

Theme: Physics

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Abstract Title: Ripple Filter in Breast Cancer Proton Therapy: Balancing Efficiency, Dose and LETd for Optimal Treatment

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Background / Aims:

The extremely narrow Bragg peaks of low energy proton beams in a synchrotron-based facility make the delivery of breast cancer treatment time-consuming. This study evaluated the impact of the ripple filter (RiFi) in scanned proton therapy for breast cancer, focusing on treatment efficiency, dose distributions, and dose-averaged linear energy transfer (LETd) to target volumes and organs at risk (OARs).

Subjects and Methods:

Treatment plans from eleven patients after breast-conserving surgery (BCS) and ten after modified radical mastectomy (MRM) treated with scanned proton beams in our center were re-optimized in RayStation treatment planning system (version 2024B) with and without RiFi. Target coverage was evaluated for clinical target volumes (CTVs) via homogeneity index (HI) and percentage volume receiving $\geq 95\%$ prescription dose (PD) (V95); Target LETd distribution was assessed using mean LETd (LETdmean) and LETd to 99% volume (LETd99). OAR dose metrics included mean heart dose, ipsilateral lung V5/V20/mean dose, mean thyroid dose, max left anterior descending branch (LAD) dose and max ribs dose. OARs LETd analysis focused on LETdmean and LETd1 for LAD, thyroid, and heart/lung/ribs receiving $\geq 50\%$ PD. Beam delivery time was calculated using in-house software.

Result:

For BCS patients, as shown in figure 1, RiFi maintained comparable CTVs V95, LETdmean, while increasing CTVtb HI by 0.002 on average and decreasing CTVtb LETd99 (-3.4%). Heart mean dose rose (+0.03 Gy(RBE)), as did max LAD dose (+1.38 Gy(RBE)) and lung V5 (+0.84%), V20 (+0.25%) and mean dose (+0.16 Gy(RBE)), when RiFi was used. RiFi reduced ribs LETdmean (-3.0%) and LETd1 (-3.1%). Delivery time was decreased by 25.0%. For MRM patients, as shown in figure 2, RiFi maintained comparable CTVchest/CTVsupra HI and V95, but increased CTVimn HI (+0.011), without altering LETd99. RiFi increased heart mean dose (+0.09 Gy(RBE)), lung V5/V20/mean dose (+2.73%/+2.66%/+0.80 Gy(RBE)), max ribs dose (+0.50 Gy(RBE)) and thyroid mean dose (+0.51 Gy(RBE)), and reduced thyroid/lung/ribs LETdmean (-2.0%/-7.0%/-4.6%) and thyroid/ribs LETd1 (-3.0%/-6.2%). Delivery time was decreased by 28.9%.

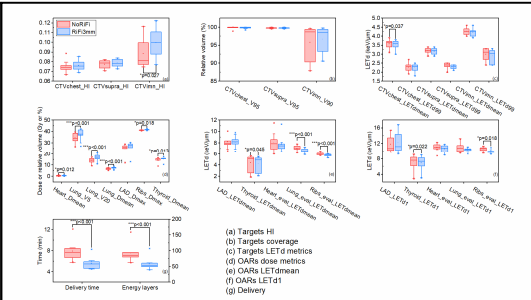
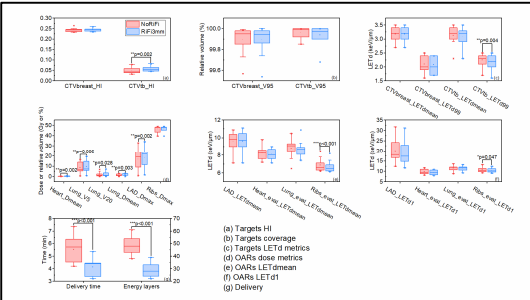


Figure 1. BCS patients statistics.

Figure 2. MRM patients statistics.