Flattening filter-free radiotherapy for paediatric brain cancer: Impact on the dose to selected out-of-field organs

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Purpose

Removal of the flattening filter influences the out-of-field dose during radiotherapy, in terms of changes in collimator scatter, internal (patient) scatter and head leakage.

This study compares the dose to selected out-of-field organs for conventional flattened and flattening filter free (FFF) volumetric-modulated arc therapy (VMAT) of paediatric brain cancer.

Methods

Out-of-field dose to the thyroid, breast and testes was measured using thermo-luminescence dosimeters (TLDs) inserted in two anthropomorphic phantoms equivalent to a 1-year and 5-year old child.

Coplanar VMAT plans (2 full arcs) were prepared for 6 MV and 6 MV FFF photon beams in Varian Eclipse 13.7, simulating post-operative treatment of an ependymoma in the posterior fossa.

For each phantom, plans were made for two different spherical sizes of PTV (2 cm and 5 cm diameter) to account for the dependence of PTV size on out-of-field dose.

Each treatment plan should deliver a dose of 54 Gy to the PTV in 30 fractions, using a Varian Truebeam linear accelerator.

Six TLDs were placed in each investigated organ. The out-of-field dose was then measured for three treatment fractions (1,8 Gy each). The contribution from daily image guidance (cone-beam CT) was included for each of the three delivered fractions.

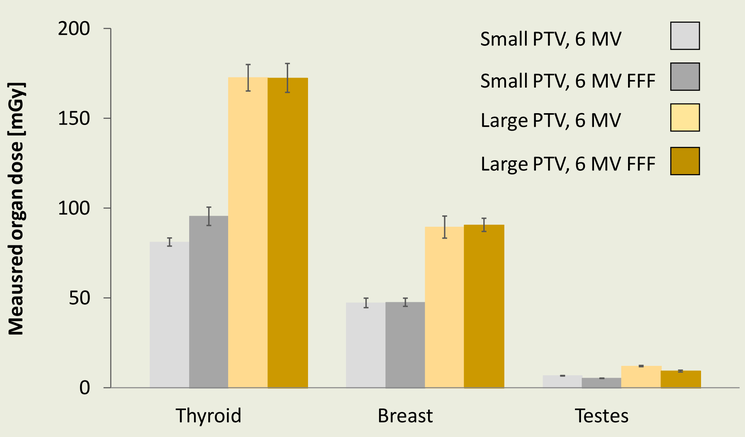
The measured doses were multiplied by 10 to correspond to the total treatment dose for 30 fractions.

Some additional irradiations were performed for the 1-year phantom with the head of the phantom removed, to investigate the contribution from internal scatter to the total out-of-field dose.

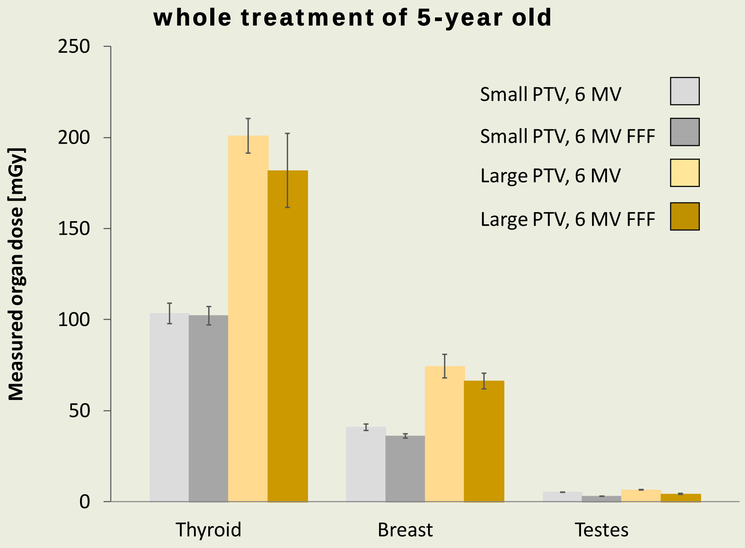
Statistical significance was evaluated by Student's t-test, significance level $p<0.05$.

Results

Measured out-of-field doses for whole treatment of 1-year old



Measured out-of-field doses for whole treatment of 5-year old



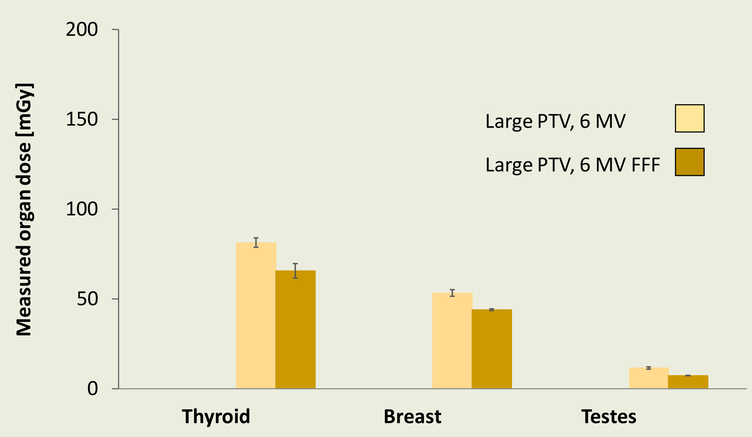
Dose to the thyroid showed a significant increase of approximately 18% for 6 MV FFF compared with 6 MV for the 1-year phantom, small PTV. In other cases, the difference between 6 MV and 6 MV FFF was insignificant.

Dose to the breast showed a significant decrease of approximately 12% for 6 MV FFF compared with 6 MV for the 5-year phantom, small PTV. Other breast doses did not show a significant difference.

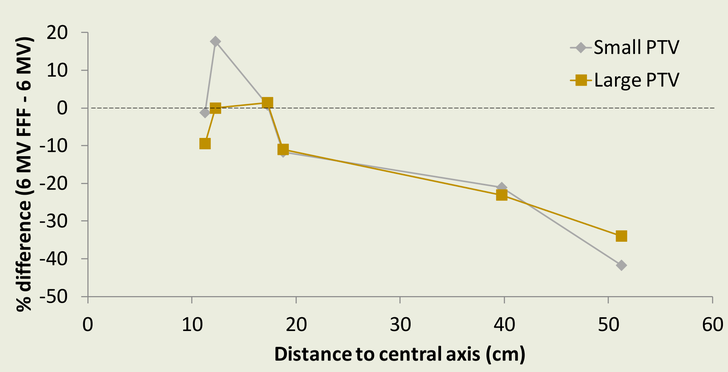
Dose to the testes showed a significant decrease between 21 and 42% for 6 MV FFF compared with 6 MV, for both phantoms as well as both PTV sizes.

The large-PTV plans were repeated for the 1-year phantom with the head removed to minimize the internal scatter contribution. In this case, the dose to all three organs were significantly reduced between 19 and 37% when comparing 6 MV FFF with 6 MV.

Head removed from 1-year old, minimizing internal scatter



Difference in out-of-field dose between 6 MV FFF and 6 MV



Consistent with results by
Kry, Vasiliev and Mohan, Phys Med Biol 2010; 55; 2155-66
and
Hälg, Besserer and Schneider, Med Phys 2012; 39:12; 7662-76

Conclusion

This study shows that doses to organs far from the treatment field are reduced for FFF VMAT compared to conventional VMAT, while doses to organs close to the field in some cases seem to increase.

The latter finding can be explained by an increase in internal scatter, caused by the softer energy spectrum of the 6 MV FFF beam of the linear accelerator model investigated.

For the investigated setup, very young paediatric brain tumour patients are therefore not expected to benefit from decreased doses to the thyroid and breast when treated with FFF VMAT.

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