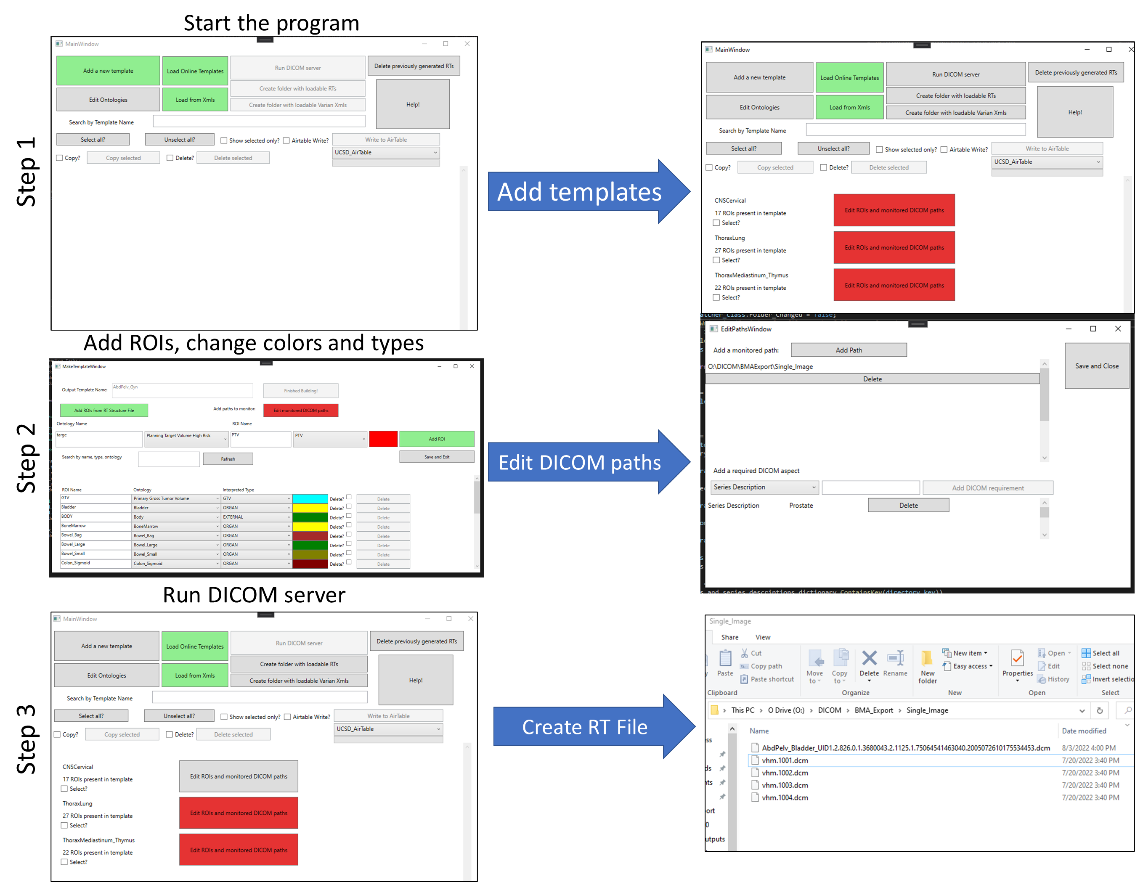


Figure 1: General workflow of the program

## Step 1: Creation of Template

The program comes with a library of over 50 premade structure set templates designed for specific anatomical sites and clinical indications which can be loaded from our online spreadsheet. The online spreadsheet containing the raw data for all templates may be found at the following link: [bit.ly/StructureNaming](https://airtable.com/shrojSoXyfnHHKzJV). Changes to the online spreadsheet are updated and viewable in the program in real time. A static version of these templates at the time of publication is displayed in Table S1. Congruent with the ASTRO consensus paper2, 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 has preset OAR and target coloration, but color selections are also customizable. 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., Anal\_Canal, Bowel\_Bag). Users can import all structures by Primary or Reverse TG-263 nomenclature, if users wish to override the default setting. The program defaults to displaying laterality after the name of the structure (e.g. Breast\_L), but can be adjusted to display laterality first.

Brachytherapy templates including breast, endobronchial, gynecological, ocular, prostate, and skin templates are available, created with guidance from the brachytherapy subgroup within the TG-263 update committee7.

If the user has pre-existing templates in Varian .xml file format, they can be easily added to the program for future maintenance.

Individual ROIs are linked across treatment sites, so changes in nomenclature can easily be transferred to all structure set templates via a single change when a clinic-specific online spreadsheet is used. For more information, refer to our Github page.

## Step 2: Manipulation of ROIs

After a template has been created, ROIs are listed alphabetically grouped within their Interpreted Type8 (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.8 ROIs can be added via the program interface or selection of an existing RT Structure file with the ‘Add ROIs from RT Structure File’ button. Users might find it easier to import a series of ROIs from a previously exported RT Structure than to add them manually, as ontologies will automatically be created after reading the RT Structure file.

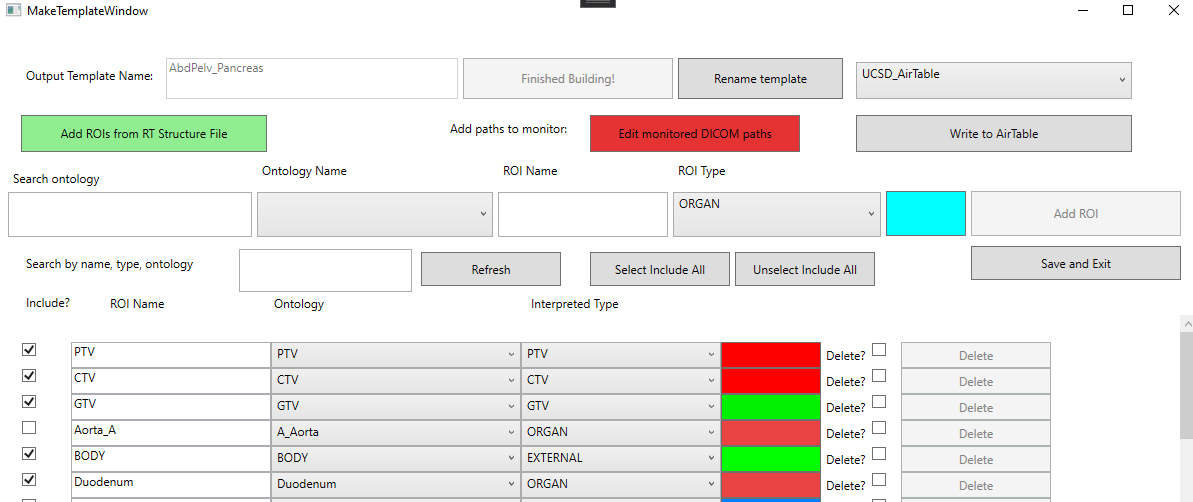


Figure : Edit within the template window for ‘AbdPelv\_Pancreas’. The user can add targets, and see the presented ROIs listed below. Here, the ‘PTV’ is about to be added.

## 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. If the DICOM images are consistently placed within the same folder, the users can also define values that need to be present within the Series Description or Study Description before an RT Structure file is created. 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 Browser8. The Interpreted Type can be changed at any time within the template software, as shown in Figure 3.

Graphical user interface, application

Description automatically generated

Figure : Example of a template named ‘TG263\_Breast’. The user has the ability to change the interpreted type of a region of interest after creation. Likewise, the color, name, and ontology can be changed.

### 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., ‘50801’. 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 code9.

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 online10.

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)11 is defined as having a code value of 5080112. An example of the ontology for ‘Brain’ is shown in Figure 4.

Graphical user interface, diagram

Description automatically generated

Figure : Demonstration of ontology for ‘Brain’. Based on the FMA model, the ‘Brain’ structure has a code value of 50801.12

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 using TG-263 standardized nomenclature. There have been previous reports of software tools used to homologate sets of previously treated structures to support retrospective data analysis13. There have also been tools created within the TPS to verify that structures names comply with TG-26314. With Open RT Structures, clinics can ensure that clinical standards are met, enable automated workflows, and facilitate data pooling and outcomes research.

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.

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. We believe this simple tool can be of significant benefit to clinics that do not have ready access to templates within their treatment planning systems or do not have sufficient resources to invest in new template creation.

# References

1. Mayo CS, Moran JM, Bosch W, et al. American Association of Physicists in Medicine Task Group 263: Standardizing Nomenclatures in Radiation Oncology. *Int J Radiat Oncol Biol Phys*. 2018;100(4):1057-1066. doi:10.1016/J.IJROBP.2017.12.013

2. Wright JL, Yom SS, Awan MJ, et al. Standardizing Normal Tissue Contouring for Radiation Therapy Treatment Planning: An ASTRO Consensus Paper. *Pract Radiat Oncol*. 2019;9(2):65-72. doi:10.1016/J.PRRO.2018.12.003

3. Chao CKS, Apisarnthanarax S. *Practical Essentials of Intensity Modulated Radiation Therapy*. 2nd ed. (Ozyigit G, Chao KSC, Apisarnthanarax S, eds.). Lippincott Williams & Wilkins; 2005.

4. 2013 MC. C# .NET 4.8.1. Accessed January 31, 2023. https://dotnet.microsoft.com/en-us/download/dotnet-framework

5. fo-dicom/fo-dicom: Fellow Oak DICOM for .NET, .NET Core, Universal Windows, Android, iOS, Mono and Unity. Accessed July 22, 2022. https://github.com/fo-dicom/fo-dicom

6. Beare R, Lowekamp B, Yaniv Z. Image segmentation, registration and characterization in R with simpleITK. *J Stat Softw*. 2018;86(1):1-35. doi:10.18637/jss.v086.i08

7. Anderson BM, Wahid KA, Brock KK. Simple Python Module for Conversions between DICOM Images and Radiation Therapy Structures, Masks, and Prediction Arrays. *Pract Radiat Oncol*. Published online February 17, 2021. doi:10.1016/j.prro.2021.02.003

8. AAPM Committee Tree - Working Group on Brachytherapy Clinical Applications (WGBCA). Accessed March 2, 2023. https://www.aapm.org/org/structure/default.asp?committee\_code=WGBCA

9. RT ROI Interpreted Type Attribute – DICOM Standard Browser. Accessed February 9, 2023. https://dicom.innolitics.com/ciods/rt-structure-set/rt-roi-observations/30060080/300600a4

10. RT ROI Identification Code Sequence Attribute – DICOM Standard Browser. Accessed February 9, 2023. https://dicom.innolitics.com/ciods/rt-structure-set/rt-roi-observations/30060080/30060086

11. 8 Coding Schemes. Accessed February 9, 2023. https://dicom.nema.org/medical/dicom/current/output/chtml/part16/chapter\_8.html

12. Foundational Model of Anatomy - Summary | NCBO BioPortal. Accessed July 22, 2022. https://bioportal.bioontology.org/ontologies/FMA?p=summary

13. onttk fma. Accessed February 9, 2023. http://fma.si.washington.edu/browser/#/?iri=http%3A%2F%2Fpurl.org%2Fsig%2Font%2Ffma%2Ffma50801

14. Schuler T, Kipritidis J, Eade T, et al. Big Data Readiness in Radiation Oncology: An Efficient Approach for Relabeling Radiation Therapy Structures With Their TG-263 Standard Name in Real-World Data Sets. *Adv Radiat Oncol*. 2018;4(1):191-200. doi:10.1016/J.ADRO.2018.09.013

15. Cardan RA, Covington EL, Popple RA. Technical Note: An open source solution for improving TG-263 compliance. *J Appl Clin Med Phys*. 2019;20(9):163-165. doi:10.1002/ACM2.12701