Validation of Manual and Assisted Alignment Techniques

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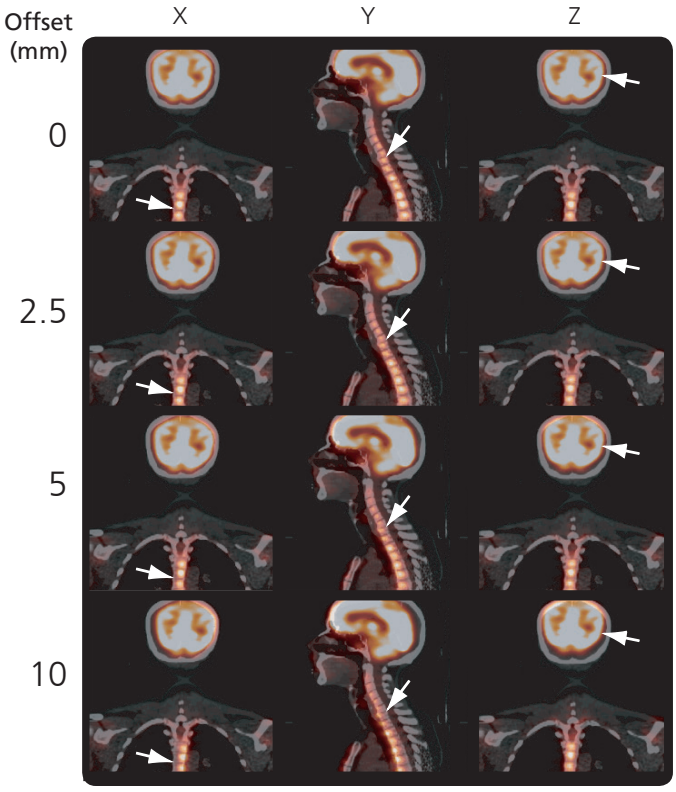
Introduction

The accuracy of the manual alignment technique was tested in two separate groups of patients who had PET and CT scans.

One group of patients consisted of 13 head and neck cancer patients[1] and the second group consisted of 10 lung cancer patients.[2] In both groups, the simulation CT image volume used for radiation treatment planning was aligned to a PET image volume acquired on a standalone PET camera.

The CT voxel size was 1.9 x 1.9 x 3.0 mm and the PET voxel size was 4.3 x 4.3 x 4.3 mm. In each instance, the immobilization device used for the CT scan was also used for the PET scan. The immobilization device for lung cancer patients was a VacBag (BIONIX Secure Vac Toledo, Ohio).



Demonstrates the loss of fusion accuracy with even small degrees of offset.

Three people with image registration experience aligned each of the patients' PET and CT image volumes three separate times. The average of the nine registrations was considered to be the actual alignment.

The mean absolute difference and standard deviation of all observations from the average alignment was calculated in three orthogonal directions for each group of patients.

Head & Neck Patients Manual Alignment

	X	Y	Z
Mean Absolute Diff	1.83mm	2.93mm	2.14mm

Lung Patients Manual Alignment

	X	Y	Z
Mean Absolute Diff	2.07mm	1.95mm	2.24mm
SD	0.49mm	0.37mm	0.67mm

The manual alignment technique was also evaluated using ProstaScint SPECT image and CT image volumes.[3] SPECT images of ten prostate cancer patients were obtained approximately 96 hours post-injection of Indium-111 ProstaScint solution.

The SPECT and CT image volumes were obtained on the same day with the patient supine and no knee elevation. The CT voxel size was 1.6 x 1.6 x 5.0 mm and the SPECT voxel size was 4.8 x 4.8 x 4.8 mm.

Bony pelvis anatomy is easily observed in both image volumes and was primarily used for alignment in all three projections. Two observers manually aligned 10 patients three separate times. The average of these six observations was considered to be the actual alignment.

The mean absolute difference and standard deviation from this average was determined in three orthogonal directions for all six observations.

ProstaScint SPECT Patients Manual Alignment

	X	Y	Z
Mean Absolute Diff	0.96mm	1.78mm	2.05mm
SD	0.59mm	0.82mm	0.70mm

The accuracy of the assisted alignment technique was tested in a similar manner. The assisted alignment method is based on maximization of mutual information measures.[4,5]

Each lung cancer patient was aligned using assisted alignment without manual alignment intervention.

The gold standard was the average of the 9 manual observations as mentioned previously.

In addition to monitoring the average alignment difference in three orthogonal directions, the net vector alignment difference accounting for all three translations and all three rotations was also calculated at radial distances of 2, 5, and 10 cm along the x-axis.

Lung Patients Assisted Alignment

	X	Y	Z
Mean Absolute Diff	1.10mm	3.00mm	2.10mm

	2cm	5cm	10cm
Vector Differences at Radial Locations Along X-Axis	2.20mm	2.20mm	2.20mm

Both manual and assisted alignment methods have alignment accuracies that are smaller than the largest voxel size. Cubic spline interpolation is used for displaying voxel intensities at sub-voxel resolutions. Sub-voxel manual alignment accuracies are also possible since whole structures such as the spine are aligned and not just single anatomic points (see figure).

The edge of the spine will be at different partial voxel dimensions for each slice which enables the operator to manually align at the best partial voxel dimension based on their observation of a large number of slices. The assisted alignment method optimizes mutual information measures using partial voxel translations and angular rotations which result in less than one voxel alignment. For Radiotherapy applications, the alignment error and set-up error combine as the square root of the sum of the square errors. Therefore, for a set-up error of 4 mm and an alignment error of 2.2 mm, the combined error is 4.6 mm.

References

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