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Dosimetry for head and neck radiotherapy using personalized quantitative MRI

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Introduction and Purpose

MRI's excellent contrast between soft tissues is of great interest for radiotherapy planning to improve normal tissue and tumor delineation. But for dose calculation electronic density is needed and is not directly accessible with MRI, unlike CT. This difficulty can be overcome with a synthetic CT (sCT) created from MR images. Several methods allow to build a synthetic CT^{1,2,3}. The electronic density depends on tissue characteristics such as the mass stopping power and the mass attenuation coefficient, which have been evaluated for different atoms and for a wide range of energies. It has been found⁴ that these values have a different evolution for the hydrogen atom than the other atoms. Quantitative MRI can provide hydrogen concentration through the measurement of proton density, which is possible with specific sequences.

This work presents a pilot study aiming to build a synthetic CT using MRI proton density measurement with a patient-specific workflow.

Method

Protocol conducted on 25 patients with head and neck cancers at the comprehensive cancer Center Léon Bérard in Lyon.

- a conventional injected CT • 7 minutes of clinical routine scan
- 4 minutes of specific sequences for treatment planning

To retrieve the proton density (PD) ρ :

$$S \propto k M_0 \frac{\sin \alpha \left(1 - e^{-\frac{TR}{T_1}}\right)}{1 - (\cos \alpha) e^{-\frac{TR}{T_1}}} e^{-\frac{TE}{T_2}}$$

If α tends towards 0° $\rightarrow S \propto k M_0 e^{-\frac{TE}{T_2}}$

$TE \approx 0$
3D Spiral VIBE UTE (WIP)^[3]

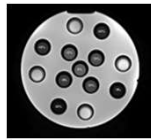
SIEMENS Healthineers $\alpha = 5^\circ$ and $TE = 30 \mu s$

$k \cdot M_0 = G \cdot \rho$ $\leftarrow S \propto k M_0$

- Estimation of the coil sensitivity maps G with a calibration phantom with tubes filled with a D_2O dilution in water with known theoretical proton density. 2 types of algorithms for the estimation :

in-line (Prescan and B1-filter)

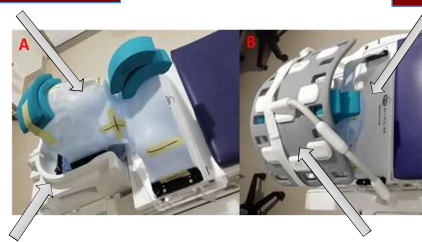
post-processing (SENSE, ESPIRiT and adaptive reconstruction)



Same immobilization material for CT, MRI and radiotherapy:

five-points fixation mask

radiotherapy table



lower part of Head coil

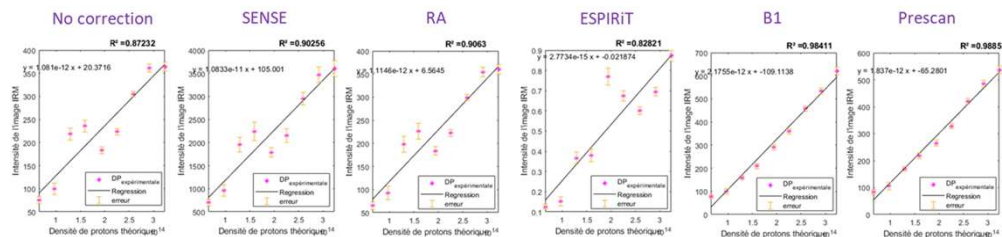
flexible anterior body coil

CT and sCT-based dose distribution were computed using MONACO software with a set of dose-volume constraints for the OARs and tumor volumes. Comparison tools :

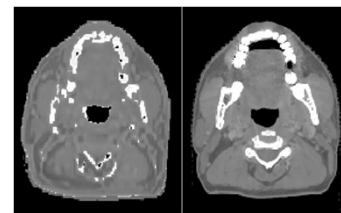
- the Mean Absolute Error (MAE)
- the Bland Altman analysis
- the dose difference
- the gamma pass rate

Results

- The linear regressions for each method of coil sensitivities are presented below. With a 32 Go RAM, INTEL I7, 2.50 GHz processor personal computer, the computation time for SENSE, ESPIRiT and AR algorithms was 1 min, 13 min 20 s and 2 min respectively.

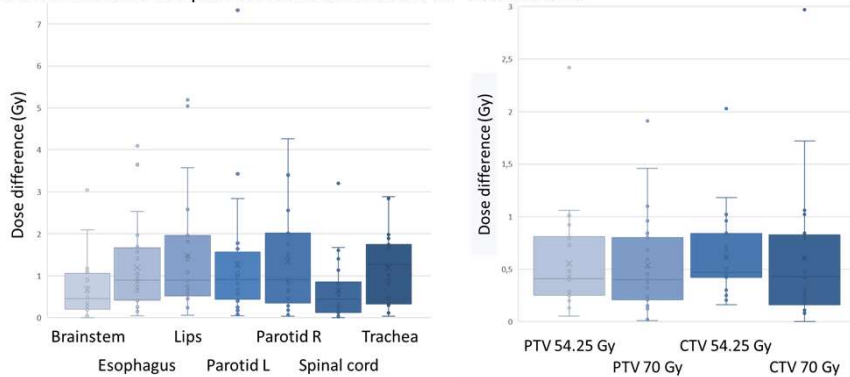


- The mean MAE between the sCT and CT of the patients was $124.6 \text{ HU} \pm 23.1 \text{ HU}$ which, as a percentage of the total range, is equivalent to $4.2\% \pm 0.8\%$.

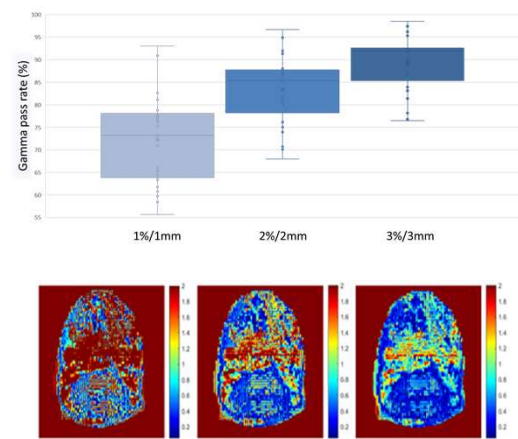


- The Bland Altman analysis showed a low bias for most of the OARs (between -0.39 and 0.4 Gy) and for the PTVs (-0.04 Gy). The variability was very low for the tumor volumes (3.17 %), it was higher for some organs at risk such as the brainstem (20.94 %) and the lips (22.70 %).

- The dose differences were computed for several OARs and tumors volumes :



- The gamma pass rates are presented for different criteria



Conclusion and Discussion

This study shows that proton density quantification with MRI allows to build a synthetic CT with a direct method. The dosimetry shows results comparable to other methods in the literature and to the reference CT-based dosimetry. This method is a first step towards personalized treatment that could be adapted to other anatomical area with the proper UTE sequence and a coil setup compatible with the immobilization material.

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