NavPhan MultiMets Phantom for Isocal Verification Measurements

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Introduction

Modern radiosurgery systems combine multiple imaging, positioning and delivery components that must function together to deliver high doses of radiation with sub-millimeter accuracy to all points within the patient. It is essential, particularly in single isocenter multiple metastases radiosurgery, to validate the setup accuracy for all treatment components under all possible treatment conditions. Although tests currently exist to validate the accuracy of setup at the isocenter (e.g., Winston-Lutz) these tests cannot quantify the accuracy of off axis points of interest, nor do they probe the angular components of the 6 DOF couch. The NavPhan QA system (NavAxis, LLC) can be used for this purpose.

The NavPhan system is made up of a combination of a spherical radiotherapy phantom, positioning base, and specialized software. Its patented design allows the sphere to be freely rotated about its center. Extremely accurate setup of the phantom at arbitrary orientations is enabled through the combination of eight embedded fiducial markers and virtual CT scans generated by the software. These virtual CT scans can be generated in arbitrary angular orientations as needed and, as a result, the fiducials can be placed in any arbitrary position in space. It is important to note that the geometry defined virtually is perfectly localized with the DICOM origin at the exact center of the sphere thus eliminating any errors propagated from CT simulation. This allows the user to probe the entire treatment space in unprecedented ways with unprecedented accuracy. The purpose of this study is three-fold: 1) To verify the setup accuracy and repeatability of the NavPhan system; 2) To cross-verify the imaging isocenter assigned by Varian's IsoCal procedure with the isocenter of the ExacTrac positioning system. 3) To determine the frequency of shifts above our clinical threshold at extreme couch angles.

Methods & Materials

The NavPhan software was used to produce a single virtual CT of the phantom with dicom point <0,0,0> centered at the machine isocenter and with fiducial rotation parameters ($\Theta=0^{\circ}$: $\phi=45^{\circ}$; voxels = 0.125mm^3). A treatment plan was created that contained fields and DRR's at the four primary gantry angles and two fields with extreme table kicks (G=0°; T = 90° & 270°).

All trials were delivered on a Varian Novalis system. IsoCal verification was performed daily prior to measurements. The ExacTrac system was calibrated using a Winston Lutz calibration procedure. The NavPhan was placed near the isocenter of the machine and rotated into the measurement orientation. ExacTrac imaging and registration was then performed and the phantom was shifted using the 6 degree-of-freedom couch (tol = 0.7mm, 0.5°). Once the phantom was within setup tolerance, kV image pairs (Varian OBI) were acquired at gantry 0° and 90°, and MV portal images were acquired at the four primary gantry angles. No further shifts were applied using these independent imaging modalities. Subsequently, extreme table kicks were performed (T = 90° and 270°) and we analyzed the ExacTrac shift requirements. All MV and kV portal images were registered to the appropriate DRR using the correlated points registration workflow in Aria software. The phantom was independently set up 11 times over two days. ExacTrac residual data was analyzed to determine setup reproducibility. Exactrac and IsoCal residuals were compared for a subset of the data (N=5).

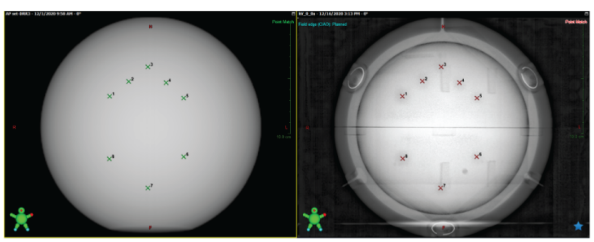
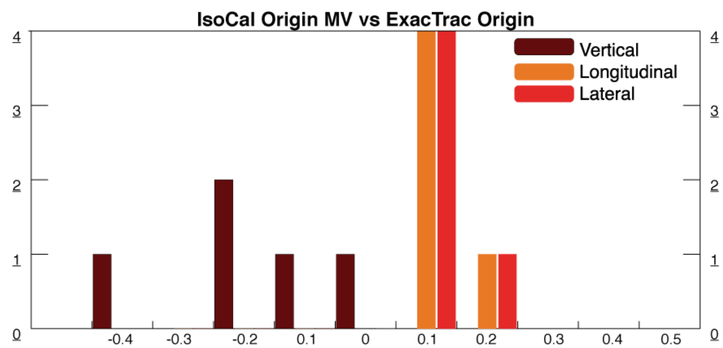
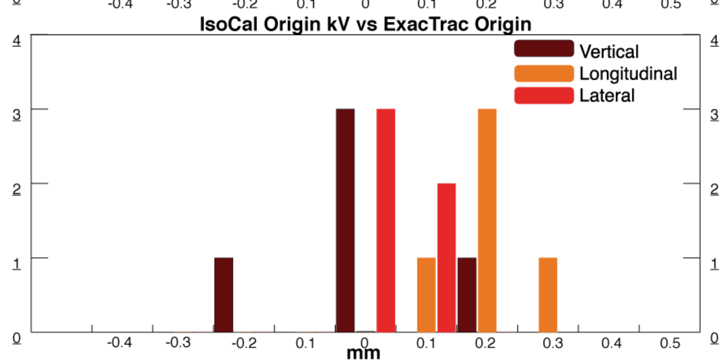


Figure 1: Example of kV image registration based on correlated points in Aria.

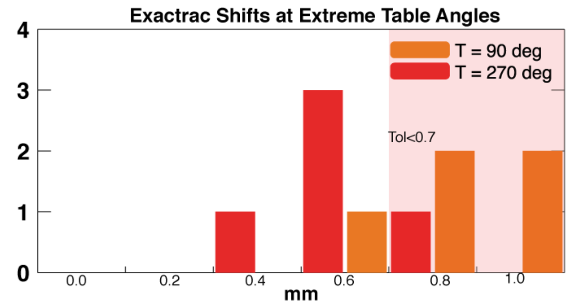




Results

Phantom setups had an average 3D displacement of 0.17±0.17mm from the mean position over 11 measurements. The IsoCal isocenter and Exactrac isocenter agree within 0.25±0.16mm (N=5). The pitch and yaw of Varian agreed with ExacTrac within 0.05°±0.28° and 0.06°±0.20° respectively.

After extreme table kicks the ExacTrac detected that phantom positioning was outside of tolerance after 80% and 20% at T = 90° and T=270° respectively (N=5). After applying the required shifts, ExacTrac and IsoCal agreed within 0.13±0.08mm.



Discussion

The NavPhan setup position was consistent and reproducible across several measurement days demonstrating the stability of the technique. Because a virtual phantom is used as the reference image set for phantom setup, the NavPhan system avoids positioning uncertainties originating in the CT simulation process. Further, since the CT scan is virtual, and the isocenter pixel is exactly defined as DICOM <0,0,0>, we can state that the difference in phantom position measured by IsoCal and ExacTrac represents the difference between their respective isocenter definitions to within the precision of our measurements. Of note, because the pixel size has 0.5mm dimensions the theoretical positioning uncertainty in each direction can be estimated to be 0.25mm due to pixel size alone. This value almost exactly agrees with our results for the difference between IsoCal and Exactrac (0.25±0.16mm) so the difference is likely dominated by the pixel resolution.

ExacTrac imaging of the NavPhan at extreme table angles frequently detected shifts from isocenter that were larger than our clinical tolerance of 0.7mm and 0.5°. This suggests that at a minimum, imaging should be performed at large table angles and potentially at every table angle of a treatment. This data also shows the NavPhan's potential utility as a tool to characterize a 6 degree-of-freedom couch.

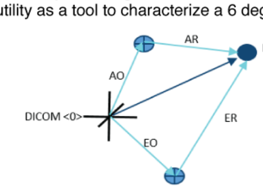


Figure 2: Definition of ExacTrac Isocenter (EO), IsoCal isocenter (AO) and Dicom isocenter.

Conclusion

The NavPhan can be used as a reliable commissioning or QA tool to verify agreement between multiple imaging systems, verify geometric setup accuracy, and test clinically relevant treatment parameters.