Dosimetric impact of Tumor Treating Field Arrays on Radiation Treatment for Locally Advanced NSCLC

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Introduction

A phase 1 study is underway that will look at the feasibility and safety of Tumor Treating Field (TTField) arrays on the treatment of locally advanced stage III non small cell lung cancer (NSCLC). This device consists of a power generator and transducer array which maintains a consistent low-intensity alternating electric field in the region of the tumor. TTFields selectively disrupt cell division, and preclinical research has demonstrated the antimitotic effects of TTFields. This clinical trial will eventually require patients to wear the array during radiation treatment while it is powered off, though left on the patient; however, no studies to date have demonstrated the impact of this array on treatment quality for lung radiation therapy, which is a prerequisite to utilizing this array on patients. We performed a preliminary, retrospective analysis of how past radiation treatments would have been impacted if the patients were wearing this array during their treatment for stage III NSCLC, as well as an end to end phantom study to validate these predictions of dosimetric impact.

Methods

We modeled TTField arrays in our treatment planning system (Eclipse/Acuros) with the most appropriate geometric and material representation to match dosimetric measurements in solid water. Next, ten previously treated patients at our clinic for stage III NSCLC representative of the population to be enrolled were anonymized, and array models integrated into the treatment plan to characterize impact that would have occurred if the array had been present during delivery. Finally, an end-to-end analysis was performed on a RANDO phantom by scanning the thorax with the array and generating a VMAT treatment plan. This plan was delivered to the phantom and the dose distribution was characterized with multiple measurement devices including film.

In addition to characterizing the impact of the arrays on dose, we also wanted to provide some guidance on workflow and the most efficient way to handle these cases, given that developing an internal methodology for handling these cases in each clinic would be extremely time intensive.

Results

Overall, dosimetric measurements show a bolus effect with a Dmax shift of ~0.5cm, increasing max skin dose within 5mm by 8.5% and 38.5% within 2mm. Attenuation by the array had moderate impact at depth due to the PDD shift and hardening of the beam (difference in D5cm=0.4% and in D10cm=5.6%). Retrospective analysis of clinical plans showed plan specific variability, with VMAT minimizing dosimetric impacts(skin dose increase~9-32%, and max dose difference beyond Dmax~3.8-7.0%).

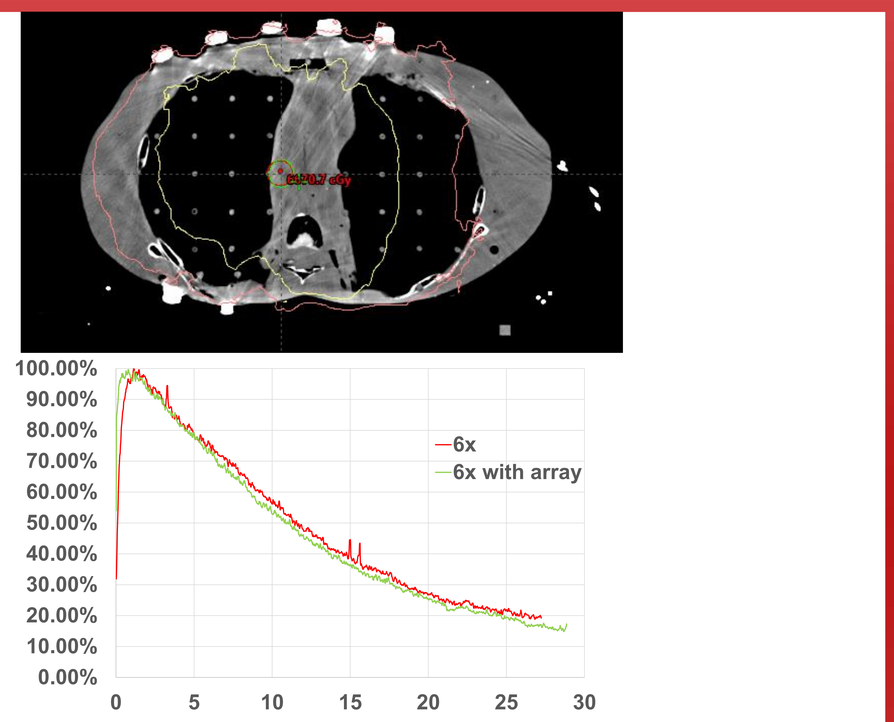

Figure 1. (Top) CT scan of Rando phantom with TTField Arrays in place. (Bottom) Measured film PDD without array in red, and with array in green. These figures demonstrate some challenges clinics will face when creating plans on these patients: with a physical density of stainless steel in the electrode, the amount of artifact caused by the arrays and the resultant overestimation of electrode size on CT (1mm in reality vs up to 20mm on scan), and the moderate dosimetric impact (particularly in relation to skin dose).

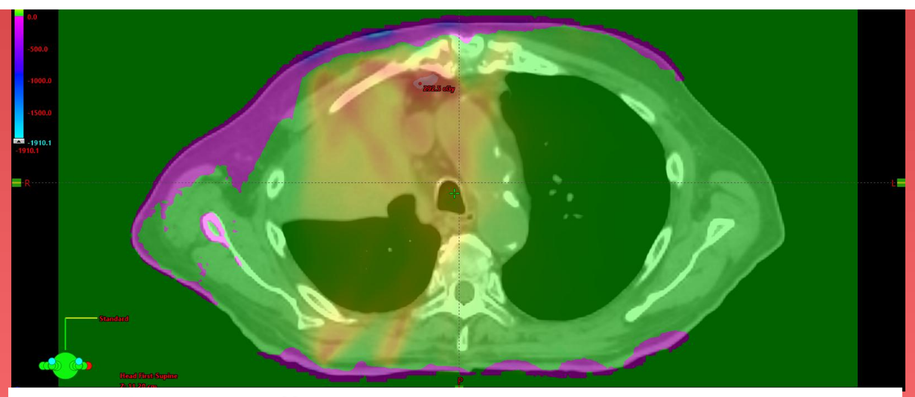

Figure 2. Dose difference map between clinical plan and retrospective recalculation of plan with array modeling in place. The greatest impact can be seen just below the array electrode, though small skin dose differences are seen all around the electrodes as well given the VMAT modality. Cold spots and cold streaks are also seen at depths beyond Dmax.

Results

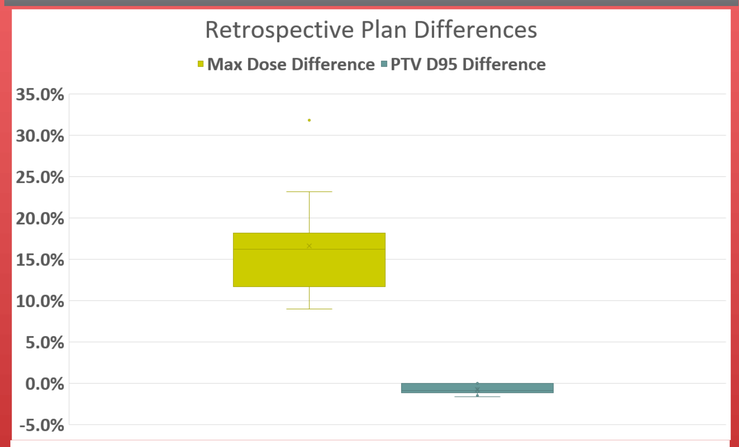

Figure 3. Box plot showing differences between the original clinical plan and the same plan with a TTField array model added. The left green distribution shows the maximum point dose difference (generally occurring near the surface), which had an interquartile range of 11.7 -> 18.2%. The right blue distribution shows the PTV D95 difference, which shows much smaller impact with an interquartile range of 0 -> -1.1%

Discussion/Conclusions

Dosimetric analysis shows moderate impact of the array, particularly for skin dose. Despite these impacts, DVH analysis shows relatively negligible impact on target coverage. Basic modeling of the array in the treatment plan is recommended as well as utilization of VMAT for delivery. PDD and treatment planning analysis shows a material override of stainless steel (in Acuros) is sufficient for accurate characterization of target and OAR dose, with possibly the exception of skin dose. A short analysis of impact vs treatment energy also shows effects likely resulting from pair production at high energies, therefore plans should be restricted to 6MV photons. During the upcoming study particular attention should be given to monitoring of patient skin toxicity. Modelling workflow that involve preconficured contours can be time intensive to apply on an individual patient level, and scanning with the array can produce major artifacts that require their own corrections. However, we found the best efficiency/accuracy ratio working with scanned arrays.

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