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# An Automated Contouring Workflow for Increased Standardization and Efficiency

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RETHINKING MEDICAL PHYSICS

## INTRODUCTION

AAPM Task Group 263 notes that standard naming benefits the practice of radiation oncology by facilitating communication during routine care and by facilitating data pooling and automatic data extraction and exchange. Consistent naming also benefits automation of downstream tasks, such as automated planning and plan review. The report explores the myriad of challenges of implementing standardized nomenclature, including at the institutional and staff levels. This work explores the approach of using automation, as opposed to staff training, to overcoming some of these challenges.

In addition to non-standardized naming, manual segmentation is time consuming and subject to inter- and intra-observer variability. Recently, technology and training tools have been developed to aid planners with the contouring task, including computer-aided automatic segmentation. Many studies have evaluated the quality of automatic segmentation, and its role in reducing observer variability and reducing contouring time, but its current clinical use is limited. This is partially a result of various challenges in implementing automatically generated contouring tools into a process that involves a range of staffing groups (e.g. physicians, dosimetrists, and physicists), while addressing technical problems and training needs.

## AIM

The purpose of this work is to describe and evaluate a new automated contouring workflow, which implements standardized contour naming, coloring, and automatic segmentation. The use of this automation helps address some of the challenges in name and color standardization, and some of the challenges in utilizing computer generated automatic segmentation. Specifically, the automated workflow reduces the training burden of these tools and lessens the dependence of staff adherence to procedures to achieve standardization. Once implemented, standard structure names and colors are automatically provided and a subset of automatically segmented structures are provided by default, allowing planners to use, manually modify, or delete them based on their routine review.

## METHOD

The workflow provides standard contour names, colors, and order for each simulation scan. A schematic depiction of the workflow is shown in Figure 1. Contour names are informed by AAPM TG-263 and previous naming practices. A central server automatically applies these contour templates to all simulation scans. Then a subset of the contours is then automatically segmented and sent back to the local server for further planning and approval. During the physics plan check, the final approved contours are returned to the central server to allow for initial contour accuracy scoring with volumetric Dice similarity coefficient and added path length, and for future contour auto-segmentation improvement with machine learning. Finally, planners were surveyed on the usefulness of the initial contours.

## RESULTS

In the first nine months of implementation, new workflow managed 511 simulation scans, constituting every simulation done in the department. This included 144 breast, 136 lung, 97 pelvis, 52 head and neck, 45 brain, and 37 abdomen simulations. On these simulations, the workflow generated 12,624 structures, of which 3,137 (~30%) structures were automatically segmented.

When comparing the initial automatically segmented structures to the final approved structures, the mean dice scores were dependent on the structure being segmented, as shown in Table 2. In aggregate, 23% of all automatically segmented structures have a VDSC > 0.99, and 71% have VDSC > 0.7. The mean APL and estimated time saved of each structure is shown in Table 3. Based on the planner surveys, the new workflow saves time on for all treatment sites. The self-reported mean time saved is 24 minutes, while there is not statically significant dependence between treatment sites, due to the small sample size (n = 3)

| Brain | Breast/ Chest Wall | H&N | Lung | Pelvis/Female | Pelvis/Male | Abdomen | Extremity |
|---|---|---|---|---|---|---|---|
| brain | breast | hn | lung | pelvis | pelvis | abdo | ext |
| | | | | | | | |
| Body | Body | Body | Body | Bladder | Bladder | Body | Body |
| Bolus_xxmm | Bolus_xxmm | Bolus_xxmm | Bolus_xxmm | Body | Body | Bolus_xxmm | Bolus_xx mm |
| Bones | Bones | Bones | Bones | Bolus_xxmm | Bolus_xxmm | Bones | Bones |
| Brain | Heart | Brain | BrachPlex L | Bone Marrow | Bone Marrow | Bowel Large | |
| Brain-PTV | LN Ax L1 L | Brainstem | BrachPlex R | Bones | Bones | Bowel Small | GTV |
| Brainstem | LN Ax L1 R | Brainstem 3PRV | Bronchial Tree L | Bowel Large | Bowel Large | Bowel Space | CTV |
| Brainstem 3PRV | LN Ax L2 L | Cochlea L | Bronchial Tree R | Bowel Small | Bowel Small | Esophagus | PTV |
| Cochlea L | LN Ax L2 R | Cochlea R | Carina | Bowel Space | Bowel Space | Heart | |
| Cochlea R | LN Ax L3 L | Esophagus | Chest Wall L | Genitalia Ext | Genitalia Ext | Kidney L | |
| Eye L | LN Ax L3 R | Larynx | Chest Wall R | Rectum | Penile Bulb | Kidney R | |
| Eye R | LN IMN L | Lips | Esophagus | SacralPlex | Prostate | Liver | |
| Lens L | LN IMN R | Mandible | Great Ves | | Rectum | Spinal Cord | |
| Lens R | LN Supraclav L | Oral Cavity | Heart | GTV | SacralPlex | Spinal Cord 5PRV | |
| Opt Chiasm 3PRV | LN Supraclav R | Parotid L | Lung Bilat | CTV | SeminalVes | Stomach | |
| Opt Chiasm | Lung Bilat | Parotid R | Skin | PTV | | | |
| Opt Nrv L | Nipple L | Spinal Cord | Spinal Cord | | GTV | GTV | |
| Opt Nrv L 3PRV | Nipple R | Spinal Cord 5PRV | Spinal Cord 5PRV | | CTV | CTV | |
| Opt Nrv R | Scar | Submandibular L | | | PTV | ITV | |
| Opt Nrv R 3PRV | Spinal Cord | Submandibular R | GTV | | | PTV | |
| Spinal Cord | Spinal Cord 5PRV | | CTV | | | | |
| Spinal Cord 5PRV | | GTV | ITV | | | | |
| | GTV | CTV | PTV | | | | |
| GTV | CTV | PTV | | | | | |
| CTV | PTV | | | | | | |
| PTV | | | | | | | |

***Table 1**: The seven anatomical treatment sites (with pelvis sub-divided between male and female), their DICOM tags, and the automatically generated contour list. The automatically generated structures were chosen by planners and physicians in an estimated > 5% of plans in that region.*

| Contour | Dice score > 0.99 | Dice score > 0.7 | Dice score < 0.7 |
|---|---|---|---|
| Lung, Left | 86% | 100% | 0% |
| Lung, Right | 79% | 100% | 0% |
| Bladder | 40% | 93% | 7% |
| Seminal Vesicles | 40% | 80% | 20% |
| Femur, Right | 39% | 83% | 17% |
| Femur, Left | 35% | 88% | 12% |
| Spinal Cord | 25% | 46% | 54% |
| Rectum | 20% | 100% | 0% |
| Eye, Left | 17% | 61% | 39% |
| Eye, Right | 17% | 44% | 56% |
| Esophagus | 15% | 50% | 50% |
| Brainstem | 14% | 64% | 36% |
| Parotid, Right | 11% | 78% | 22% |
| Optic Chiasm | 11% | 44% | 56% |
| Heart | 5% | 97% | 3% |
| Prostate | 0% | 100% | 0% |
| Mandible | 0% | 100% | 0% |
| Parotid, Left | 0% | 75% | 25% |
| Oral Cavity | 0% | 33% | 67% |
| Optic Nerve, Left | 0% | 38% | 63% |
| Optic Nerve, Right | 0% | 57% | 43% |

***Table 2**: The percent of automatically segmented structures that have a dice score of greater than 0.99, 0.9, and 0.7 when compared with the final approved structures. These represent contours that of decreasing usefulness to planners.*

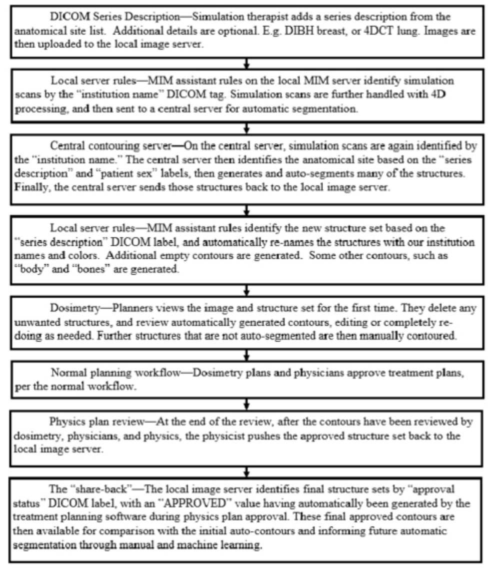


*Figure 1: The schematic of the new automated workflow. The workflow is initiated at the time of initial CT-simulation, when the simulation therapist assigns a DICOM tag to each scan in the "series description" label, describing the scan as one of seven pre-determined anatomical treatment sites*

## CONCLUSIONS

The implementation of the new workflow has two principle benefits. First is the increased standardization of contour name, color, and order, which anecdotally improves routine patient care. Physicians and planners note fewer instances of contours being forgotten and easier plan review, as OAR and target volume dose constraints are examined quickly with predictable structure color and order. And the second benefit is reduced contouring time. Both methods of evaluating the effect of implementing the new workflow show some amount of time saving.

In order to utilize the new workflow, some training efforts are required. Specifically, simulation therapists need to be trained to label simulation scans with the correct DICOM tag identifying the treatment site, and planners need to be trained to delete and restart a structure, and not attempt to modify it, if the initial structure is considerably incorrect.

Future work will automate some contouring work done after structures have been reviewed. The expansion of OARs into planning organ at risk volumes (PRV) and the creation of planning pseudo-structures can be similarly automated. Additionally, the standardization of names and automatic segmentation allows for easier and potentially fully automatic planning with knowledge-based planning.

This workflow is scalable to radiation treatment centers of any size. Aside from increased structure standardization, this process has been demonstrated to reduce planner contouring time with automatic segmentation that provides time saving initial structures to planners. Finally, this automated contouring workflow can be implemented without major re-training of therapists and treatment planners.

## REFERENCES

[1] Mayo CS, Moran JM, Bosch W, et al. American Association of Physicists in Medicine Task Group 263: Standardizing Nomenclatures in Radiation Oncology. *International Journal of Radiation Oncology*Biology*Physics*. 2018;100(4):1057-1066. doi:10.1016/j.ijrobp.2017.12.013
[2] Santanam L, Hurkmans C, Mutic S, et al. Standardizing Naming Conventions in Radiation Oncology. *International Journal of Radiation Oncology*Biology*Physics*. 2012;83(4):1344-1349. doi:10.1016/j.ijrobp.2011.09.054
[3] Fiorino C, Reni M, Bolognesi A, Cattaneo GM, Calandrino R. Intra- and inter-observer variability in contouring prostate and seminal vesicles: implications for conformal treatment planning. *Radiotherapy and Oncology*. 1998;47(3):285-292. doi:10.1016/S0167-8140(98)00021-8
[4] Louie AV, Rodrigues G, Olsthoorn J, et al. Inter-observer and intra-observer reliability for lung cancer target volume delineation in the 4D-CT era. *Radiotherapy and Oncology*. 2010;95(2):166-171. doi:10.1016/j.radonc.2009.12.028
[5] Yang J, Wei C, Zhang L, Zhang Y, Blum RS, Dong L. A statistical modeling approach for evaluating auto-segmentation methods for image-guided radiotherapy. *Computerized Medical Imaging and Graphics*. 2012;36(6):492-500. doi:10.1016/j.compmedimag.2012.05.001
[6] Hyunjin Park, Bland PH, Meyer CR. Construction of an abdominal probabilistic atlas and its application in segmentation. *IEEE Transactions on Medical Imaging*. 2003;22(4):483-492. doi:10.1109/TMI.2003.809139
[7] Gillespie EF, Panjwani N, Golden DW, et al. Multi-institutional Randomized Trial Testing the Utility of an Interactive Three-dimensional Contouring Atlas Among Radiation Oncology Residents. *International Journal of Radiation Oncology*Biology*Physics*. 2017;98(3):547-554. doi:10.1016/j.ijrobp.2016.11.050
[8] Teguh DN, Levendag PC, Voet PWJ, et al. Clinical Validation of Atlas-Based Auto-Segmentation of Multiple Target Volumes and Normal Tissue (Swallowing/Mastication) Structures in the Head and Neck. *International Journal of Radiation Oncology*Biology*Physics*. 2011;81(4):950-957. [1] doi:10.1016/j.ijrobp.2010.07.009
[9]Anders LC, Stieler F, Siebenlist K, Schäfer J, Lohr F, Wenz F. Performance of an atlas-based autosegmentation software for delineation of target volumes for radiotherapy of breast and anorectal cancer. *Radiotherapy and Oncology*. 2012;102(1):68-73. doi:10.1016/j.radonc.2011.08.043
[10] Kim H, Jung J, Kim J, et al. Abdominal multi-organ auto-segmentation using 3D-patch-based deep convolutional neural network. *Scientific Reports*. 2020;10(1):1-9. doi:10.1038/s41598-020-63285-0
[11] Thomson D, Boylan C, Liptrot T, et al. Evaluation of an automatic segmentation algorithm for definition of head and neck organs at risk. *Radiat Oncol*. 2014;9(1):173. doi:10.1186/1748-717X-9-173

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