Can lead shielding during paediatric brain radiotherapy reduce the risk of secondary cancer?

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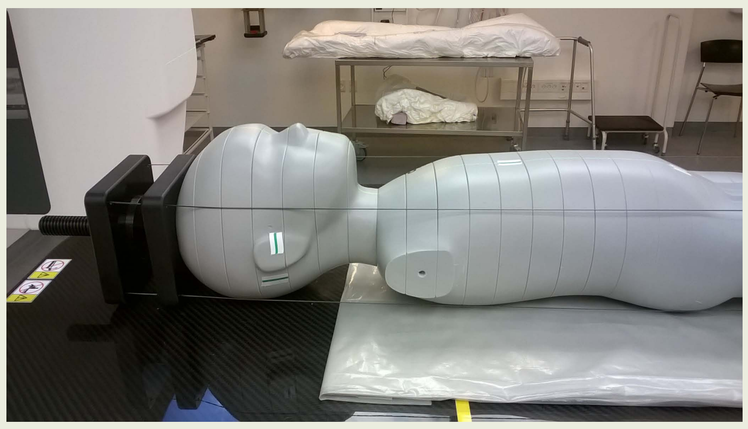
Purpose

Radiotherapy of paediatric patients comes at the expense of increased secondary cancer risk, caused by scattered radiation from the treatment itself as well as from daily image guidance.

This study examines whether lead shielding can reduce the risk of secondary cancer for the thyroid and breast when treating a paediatric brain tumour using volumetric-modulated arc therapy (VMAT).



Methods

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

Coplanar VMAT plans (6 MV x-rays, 2 full arcs) were made to simulate post-operative radiotherapy of an ependymoma in the posterior fossa. The planned total dose was 54 Gy to the PTV, delivered in 30 fractions.

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

For each phantom, out-of-field dose measurements were performed for small and large PTV, with and without lead shielding of the phantom's torso.

The shielding (1 mm lead equivalent) was applied by covering each phantom using lead rubber sheets. A 1 mm lead plate was furthermore placed underneath the phantom's torso.

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

The doses read out from the TLDs were multiplied by 10 to correspond to the total treatment dose for 30 fractions.

The measured doses were subsequently used to calculate lifetime attributable risks for cancer incidence, for the total treatment dose, in accordance with the BEIR VII report[1].

Results

Only risks for females are presented, since the risks tabulated in the BEIR VII report are consistently higher for females than for males.

Measured doses were higher for the large PTV than for the small, since the thyroid and breast were closer to the treatment field and the amount of internally scattered radiation is larger for a larger field.

With shielding, the measured doses were reduced by 8-18 % for the thyroid and 12-18 % for the breast.

The highest risk for secondary cancer was found for a 1-year old female, treated using the large-PTV plan. The use of lead shielding reduced this risk by 0.2 % for the thyroid and 0.1 % for the breast.

Measured out-of-field doses and associated secondary cancer risk for whole treatment of 1-year old female

Organ	PTV	Without shielding		With shielding	
		Mean dose (cGy)	Risk (%)	Mean dose (cGy)	Risk (%)
Thyroid	Small	8,12	0,51	7,18	0,46
	Large	17,26	1,09	14,12	0,90
Breast	Small	4,73	0,55	4,00	0,47
	Large	8,95	1,05	7,87	0,92

Measured out-of-field doses and associated secondary cancer risk for whole treatment of 5-year old female

Organ	PTV	Without shielding		With shielding	
		Mean dose (cGy)	Risk (%)	Mean dose (cGy)	Risk (%)
Thyroid	Small	10,34	0,43	8,63	0,36
	Large	20,09	0,84	18,54	0,78
Breast	Small	4,09	0,37	3,44	0,31
	Large	7,45	0,68	6,08	0,56

Conclusion

Lead shielding of the torso was shown to reduce the out-of-field dose from VMAT and daily image guidance to the thyroid and the breast. The reduced doses translated into reduced secondary cancer risks.

The risks for secondary cancer were small, but not negligible. The risk was largest when calculated for a 1-year old female. The use of lead shielding reduced the risk by as much as 0.2 %.

Out-of-field doses to radiosensitive organs should be quantified whenever introducing new delivery techniques in paediatric radiotherapy, to evaluate secondary cancer risk.

[1] National Research Council. Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2. National Academies Press 2006

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