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Joint estimation of radiation-induced late toxicity and cancer recurrence risks for bilateral breast cancer after photon versus spot-scanning proton therapy

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Purpose

Comparative planning of photon therapy versus spot-scanning proton therapy for patients with bilateral breast cancer.

Joint estimation of risks of radiation-induced secondary lung cancer and ischemic heart disease modeled with consideration of patient-level risk factors and risk of cancer recurrence caused by compromising target coverage.

Conclusion

Proton therapy did reduce the predicted risk of secondary lung cancer and ischemic heart disease by up to 3.3% and 5.5%, respectively, and the risk of recurrence by up to 1.6% in individual patients.

Methods

Five bilateral breast cancer patients treated with postoperative radiotherapy in 2013-2016 were selected for comparative dose planning. Two patients received chest wall and comprehensive nodal irradiation incl. internal mammary nodes (2 Gy x 25), two patients received whole breast irradiation (2.67 Gy x 15) and one patient received whole breast and left-sided lymph node irradiation incl. internal mammary nodes (2 Gy x 25). Two patients were treated with 3DCRT and three patients with VMAT.

All patients were re-planned with intensity modulated spot-scanning proton therapy. One or three fields were used (anterior, left anterior oblique and right anterior oblique) with multi-field optimization. A range shifter of 5 cm was used. Bolus were not used in the proton plans. If bolus was used in the photon plan, its Hounsfield units were overridden to be air for the proton plan.

Models estimating risks of secondary lung cancer and ischemic heart disease were developed from published dose-response data (Grantzau et al. 2014 and Darby et al. 2013) using mean dose to heart and lungs as input parameter. A linear-no-threshold model for risk of recurrence was derived based on hazard ratios from published randomized trials (EBCTCG 2011 and Budach et al. 2015).

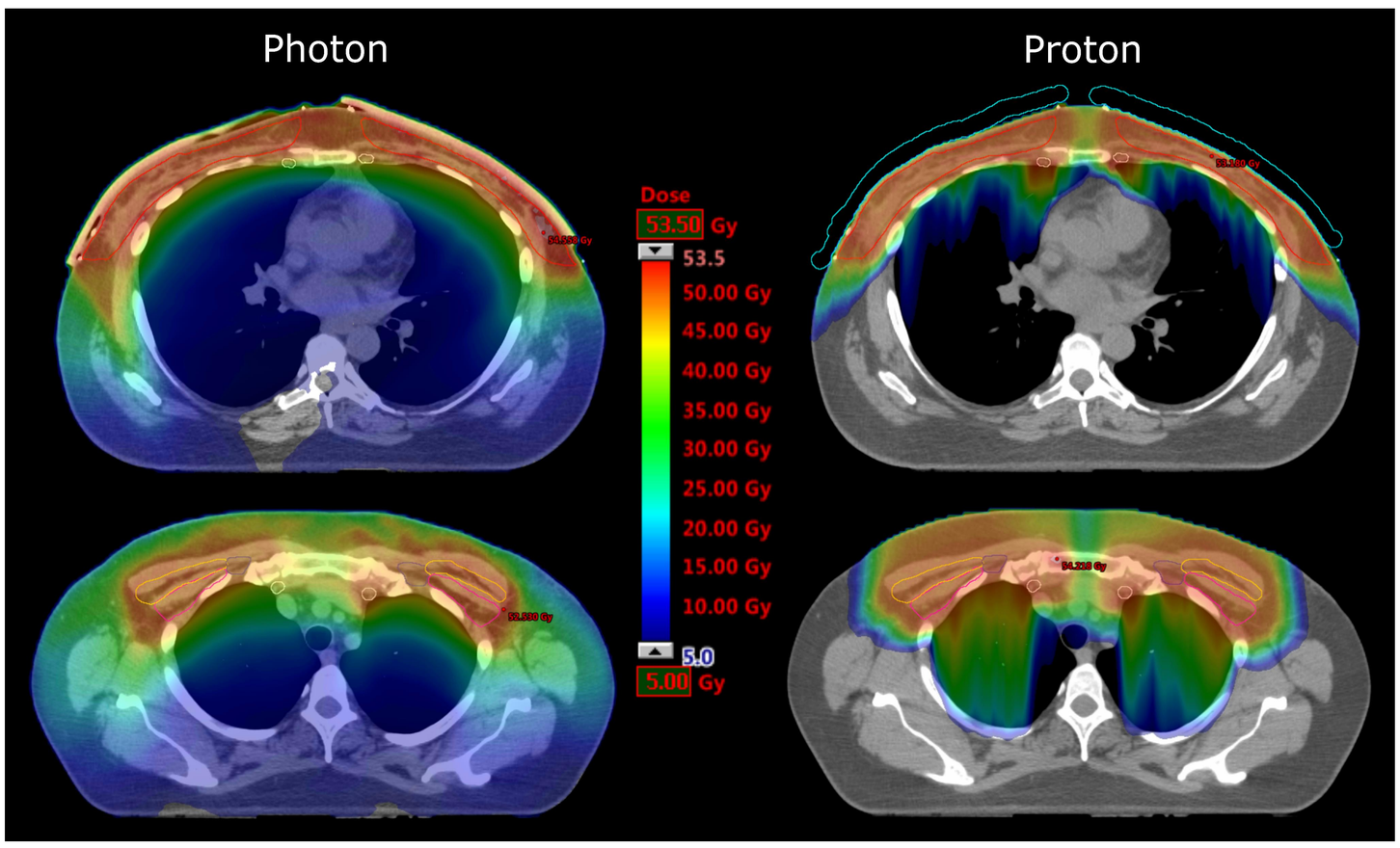

Figure 1: Example of comparative plans for one patient (prescription dose: 2 Gy x 25). Clinically delivered VMAT photon plan (left) and comparative spot-scanning proton plan (right). The dose ranges from 5 Gy (blue) to 53.5 Gy (red). The bolus was assigned to be air for the purpose of proton planning. Delineated clinical target volumes: chest wall (red), internal mammary nodes (white), interpectoralis (yellow), level II (magenta) and level III (blue).

Results

	Photon	Proton
Heart [median (range)]		
Mean [Gy (RBE)]	8.9 (1.5-12.7)	0.2 (0.0-0.4)
$V_{10\ Gy}$ [%]	18.7 (1.4-70.2)	0.5 (0.0-1.0)
Lung [median (range)]		
Mean [Gy (RBE)]	13.5 (5.2-16.3)	5.7 (0.8-9.2)
$V_{20\ Gy}$ [%]	23.1 (10.1-27.4)	9.3 (0.8-19.1)
Excess absolute risk [median (range)]		
Secondary lung cancer, non-smoker [%]	2.6 (0.6-2.8)	1.2 (0.1-1.6)
Secondary lung cancer, smoker [%]	5.3 (1.1-5.7)	2.4 (0.2-3.2)
Ishemic heart disease, no cardiac risk factors [%]	2.3 (0.2-3.2)	0.1 (0.0-0.1)
Ishemic heart disease, ≥1 cardiac risk factors [%]	4.5 (0.5-5.6)	0.1 (0.0-0.2)
Breast cancer recurrence [%]	0.9 (0.1-1.9)	0.1 (0.1-0.3)

Table 1: Dosimetric results and risk estimates for the comparative treatment planning. Relative biological effectiveness (RBE) was assumed to be 1.1.

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