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Open RT Structures: A Solution for TG-263 Accessibility

--Manuscript Draft--

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Corresponding Author:	Brian Mark Anderson, Ph.D. San Diego, CA UNITED STATES
First Author:	Brian Mark Anderson, Ph.D.
Order of Authors:	Brian Mark Anderson, Ph.D.
	Laura Padilla, PhD
	Jeffrey M. Ryckman, MD
	Elizabeth Covington, PhD
	David S. Hong, MD
	Kaley Woods, PhD
	Matthew S Katz, MD
	Raed Zuhour, MD
	Chris Estes, MD
	Kevin L. Moore, PhD
	Casey Bojechko, PhD
Abstract:	Background: Consistency of nomenclature within radiation oncology is increasingly important as big data efforts and data sharing become more feasible. 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: 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 brachytherapy templates. An informal consensus on OAR and target coloration was also achieved, though color selections are fully customizable within the program. Results: The resulting 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 to easily create and name DICOM-RT structures sets that are TG-263-compliant for all planning systems utilizing the DICOM standard. The program and source code are publicly available via GitHub, encouraging feedback from community users for improvement and guide further development.

Editors' comments:

The authors have improved the manuscript and the figures. There is still a need to edit the language of the manuscript and to improve clarity. The reviewers pointed out specific sentences and paragraphs and made useful suggestion that we encourage the authors to follow.

Thank you, we believe that we have addressed the recommendations presented by the reviewers.

Reviewer 1 Comments to Author: Open RT Structures: A Scalable Solution for TG-263 Accessibility

General comments:
Thank you for the opportunity to read this paper. The submission is interesting and can potentially add significant value to the radiation oncology community.

1. Please comment on the importance of this question and the originality of the findings for the readers of Red Journal.

The paper questions how standardized naming conventions can be efficiently and consistently obtained and used in radiation treatment planning. While the extent of this problem and the repercussions of mislabeled structures is not well described, the problem is significant enough to warrant an AAPM Task Group on the problem.

Thank you for the comment. We have elaborated on the importance of properly labeled structures as noted below. *"The proper labeling of these structures is important in the evaluation of generated treatment plans, when comparing with plans from other individuals/institutions, and when curating large data sets from multiple institutions. In large groups, incorrectly labeled data would be extremely difficult to identify, and so proper and consistent labeling is exceedingly important."*

The originality of the work stems from a few things. First, the authors provide open-source code to create these structures. It needs to be noted that not every clinic will have the skills necessary to deploy this in their clinic. Second, the structures abide by standardized structure nomenclature and provide DICOM RT Structure Set data. Finally, although less clear to the reader, the datasets generated are theoretically vendor agnostic as they would, at the very least, adopt DICOM (SS) standards.

Thank you for the comment. To the note that every clinic might lack the skills to deploy this, we have released a series of YouTube videos explaining every process: from installation, to changing templates in Eclipse, or running it as a standalone server.

2. Please comment on the appropriateness of the study approach and experimental design.

The submission is not a study, and thus details for experimental design and study approach are unnecessary; however, there are still areas where there is a mix-up between 'results' and 'methods' as this reviewer would prefer. As it stands, the 'story' jumps between methods and results. This needs to be a bit clearer in the text. This reviewer encourages the authors to clearly define what was done in the methods and the findings of that work in the results (how to use the code).

Thank you for the comment, we agree that the storyline does jump around. We have rewritten and clarified the Methods section to better explain the overall purpose and flow of the program.

4. Please comment on the analysis and interpretations of the data. Do you agree with the proposed conclusions?

Again, this revision does a nice job addressing concerns raised by reviewers, particularly by including a high-level figure. However, a number of changes to the document should be made to make it more readable and highlight the shortcomings in addition to the issues raised above.

5. Please comment on weaknesses or limitations of the study. (Examples are: selection biases, sample size limitations, missing data.)

The range of usefulness challenges is now addressed, and it now may be left to readers to judge the quality of the tool created.

6. Please comment on the writing and organization of the paper. Is the paper overly wordy? Is the English language acceptable?

The paper remains well-written with few (if any) grammatical issues, but some of the text sometimes reads a bit loose and informal.

Thank you for the comment. We have gone throughout the manuscript to try and remove some of the more informal language.

The sentence including *headache* has been rephrased to be

"This plugin was coded to alleviate tedious manual work in exporting Varian templates to the program."

We have removed the word 'dummy patient' in favor a more detailed explanation.

"If the user instead wishes to create an anonymous CT and load RT Structure files, to later 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."

"While adoption of the standard nomenclature has popular support, in a recent survey2 conducted by the TG-263U1 Task Group, the majority of respondents had not yet adopted the standardized nomenclature. From this survey, the largest difficulties were lack of time/resources to create new templates, and/or difficulty with retraining staff if templates are not available."

7. Please comment on the necessity and clarity of the figures and tables. Can they stand independently of the text?

Again Figure 2 is not helpful with low-resolution text.

We have recreated Figure 2 with higher resolution text.

8. Please comment on any need for a formal statistical review.
Na

Specific comments

Title: Again, 'scalability' is loosely defined and, in this reviewer's opinion, inaccurate.
The authors state : "Thank you. We hope this addition to the introduction will help to clarify: "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 tool can monitor folders and automatically add patient-specific structure sets, or create loadable RT structure/.xml templates and is a scalable solution focused on compatibility with all Treatment Planning Systems (TPS) utilizing the DICOM standard." If this is not agreeable, we will gladly remove "scalable solution" from the title of the manuscript. "

When one thinks of 'scalability', the first thought is that the software is able to accommodate things like workload or performance handling or resource utilization, handle various volumes of data, accommodating new features or functions without dramatic changes to the major components of the software, or allow the system to expand easily to accommodate other functions. Only one or maybe two aspect of 'scalability' in this work is presented: utilizing and processing different structure templates based on patient treatment protocols and accommodating different sizes of datasets. We do not know, for example, if the system can be easily expanded for other functions or accommodate different datatypes. I do not think scalability is the correct term and could misrepresent the work.

We have removed 'scalability' from the title, it now reads "Open RT Structures: A Solution for TG-263 Accessibility", we have also removed the word 'scalable' from the paper.

Keywords: na

Abstract:
L25: need to clarify better what was being done in relation to brachytherapy (templates for HDR or LDR? various sites?) Details are needed or should be removed in the abstract. What working group(s)?

Thank you for the comment, we rephrased the section in the abstract and added the following clarification

"Brachytherapy templates were created with the guidance of the TG-263 brachytherapy members who share membership on the AAPM Brachytherapy Subcommittee and Working Group on Brachytherapy Clinical Applications L33: does the tool 'create' structures and rename them? Clarity needed."

Thank you for the comment. To clarify this in the abstract we have changed the phrasing to be

"We have developed a tool which runs on any Windows system to easily create ***and name*** *DICOM-RT structures sets that are TG-263-compliant for all planning systems utilizing the DICOM standard"*

L37: (I don't see a need to include the last sentence since you're already providing a public forum for the software)

Thank you for the comment, we have reduced the last sentence to better flow and remove unnecessary words.

"The program and source code are publicly available via GitHub, encouraging feedback from community users for improvement and guide further development."

Introduction:
L10: is it more accurate to say DICOM-RT standards specify structure formats? DICOM is the global phrase used but generally refers to images.

Thank you, to avoid confusion we have added the specifier 'RT' to DICOM-RT.
L33: strictly speaking, you are not disseminating standardization, you are providing a means for ensuring structures have consistent nomenclature as per TG-263.

Thank you, we have changed this statement to more accurately reflect what the program is capable of.

Our aim in this work is to lower the barrier to adoption of TG-263 nomenclature in English, Spanish, or French by providing a means of standardization to facilitate data sharing and consistency

L37: please consider writing out what xml format is (eXtensible Markup Language) before using its acronym.

Thank you, we have added this to the manuscript

"update Variant eXtensible Markup Language (.xml) templates."

Methods and Results:
While I commend the authors for presenting the work, the current layout of the Methods and Results remains awkward, inherently because of the nature of the material presented. I recommend having a detailed Methods section that describes exactly what was done and why (e.g., Figure 1) and having a separate Results section to describe the working interface and provide a real-world example (Figure 2). Information on how fast it takes can be included in the results. The authors discussed using brachytherapy templates: it would be valuable to the reader to see an example of this in the results.

Thank you for the comment, we have split up Methods and made extensive changes.

Stylistically, consider rephrasing sentences like "We wanted to make..." into something more descriptive, such as "The software was designed to ensure the model was compatible with different manufacturers and versions of treatment planning software."

Thank you for the comment, we have adjusted the manuscript accordingly.

P9, L54: 'headache' is not a good word. Please clearly identify what the concern/challenge is.

Thank you for the feedback. We have rephrased this sentence to be more formal and express the challenge associated with this action.

"This plugin was coded to alleviate tedious manual work in exporting Varian templates to the program."

P10, L54: consider replacing 'dummy' with something more descriptive. You are creating a patient dataset to permit users to create multiple structure templates that can be exported for treatment planning templates.
Thank you for the comment, we have changed the sentence to better express why you might want to import this anonymous CT.

"If the user instead wishes to create an anonymous CT and load RT Structure files, to later 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."

Discussion:
P11: L40: rephrase to state what the program does more concisely: "... the program never..." should be replaced with something along the lines of "... the software is coded to ....? check what? etc.)

Thank you for the comment, we agree this is confusing. We have rephrased this section to better clarify the risk of continual recreation of DICOM RT structure files.

"The largest risk that we could foresee is that the program continually updates its 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 is coded to check if each template RT Structure file already exists, and so prevents a continuous recreation of the same set. As an additional safety measure, the software is coded to only create new RT structure files and will not open or edit an already existing RT Structure file, and so presents no risk to existing work flows present by the user."

References: na

Figures:
Figure 1: great!
Figure 2: I still believe the text is too small here.\

Thank you, we have expanded the size of the figure to better allow the reader to view the text.
Tables: na

Reviewer 2 Comments to Author: 1. Please comment on the importance of this question and originality of the findings for the readers of Red Journal.

The software application is original. Approaches to simplify adoption of standards into clinical practice is very important for creating large scale data sets. The premise of the present manuscript is that implementation of the application they developed requires less effort than manual approaches to implement TG-263 standardizations, and subsequent updates to it, into clinical practice. Information supporting that point is lacking.
Thank you for the comment.

2. Please comment on the appropriateness of the study approach and experimental design. (Examples: retrospective or prospective cohort, case-control, cross-sectional, ecological, case series; clinical trial or secondary analysis of clinical trial; registry-based; critical review; metaanalysis or systematic review; experimental, based on cell cultures, animal models, physical models, or method/technique development.)
This is a description of a software application.

3. Please comment on the appropriateness and reproducibility of the data collection and experimental techniques. (If applicable, does the study comply with the CONSORT, PRISMA and/or REMARK statements? If applicable, was the study IRB-approved or registered on clinicaltrials.gov?
No collected data was evident.

4. Please comment on the analysis and interpretations of the data. Do you agree with the proposed conclusions? No the information presented does not support the assertion that the application will drastically reduce effort. That may be true, but they have omitted data that would help them to support that point. They have also not clarified how this remains directly linked to TG-263 as updates proceed over time, so that it is maintained as the standard. See response at item #6
Thank you for the comment. We apologize for not stressing this enough, and have added the following to better express that this project is endorsed by members of TG-263, and will be maintained by them as updates progress.

"maintained by members of the TG-263U1 Task Group which ensures continuous access to up-to-date templates"

"An online spreadsheet, Airtable[6], was utilized to house all templates in an evergreen fashion, which will be continually updated by members of TG-263 as recommendations continue to develop over time."

5. Please comment on weaknesses or limitations of the study. (Examples are: selection biases, sample size limitations, missing data.)
Lack of detail on implementation, see response at item #6

6. Please comment on the writing and organization of the paper. Is the paper overly wordy? Is the English language acceptable?

The paper continues to have issues with clarity of writing. Reviewer #1 had specifically identified several which remain uncorrected in the second revision. The article needs to be proof read, avoiding ambiguous or colloquial language and correcting typos.

Thank you for the comment. We agree that the language was too colloquial and have worked hard to correct the manuscript in this regard.

"An online spreadsheet, Airtable6, was utilized to house all templates in an evergreen fashion." What is an "evergreen", why is it relevant?

Thank you for the comment. We have clarified that 'evergreen' in this form means continually maintained by members of the 263 Task Group as ROI recommendations evolve over time.

"An online spreadsheet, Airtable[6], was utilized to house all templates in an evergreen fashion, which will be continually updated by members of TG-263 as recommendations continue to develop over time."

"Target color selection was based on preferences at UCSF (Dr. Sue Yom), MDACC (Dr. Anna Lee), and Michigan (Dr. Charles Mayo), reflecting the Clifford Chao's IMRT book." Reformt the sentence, making less colloquial and shifting citations to individuals into the references. e.g. private communication, or adding an acknowledgement section where the individuals are cited for their contribution of information.

Thank you for the comment, we have addressed this into the acknowledgements section and references, removing the names.

"Target color selection was based on discussions with physicists and physicians at UCSF, MDACC, and Michigan, and reflect the available literature[5]. Due to the informal nature of color selection and difficulty achieving consensus, colors remain fully customizable within the program."

"The program was written (BMA) using C# , ensuring it's computability with windows systems." What is BMA?

Thank you for the comment. (BMA) refers to the initials of the programmer, these have been removed.

"computability" do you mean "compatibility", even so why is the phrase needed? Further along in the paragraph the author is suddenly discussing Python and DICOM. The paragraph seems to be attempting to condense in a much longer technical discussion into a single paragraph, at the cost of clarity.

Thank you for the comment, we have broken this section up into what we feel are more appropriate sections of the manuscript.

"The subsequent sections expand on each step of the program's workflow. A series of videos explaining each step of the program, including installation, is available on YouTube. The link to these videos is found at the bottom of the program GitHub page: anon for review and are continually updated to demonstrate current features and performance of the program."

Creation of DICOM-RT files

"DICOM-RT files are created 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, and a similar process is used here."

The online structure template has FMAID codes, it does not have SNOMED codes. This was a specific request of reviewer #2, which the responses said had been met.

Thank you for the comment. We apologize for the confusion, this request has been met. We believe the reviewer is referring to the column 'FMAID' being present. This column will continue to remain for those users who wish to continue using FMAID. However, this is another column called 'SchemeCode' and 'Scheme', specifying both 'SCT' and the associated code number. We apologize for any confusion this has caused.

The source for structure names and mapping to coding systems (SNOMED, FMAID) needs to be the TG-263 standards group AAPM SC-263. This includes updates, e.g. TG-263-U1. It is not clear how the application pulls directly from the standards created by that group, or how updates are incorporated. Does this not imply that the Airtable effectively becomes the standard source of information?

Thank you for these comments. Everything within the structure name and mapping is AAPM SC-263 and 263-U1. We ensured everything programmed within the table is directly from AAPM SC-263.

Why aren't the templates more simply provided as a downloadable PDF or excel document? Additionally, why are they not in a format that can be imported directly into the treatment planning systems used. If anyone can make changes to the spread sheet at any time, then how does this work as a reference? How is direct linkage to TG-263 and updates maintained, so that it is not promoted as an alternate standard?

Thank you for the comment. We agree that it would be very useful to have a format which is directly importable into TPS used. Unfortunately, what is required for this varies based on TPS: Eclipse can import an anonymous CT and save the structure templates, but only the latest version of Raystation enables importation of 'empty' structures. Similar with Pinnacle. This is why we created the ability to make RT-Structures on incoming patients in a 'server' form.

We have added the following statement as clarification that only the members of TG-263 are able to make edits to the reference AirTable.

"While the Airtable can be downloaded by anyone, only specific members of the working group can make changes to the spreadsheet."

The manuscript attempts to provide a technical discussion of the application developed and how to implement it in a clinic. The current writing is difficult to follow. Hand-offs and dependencies between the technologies them are not clear.

We agree that this is not clear. We have worked hard to clarify this in a manner that we hope makes things more clear.

The key piece of evidence for ability to implement it would be discussion of the range of clinics which had implemented the software. This is only given passing mention. This was requested by Reviewer #2. The present treatment still has not provided detail on number of clinics implementing the application, challenges faced in implementing, gains and reduction of burden in creating and maintaining TPS structure templates in using it, etc. The most that the reader gets is "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. "

We piloted this informally at five institutions with different TPS to ensure compatibility with various TPS. We have also added the following text:

"Early rollout required hands on training with video conferences to demonstrate how to use the software. Therefore, we had to create videos for other physicists to watch to learn how to use the software and hope this paper serves as a narrative review of its capabilities."

Note also that TPSs utilize the DICOM standard for input of images, that does not mean that functionality extends to import of templates for structures.

Thank you for the comment. We agree, this was the leading factor in our decision to include a patient-specific option, for TPS which do not allow blank templates, and unfortunately makes it difficult to create a 'format which is imported directly into the TPS' for all TPS, as requested above.

The opening sentence in the Conclusion, highlights the challenge for this paper with writing that mixes evidence with aspiration.
"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."

Thank you for the comment, please see the closing comments below.

Ease of installation and use are key to ability for the application to reduce effort. No data is presented to assess that point or the assertion of "drastically". In the sentence "may" further highlights what we don't know. We do not know how many people used the software in this testing, who they were (physicist, dosimetrist, physician, …) , or what specific skills were needed to set up the application or how many and what types of templates they successfully implemented using it. Setting up Dicom servers and applications reaching out from behind institutional firewalls to internet based applications, such as Airtable, is not uniformly easy dependent upon the policies of institutional IT groups. What was the experience in multiple institutions with implementation? Airtable is not a standard software application and is not under the control of the authors. How does their application function if Airtable is not available? Because the application is dependent on at least four different technologies used in concert (Airtable, their C# application, their Python scripts, DICOM server) understanding challenges and risks in implementing is relevant.

Thank you for the comment, and we apologize for the confusion. We have added further clarification within the manuscript of the following: 1) Python scripts are not used, it is simply that the author of this program has written a similar one in Python, which the DICOM manipulation is based on. 2) The DICOM server is locally run, not a cloud server. 3) Airtable is like a Google Excel sheet, the user has no obligation to use it if they do not desire. 4) C# is one of the base programming systems for Windows, this simply indicates that the program is designed to run on Windows computers.
We have clarified to say physicists or physicians piloted the importing of the generated structure sets within their TPS. In our experience utilizing this software at institutions there were not issues. But if issues do arise, the entirety of the AirTable can be downloaded to an excel sheet from a non-institutional computer. We can add a video expressly showing how to manually do this, if desired.
The authors are to be commended for the application that they have developed. It has promise, but the present manuscript leaves important details unclear or unanswered. It is my hope that the authors will revise their manuscript. I strongly encourage them to have the manuscript proof read, by at least two IJORBP readers (e.g. physician and physicist) who are not part of their work.

We do believe this automated structure set generator reduces burden and facilitates adoption of TG-263 standardized nomenclature.

This program can quickly generate all 53 templates in Table S1 in under a minute, which is much faster than any human could build these ASTRO-endorsed site-specific templates.

We hope that rewriting the paper in a more narrative tone helps to answer some of these very important discussion topics.

7. Please comment on the necessity and clarity of the figures and tables. Can they stand independently of the text?
Yes figures are acceptable

8. Please comment on any need for formal statistical review.
Statistical review is not needed

Title Page (WITH Author Details)

Open RT Structures: A Solution for TG-263 Accessibility

Brian M. Anderson PhD[1], Laura Padilla PhD[1], Jeffrey M. Ryckman MD, MSMP[2], Elizabeth Covington PhD[3], David S. Hong MD[4], Kaley Woods PhD[4], Matthew S Katz, MD[5], Raed Zuhour, MD[6], Chris Estes, MD[7], Kevin L. Moore PhD[1], Casey Bojechko PhD[1]

[1]Department of Radiation Medicine and Applied Sciences, University of California San Diego, San Diego, California
[2]Department of Radiation Oncology, West Virginia University Medicine Camden Clark Medical Center, Parkersburg, WV
[3]University of Michigan, Ann Arbor, Michigan
[4]University of Southern California, Los Angeles, California
[5]Radiation Oncology Associates PA, Lowell, Massachusetts
[6]Department of Radiation Oncology, University Hospitals Seidman Cancer Center, Case Western Reserve University, Cleveland, Ohio
[7]Mercy Hospital, Springfield, Missouri

Corresponding Author: Brian Mark Anderson, b5anderson@ucsd.edu

Author Responsible for Statistical Analysis: Brian Mark Anderson, b5anderson@ucsd.edu

Disclosures: Brian Anderson has no disclosures. Casey Bojechko has no disclosures. Elizabeth Covington has no disclosures. Matthew Katz has stock in Pfizer, Bavarian Nordic, Dr. Reddy's Laboratories, Quest Diagnostics, Healthcare Services Group, Moderna. Kevin Moore has grants by Varian, royalties by Varian, consulting fees by Varian, honoraria by Varian, stock in Varian. Laura Padilla has no disclosures. Jeffrey Ryckman has no disclosures. Kaley Woods has no disclosures. Chris Estes has stock in Novocure. Raed Zuhour has no disclosures. David Hong has no disclosures.

Funding: None

Research data are available at github.com/brianmanderson/DicomTemplateMakerCSharp

Abstract

~~Purpose~~Background: Consistency of nomenclature within radiation oncology is increasingly important as big data efforts and data sharing become more ~~prevalent~~feasible. 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**~~~~.~~

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Results: The resulting 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.**

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Conclusions: We have developed a tool~~ which runs on any Windows system~~ to easily create and name DICOM-RT structures sets that are TG-263-compliant ~~structure template libraries~~ for all planning systems utilizing the DICOM standard. The program and source code are publicly available via GitHub, encouraging ~~. F~~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 treatment volumes (TVs) and organs at risk (OARs). Proper labeling is important in the evaluation of generated treatment plans, both for comparing plans from other individuals/institutions, and for curating large data sets from multiple institutions. With large datasets, incorrectly labels are extremely difficult to identify, and so proper and consistent labeling is exceedingly important. Standardized nomenclature also enables automated structure segmentation and treatment planning workflows.

While Digital Imaging and Communications in Medicine radiation therapy (DICOM-RT) standards specify data formats required to electronically communicate information about ~~these~~ the structures~~structures~~, users are individually responsible for creating and ~~naming sets of structures for each treatment plan in their~~naming these in the treatment planning systems (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 OARs[1]~~.

While many TPS provide the option to ~~of~~ maintain~~ing~~ templates~~ libraries~~ (groupings of specific treatment volumes and OARs), ~~to let users load a specific set of ROIs for a particular treatment,~~ these ~~libraries~~templates are often manually created and maintained and not universally shared between institutions. Therefor, the creation process can~~, making the process~~ be relatively time-intensive~~, both for their initial creation and subsequent updates~~, and updates~~, and~~ remain vulnerable to the issues listed above.

The American Association of Physicists in Medicine (AAPM) has published 'Standardizing Nomenclatures in Radiation Oncology'[1], a report from Task Group 263 (TG-263) in order to create a standard nomenclature for both treatment volumes and OARs. ~~ROIs and dosimetric data.~~ While adoption of the standard nomenclature has popular support, in ~~its implementation is time-consuming and resource-intensive. In~~ a recent survey[2] conducted by the TG-263U1 Task Group, the majority of respondents had not yet adopted the standardized nomenclature. From this survey~~, indicating that~~ the largest ~~hurdles~~ difficulties were lack of time/resources to create new templates, and/or difficulty with retraining staff if templates were not available.

Our aim in this work ~~was~~ is to lower the barrier to adopt~~ion~~ standardized ~~of~~ TG-263 nomenclature ~~in English, Spanish, or French by disseminating standardization that may~~to facilitate data sharing and consistency. This includes tools to create patient-specific structure sets, import RT structure sets on an included anonymized patient to create templates, or update Varian eXtensible Markup Language (.xml) internal templates in English, Spanish, or French. The program presented (written using C#[7])~~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~~ runs on any Windows system~~presents a scalable solution focused~~ and ensures ~~on~~ compatibility with all ~~Treatment Planning Systems (~~TPS~~)~~ by utilizing the DICOM-RT standard.

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Methods ~~and Results~~

To standardize the recommended targets and OARs, a subsection of the TG-263 group created ~~The~~ 53 pre-made structure templates for external beam and brachytherapy sites. These templates ~~are arranged by treated organ and include treatment sites based~~are based on an American Society for Radiation Oncology (ASTRO) consensus paper[3]. Templates were further customized with common targets and relevant OARs ~~(e.g., Spleen for anatomically appropriate sites such as gastroesophageal junction or stomach)~~. Additional subsite-specific templates (e.g., partial breast, whole breast, intact prostate, postoperative prostate, etc.) and brachytherapy templates were created. Brachytherapy templates were created with the guidance of the TG-263 brachytherapy members who share membership on the AAPM Brachytherapy Subcommittee and Working Group on Brachytherapy Clinical Applications. Common prefixes of template names include “Targets” (including 1 dose level, 2 dose levels, and 3 dose levels, and 4 dose level templates), “AbdPelv” (i.e., Abdomen and Pelvis primary disease sites), “Brachy” (i.e., Brachytherapy), “CNS” (Central Nervous System), “Extremities”, “H&N” (Head and Neck), and “Thorax”. ~~Table~~Supplementary Table 1 contains ~~-~~ an excel file of the site-specific structures as of the time of publications, although it is recommended that the user refer to the online AirTable in case of updates~~S1 provides examples of all 53 provided site-specific templates at the time of publication.~~.

An online spreadsheet, Airtable[6], was utilized to house all templates in an evergreen fashion, which will be continually updated by members of TG-263 as recommendations continue to develop over time. Changes to the online spreadsheet are updated and viewable ~~in~~by the program in real time. While the Airtable can be downloaded by anyone, only specific members of the working group with administrative privileges can make changes to the spreadsheet. The online spreadsheet containing the raw data for all templates may be found at the following link: bit.ly/StructureNaming. Congruent with the ASTRO consensus paper[3], there are two ~~types~~ categories 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.~~

An informal consensus on OAR and target coloration was achieved. Twenty-four colors were utilized in total (Supplementary Figure 1~~2~~), loosely based on the 24 default colors available within Pinnacle. Target color selection (Supplementary Figure 2) was based on discussions with physicists and physicians at UCSF, MDACC, and Michigan, and reflects the available literature[5]. Due to the informal nature of color selection and difficulty achieving consensus, colors remain fully customizable within the program.

The program workflow is broken down into three major steps, as illustrated in Figure 1: (1) the population of templates (templates hereafter refers to a collection of structures: being ROIs or target volumes), (2) manipulation of ROIs within those templates, and (3) running a DICOM patient-specific server, and/or creating loadable DICOM/XML files. Resulting output is compatible with all treatment planning systems which utilize the DICOM-RT standard.

The program was piloted by physicians and physicists at multiple sites with Eclipse v15.6 ~~(JR, KW, DH)~~, Pinnacle v16.2.1 ~~(RZ)~~ and Raystation[4] v12.1 ~~(CE)~~ to ensure compatibility across multiple TPS. Feedback was collected and used for program evaluation and improvement, see below.

The language of the structures within each ~~-DICOM files are manipulated via the publicly available FellowOakDicom package[8], and a C# wrapper for the ITK coding package, SimpleITK[9]. The framework for creating RT Structure files in Python has been previously reported[10]. Videos for the installation and running of the program can be found linked at the bottom of the publicly available GitHub page: **anon for review**, 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 can be selected as English, Spanish, or French, with English as default if Spanish or French translations are not available. Per TG-263, structures can be referred to as ‘primary’ (e.g., ‘Canal_Anal’) or ‘reverse’ order (e.g., ‘Anal_Canal’). After discussion with the piloting physicians and physicists~~By default~~, the program orders the structures using a combination of primary and reverse orders to best~~, as reverse order~~ reflect~~s~~ natural language ~~more clearly~~ for certain structures (e.g., ~~Reverse order of~~ Anal_Canal, Bowel_Bag~~, Mandible_Bone, and Submand_Glnd reflects natural language more than Primary order of Canal_Anal, Bag_Bowel, Bone_Mandible or Glnd_Submand~~) along with~~.~~ ~~O~~organ-first naming ~~was preferred by default~~, so that laterality did not dictate sorting order withing TPS (e.g., "Lung_R” ~~Primary Order was~~ favored over “R_Lung” ~~Reverse Order~~). However, u~~U~~sers can choose to import ~~all~~ individual structures in either primary or reverse order according to their institutional preference.

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~~The subsequent sections expand on each step of the program’s workflow. A series of videos explaining each step of the program is available on YouTube, linked through our GitHub page.~~Results / Program Workflow

Ultimately, there are two main routes to use this program in practice. Some clinics may wish to utilize the program to create patient-specific structure sets that appears in a monitored folder. Other clinics may prefer to utilize the TPS to assign structure sets to patients, as the program may be used to automatically build over 50 site-specific structure sets which can be directly imported (and saved) to their TPS in a few clicks.

Program Piloting

The program was successfully piloted at five institutions and enabled template creation using the Eclipse, Raystation, and Pinnacle systems. Users reported installation and setup times of less than ten minutes after watching the provided video tutorials, with no additional assistance required. To avoid institutional IT restrictions, most users downloaded the program onto non-hospital devices then transferred the created template files. Minor discrepancies in structure settings and colors were identified and corrected during this testing phase, and suggested improvements were implemented.

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Step 1: Creation of Template

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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 from the online Airtables, 2) creating a new template from a previous RT structure file or Varian xml file or 3) m~~M~~anual 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.~~

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~~ coded to ~~remove~~ alleviate tedious manual work in~~any headache of~~ exporting ~~templates from the~~ Varian templates ~~system~~ to ~~our~~ the program or can be used to populate the program from these Varian templates. ~~Lastly, the user may create a new template, by adding ROIs and selecting new colors manually.~~

Step 2: ~~Manipulation~~ Manipulation of~~of~~ ROIs

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After ~~a~~ template(s) has~~s~~ been built~~created~~, ROIs are listed alphabetically grouped within their Interpreted Type[11] (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, per ~~(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 S~~s~~tructure files into a single template. ~~Furthermore, adding RT structures automatically populates the ontologies list.~~

Step 3a: Running as a server: Setting DICOM paths and requirements~~, and/or creating loadable DICOM/XML~~

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Some TPS do not enable the internal creation of site-specific templates. For these cases, ~~T~~the program can function as a server with which to create a structure set for ~~each~~ any patient image that appears in a monitored folder ~~designated by the user~~location. ~~The program also may create structure templates to be assigned to patients within the TPS.~~

~~If set up as a server~~In server setup, 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, monitoring file changes~~waiting a period of time between each change~~ to ensure all files are uploaded before ~~the~~ processing 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, regardless of network latency or scan size.~~.~~

If ~~the~~ DICOM images are consistently placed within ~~the~~ a single~~same~~ folder location~~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 created~~run automatically~~. For example, including the tag 'Breast_CW' in the Series Description during acquisition ~~could~~ would indicate~~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.~~

Step 3b: Creating loadable DICOM-RT

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If the user's TPS enables the creation of templates, they can utilize the anonymous CT creator to generate a DICOM-RT file for each template using ~~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.

Step 3c: Creating/Editing Varian XML templates

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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 and editing.

Detailed descriptions of what is occurring 'behind the scenes' can be found within the supplementary documentation.

Creation of DICOM-RT files

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DICOM-RT files are created via the publicly available FellowOakDicom package[8], and a C# wrapper for the ITK coding package, SimpleITK[9]. The framework for creating RT Structure files in Python has been previously reported[10], and a similar process is used here.

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~~ consistent 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-RT standard. Early rollout required hands-on-training with video conferences to demonstrate how to use the software. Therefore, we had to create videos for other physicists to watch to learn how to use the software and hope this paper serves as a narrative review of its capabilities.

There have been previous reports of software tools used to homologate sets of previously treated structures to support retrospective data analysis[12]. There have also been tools created within the TPS to verify that structures names comply with TG-263[13]. 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 Open RT Structures program~~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~~its 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 is coded to check if each template RT Structure file ~~never opens or edits an~~ already exists~~ing RT Structure file~~, and so prevents a continuous recreation of the same set~~so presents no risk to work flows already present by the user~~. As an additional safety measure, the software is coded to only create new RT structure files and will not open or edit an already existing RT Structure file, and so presents no risk to existing work flows present by the user.

To support large-scale, multi-institutional, and international data sharing, the Open RT Structures~~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 Open RT Structure~~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 Open RT Structures~~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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Abstract

Background: Consistency of nomenclature within radiation oncology is increasingly important as big data efforts and data sharing become more feasible. 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: 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 brachytherapy templates. An informal consensus on OAR and target coloration was also achieved, though color selections are fully customizable within the program.

Results: The resulting 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 to easily create and name DICOM-RT structures sets that are TG-263-compliant for all planning systems utilizing the DICOM standard. The program and source code are publicly available via GitHub, encouraging feedback from community users 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 treatment volumes (TVs) and organs at risk (OARs). Proper labeling is important in the evaluation of generated treatment plans, both for comparing plans from other individuals/institutions, and for curating large data sets from multiple institutions. With large datasets, incorrectly labels are extremely difficult to identify, and so proper and consistent labeling is exceedingly important. Standardized nomenclature also enables automated structure segmentation and treatment planning workflows.

While Digital Imaging and Communications in Medicine radiation therapy (DICOM-RT) standards specify data formats required to electronically communicate information about the structures, users are individually responsible for creating and naming these in the treatment planning systems (TPS). Labeling structures manually is tedious, error-prone (e.g., 'Brian' instead of 'Brain'), and variable (e.g., 'Lung_R' vs 'Right Lung')[1].

While many TPS provide the option to maintain templates (groupings of specific treatment volumes and OARs), these templates are often manually created and maintained and not universally shared between institutions. Therefor, the creation process can be relatively time-intensive, and updates remain vulnerable to the issues listed above.

The American Association of Physicists in Medicine (AAPM) has published 'Standardizing Nomenclatures in Radiation Oncology'[1], a report from Task Group 263 (TG-263) in order to create a standard nomenclature for both treatment volumes and OARs. While adoption of the standard nomenclature has popular support, in a recent survey[2] conducted by the TG-263U1 Task Group, the majority of respondents had not yet adopted the standardized nomenclature. From this survey, the largest difficulties were lack of time/resources to create new templates, and/or difficulty with retraining staff if templates were not available.

Our aim in this work is to lower the barrier to adopt standardized TG-263 nomenclature to facilitate data sharing and consistency. This includes tools to create patient-specific structure sets, import RT structure sets on an included anonymized patient to create templates, or update Varian eXtensible Markup Language (.xml) internal templates in English, Spanish, or French. The program presented (written using C#[7]) runs on any Windows system and ensures compatibility with all TPS by utilizing the DICOM-RT standard.

Methods

To standardize the recommended targets and OARs, a subsection of the TG-263 group created 53 pre-made structure templates for external beam and brachytherapy sites. These templates are based on an American Society for Radiation Oncology (ASTRO) consensus paper[3]. Templates were further customized with common targets and relevant OARs. Additional subsite-specific templates (e.g., partial breast, whole breast, intact prostate, postoperative prostate, etc.) and brachytherapy templates were created. Brachytherapy templates were created with the guidance of the TG-263 brachytherapy members who share membership on the AAPM Brachytherapy Subcommittee and Working Group on Brachytherapy Clinical Applications. Common prefixes of template names include "Targets" (including 1 dose level, 2 dose levels, and 3 dose levels, and 4 dose level templates), "AbdPelv" (i.e., Abdomen and Pelvis primary disease sites), “Brachy” (i.e., Brachytherapy), “CNS” (Central Nervous System), “Extremities”, “H&N” (Head and Neck), and “Thorax”. Supplementary Table 1 contains an excel file of the site-specific structures as of the time of publications, although it is recommended that the user refer to the online AirTable in case of updates.

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Ultimately, there are two main routes to use this program in practice. Some clinics may wish to utilize the program to create patient-specific structure sets that appears in a monitored folder. Other clinics may prefer to utilize the TPS to assign structure sets to patients, as the program may be used to automatically build over 50 site-specific structure sets which can be directly imported (and saved) to their TPS in a few clicks.

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All default templates load in ABC order, arranged by the name of the template (Table S1). This plugin was coded to alleviate tedious manual work in exporting Varian templates to the program or can be used to populate the program from these Varian templates.

Step 2: Manipulation of ROIs

After template(s) has been built, ROIs are listed alphabetically grouped within their Interpreted Type[11] (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 will populate first in alphabetical order as default-checked, while all Consider structures will populate below in alphabetical order as default-unchecked, per the ASTRO consensus paper.[3]

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.

Step 3a: Running as a server: Setting DICOM paths and requirements

Some TPS do not enable the internal creation of site-specific templates. For these cases, the program can function as a server with which to create a structure set for any patient image that appears in a monitored folder location.

In server setup, 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, monitoring file changes to ensure all files are uploaded before processing begins. This file system watcher ensures the entire DICOM dataset is present before an RT structure is generated, regardless of network latency or scan size.

If DICOM images are consistently placed within a single folder location, the users can define values within the Series Description or Study Description to indicate which template should be created. For example, including the tag 'Breast_CW' in the Series Description during acquisition would indicate the program to 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'.

Step 3b: Creating loadable DICOM-RT

If the user's TPS enables the creation of templates, they can utilize the anonymous CT creator to generate a DICOM-RT file for each template using 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.

Step 3c: Creating/Editing Varian XML templates

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 and editing.

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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 consistent 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-RT standard. Early rollout required hands-on-training with video conferences to demonstrate how to use the software. Therefore, we had to create videos for other physicists to watch to learn how to use the software and hope this paper serves as a narrative review of its capabilities.

There have been previous reports of software tools used to homologate sets of previously treated structures to support retrospective data analysis[12]. There have also been tools created within the TPS to verify that structures names comply with TG-263[13]. 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 Open RT Structures program 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 its 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 is coded to check if each template RT Structure file already exists, and so prevents a continuous recreation of the same set. As an additional safety measure, the software is coded to only create new RT structure files and will not open or edit an already existing RT Structure file, and so presents no risk to existing work flows present by the user.

To support large-scale, multi-institutional, and international data sharing, the Open RT Structures 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 Open RT Structure 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 Open RT Structures, along with field testing at several clinical sites.

Conclusion

We have created open-source software that may 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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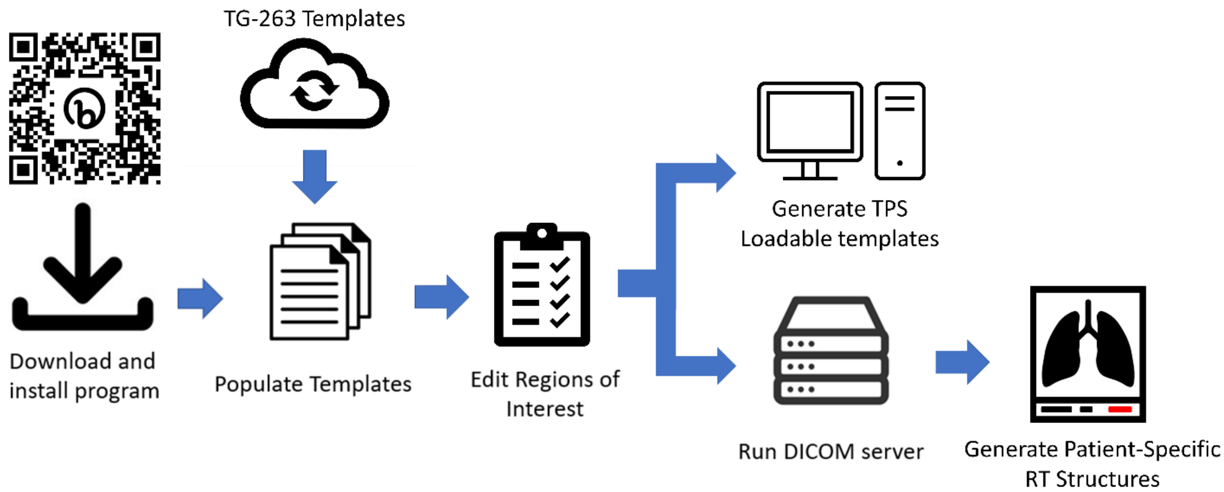

Figure 1: General workflow of the program. A visualization of each step from the program can be found in the supplementary document.

Figure 2

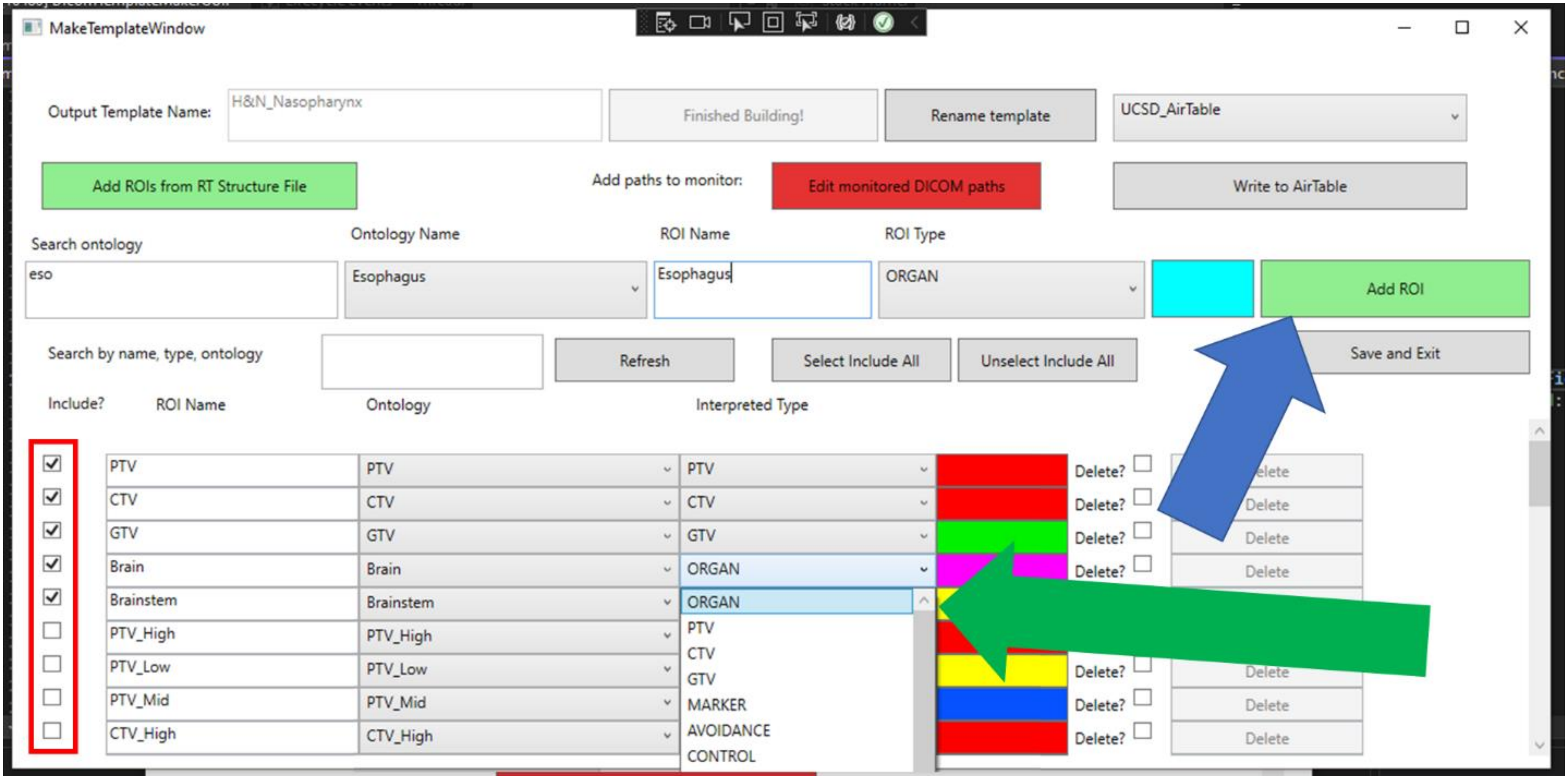

Figure 2: Edit within the template 'H&N_Nasopharynx'. The red box on the bottom left shows that only PTV, CTV, GTV, Brain, and Brainstem have been checked as 'Include?' for the RT Structure file. The 'Incuded?' ROIs are listed above the non-included ROIs. The ROIs are grouped PTV -> CTV -> GTV -> ORGAN, 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.

Supplementary Figure 1

Supplementary Figure 2

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Supplementary Material
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Supplementary Figure 3

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Supplementary Table 1

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Supplementary Material

Table S1 Structure Naming.xlsx

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