Development of a multi-modality QA phantom for the gamma knife procedure

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ABSTRACT

The purpose of this project was to develop a unified phantom which can be used to assess the quality of the calibration of CT, MRI, and DSA imaging modalities. A mixture of liquid CT and MR contrast agents was placed in a 3D printed matrix of tubes, which ran in the X, Y, and Z axes. Each of the tubes intersect at known locations in space, and will serve as reference points. The locations of these points in the images can be compared to their known locations to assess the quality of the calibration. This phantom can be used to increase the quality of Gamma Knife treatments by ensuring the accuracy of their imaging equipment.

BACKGROUND

Gamma Knife radiosurgery is an essential tool in the treatment of brain tumors. In order for these treatments to be effective, the radiation dose must be precisely delivered to the tumor, while avoiding the healthy tissue. This is accomplished via the analysis of medical images with a treatment planning software (Leksell GammaPlan). To ensure the accuracy of the images, the equipment must be properly calibrated. Currently, there exists no unified phantom that can be used to calibrate both CT and MRI modalities to a single standard. Our prototype will increase the level of confidence of the physicians by mitigating error introduced from the calibration process.

METHODS

Contrast

To obtain a useable image in both CT and MRI, we decided to use a mixture of contrast agents, each of which is known to produce a signal in their respective modalities. We used Hypaque and Magnevist as CT and MRI contrast agents, respectively. This mixture was then placed into the tube matrix contained within the body of the phantom.

Points of Interest

In order to assess the calibration of the imaging equipment, 27 points were chosen to represent key locations across the stereotactic space (treatment space). To this end, we established a coordinate system within the phantom body that could then be transformed to match those used by GammaPlan. The transformation equations are as follows:

$$x_s = x + 100$$
$$y_s = y + 100$$
$$z_s = z + 191$$

x_s, y_s, z_s are the stereotactic coordinates which correspond to the position (x, y, z) of each point of interest within the phantom.

This coordinate transform allowed us to establish the known locations of the points of interest in the image space, to be compared to the coordinates determined by GammaPlan.

METHODS contd.

Design

We designed the physical layout of the phantom using SolidWorks 3D design software. In order for the quality assessments to be reproducible, the phantom must rigidly attach to the head frame used during Gamma Knife treatments. We designed the phantom to fit within the stereotactic space, while rigidly affixing to the threaded holes at the bottom of the head frame.

a) 

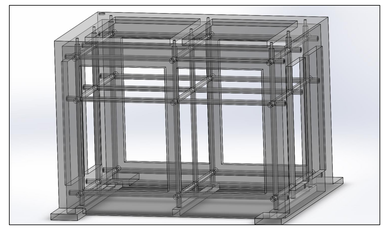
b) 

Figure 1: a) Stereotactic head frame used in the Gamma Knife procedure. b) SolidWorks rendering of the body of the phantom.

RESULTS

The phantom was 3D printed using the Objet Eden 260V printer at the Toshiba Stroke Research Center. The points of interest are positioned at known locations to be compared with the image coordinates. The contrast material is contained in the tubes by a lid, which affixes to the top of the phantom. Additionally, the phantom possesses attachment points which allow for reproducible attachment to the head frame. These factors allow for reliable assessment of the quality of equipment calibration.

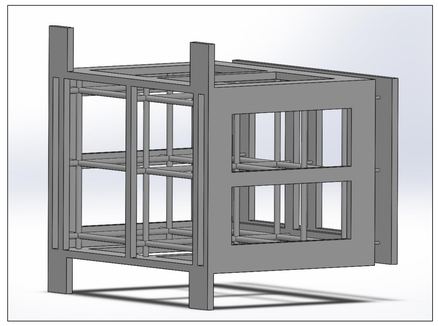


Figure 2: Rendering of the completed phantom.

CONCLUSIONS

This unified phantom can be used to verify proper calibration of imaging equipment across multiple modalities. This cross-platform approach will improve the quality of Gamma Knife treatments by increasing the physicians' confidence that the images that they are receiving will be accurate. This phantom can potentially be used by any facility that performs Gamma Knife treatments.

REFERENCES

1) *Leksell Stereotactic System: Instructions for Use,* Elekta Instrument AB., Stockholm, Sweden, 2008.
2) Cernica, G. et al., "Investigation of gamma knife image registration errors resulting from misalignment between the patient and the imaging axis" *Med. Phys*., 33, 941 (2006).