Quantifying Dosimetric Differences between SECT and DECT in Brain Malignancy Patients Undergoing IMPT: Mitigating Proton Range Uncertainties

Pouya Sabouri[1], Anthony Koroulakis[2], Dina Cusatis[3], Kara Lehman[3], Patrick Wohlfahrt[4], Jainil Shah[5], Jason Molitoris[3], Sina Mossahebi[3]

[1]University of Arkansas for Medical Sciences, Radiation Oncology, Little Rock, USA
[2]Anne Arundel Medical Center, Radiation Oncology, Annapolis, USA
[3]University of Maryland School of Medicine, Radiation Oncology, Baltimore, USA
[4]Siemens Healthineers, Radiation Oncology, Forchheim, Germany
[5]Siemens Healthineers, Radiation Oncology, Cary, USA

BACKGROUND:

To account for proton range uncertainties (RU), the irradiated volume is generally expanded distal to the target. This expansion can elevate doses to nearby organs at risk (OARs) which reduces the benefits associated with proton therapy. Multiple phantom and animal studies have shown that dual-energy CT (DECT) can reduce RU compared to single-energy CT (SECT).

AIM:

This study aims to quantify the dosimetric differences between SECT and DECT for patients with brain malignancies treated with intensity modulated proton therapy (IMPT).

MATERIALS/METHODS:

- Under IRB approval, SECT and DECT scans from 15 IMPT brain patients were acquired using a Siemens Somatom Definition Edge CT scanner (Siemens Healthineers, Germany).
- Clinical plans were generated on SECT images using robust optimization settings of 3.5% RU and 3 mm setup uncertainty (Figure 1 A).
- Subsequently, the clinical plans were generated on the SECT images, and recomputed on the DECT image set using SPR calibration curve (Figure 1 B).
- For each patient, SECT and DECT SPR images were imported to a commercial treatment planning system. Target coverage and OAR dose parameters were compared for both image sets.
- Figure 1C and 1D show the change in the beam range and dose distribution of one beam for one brain patient.

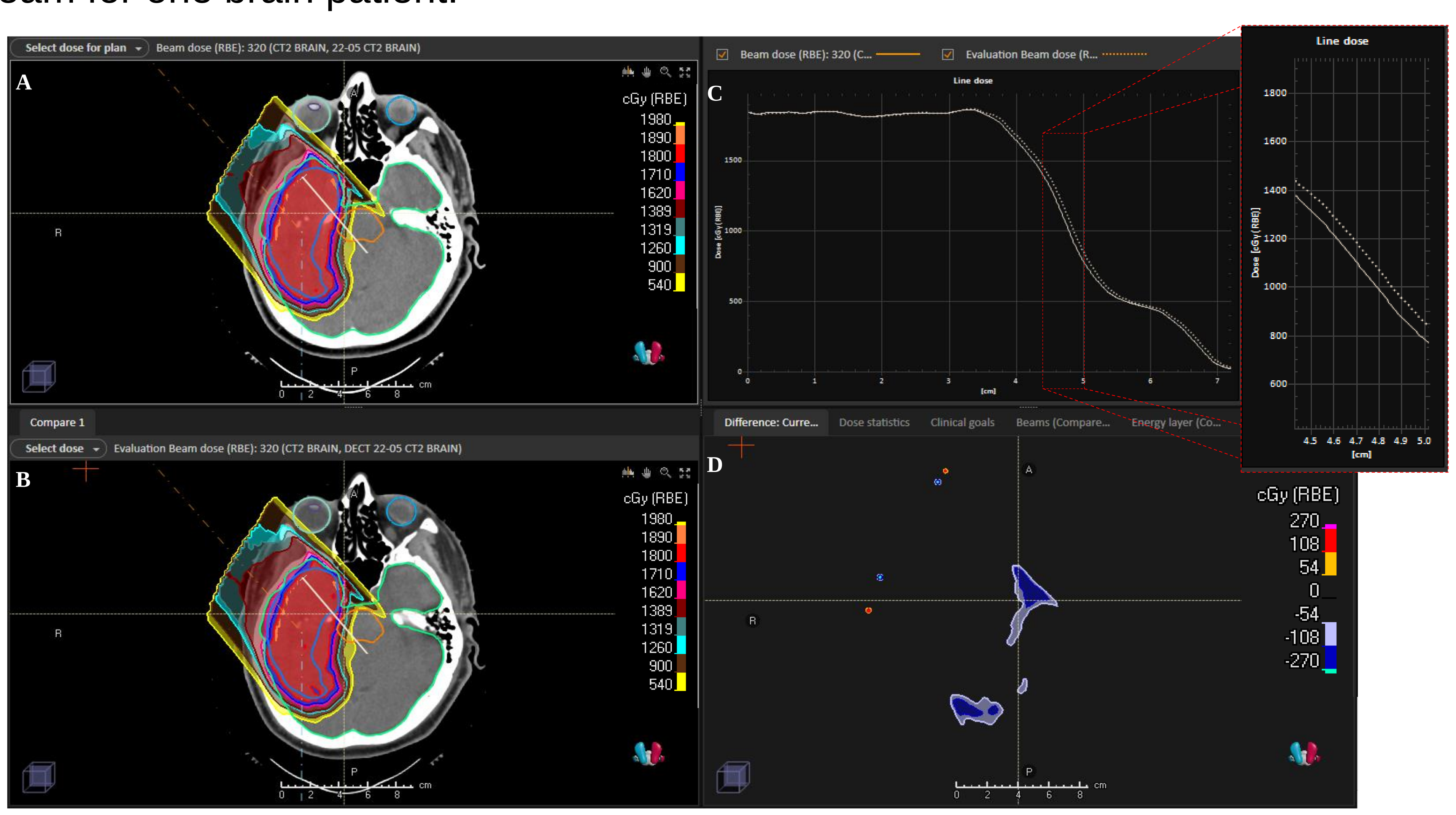

Figure 1. *The 320° beam dose distribution of a clinical brain plan A) calculated on SECT scan, B) recalculated on DECT scan, C) the change (~0.7 mm) in the beam range and D) the beam dose difference shows lower dose at the end range of the beam on SECT relative to DECT scan.*

RESULTS:

- A maximum variation of 1.3% in D99% was observed with the recalculated plan on the DECT scan, indicating target under-dosage compared to the plan calculated on the SECT image set.
- On average, SECT overestimated target V100% by 1.3% when compared to DECT.
- Since all clinical plans were optimized robustly to meet V95% coverage, higher agreement (<0.5%) was achieved for V95% (100.0±0.04%) and D95% (99.7±0.3%).
- Analysis of fifteen brain patients showed that DECT relative to SECT indicated slightly different OAR maximum doses (percent difference of D1%) for spinal cord (1.07±3.06%), brainstem (-0.69±4.44%), cochlea (4.03±6.85%), optic nerves (1.87±5.95%) and optic chiasm (-2.32±4.46%).
- Figure 2 shows the distribution of difference between OAR and target dose parameters of two plans (based on SECT and DECT) for 15 brain patients.

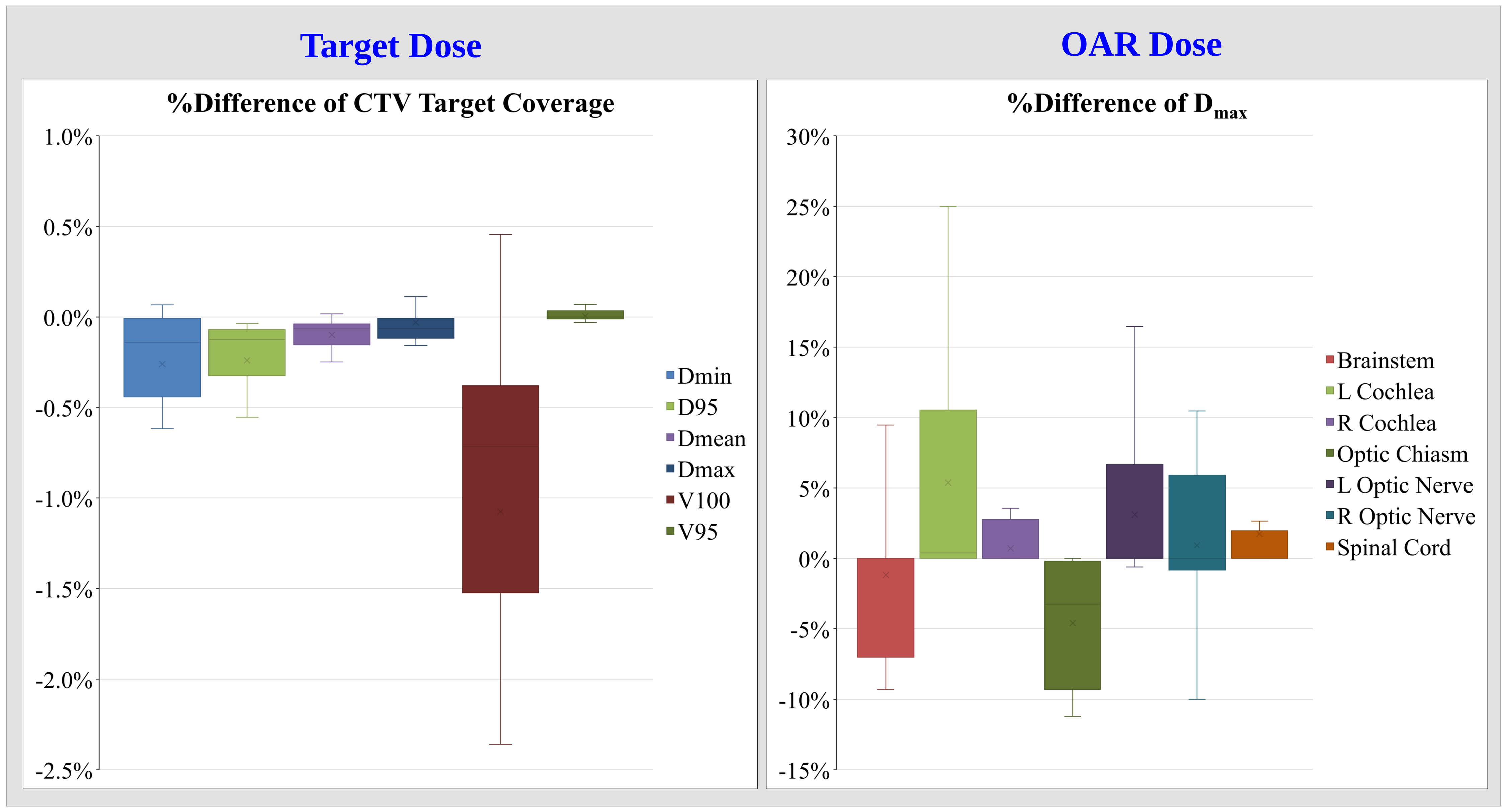

Figure 2: *The distribution of left: percent difference of target (CTV) coverage and right: maximum dose (Dmax) difference (in percent) of OARs between two plans (based on SECT and DECT) for 15 brain patients.*

CONCLUSION:

Given the homogenous geometries encountered in brain malignancies, DECT and SECT show a high level of agreement. However, as a lower RU is associated with DECT, its use improves dose calculation accuracy of critical OARs to within the values that are presented in this work.

CONTACT INFORMATION:

Sina Mossahebi, PhD

Associate Professor
Maryland Proton Treatment Center
Department of Radiation Oncology
University of Maryland School of Medicine
sinamossahebi@umm.edu