Impact of magnetic field on dose distribution in MR-guided radiotherapy of head and neck cancer

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INTRODUCTION

In radiotherapy of head and neck (H&N) cancer, MR image guidance provides many benefits [1-4], which are useful for real-time high-contrast visualization of the tumor and organs at risk (OARs). Apart from the benefits of MR image guidance, it is important to investigate the impact of the magnetic field on the dose distribution.

A single beam at a highly oblique surface can result in a dose increase of up to 56% to the exit point [5]. The ERE can vary in terms of the incident angle of the beam to the surface, and oblique angles induce the largest dose increase at the interface. However, at perpendicular interfaces this effect can be compensated by using opposing beams [5]. Most parts of target volumes in H&N are superficial and relatively large, which results in a relatively large area of skin irradiation. Furthermore, H&N tissues contain in vivo air cavities, including the nasopharynx, oropharynx, larynx and trachea, in which the ERE may be problematic because the tissue-air interface affects the dose distribution.

AIM

To investigate the impact of a magnetic field on dose distribution in MR-guided radiotherapy of H&N cancer, concentrating on:
(1) Magnetic field induced variation of plan quality, and
(2) ERE induced dose increases to the skin and tissues containing air cavities.

METHOD

1. Patient selection and regions of interest

- 10 patients with hypopharyngeal carcinoma who were treated with conventional fractionated radiotherapy were reviewed.
- The skin and tissues containing air cavities were contoured.

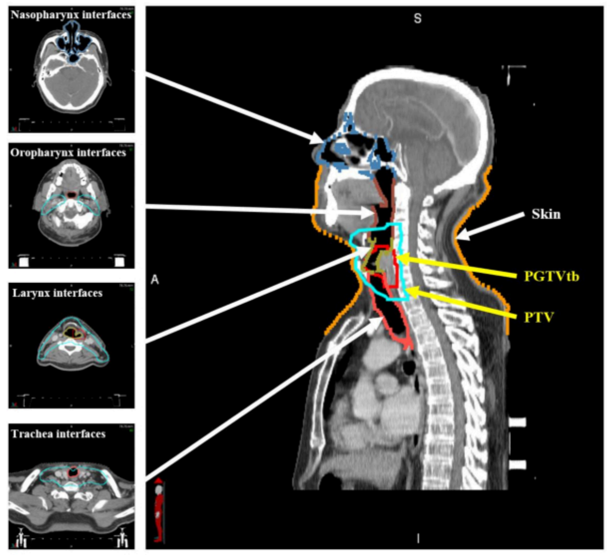
2. IMRT planning

- Three plans were generated for each patient in the Monaco with an Elekta Unity MR-linac.
  a) The first plan was optimized without magnetic field ($plan_{0T}$).
  b) The second plan was re-calculated in presence of a 1.5 T magnetic field ($plan_{1.5T\_reCal}$).
  c) The third plan was re-optimized in presence of a 1.5 T magnetic field ($plan_{1.5T\_reOpt}$).
- The planning process was repeated and the parameters were averaged for each plan to address the effects of variation stemming from the Monte Carlo calculation.

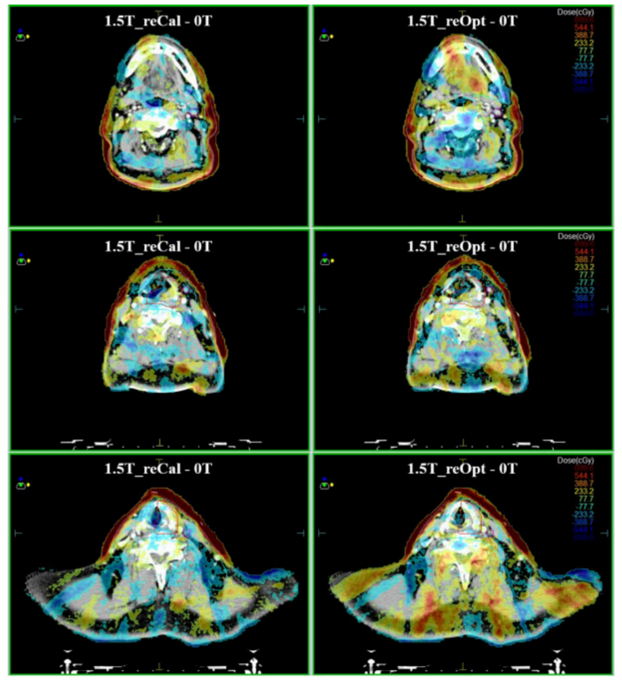
3. Study endpoints

- Target: V_p (the percentage of the target volume receiving the prescribed dose), homogeneity index, conformity index.
- D_{max} of the brain stem and brain stem PRV, D_{max} of the spinal cord and spinal cord PRV, D_{mean} of the parotids, D_{mean} of the normal tissue.
- The quality score S of each plan is the sum of the PQM values of the 15 sub-metrics: $S = \sum_{i=1}^{k} S_i$

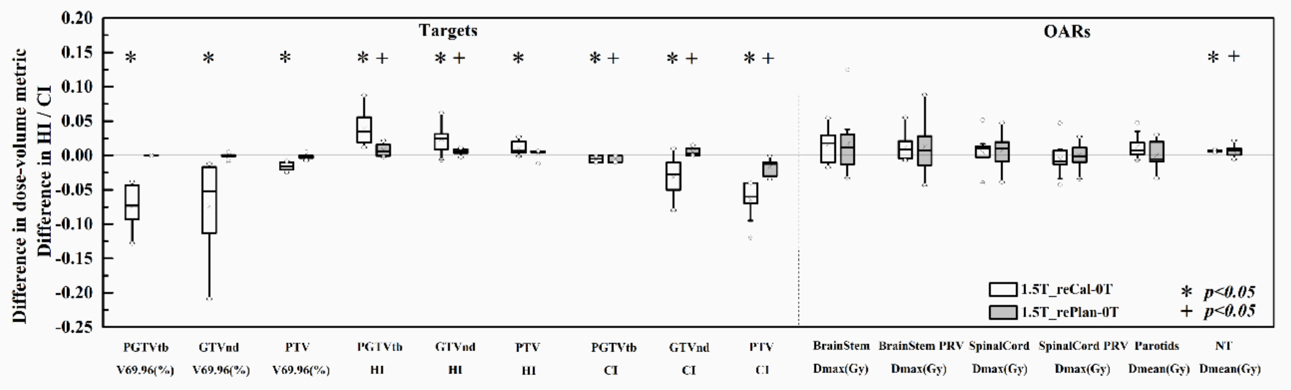
RESULTS



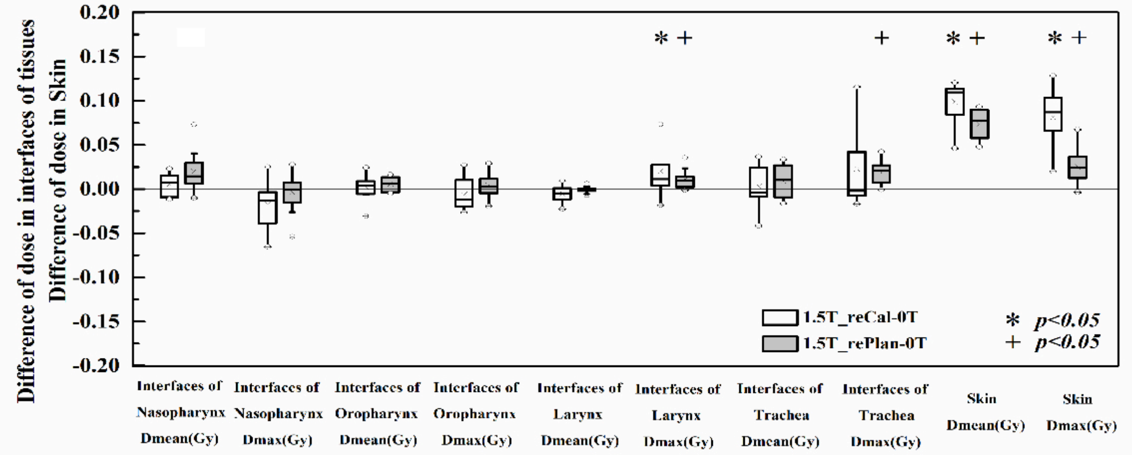
A patient CT scan with delineated regions of interest (ROIs)



Maps of dose differences (in cGy) per voxel relative to the situation of no magnetic field. Examples of three transversal slices are depicted in each consecutive row, and two types of plans are arranged per column, i.e. Left: 1.5T_reCal - 0T; Right 1.5T_reOpt - 0T. Differences range from -700 cGy (dark blue) to +700 cGy (dark red).



Differences in ***the investigated dose-volume metrics*** *between the plans designed for the 1.5 T MR-linac with either re-calculated or re-planned and the 0 T linac*.*



Dose differences in ***the interfaces of tissues containing air cavities and skin*** *between the plans designed for the 1.5 T MR-linac with either re-calculated or re-planned and the 0 T linac*.*

Table. The quality scores of the three types of plans

Patient number	0T	1.5T_reCal	1.5T_reOpt
1	88.4	72.8	81.6
2	73.0	58.1	67.8
3	89.7	81.6	90.0
4	82.0	65.6	81.3
5	79.7	75.9	79.8
6	79.2	62.1	76.4
7	88.8	64.9	82.2
8	72.8	52.2	74.1
9	93.0	81.7	92.6
10	75.8	65.7	74.7
Mean	82.2 ± 7.0	68.0 ± 9.2	80.0 ± 7.0
Median	80.9	65.6	80.6
Significance level	0T vs 1.5T_reCal 0.005	0T vs 1.5T_reOpt 0.059	1.5T_reCal vs 1.5T_reOpt 0.005

**Note: Numerically positive differences mark an increase in the respective metric for the 1.5 T MR-Linac plans. Displayed are the first and third quartiles (boxes), medians (bands inside), average values (crosses), standard deviations (whiskers) and outliers (circles)*

CONCLUSIONS

In summary, this study has shown that the magnetic field has a great impact on the quality of $plan_{1.5T\_reCal}$, the recalculated plan. However, re-optimizing the plan in the presence of a 1.5 T magnetic field ($plan_{1.5T\_reOpt}$) increases the feasibility of achieving a clinically acceptable treatment plan for hypopharyngeal carcinoma. Furthermore, there is a significant increase to the skin dose in the presence of a 1.5 T magnetic field, and there were no significant differences in the metrics of interfaces of tissues containing air cavities except for an increased maximum dose to the larynx and trachea.

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