Ashleigh Sammataro, B.S., RT(T)
Grand Valley State University
sammataa@mail.gvsu.edu

Craniospinal Irradiation Volumetric Modulated Arc Therapy (VMAT) planning: A dosimetric contrast utilizing anterior avoidance sectors

Ashleigh Sammataro, Jared Scroggins, Daniel Alexander
Dartmouth-Hitchcock Medical Center

Introduction

Craniospinal irradiation (CSI) is often required for certain tumor types in both pediatric and adult patients. This technique is a cornerstone in the treatment of malignancies involving the central nervous system (CNS).

Traditionally, patients undergoing CSI treatment would be treated with three-dimensional conformal radiotherapy (3D-CRT), which involved complex field-matching techniques to manage dose homogeneity at junctions.

VMAT is the current standard for photon CSI, but comparative evidence is sparse. This study directly evaluates Full Arc and Anterior-Avoidance (AVD) VMAT techniques to establish the most effective clinical approach.

Methods

A retrospective analysis was performed on eight anonymized patients previously treated with CSI. Eligible cases included patients of any age or sex, including those treated under anesthesia. Patients immobilized in the prone position or presenting with excessively long craniospinal field lengths were excluded.

Clinical target volume (CTV) brain and spine were delineated by the dosimetrist per institutional guidelines, reproducing the Radiation Oncologist-defined volumes. The Organs at risk (OARs) analyzed included all structures located inferior to the mandible and the most anterior OARs to appropriately evaluate dose distribution relative to the avoidance sectors (110°-250° and 250°-110°). Two plans were generated per patient, with the AVD plan optimized first to prevent planning bias prior to creation of the Full Arc plan.

Optimization structures

zPTV_BrainOPt (Brain + 0.1cm margin)
zPTV_SpineOpt (Spine + 0.1cm margin)
Ring structures
zNT: extract wall: 5cm outside PTV; 2.5cm inside PTV
zTRV: extract wall: 3cm outside PTV; -0.5cm inside PTV

- Automatic NTO; Priority 100

Results

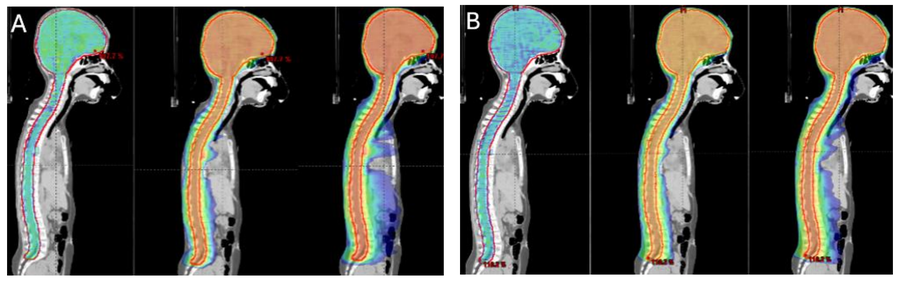

Figure 1. Sagittal dose-wash visualization comparing 100%, 50%, and 25% isodose coverage between Full Arc (A) and AVD (B) showing similar PTV coverage and reduced normal tissue dose with AVD technique

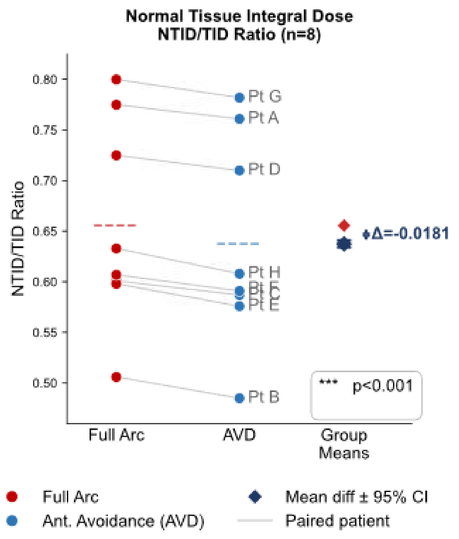

Fig 2. (Left) Paired dot plot illustrating AVD technique reduced NTID/TID ratios versus Full Arc ($p<0.001$)

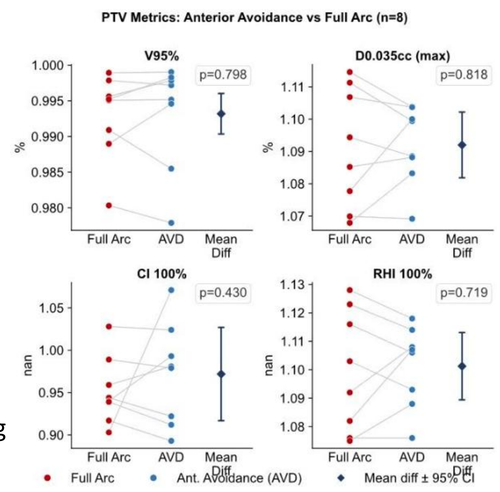

Fig 3. (Right) Paired dot plot highlighting that PTV metrics remained unchanged between AVD and Full Arc plans

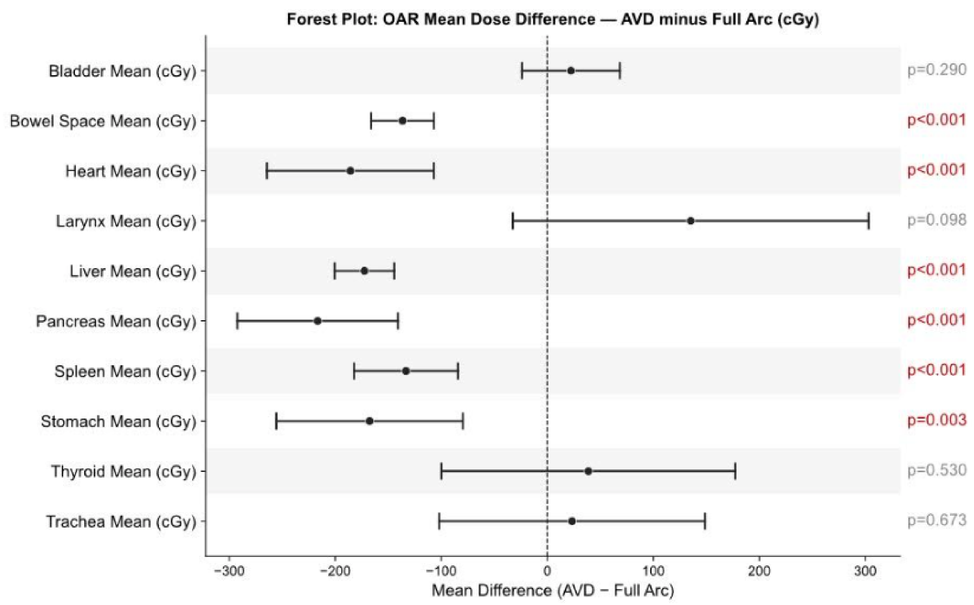

Fig 4. Forest plot showing organ-at-risk mean dose differences between AVD and Full Arc plans highlighting the structures with significant dose reductions

Conclusion

Differences in target coverage, conformity, homogeneity, and maximum dose between AVD and Full Arc planning were not statistically significant. An integral dose ratio was calculated as the integral dose to BODY-PTV (NTID) over the integral dose to BODY (TID). The NTID/TID ratio and mean doses to heart, liver, pancreas, bowel space, spleen, and stomach were all statistically significantly lower with AVD. Differences in thyroid, trachea, larynx, and bladder mean doses were not statistically significant.

AVD and Full Arc VMAT planning produced equivalent target coverage and plan quality, while AVD significantly reduced normal tissue integral dose and mean dose to anterior OARs. These findings supports the use of anterior avoidance as a dosimetrically advantageous approach for CSI.

Limitations

Only eight patients met the criteria for inclusion, underscoring the infrequency of CSI treatments and the considerable technical complexity involved in delivering them. Although the small sample size limits broad extrapolation, the analysis provides valuable early evidence that can guide future investigations into optimization and standardization of CSI planning.

References

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