A framework to evaluate synthetic CTs generated for the first AI-driven online adaptive radiotherapy system

A QUINN[1], J KIPRITIDIS[1], D JAYAMANNE[1], and J BOOTH[1]
[1]Royal North Shore Hospital, NSW, Australia

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INTRODUCTION

Online adaptive radiotherapy with the first AI-driven linear accelerator is underpinned by the concept of a synthetic CT (sCT) derived from planning CT (pCT) -CBCT deformable image registration (DIR).

Confidence in sCT for AI-driven online adaptive radiotherapy is crucial.

AIM

Develop a framework for independent assessment of the underlying DIR used to generate the sCTs.

METHOD

Ten bilateral head and neck (HN) patients, including the first HN patient treated with online adaption, were retrospectively analysed.

The pCT-CBCT deformation vector field is not accessible thus indirect assessment of the sCT-CBCT agreement was performed. For each fraction (N=30):

1. A qualitative comparison of the blended CBCT and sCT
2. A geometric evaluation was assessed with HU histogram analysis.
3. The target registration error (TRE) was calculated using the Scale Invariant Feature Transform (SIFT) algorithm[1] to identify matching sCT-CBCT characteristics points.

Analysis was completed in Velocity (v4.1, Varian Medical Systems, Inc), Matlab (R2019a, The MathWorks, Inc), and Plastimatch (v1.8.0, www.plastimatch.org).

RESULTS

Visual alignment of bony anatomic structures between sCT and CBCT were within 1 voxel (2 mm). Discrepancies up to 5 voxels (10 mm) were observed at air cavities, and skin surface.

Mean average value of difference image ranged from 3 – 5 HU

Mean squared difference between images ranged from 1200 – 1400 HU

Mean pCT- sCT difference was up to 20 HU for target and key OAR structures

SIFT identified 300 – 700 points per sCT/CBCT comparison.

Match point TRE: Mean = 2-4mm Median = 2-3mm Std = 3-6mm

85% of match points were within 5mm

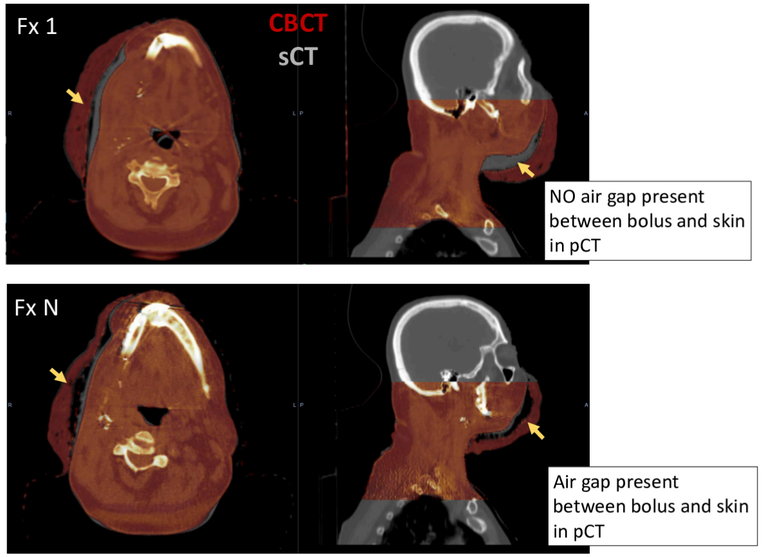

*Figure. Patient experienced reabsorption of seroma between pCT and treatment. In the top image, **yellow** arrows indicate regions where the pCT-CBCT deformation does (TOP) and does not (BOTTOM) produce a sCT representative of reality. CBCT (red scale) blended with sCT (grey scale).*

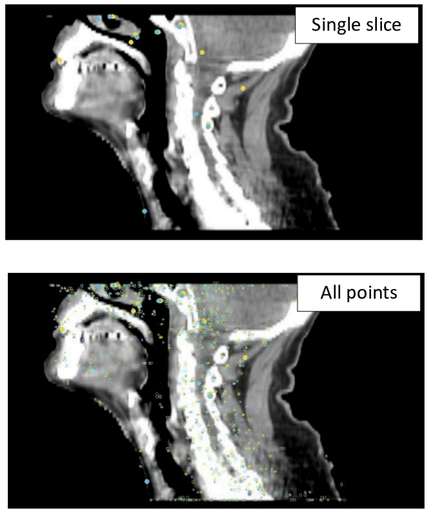

Figure. Visual display of the characteristic matching points identified on the CBCT (yellow) and sCT (blue) in the sagittal view with the SIFT algorithm. Both sets are overlaid on the CBCT.

CONCLUSIONS

- The method described enables the evaluation of sCTs generated for online AI-driven radiotherapy.
- This is an approach which any clinic could implement to build an understanding of the variables which influence formation of sCTs.
- The application to further HN patients and sites will build new knowledge regarding how the system behaves and help drive development of adaptive radiotherapy workflows.

FUTURE WORK

Investigate the impact of the sCT accuracy on the delivered dose presented, as well as plans generated utilising the sCT.

REFERENCES

[1]Lowe DG. Distinctive Image Features from Scale-Invariant Keypoints. *Int J Comput Vis 2004; 60(2): 91-110*

CONTACT INFORMATION

alexandra.quinn@health.nsw.gov.au