Evaluation of a FourPi approach to stereotactic treatment planning in cranial SRT

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Introduction and Objectives

Recent literature has demonstrated that trajectory-based or FourPi approaches to external beam treatment planning may be beneficial with regard to dose compactness and sparing of specified organs-at-risk [1-4]. Previously, MacDonald *et al* described a FourPi technique that defines fully dynamic arcs while minimizing overlap of target volumes and organs-at-risk (OARs) and rewarding beam angles that provide immediate sparing of proximal OARs [3,4]. In this study we evaluate a commercial adaptation and deployment of that approach (Elements Cranial SRS, Brainlab AG). Dosimetric effects of the new method are isolated by planning 10 vestibular cases and 10 pituitary cases with and without FourPi. Results are compared to our clinical status quo approach (RapidArc, Varian Medical).

Methods

FourPi treatment planning begins with default arc templates supplied by the planner according to the indication. Where multiple templates are provided, the most appropriate is selected automatically by an objective function that minimizes Planning Target Volume (PTV)/OAR overlap and radiological depth to the target (figure 1). From this template, a set of new candidate arcs is generated by adjusting table angles, and the most dosimetrically favorable are selected while minimizing the risk of collision. Finally, these arcs may be shortened by considering each control point of gantry rotation and truncating where PTV/OAR overlap is high relative to the average over the arc. Where table and gantry start/stop angles are altered, the latitude in deviating from the initial template is set by the planner. Once the FourPi arc customization is complete, VMAT optimization is performed.

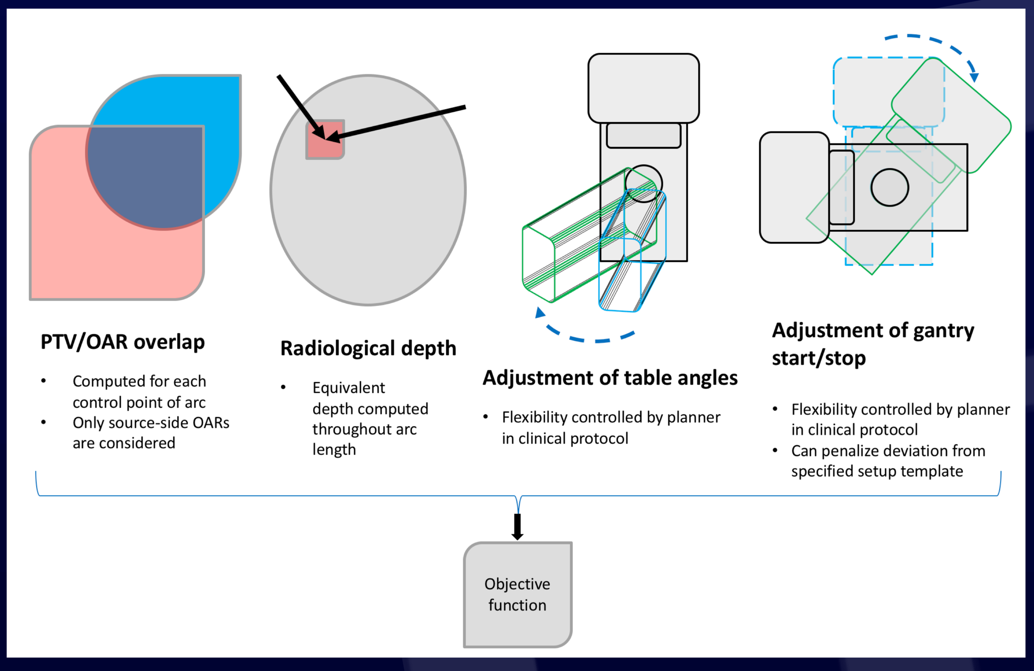

Figure 1. VMAT arc geometry is optimized by minimizing an objective function that considers PTV/OAR overlap and radiological depth. Table angles are modified and gantry arcs may be shortened. The freedom for this adjustments are controlled by the planner.

To evaluate the FourPi method, ten vestibular schwannoma (VS) and tem pituitary adenoma (PA) cases were first planned using the standard technique in our centre (RapidArc, Varian Medical). The same arc geometry was supplied to Elements Cranial SRS (Brainlab AG). In this system, all cases were planned i) without FourPi optimization, ii) with FourPi but eliminating the brainstem from the objective function (VS only) since it was present in almost all beams-eye-views, and iii) with all relevant OARs. Results were compared with regard to brainstem max and mean dose, maximum dose to optic nerves, chiasm, eye and lens. In addition, the MU per unit dose was quantified for all plans.

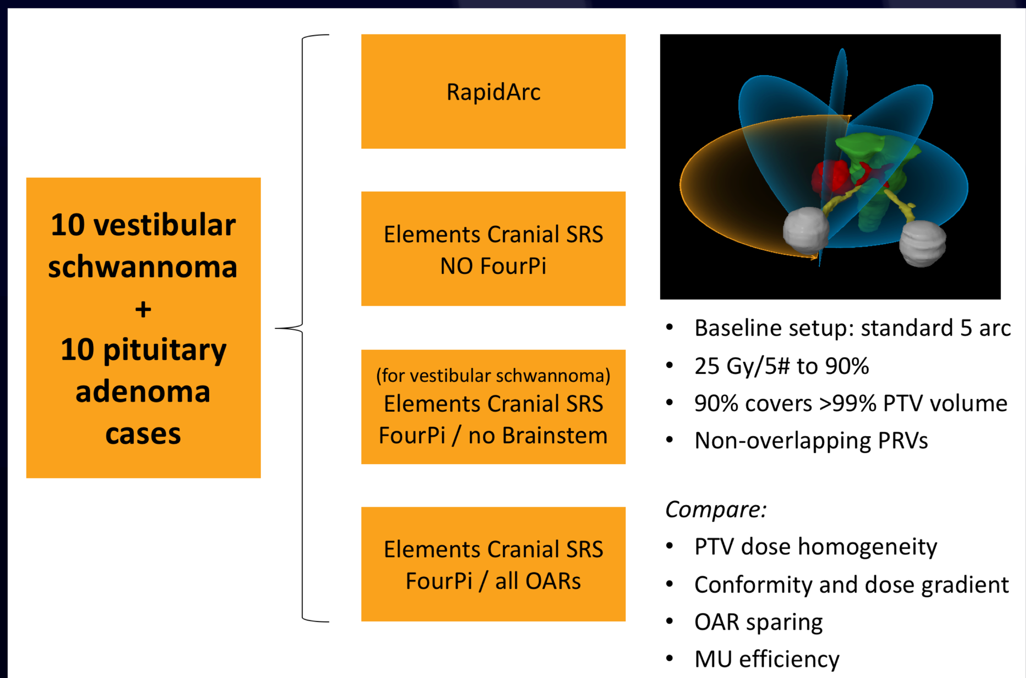

Figure 2. Ten vestibular schwannoma and ten pituitary adenoma cases were planned with RapidArc (Varian Medical), Elements without FourPi, Elements with FourPi but without the brainstem (vestibular schwannoma only) and Elements with FourPi and all relevant OARs.

Results and Conclusions

Vestibular schwannoma (VS)

FourPi treatment planning most frequently customized VS cases by moving arcs to the ipsilateral side and shortening to avoid OARs (figure 3). The mean dose to the brainstem was reduced but this was not statistically significant. Maximum brainstem dose was not affected on average due to the immediate proximity of this structure (figure 4). Optic nerves, chiasm, eyes and lenses were spared significantly ($p<0.05$) with regard to maximum dose (figure 5).

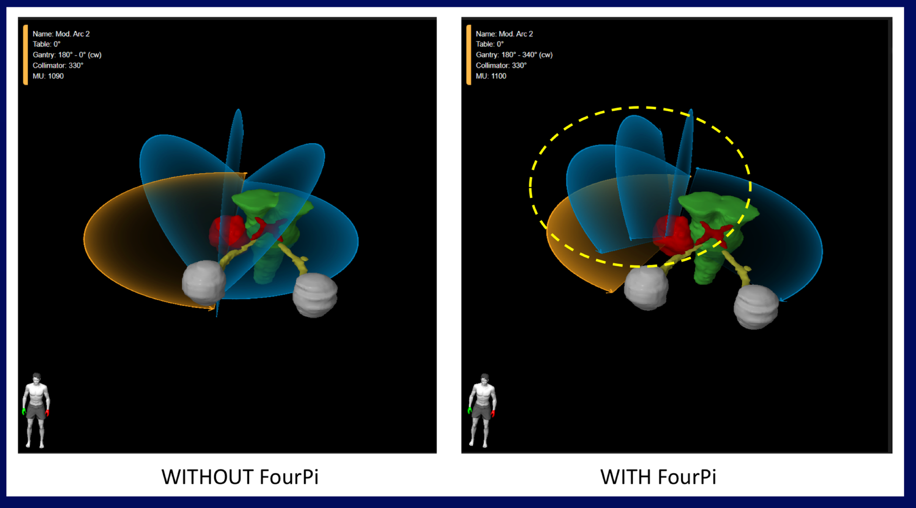

Figure 3. For most VS cases, the FourPi algorithm automatically moved three of five arcs to the ipsilateral side and shortened them to avoid optic structures.

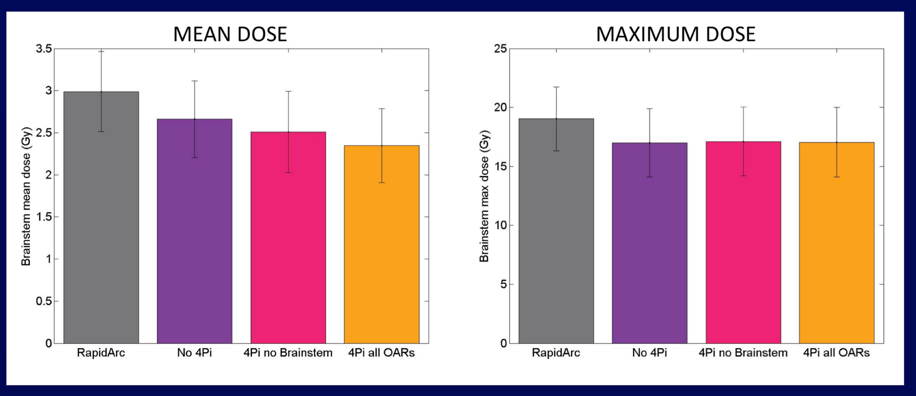

Figure 4. For all cases (VS and PA) improvements in mean brainstem dose were observed but were not statistically significant. Maximum dose to brainstem was not affected.

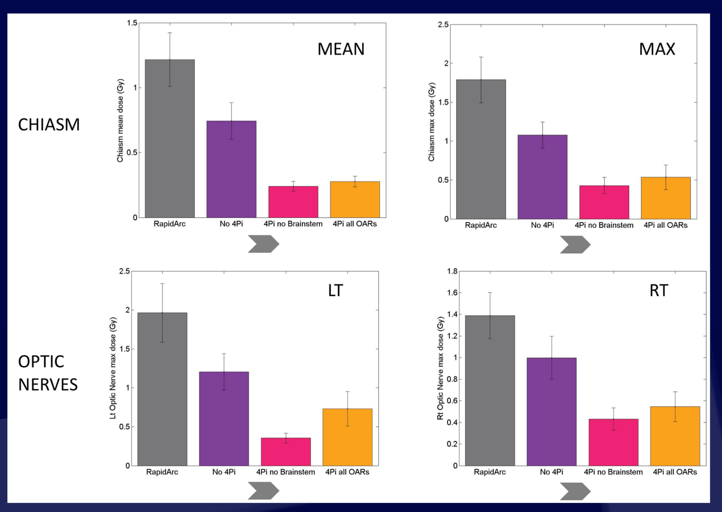

Figure 5. For VS, FourPi reduced optic nerve and chiasm doses significantly. Sparing was compromised slightly when the brainstem was introduced into the objective function.

Pituitary Adenoma (PA)

For most PA cases, template arcs were tipped to approach the vertex and shortened to spare brainstem or optic nerve OARs (figure 6). As for VS cases, the mean brainstem was lowered by FourPi but not significantly. Optic structures (e.g., Figure 7) were spared significantly with regard to maximum dose. For PA cases, complex VMAT MLC apertures were simplified resulting in improved MU efficiency on average (figure 8).

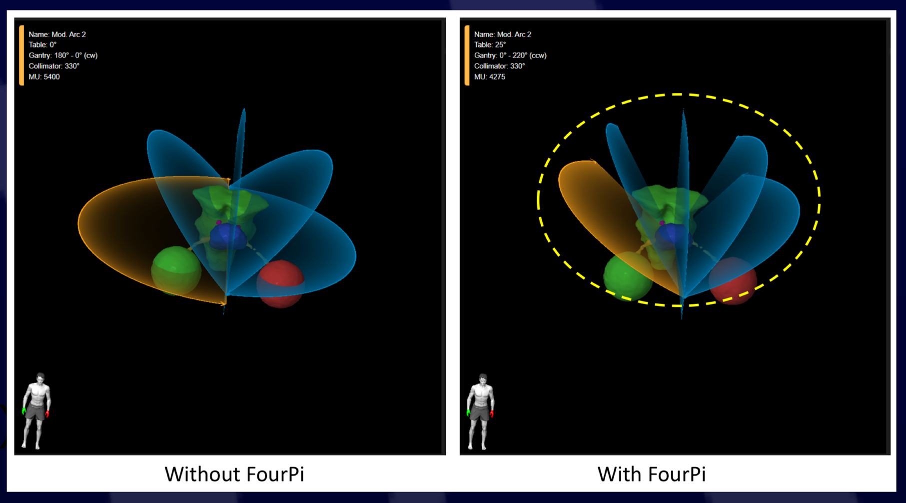

Figure 6. For PA cases, the template was modified by the FourPi algorithm by tipping arcs toward the vertex and shortening arcs to spare the brainstem.

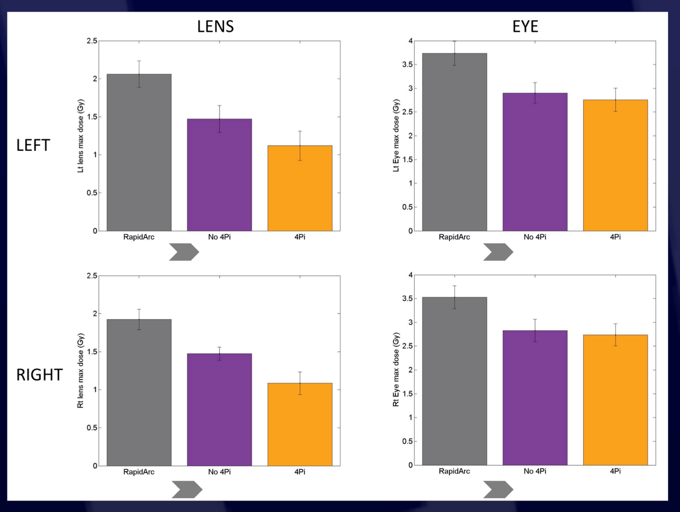

Figure 7. As for VS cases, improved sparing of optic structures was seen for PA, however this was statistically non-significant over the sample.

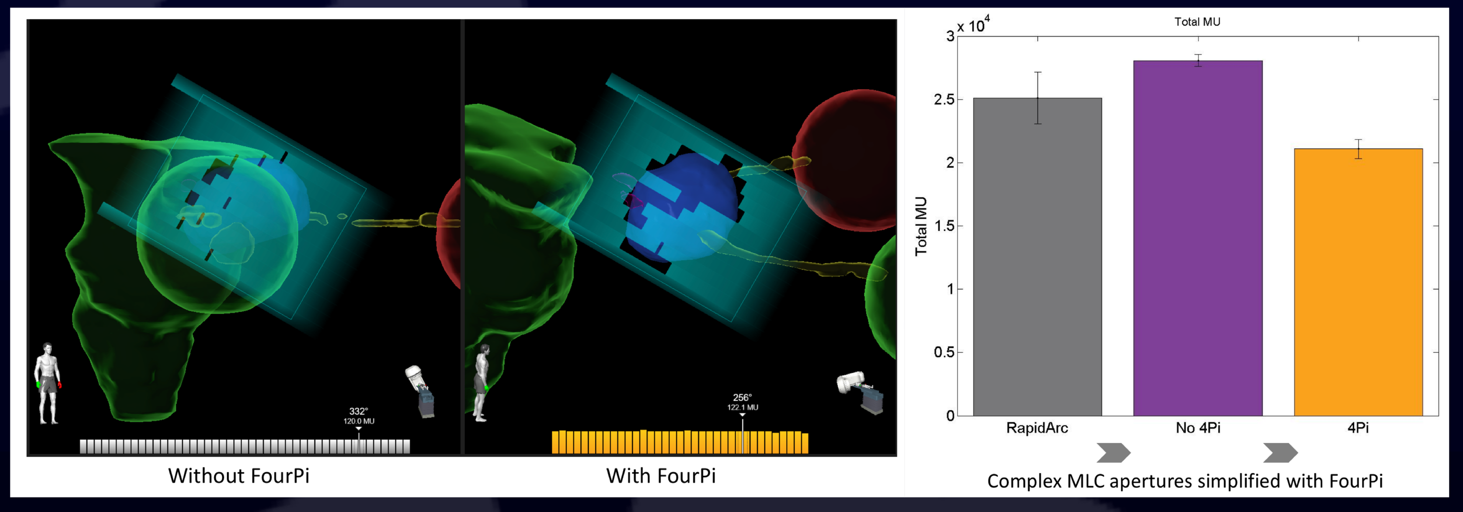

Figure 8. An unanticipated effect of FourPi planning was simplification of VMAT apertures due to minimization of intersection with OARs (left). This was most pronounced for PA cases where apertures were more complex without FourPi and resulted in reduction of total MU per unit dose (right).

References

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Disclosure: research on FourPi optimization has been supported by Brainlab AG.

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