

Dosimetric Comparison of VMAT for Craniospinal Irradiation across Multiple Linac Platforms and Flattening Filter Modes

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ABSTRACT

Background

The target volume for craniospinal irradiation (CSI) is relatively long, and VMAT with a multi-isocentric technique is typically required. The junction method between different isocentric fields significantly affects the dose homogeneity of the target volume. Meanwhile, setup errors and other factors may lead to cold or hot spots at the junction area, which has always been a challenging issue in clinical practice. The novel TaiChiPro linear accelerator is equipped with an intelligent couch-shifting function, enabling automatic movement from one isocenter to the next, thereby effectively reducing setup errors associated with manual positioning. However, no study has yet reported a dosimetric comparison for craniospinal irradiation using the TaiChiPro accelerator. In this study, we aim to design VMAT plans on both the TaiChiPro accelerator and the Elekta Axesse accelerator and perform systematic dosimetric analysis, with the goal of comparing dose differences in target volumes and key organs at risk during craniospinal irradiation between the two accelerators. Furthermore, we will investigate the dosimetric characteristics of VMAT plans for craniospinal irradiation under different flattening filter modes.

INTRODUCTION

The purpose of this study was to compare the volumetric modulated arc therapy (VMAT) plans of the TaiChi accelerator in flattening filter free (FFF) mode and the Elekta Axesse accelerator in both flattening filter free (FFF) and flattening filter (FF) modes during craniospinal irradiation (CSI), to analyze their differences in dose to the planning target volume (PTV) and critical organs at risk (OARs) as well as differences in monitor units (MU), and to perform γ -pass rate verification for the TaiChiPro accelerator plans, in order to provide guidance for clinical treatment.

METHODS AND MATERIALS

Ten CSI patients were selected from the Fourth Hospital of Hebei Medical University between January 1, 2022, and December 31, 2024. Group A comprised TaiChiPro FFF VMAT plans; Groups B and C comprised Elekta Axesse FFF and FF VMAT plans, respectively. All plans were prescribed 36 Gy in 20 fractions. Plan evaluation included the conformity index (CI), homogeneity index (HI) for the PTV and its junction regions, doses to OARs, and MU; the gamma passing rates for Group A plans were verified using third-party software.

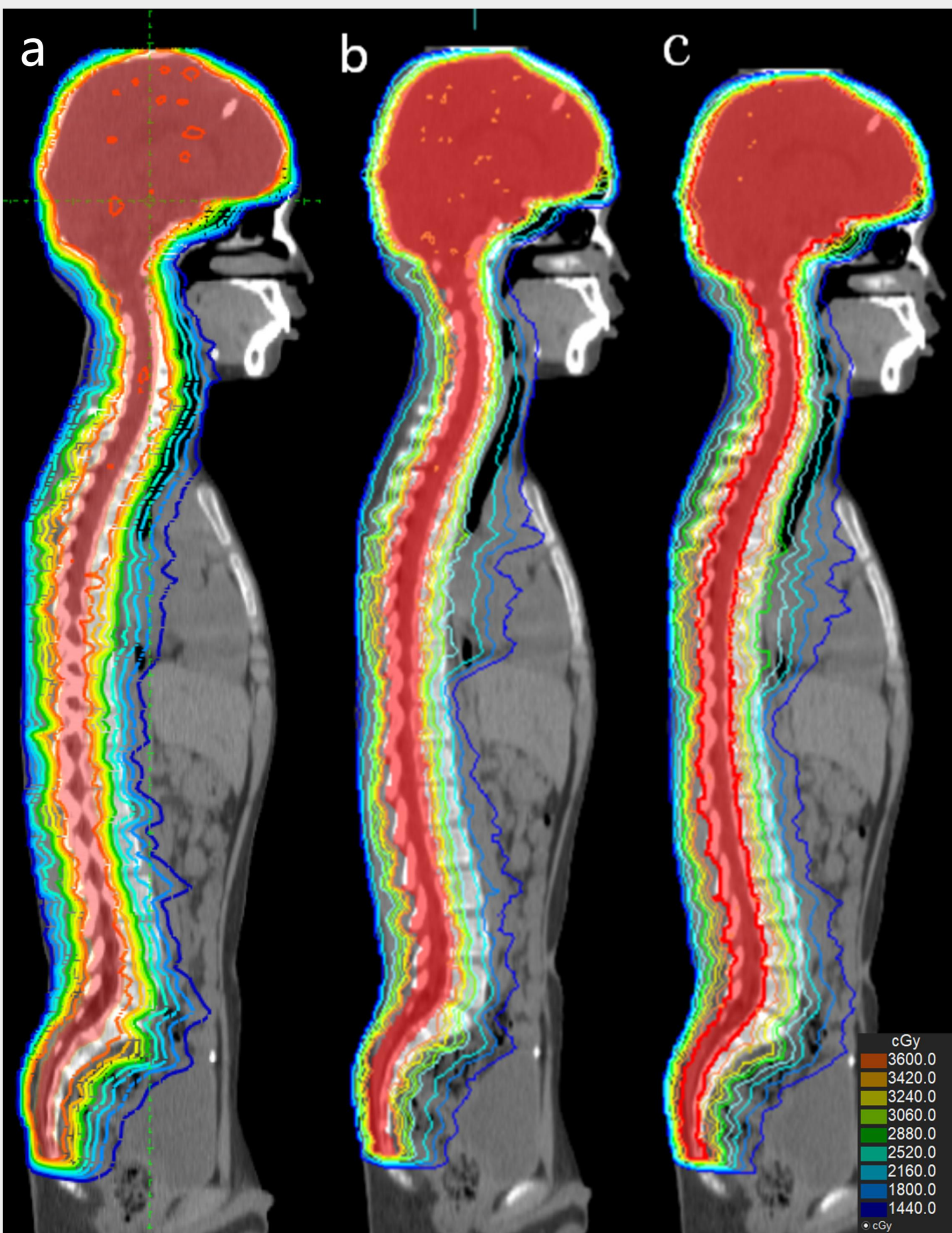


Fig 1: O-shaped TaiChiPro linear accelerator with intelligent couch shifting function.



Fig 2: Elekta Axesse linear accelerator with a 6-degree-of-freedom couch and Agility multileaf collimator.

Fig 3: Comparison of sagittal dose distributions in a craniospinal irradiation case among three plans. Dose distributions are displayed for (a) the TaiChiPro accelerator in flattening filter-free mode (Group A), (b) the Elekta Axesse accelerator in flattening filter-free mode (Group B), and (c) the Elekta Axesse accelerator with the flattening filter mode (Group C).



RESULTS

All plans satisfied clinical dosimetric requirements. Group A showed significantly higher V95% for PTV-all and PTV-1 , lower Dmax to lenses and optic nerves, reduced Dmean to spinal cord and lungs, and decreased V5 and Dmean to right kidney and normal tissue versus Groups B and C.Conversely, group B demonstrated superior V110% for PTV-all and PTV-1 and better HI in junction region 1 versus Group A , as well as a better HI in junction region 2 versus Group C . Conversely, Group C showed improved HI for PTV-2 compared to Group A. Groups A and C required significantly fewer MU than Group B. The three groups showed no significant differences in HI and CI for PTV-all, Dmax to brainstem and spinal cord, or V5 for lungs, heart, and liver. Group A achieved a 3%/3 mm gamma passing rate >95% in 9 of 10 cases, with one case at 93.93%.

Fig 4: Comparison of Conformity Index (CI) and Homogeneity Index (HI) for PTV-all among three plan groups.

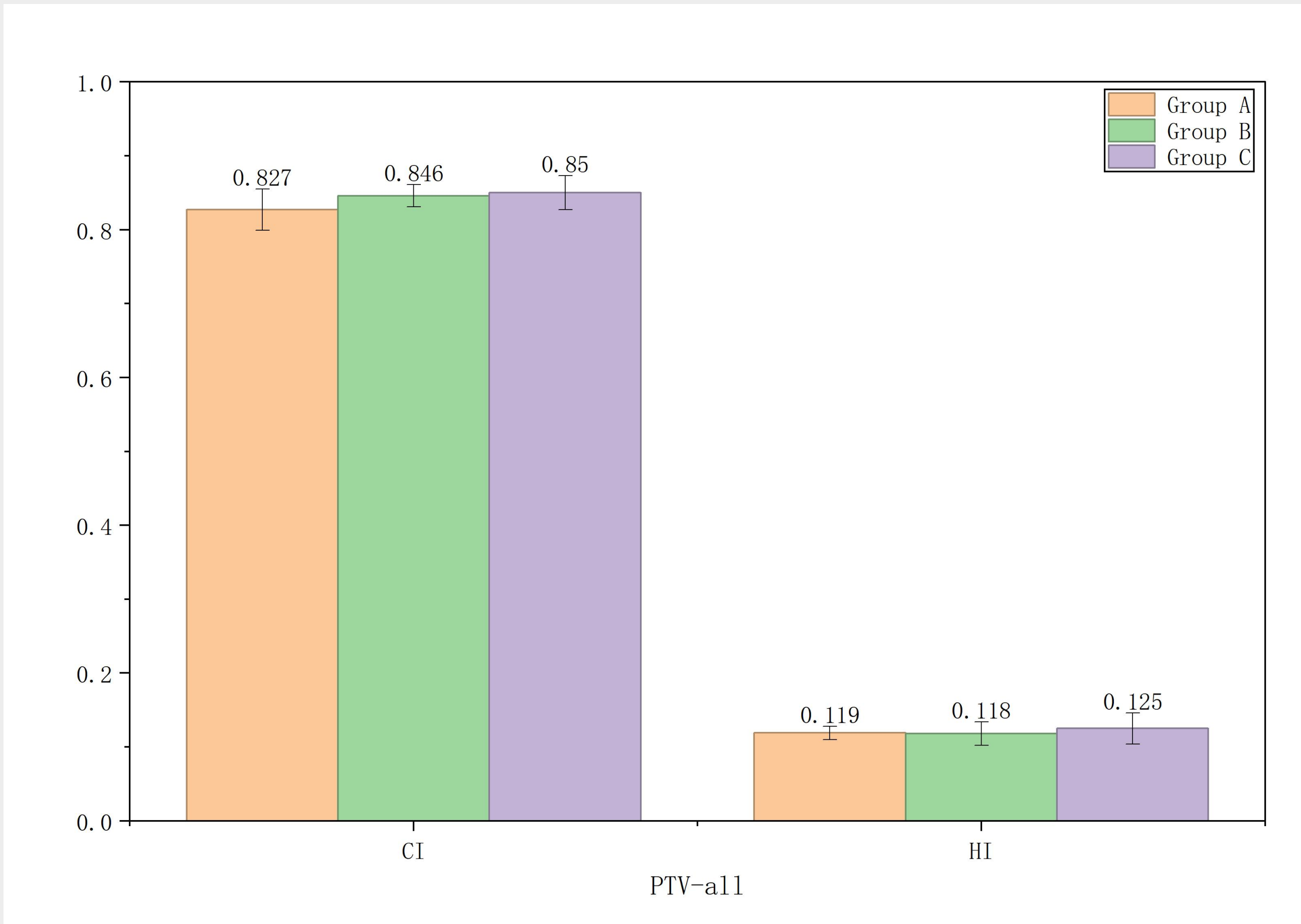
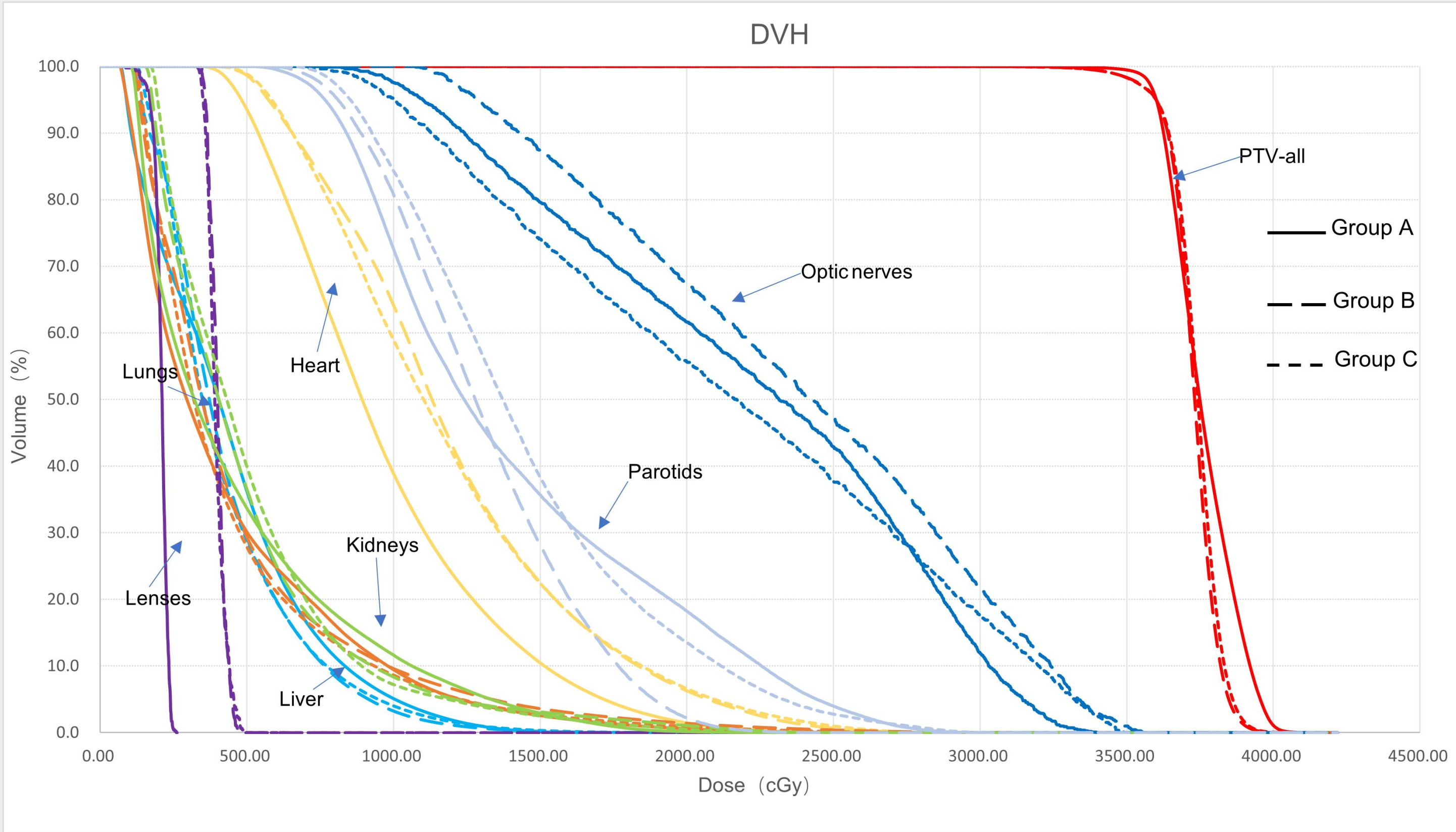


Fig 5: Comparison of dose volume histograms in a craniospinal irradiation case among three plans. Dose volume histograms are displayed for (a) the TaiChiPro accelerator in flattening filter-free mode, (b) the Elekta Axesse accelerator in flattening filter-free mode, and (c) the Elekta Axesse accelerator with the flattening filter mode.



CONCLUSIONS

For craniospinal irradiation, the group A demonstrates favorable dosimetric performance and represents a promising clinical option.. It provides adequate target coverage, reduces OARs doses and MU, and improves workflow efficiency via auto-couch. However, group A is slightly inferior to B and C in junction-region HI and high-dose control. Groups B and C show no significant difference in target coverage or OARs sparing.

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