JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

Standardization of CSI Treatment Planning and its Evaluation Using a DVH Registry

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INTRODUCTION

In complex techniques like craniospinal irradiation (CSI) for pediatric patients, lack of standardization may lead to an increased risk of side effects post-radiation therapy [1]. CSI is a challenging type of treatment for patients with malignancies in the brain such as medulloblastomas, with a 40% probability of metastasis throughout the spinal cord [2]. Due to the infrequent number of patients with this pathology, in addition to the difficulty of prioritizing dose constraints to the target and organs at risk, planners and physicians regularly refer to previously-treated plans for guidance.

This ad hoc manner of planning new patients receiving CSI can be greatly improved by implementing a dose-volume histogram registry (DVHR) able to aggregate previous patient data to provide constraint guidance for organs at risk.

AIM

This study evaluates the ability of dosimetric constraints established using a DVHR to standardize pediatric CSI treatment planning

METHODS

Between 2007 and 2014, custom software was used to incorporate into a DVHR the DVH data of nine patients previously treated with CSI (36 Gy in 18 fractions). These data were used to derive DVH planning constraints based on population median values. Physicians and planners were asked to use the new constraints to plan CSI going forward. In 2020, Mann-Whitney U statistical tests and mean differences at 95% confidence intervals were used to compare the DVHs of 10 plans from the pre-constraints cohort with 9 plans from the post-constraints cohort. Comparisons were performed at specific dosimetric points (V_5, V_{10}, V_{15}, V_{20}, D_{mean}, D_{median}, $D_{minimum}$, and $D_{maximum}$) for each structure.

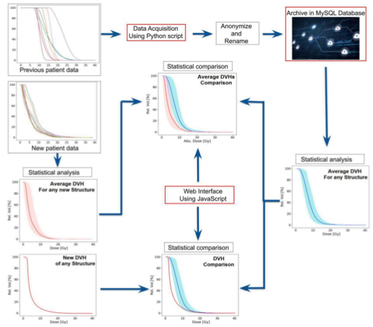

Figure 1 - Schematic showing the data flow of the DVH registry.

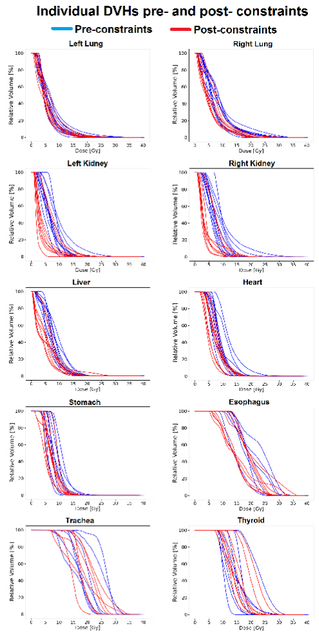

Figure 2 - Individual DVHs before and after the intervention of the DVHR for all OARs. Each line represents a different anonymized patient treated with CSI at our centre.

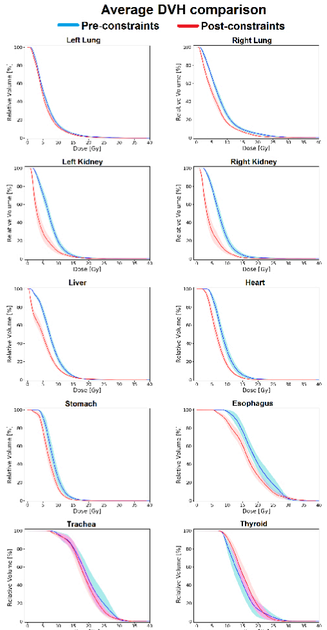

Figure 3 - Comparison of population-average DVHs of all OARs before and after the intervention of the DVHR. Shaded regions indicate the standard uncertainty of the mean.

RESULTS

Organ at risk	Relative volume [%]		
	$V_{5\,Gy}$	$V_{10\,Gy}$	$V_{20\,Gy}$
Heart	92	23	0
Left Lung	52	11	1
Right Lung	68	17	4
Left Kidney	62	15	0
Right Kidney	75	13	0
Esophagus	100	100	35
Liver	63	21	0
Stomach	100	26	0
Trachea	100	100	22
Thyroid	100	91	2

Table 1 - OAR constraint values for CSI prescriptions of 36 Gy in 18 fractions, as derived from the median DVH values of the nine previously-treated plans entered into the DVHR in 2014.

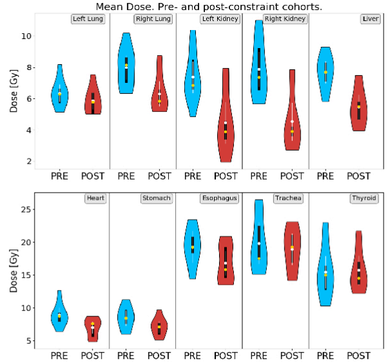

Figure 4 - Violin plots of the mean dose delivered to all OARs before and after the intervention of the DVHR. Mean and median are demarcated by white and yellow dots, respectively. Additionally, the 95% confidence intervals are shown as white lines, and the interquartile ranges as black lines

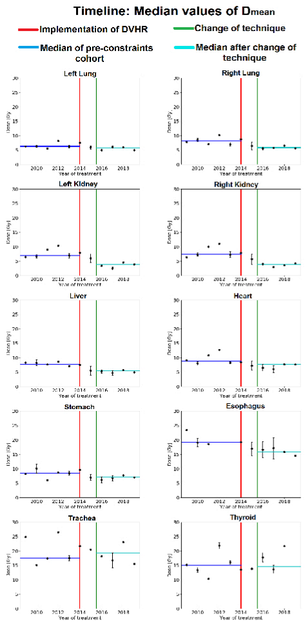

Figure 5 - Time scale evaluation of the population median values of D_{mean} over the years of the study. A total of 19 patients were used in each figure, separated into 12 year-groups, from 2009 to 2019. The vertical red line represents the year in which the DVHR was implemented in the clinic and the green line refers to the beginning of CSI treatments using a different technique. Horizontal lines represent the median values of D_{mean} before the intervention (Blue) and after the change of technique (Cyan).

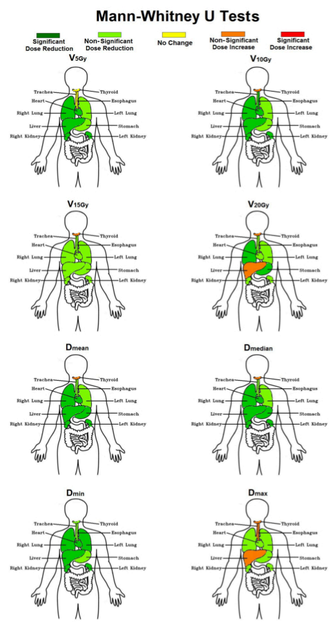

Figure 6 - Hypothesis test results after performing the 2-tailed (p-value < 0.05) Mann Whitney U test. The parameters evaluated were the V_{5Gy}, V_{10Gy}, V_{15Gy}, V_{20Gy}, D_{mean}, D_{median}, D_{min}, and D_{max} values delivered to each structure. p-values and dose reduction results were combined to display five possible colors for each OAR: Green (statistically significant dose reduction), light green (statistically non-significant dose reduction), yellow (statistically no change), orange (statistically non-significant dose increase), and red (statistically significant dose increase).

CONCLUSIONS

We have shown that implementation of dosimetric constraints based on DVHR-derived data improved the standardization of pediatric CSI planning at our centre. After analyzing the data accumulated, we found evidence of improved post-intervention standardization compared to pre-intervention. Although we cannot state categorically that the DVHR was entirely responsible for the reduced dose to the OARs, due to the confounding factor of a change in technique, guidance for the change in technique was itself provided by the DVHR constraints, which certainly contributed to practice standardization across techniques. As a future work, outcomes and toxicities can be correlated after and before the intervention. The concept of a DVHR can be extrapolated to other types of cancer treatments that lack practice standardization.

REFERENCES

[1] Duffner PK, Cohen ME, Thomas P, Late effects of treatment on the intelligence of children with posterior fossa tumors, Cancer, 1983; 51: 233–237.

[2] Bernier V. Technical aspects in cerebrospinal irradiation. Pediatric Blood Cancer. 2004;42: 447–451.

ACKNOWLEDGEMENTS

This work was partially supported by the NSERC Discovery Grant of Dr. John Kildea. We acknowledge the work space and resources provided by the Medical Physics Department of the McGill University Health Centre.

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