# Automated Alignment Accuracy of FDG PET and Simulation CT for Radiation Therapy Planning of Lung Cancer

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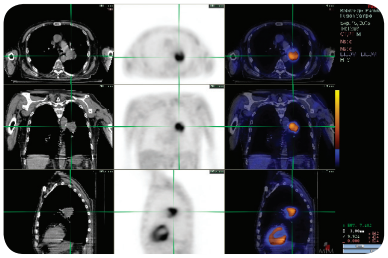
Several studies indicate that the fusion of FDG-PET to Radiation Therapy (RT) simulation CT images alters target volume and location for RT treatment planning. The purpose of this study is to determine the accuracy of automated alignment between PET and simulation CT using an average of nine manual registrations by three observers as the gold standard.

Both manual and automated alignment was performed using the MIM software package (MIMvista Corp., Cleveland Ohio). The automated alignment between the PET emission volume and CT was performed using a mutual information algorithm. The table in the CT volume was masked out for alignment purposes. The PET voxel size in the X, Y, and Z directions is 4.3 x 4.3 x 4.3 and CT voxel size is 1.9 x 1.9 x 3.0 mm. For both PET and CT procedures, the patient was imaged on a flat palette with the aid of a VacBag (BIONIX Secure Vac Toledo, Ohio) for purposes of immobilization, Figure[1]. Images were obtained during quiet respiration. Nine patients with lung cancer were manually aligned three independent times by three separate observers, Figure[2]. Automated alignments were typically completed in less than 10 seconds.

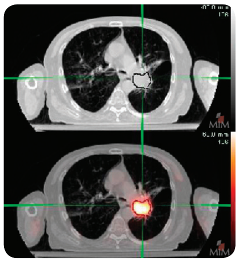
**Figure[1]**

*Patient positioned in a VacBag for purposes of immobilization.*

**Figure[2]**

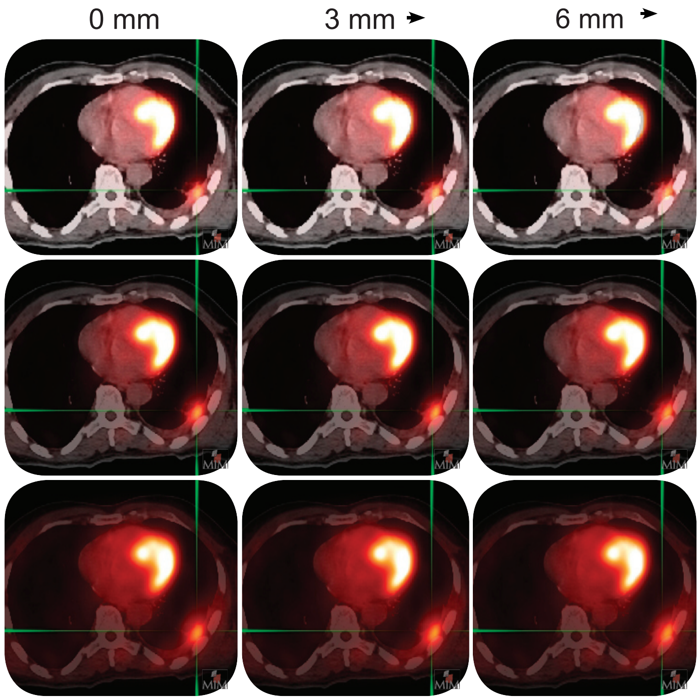


*Alignment was evaluated by true color addition of fixed and aligned images in three orthogonal planes for operator selected slices. The contribution of each image (PET or CT) to the combined image was under continuous operator control. Interpolation was used to view images at sub-pixel resolution.*



*For therapy systems with fusion capability, PET image volumes aligned with simulation CT are sent to Radiation Therapy. Otherwise, tumor regions of interest can be defined in fusion images, embedded in the CT, and then sent to RT.*

**Figure[3]**




*Varying degrees of offset in the X axis.*

Translation differences between manually and automatically aligned volumes were evaluated, Table[1]. The net effect of both translation and rotation was compared at three radial locations, Table[2]. The initial location of these radial points was 2.0, 5.0, and 10 cm along the X axis. The distances between automatic and manually aligned points are shown in Table[2]. The data show less than 3 mm average distance between manual and automatic alignment.

**Table[1]**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| X | 1.3 | 0.1 | 2.5 | 0.2 | 0.5 | 3.2 | 1.6 | 0.1 | 1.0 | **1.1** |
| Y | 2.3 | 6.9 | 0.6 | 3.3 | 1.7 | 2.2 | 2.2 | 2.7 | 5.5 | **3.0** |
| Z | 2.3 | 0.5 | 4.0 | 3.9 | 5.1 | 0.6 | 0.6 | 0.2 | 0.8 | **2.1** |

*Displacement of auto aligned volume from average manual aligned volume in X, Y, and Z directions. Distances in mm.*

**Table[2]**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 cm | 2.4 | 2.2 | 3.4 | 3.0 | 2.8 | 0.4 | 1.2 | 1.0 | 3.4 | **2.2** |
| 5 cm | 2.3 | 2.2 | 3.4 | 3.3 | 2.8 | 0.3 | 1.2 | 1.0 | 3.3 | **2.2** |
| 10 cm | 2.2 | 2.3 | 3.4 | 3.9 | 2.9 | 0.0 | 1.2 | 0.8 | 2.9 | **2.2** |

*Vector distance of auto aligned volume from average manual aligned volume at radial distances of 2.0, 5.0, and 10.0 cm. Distances in mm.*

In a previous study we reported that the consistency of manual alignments of FDG-PET to simulation CT for lung cancer patients has a mean variability of approximately 2 mm in all directions[1]. The ability to detect small amounts of offset is shown in Figure[3]. The current study indicates that automatic alignment and manual alignment agree nearly as well as separate observers. Reported simulation patient setup errors in radiation therapy are 4 to 6 mm[2,3] for lung cancer patients. The net increase in setup error using automated alignment and assuming Gaussian distributions is less than 1 mm.

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[2] Erdi YE, et al Radiotherapy treatment planning for patients with non-small cell lung cancer using positron emission tomography (PET). Radiother Oncol. 2002 Jan;62(1):51-60

[3] Vanuytsel LJ, et al The impact of (18)F-fluoro-2-deoxy-D-glucose positron emission tomography (FDG-PET) lymph node staging on the radiation treatment volumes in patients with non-small cell lung cancer. Radiother Oncol. 2000 Jun;55(3):317-24