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Analysis of deformations in CBCTs and their effect on proton dose coverage in mediastinal thoracic patients

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Introduction

In this retrospective planning study, the changes in anatomy as measured from CBCTs are compared to dose coverage of proton double scattering plans (DS).

Materials and methods

We selected fourteen thoracic cancer patients who received a planning CT (PCT) as well as several CBCTs. Fig. 1 shows an example of the CBCT in comparison to the PCT. Level 7 lymph nodes (LN7) were contoured by experienced oncologists on PCTs. They were then propagated to the CBCTs using Elastic Deformation and verified by experienced oncologists. LN7 Contours were recopied to the PCTs using the rigid image registration to evaluate the dissimilarity coefficient (DIC), the Center of mass shift (3Dshift) and maximum isotropic margin expansion (IME) of the initial LN7 on PCT which could enclose LN7 on CBCTs (see Fig.2). DS proton plans were designed for LN7 on PCTs. The plans were designed for 5mm lateral shift per field and up to 5% change in density. The plans were tested for each field and each perturbation. If a field dose failed the perturbation test, re-planning was undertaken. The plans were afterwards projected on CBCTs and $D_{95\%}$ was analyzed for each field separately. In total, 10 fields were analyzed on 14 PCTs and 147 CBCTs.). A failure in dose coverage of LN7 was considered if >±5% change in the $D_{95\%}$ of LN7 were observed (see **Fig. 3 & 4**).

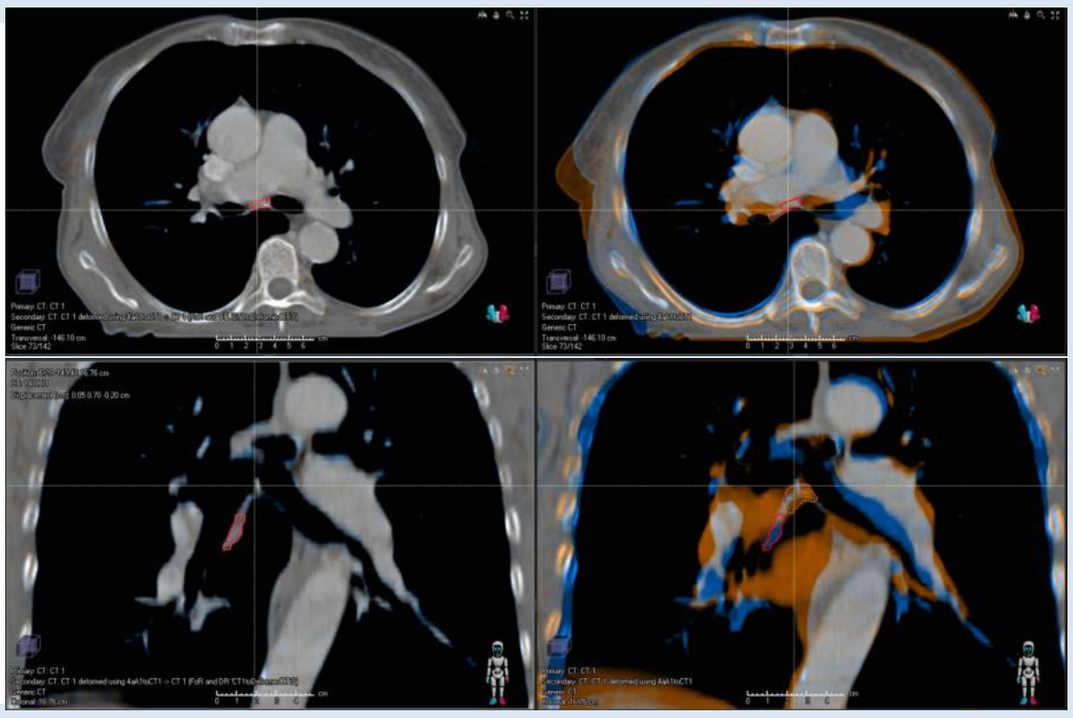

Fig.1: Example of PCT (blue) and the difference to 4th Fraction CBCT of Pat4. The LN7 contour on the PCT (red) and on the CBCT (pink) are shown. The images to the left display the results of deformable registration of the CTs. Wile images to the right display the initial position of the CTs and contours.

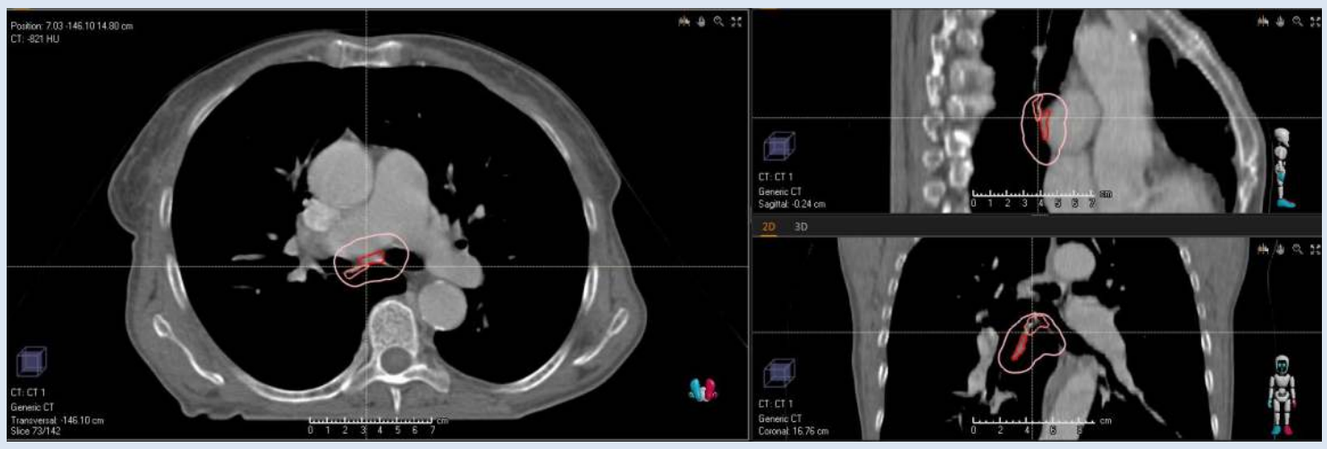

Fig. 2: Isotropic margin expansion (IEM) of 1 cm to the LN7 volume (IEM) would be needed to include the volume based on CBCT for the Pat4 and 4th Fraction CBCT.

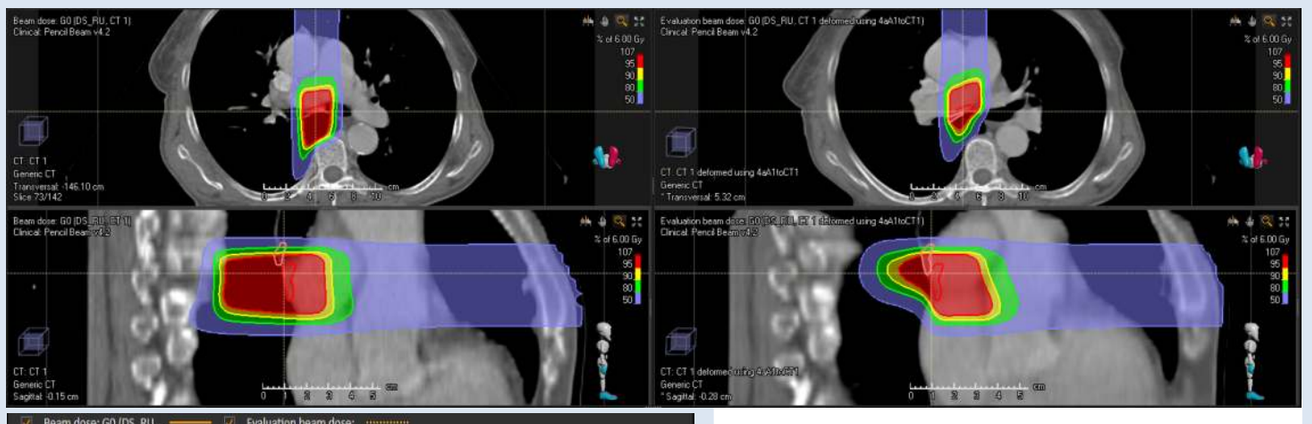

Fig.3: Above shows an example of dose coverage comparison for Pat4 and 4th Fraction CBCT as compared to PCT for a single field from 0° Gantry position.

Fig.4: DVH comparison of the dose example of Pat4 and 4th Fraction CBCT. Dashed is the Distribution on CBCT.

Results and conclusion

172 out of 1470 analyzed points failed despite optimizing the plans designed 5mm and 5% perturbations. IME, 3Dshift and (1-DIC) are strongly inter-correlated (see **Fig. 5 & 6**). Correlation between $D_{95\%}$ and 3Dshift was significant (P=0.0076). Additionally, >50% dose points failed for 3Dshift > 4.5mm, IME> 4.9mm, and DIC < 0.56 (see Fig. 6).

In conclusion, geometrical evaluations of target volume deformations in CBCT offer an insight to robustness an and dose coverage in DS plans. Furthermore, plan perturbations do not guarantee sufficient dose coverage in central thoracic tumors even if geometrical changes were below evaluated perturbations.

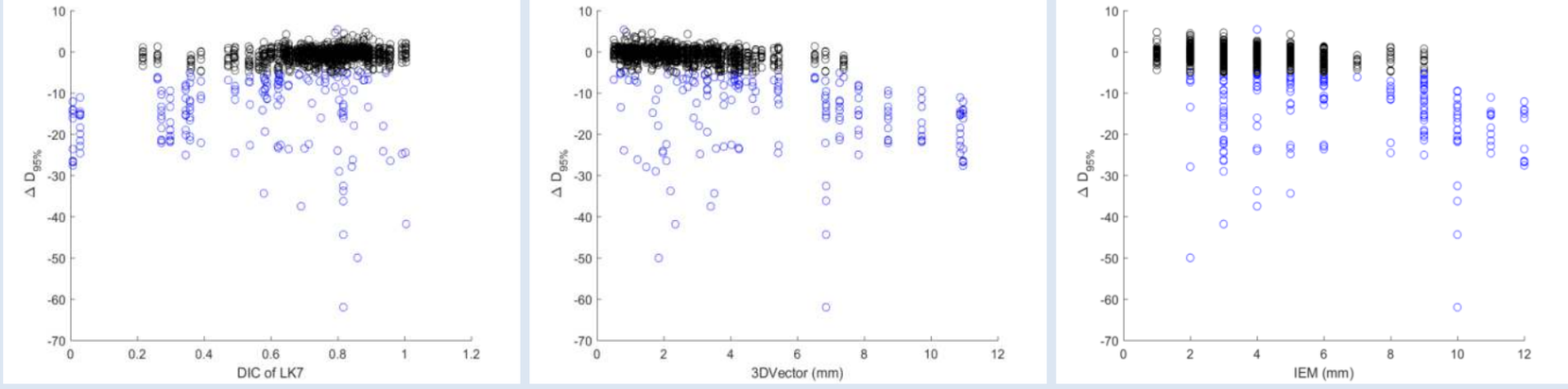

Fig.5: Analysis of the $D_{95\%}$ as a function of the DIC , 3DShift and IEM. The failing points (blue) an passing points (black) are shown. The resulting Histograms are shown below. Green is all data points, failing points (Change in $D_{95\%}$<5%) .

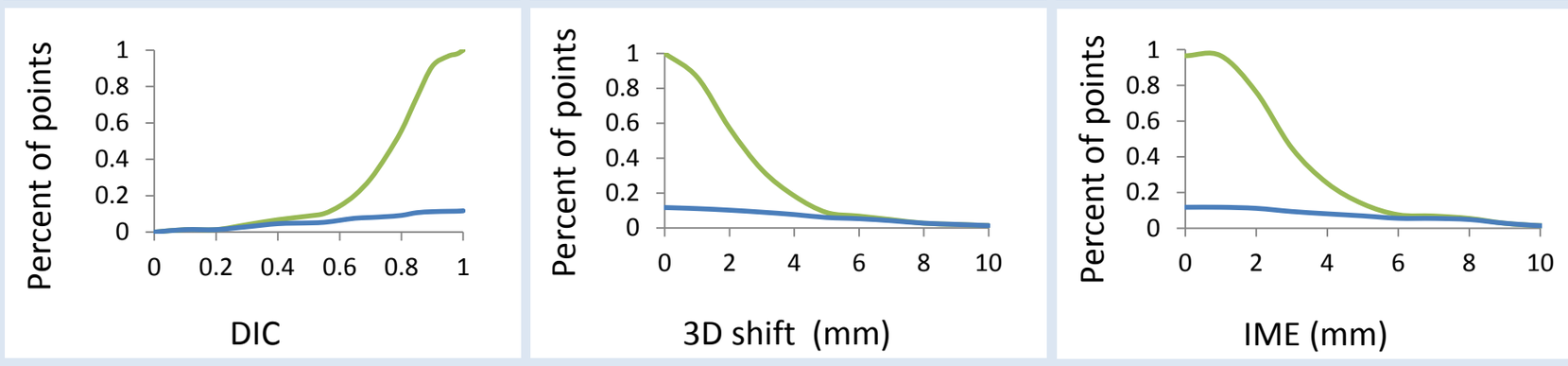

Fig.6: Relation between histograms of IEM , (1-DIC) and 3DShift show strong correlation between parameters.