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MRI-only treatment planning for 1.5 T MR-Linac: Assessment electron density effects on dose calculation and optimization accuracy for cervical carcinoma

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INTRODUCTION

In the clinical radiotherapy workflow, use CT in radiation therapy because reference image generation for patient position verification based on in-room x-ray imaging and dose calculations used the electron density information, while the advantages of magnetic resonance imaging (MRI) rest with its high soft tissue contrast and biological/functional imaging capabilities. However, a major limitation in the use of MRI as the primary imaging modality for radiotherapy planning is the lack of a relationship between the electron density (ED) information and the MRI signal intensity. The Unity MR-Linac (Elekta, AB, Stockholm, Sweden) combined 1.5 T magnetic field and 7 MV linear accelerator can visualize the tumor and the surrounding organs directly before, during and after treatment, while offering the potential ability to improve treatment outcome. For cervical patients planning, conventionally only part of the bony regions for example femoral heads will be contoured on the original CT, which can lead to the misinterpretation for the undelineated bones on the bulk rED assigned MRI-only planning.

AIM

This study aims to assess the impact of these undelineated bone regions on dose calculation and optimization results of MRI-only based IMRT plans for cervical cancer treated on the 1.5 T MR-Linac.

METHOD

Our study is broken up into two parts, where the two sections investigate the effect of these undelineated bone regions on dose calculation/optimization results of MR-only based IMRT plans for cervical cancer treated on the 1.5 T MR-Linac.

- **Synthetic CTs generation**

All of the five retrospective cervix patients who were treated on the Elekta 1.5 T MR-Linac with their original CT and MRI T2 datasets were used for the study. The different s-CTs were generated by adjust the layers of structures in Monaco (Figure 1).

- **Treatment planning**

Different plan's dataset (Bone-MRI, NoBone-MRI), optimization and dose calculation combinations investigated.

- **Plan comparison and analysis**

These simulated plans were evaluated for optimization and dose calculation error through dose-volume parameters (DVPs) analysis and global gamma analysis of dose.

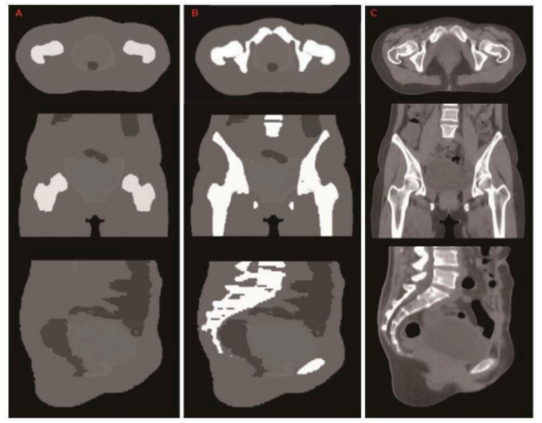

Figure 1 Overview of all the s-CTs used in this study. (A) shows the s-CT generated with only femoral heads, (B) shows the s-CT generated with all the bone regions, (C) shows the original CT.

RESULTS

- **The effect on dose calculation accuracy for MRI-only IMRT planning**

In comparison of the recalculation plans on two s-CT sets, the various DVPs of PTV were found to be increased when only the femoral heads were delineated (Figure 2).

Then the dosimetric differences for the recalculation plans on two s-CT sets and original CT were investigated. Comparing the recalculation plans on original CT, there was significantly increase for the doses to PTV and OARs for the two s-CT sets based plans. However, the results showed that the BoneRC-MRI plans lead to smaller dose effect than NoBoneRC-MRI by comparing RC-CT, , with the difference being 0.7% and 1.2% respectively (Figure 2).

The gamma analysis results showed that the GPA of BoneRC-MRI were better than NoBoneRC-MRI (Table 1).

- **The effect on optimization accuracy for MRI-only IMRT planning**

Comparing the reoptimization plans on two s-CT sets, the results showed no significant difference for quality of plans between BoneRO-MRI and NoBoneRO-MRI.

In comparison of reoptimized plans on original CT and s-CT, the results showed that the BoneRO-MRI plans also lead to smaller dose effect than NoBoneRO-MRI by comparing BoneRO-CT and NoBoneRO-CT, with the difference being 0.7% and 1.3% respectively (Figure 3 and 4).

The Gamma analysis results showed that the GPA of BoneRO-MRI were also better than NoBoneRO-MRI (Table 1).

Table 1 Global Gamma analysis for all IMRT plans on the s-CT sets.

Plan type	Gamma Pass Rate
BoneRCMRI/CT	99.58±0.3
NoBoneMRI/CT	99.58±0.3
BoneROMRI/CT	99.58±0.27
NoBoneROMRI/CT	99.12±0.41
BoneRC vs NoBoneRC	**P = 0.049**
BoneRO vs NoBoneRO	**P = 0.008**

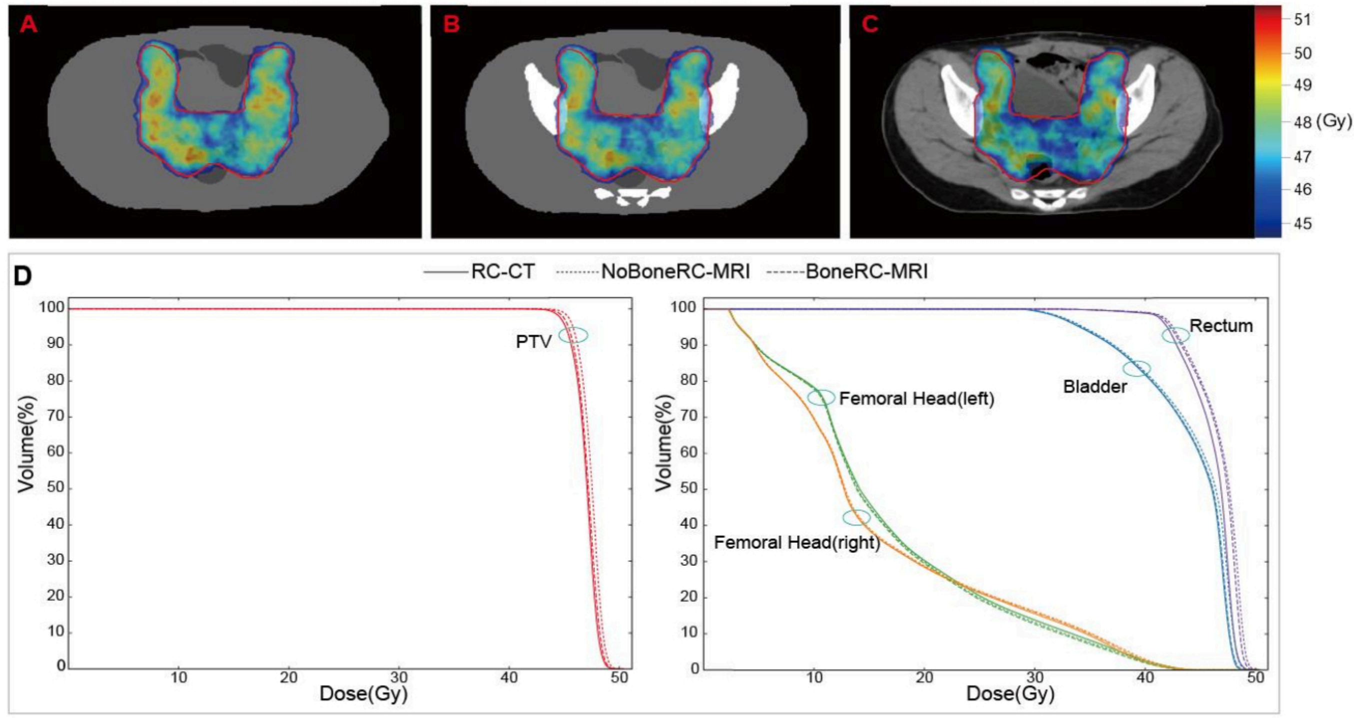

Figure 2 The dose distributions and DVH for recalculation plans on s-CT sets and original CT. (A) shows the recalculation plan on the s-CT generated with only femoral heads. (B) shows the recalculation plan on the s-CT generated with all the bone regions. (C) shows the recalculation plan on the original CT. (D) shows the DVH for recalculation plans on s-CT sets and original CT.

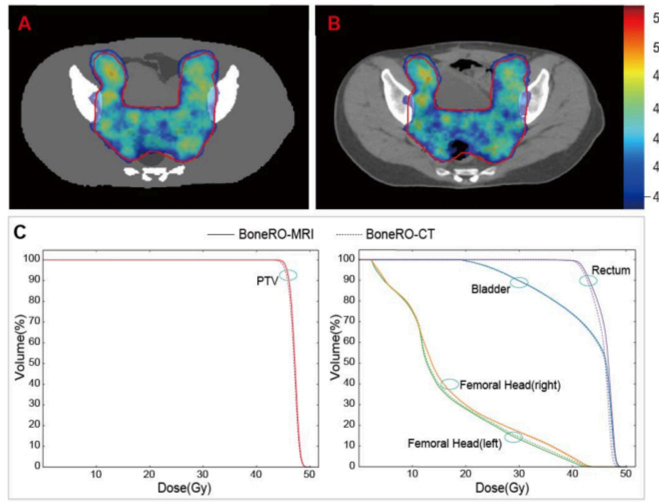

Figure 3 The dose distributions and DVH for reoptimization plans on original CT and s-CT generated with all the bone regions. (A) shows the reoptimization plans on the s-CT. (B) shows the above reoptimization plan on the original CT. (C) shows the DVH reoptimization plans on s-CT sets and original CT.

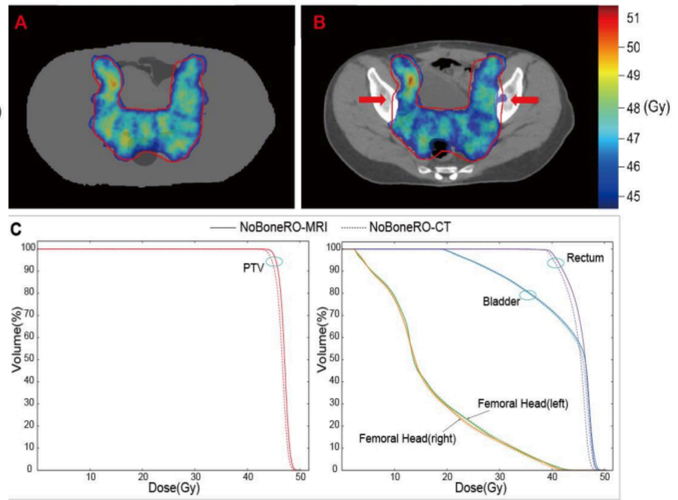

Figure 4 The dose distributions and DVH for reoptimization plans on original CT and s-CT generated with only femoral heads. (A) shows the reoptimization plans on the s-CT. (B) shows the above reoptimization plan on the original CT. (C) shows the DVH reoptimization plans on s-CT sets and original CT.

CONCLUSIONS

- The adaptative plans with fully delineation of the bones achieved more accurate dose distributions than plans with only delineation of femoral heads by comparing original CT based plans.
- The commonly used bulk ED assignment with only part of bone delineation may not be sufficient for cervical cancer MRI-only planning.
- Fully delineation of the bones and considering the effect of bone electron density have the potential to reduce the error of s-CT generation and dosimetry. It is recommended to be taken into account for improving the MRI-only planning accuracy in 1.5 T MR-Linac.

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