Geometric and Dosimetric Differences due to Image Registration Workflows for Frameless GammaKnife Icon Patients

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Purpose

- The GammaKnife® Icon™ has an onboard cone-beam CT (CBCT) system for stereotactic localization, facilitating frameless treatments
- Patients receive a diagnostic MRI for target, OAR, and skull definition, which is registered to an in-mask CBCT for localization and planning (Figure 1)
- An alternate registration workflow is proposed: The MRI is registered to a diagnostic CT, which is then registered to the CBCT
- MRI and CBCT share limited mutual information; it is expected that including a diagnostic CT in the registration process will improve registration accuracy (Figure 2)
- We aim to quantify geometric and dosimetric differences between workflows, and to identify which situations are more susceptible to these differences

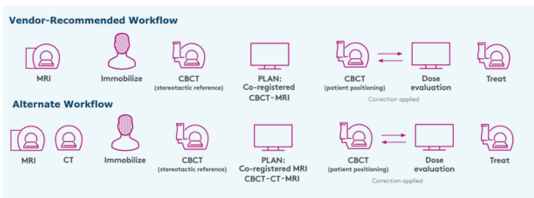
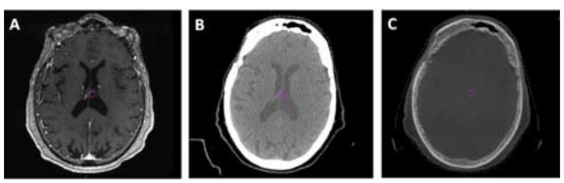


Figure 1 (above): Vendor-recommended and alternate registration workflows

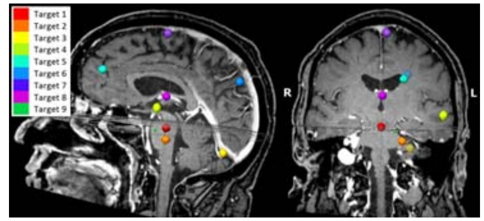
Figure 2 (below): A) MRI, B) Diagnostic CT, and C) CBCT slices at the level of one 4 mm target for the same patient.



Methods

- A set of eight 4mm diameter spherical targets and one 0.14mm dimeter target (Target 9) were created and transferred to the MRI for 12 patients (Figure 3)
- The MRI was registered to the diagnostic CT, then CT registered to CBCT
- Single-shot per target plans maximizing conformity and selectivity, while maintaining 100% target coverage were created for each patient
- The MRI was then registered to the CBCT directly and the plan was copied
- Differences in target locations and coverage between the workflows were recorded
- All registrations were done using GammaPlan's automatic registration process with a volume of interest (VOI) encompassing the whole skull
- All registrations were reviewed and determined to be clinically acceptable

Results



Target	Location
1	Brainstem
2	Lt CPA
3	Lt post cerebellum
4	Lt lat temp lobe
5	Lt frontal
6	Lt parietal
7	Lt parasagittal sinus
8	Thalamus
9	Trigeminal Nerve

Figure 3 (far left): Target locations throughout the skull.

Table 1 (left): Target location descriptions. Target locations were selected to represent typical anatomic locations.

- The mean 3D displacement of target center position was 0.50±0.26 mm (max=1.3 mm) (Figure 4)
- The mean decrease in target coverage was 4.4±5.2% (max=32%) (Figure 4)
- Posteriorly located targets (3 & 6) had larger displacements because they were more greatly affected by pitch in the registration
- Smaller targets (9) are susceptible to larger losses of target coverage for a given displacement

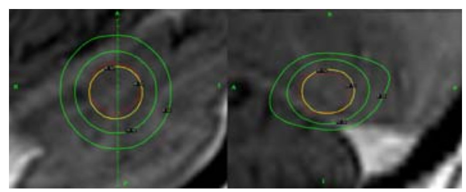


Figure 5: Axial and sagittal slices through target 3 (red) on patient 8 depicting a 10% loss of target coverage for a 1mm 3D displacement. The prescription isodose line is indicated in yellow. Scale markings indicate 1mm.

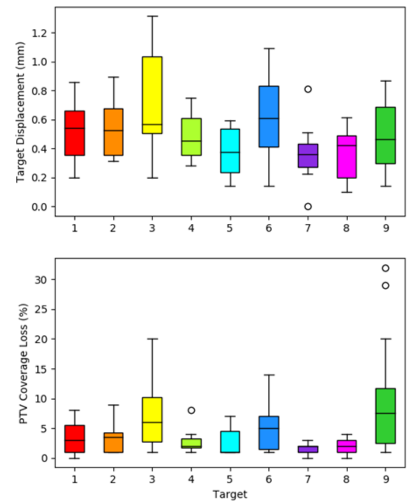


Figure 4: 3D target displacement and PTV coverage loss when the vendor-recommended registration workflow is used. Targets 3 & 6 had the highest mean displacements (0.76 and 0.68mm).

Discussion & Conclusion

Our data indicate that geometric differences exist between the two workflows and that these geometric differences can result in marked losses of target coverage.

- Patients with posteriorly located targets are more susceptible to these differences, and should receive a diagnostic CT for registration purposes.
- Patients with CBCT volumes that do not capture base of skull may be more susceptible to differences between registrations. This may occur in patients with larger necks/shoulders as it is difficult to slide superiorly in the head/mask cup.
- This work was done using the entire skull as a VOI, which would be used in cases of multiple-target treatments. Future work will aim to quantify these differences in cases with single and non-spherical targets, and aim to determine the appropriate VOI when performing CBCT-MRI registrations.

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