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The Accuracy of the 3D Reference Coordinate Definition with G-Frame for Gamma Knife ICON

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I. INTRODUCTION

After co-registering CBCT and planning reference images, Gamma Knife ICON software often reports differences in patient treatment position relative to the patient position used for planning, even for patients immobilized with the Leksell G-frame during Gamma Knife radiosurgery (GKRS). The software subsequently reports large negative changes of dosimetric parameters for the target volumes. We believe that the position differences are a result of inaccurate image registration, else, the rigidity of the G-frame, and thus overall fixation accuracy for frame- based GKRS would be fallible and therefore necessitate realignment prior to treatment.

II. METHODS

We acquired a CBCT for 49 patients having a total of 71 tumors with GKRS using the G-Frame for head fixation prior to treatment. After co-registering the CBCT images with planning reference images, we recorded the difference in patient treatment position relative to the patient position used for planning, presented as a geometric rotation and translation of the Leksell central point (100, 100, 100), and the resulting maximum shot displacement. We analyzed the differences between the planned and delivered dosimetric data, given the change in position reported by the co-registration. We repeated this study using a 16-cm diameter spherical phantom filled with water-equivalent polymer gel, using both CT and MRI as planning reference images. The phantom was rigidly fixed with the G-Frame, such that position changes during imaging and pre-treatment planning were avoided. Therefore, any position difference suggested by the co-registration of the CBCT and planning reference images was determined to be an image registration error.

III. RESULTS

The position difference suggested by the co-registration of CBCT and planning reference images produced dosimetric differences so large that, for some treatments, the tumor coverage is unacceptable. Meanwhile, the same measurements with a rigidly-fixed phantom show the same magnitude of position differences, suggesting that the co-registration of the CBCT to planning reference images suffers some degree of uncertainty. Such uncertainty causes erroneous results of repositioning data.

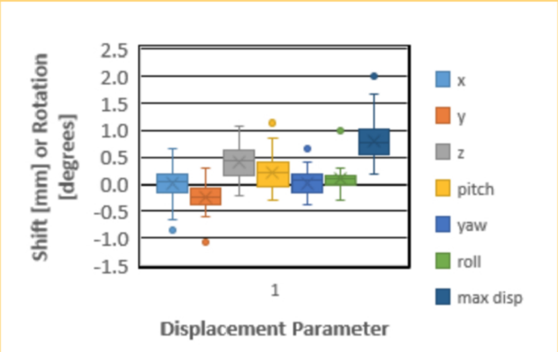

Fig. 1. Shift and rotation and co-registration

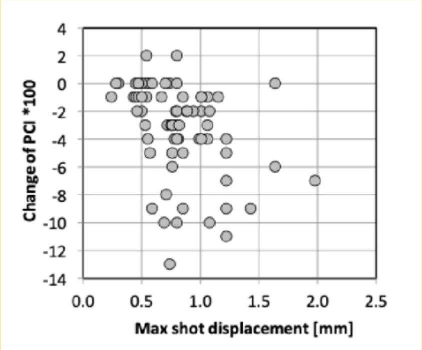

Fig. 2. Percentage change of PCI vs. maximum displacement

Figure 1 shows the observed positional differences in x-, y-, and z-directions, rotational angles corrections of pitch, yaw, and roll, and the maximum displacement between shot positions for the planned vs. treatment positions. This figure shows the box-whisker graph with the median/mean, and distribution of position change data for 71 tumors of 49 patients.

Figure 2 shows the percentage change of the Paddick conformity index (PCI) as a function of the maximum shot displacement, as the patient is not repositioned according to co-registration. There are significant changes of PCI, implying large changes in the target coverage and dose conformity. Similarity between Figures 1 and 3(a) imply that the positional changes suggested by the co-registration of the CBCT and planning CT images are not valid, rather the result of erroneous image registration. Figure 3(b) indicates the co- registrations of CBCT with planning MR images were not correctly performed, resulting in often very large errors. This further demonstrates the inadequacy of image registration for defining the stereotactic space.

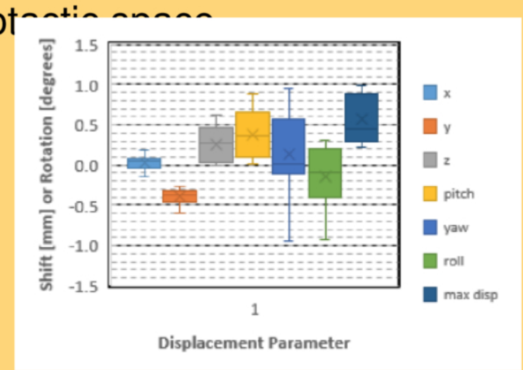

Fig. 3a. Shift and rotation after co-registration (phantom with planning CT)

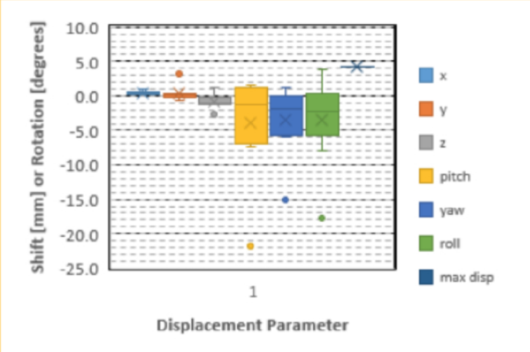

Fig. 3b. Shift and rotation after co-registration (phantom with planning MRI)

IV. CONCLUSIONS

The position differences reported by CBCT are within the accuracy limit of image registration. Hence, we do not advise position adjustment for G-Frame based GKRS using the co-registration recommended shifts.