Evaluation of Surface Registration Accuracy for Patient Positioning in Head and Neck Radiotherapy Using Normal Distribution Transform Algorithm

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INTRODUCTION

Cone Beam Computed Tomography (CBCT) is the common modality used for patient set up in head and neck radiation therapy. CBCT can easily be utilized to account for inter-fraction setup variations but not for intra-fraction ones. In this study, we present a dose-free and non-invasive method for set up and positioning of the patients with head and neck cancer with a high degree of reproducibility which can be used during the treatment delivery.

METHOD

Surface image guided radiotherapy (SIGRT) and a Rando phantom were used for this study. The entire surface of the phantom's face was covered with white masking tape in order to be visible by the SIGRT cameras. The phantom was immobilized using a standard clinical thermoplastic mask. The material from the midface portion of the mask was removed to provide an adequate surface for detection by SIGRT system (Fig.1). The phantom was CT scanned and a surface image was recorded using C-RAD Sentinel to create the reference image dataset. In the treatment room, both CBCT scan and surface image (using C-RAD CatalystHD) were acquired.

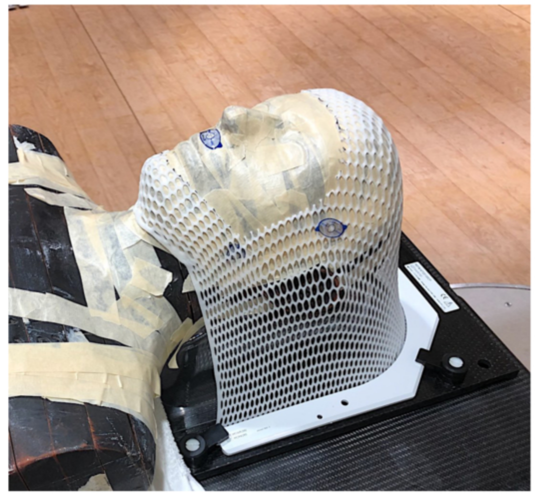

Fig.1: The entire face of a male Rando was covered with white masking tape. The thermoplastic mask was cut open to provide adequate surface to be detected by SIGRT systems.

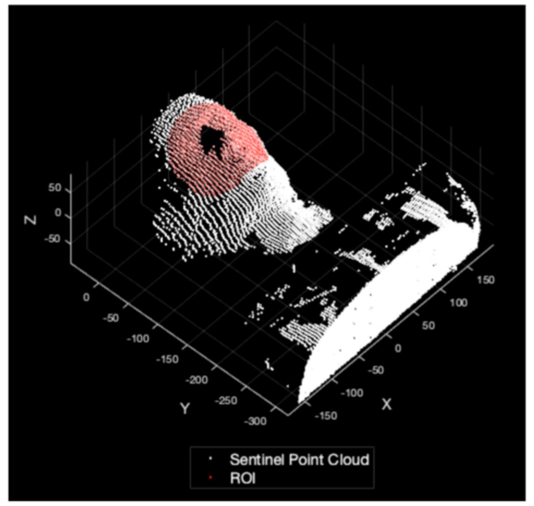

Fig.2: A circle on the open section of the mask was selected as the region of interest (ROI).

After exporting image files from C-RAD, the 3D Normal Distribution Transform (NDT) point cloud registration algorithm was used to calculate the relative translations and rotations to align the treatment scan to the reference one (Fig.3 and Fig.4). The shifts calculated by CBCT were compared with NDT registration results and Catalyst-calculated shifts.

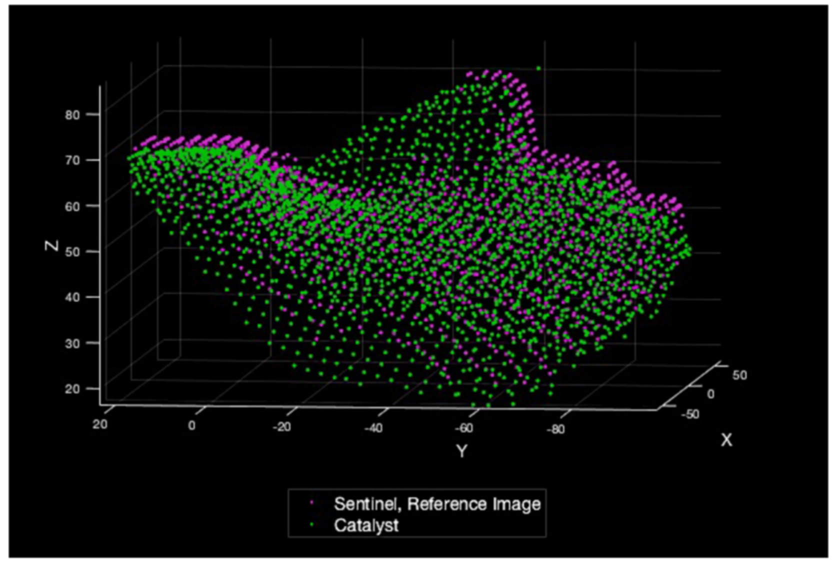

Fig.3: Representation of point cloud ROIs selected from Sentinel and CatalystHD images before registration.

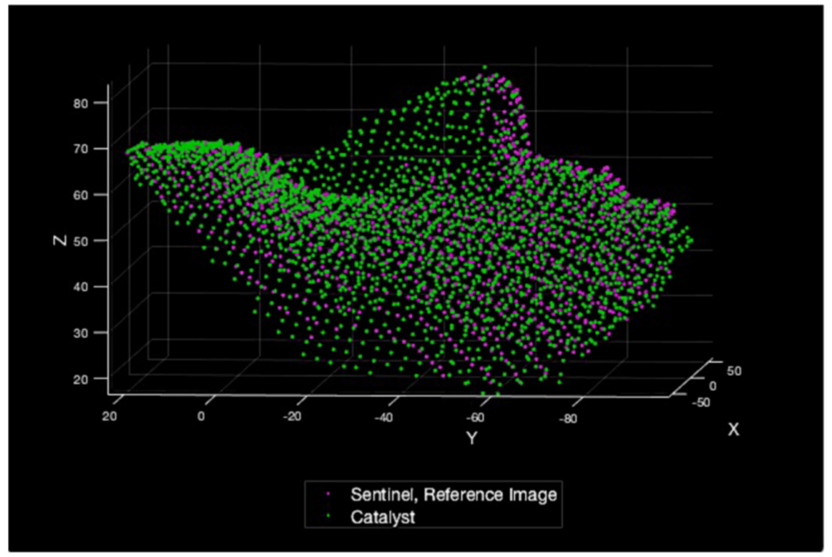

Fig.4: Representation of point cloud ROIs selected from Sentinel and CatalystHD images after registration.

RESULTS

Table 1 summarizes the average and standard deviation of differences between CBCT-calculated shifts and those calculated by the NDT registration algorithms and by the CatalystHD software itself. This table shows that NDT point cloud registration algorithm can calculate the shifts more accurate than the CatalystHD software. The NDT registration has larger deviation in shift calculation along Z-axis compare to the other two directions.

	CBCT – Point Cloud Registration (Mean ± SD)	**CBCT – Catalyst** (Mean ± SD)
Translation (mm)		
Lat (X)	-0.10 ± 0.40	-0.32 ± 1.8
Long (Y)	0.22 ± 2.64	2.50 ±2.53
Vert (Z)	-2.64 ± 0.15	-3.14 ± 0.37
Rotation (deg)		
Pitch(x)	0.0 º ± 0.1	-0.26 ± 0.58
Roll(Y)	0.0 º ± 0.1	0.46 ± 0.25
Rotation(Z)	0.4º ± 0.1	-0.46 ± 0.34

Table 1: Average and standard deviation of differences between shifts calculated by CBCT, NDT point cloud registration and C-RAD software.

CONCLUSIONS

Surface image registration with an open mask is a viable option for positioning in head and neck radiotherapy, providing a high degree of registration accuracy. NDT point cloud registration algorithm is faster and more accurate than other surface registration algorithms such as iterative closet point (ICP) tested in other studies as a substitute for volumetric registration like CBCT.