Dosimetric Impact of CBCT-Based Setup Corrections In G-Frame Gamma Knife Radiosurgery for Post-Craniotomy Patients

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ABSTRACT

We examine pre-treatment CBCT co-registration parameters for G-frame based patient setup on a ESPRIT Leksell Gamma Knife (LGK) (Elekta AB, Stockholm, Sweden) system for Stereotactic radiosurgery (SRS) for post-craniotomy patients.

A clearer correlation between the *Y displacement* impacting the overall maximum displacement correction adjustment is noted. There is a mean displacement of 1 ± 0.46 mm from 52 patient treatment deliveries with 109 total Target lesions, with a maximum noted displacement of 2.1 mm. Dosimetric plan quality was impacted when displacement corrections exceeded 0.5 mm.

A practice recommendation of using CBCT setup for all patients, and rejecting the coordinate registration obtained from the MR/CT indicator box, re-planning, and accepting the CBCT stereotactic coordinate registration for CBCT setup corrections over 0.5 mm is suggested.

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INTRODUCTION

The Leksell Gamma Knife G-frame has been the "gold standard" for rigid cranial immobilization in radiosurgery. This frame based coordinate definition is primarily used with the MR/CT indicator box for stereotactic coordinate definition. The on-board cone beam CT (CBCT), available in newer models of Gamma Knife; such as ICON and ESPRIT, allows for co-registration and verification of the registration accuracy before treatment delivery. It also allows replacing this definition with the CBCT based stereotactic coordinate definition.

In our current practice based in an academic hospital with over 500 unique treatments delivered annually, about a fifth of the patients present to Gamma Knife after having undergone craniotomy. In this study, we wanted to ascertain the quality of the setup corrections for this group of post-craniotomy patients.

The present effort is to revisit the robustness of the MR indicator box for stereotactic coordinate definition, rigidity of the frame placement, and to understand the significance of the setup displacement corrections obtained from the CBCT co-registration.

METHODS AND MATERIALS

Routine MR imaging for treatment planning was performed on 52 post-craniotomy patients with G-Frame and MR indicator box attached. Patients had a total of 109 tumor targets. The pre-treatment setup was verified by CBCT co-registration before treatment delivery.

Due to the inherent nature of the Gamma Knife delivery system, the CBCT calculated setup corrections do not apply by moving the patient on the treatment couch where the patient is rigidly fixed. Instead, in order to apply the CBCT based corrections, the MR indicator box based definition is rejected, and a re-plan is initiated, and only then the CBCT based stereotactic definition could be applied.

The co-registration parameters included three translational shifts and three rotation angles displayed after the CBCT is co-registered with the plan CT/MRI, (X, Y, Z, Pitch, Yaw, and Roll), the maximum displacement

A noticeable drop in the target minimum dose followed if the CBCT based corrections greater than 1 mm were NOT applied. The maximum, and mean dose coverage was not affected appreciably. Target coverage, and Paddick Conformity Index, PCI, were sensitive to these setup corrections, and followed identical trends when displacement correction was indicated by CBCT co-registration.

RESULTS

There appears to be a correlation (Figure 1) between displacement corrections along Y, and the maximum displacement error, as also seen from the Box–Whisker plot in Figure 2.

Previously, authors [1] have seen a correlation between Z displacement contribution to the overall maximum displacement. We note that, in our present study, a Y displacement contribution to the overall maximum displacement has a noticeable correlation (R-squared = 0.432) compared to X or Y displacement.

The maximum displacement of 1 mm is mostly associated with a noticeable drop of up to 15% in plan quality parameters, as seen from Figure 3. A 5% drop in coverage was associated with CBCT corrections of 0.5 mm maximum displacement. We suggest this as a threshold to initiate re-plan. CBCT based stereotactic coordinate definitions can be used instead.

Figure 1. Maximum displacement (Y axis) vs X, Y & Z displacements

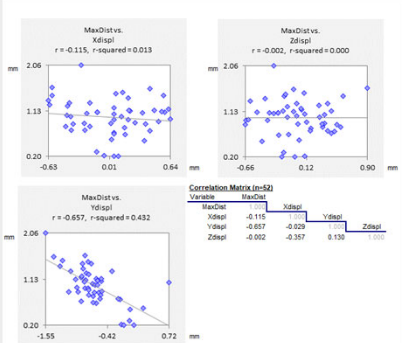
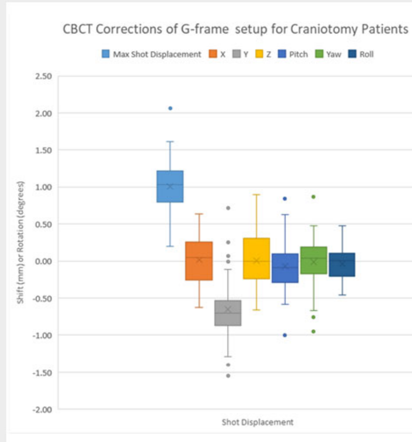


Figure 2. A box and whisker plot of the displacement parameters



Dosimetric Impact

Figure 3. % Change (Y axis) of minimum dose coverage vs maximum displacement

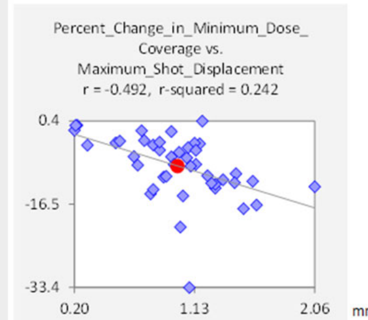
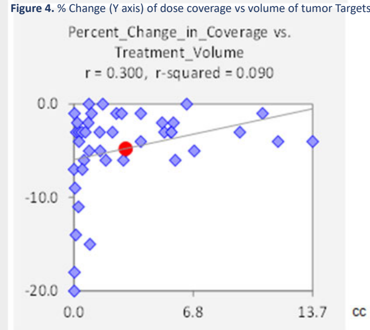


Figure 4. % Change (Y axis) of dose coverage vs volume of tumor Targets



CONCLUSIONS

We observe that setup corrections were within normal expected limits for post-craniotomy patients.

There was a noticeable correlation between the CBCT indicated maximum displacement correction, and the patients displacement correction along Y, which is along patient's anterior-posterior direction when rigidly docked on the treatment couch.

The MR/CT indicator box defined stereotactic coordinate definition might be adequately replaced by CBCT based stereotactic coordinate definition, improving workflow efficiency and accuracy of treatment delivery.

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