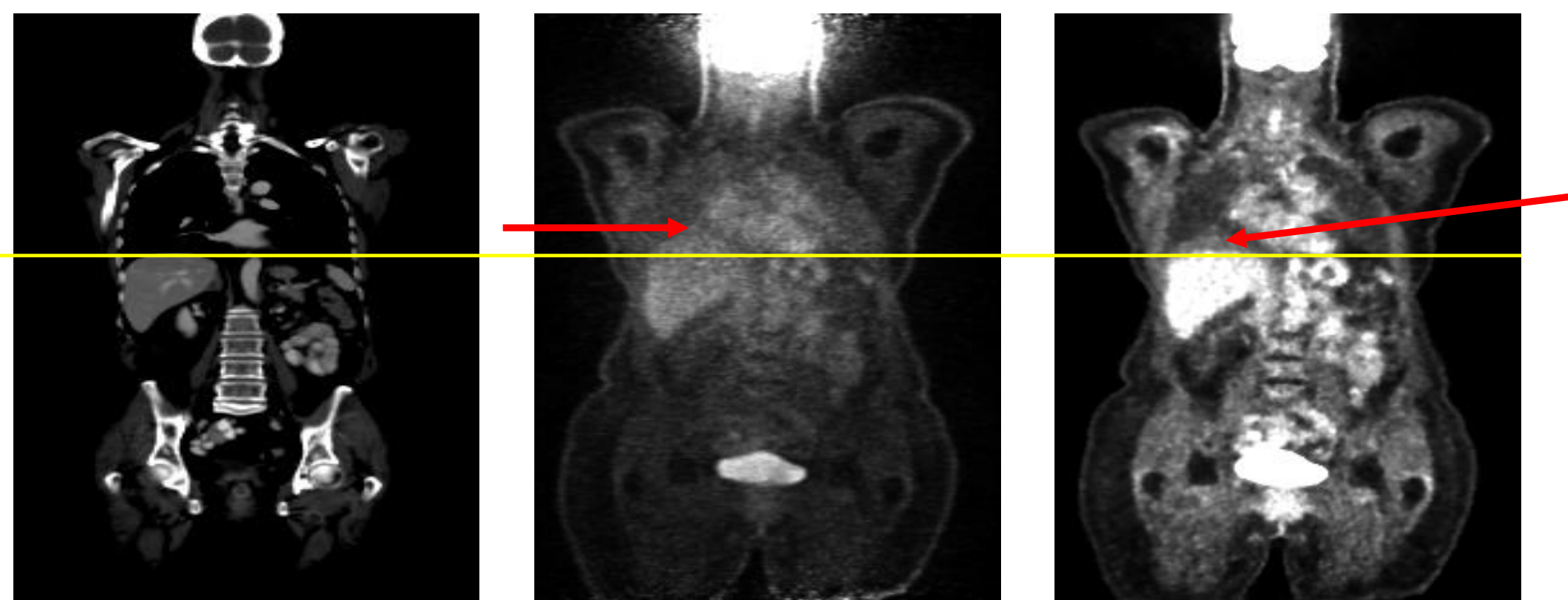


Introduction

CT-based attenuation correction is an essential aspect of PET reconstruction. Without attenuation correction images cannot be quantitatively accurate and multiple artifacts are present, including, in some extreme cases, showing radioactivity where there was none. The CT-based attenuation correction can itself lead to artifacts if, for example, there was patient motion between the PET and CT.

A common cause of such an artifact is a mismatch between the location of the dome of the liver in the CT and NAC PET image sets, which leads to an artificially dark region at the top of the liver, as shown in Figure 1. This is caused by a difference in the respiratory cycle for a patient during the CT scan versus the PET scan.



Coronal CT, NAC PET, and AC PET images of a patient with a respiratory artifact

Time-of-Flight (TOF) technology can reduce the artifacts in non-attenuation-corrected PET images as well as some artifacts from improper attenuation correction. We have studied respiration-related PET artifacts in a controlled phantom experiment and retrospectively evaluated the both artifact and developed an algorithm to quantitate the difference in diaphragm position in PET and CT images in FDG and PSMA PET/CT studies.

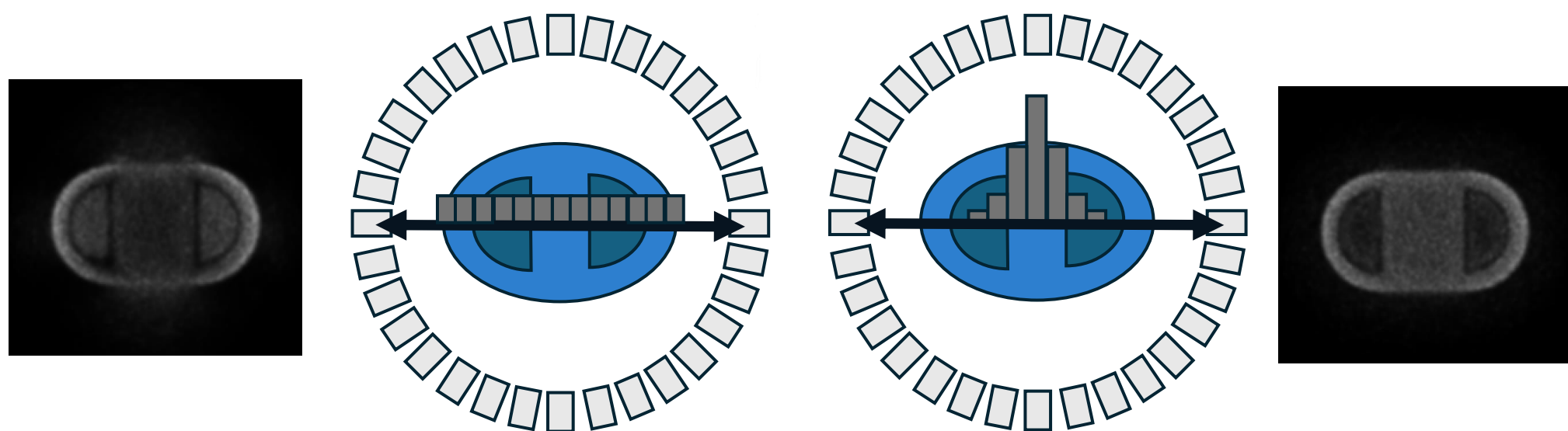


Illustration of NAC PET with and without TOF capabilities

Phantom Based Experiments

Semicylindrical lung inserts were added to a NEMA abdomen phantom. Two 20 mm spheres were inserted beneath each insert. Two spheres were filled with 3:1 activity concentration relative to the background, and two were filled with 6:1 to simulate hot lesions in the liver. The lung inserts were left empty. A photograph of the phantom is shown below.



Photograph of abdomen phantom with lung inserts

To simulate a mismatch in the phase of the respiratory cycle in the CT and the PET, we took 6 CTs of increasing displacement from the PET scan and generated an AC PET image set using each CT set. Additionally, to simulate free breathing during the PET, we averaged a 90 second PET with no displacement with two 45 second scans with 1 and 2 cm of displacement.

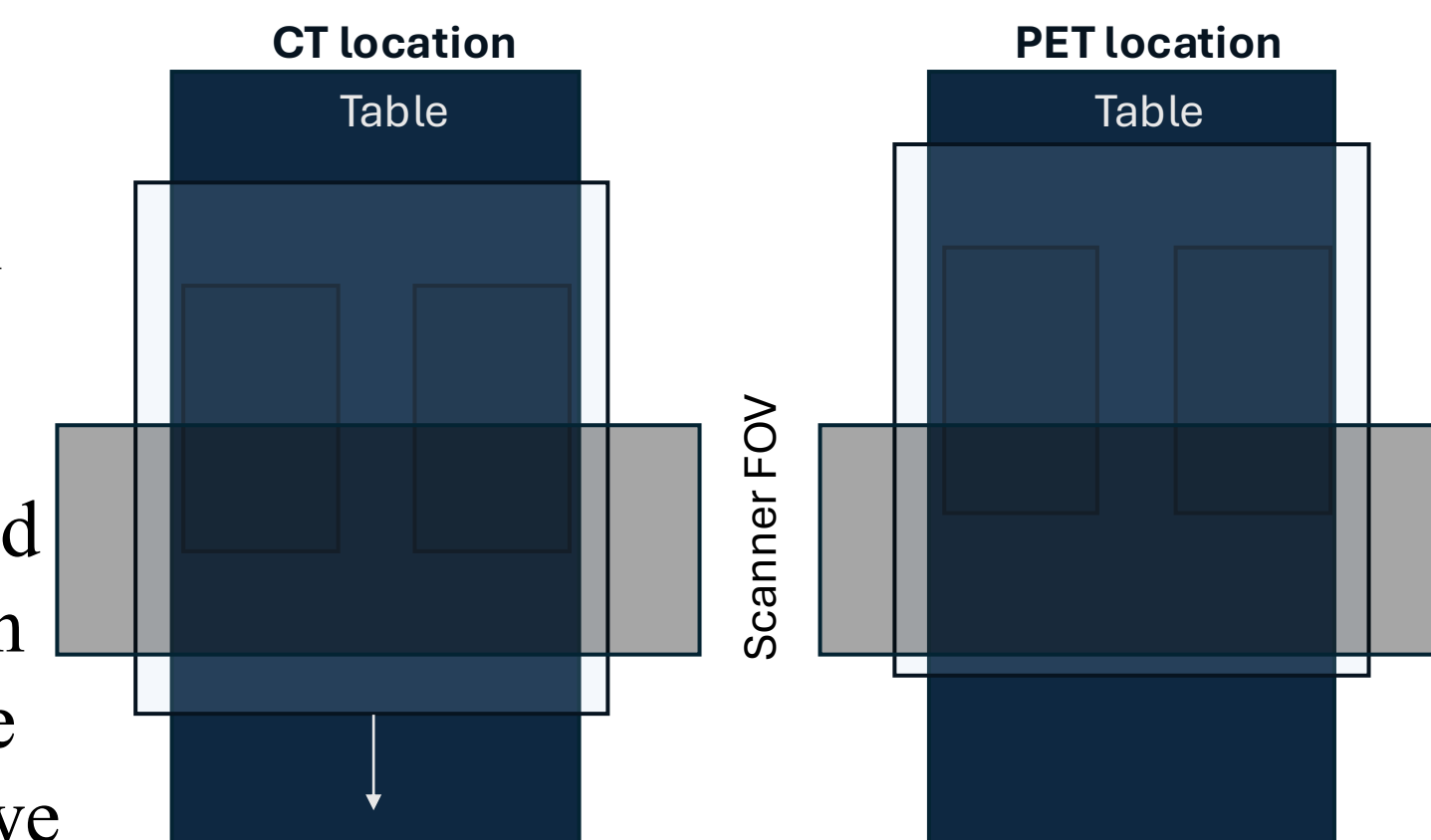
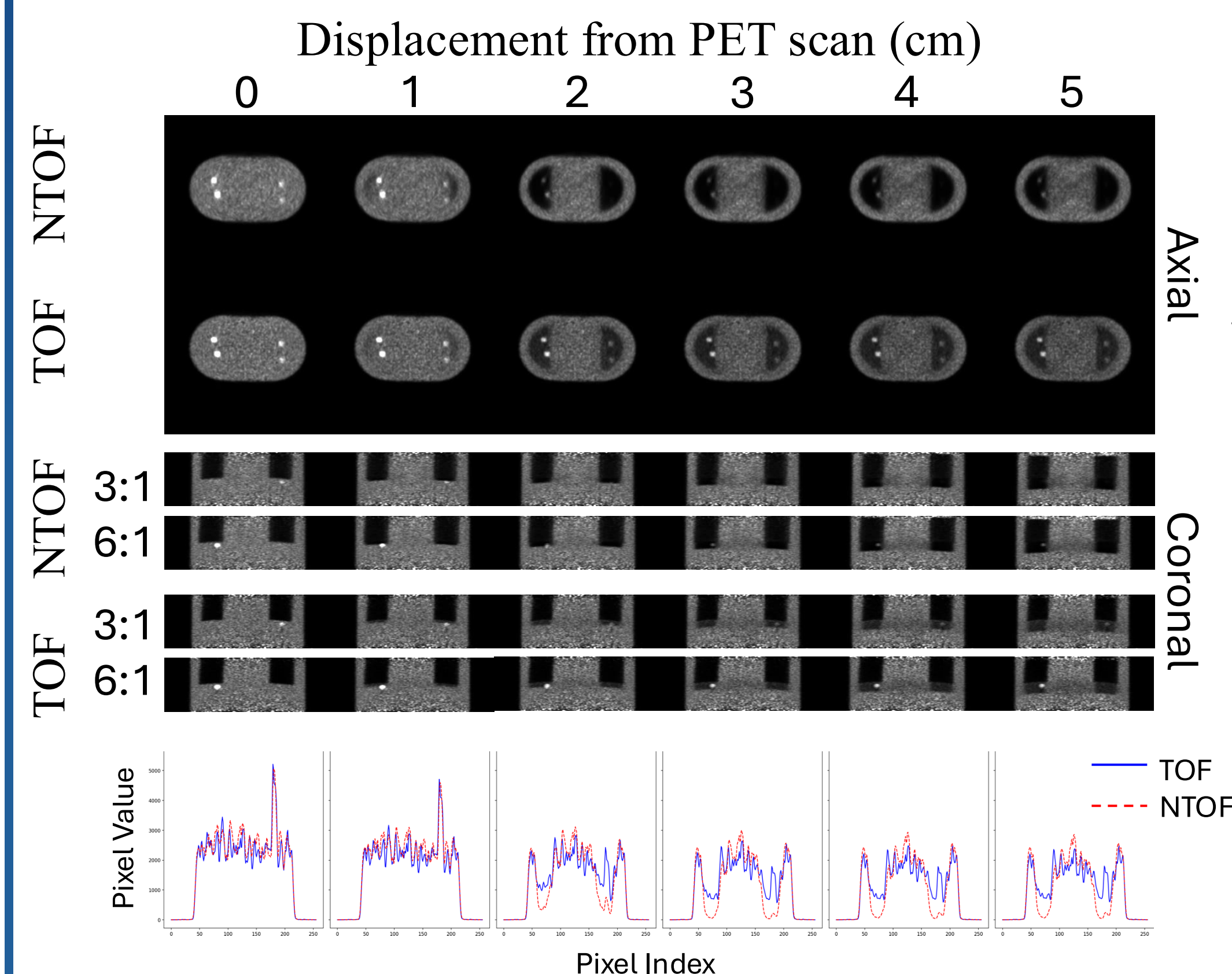
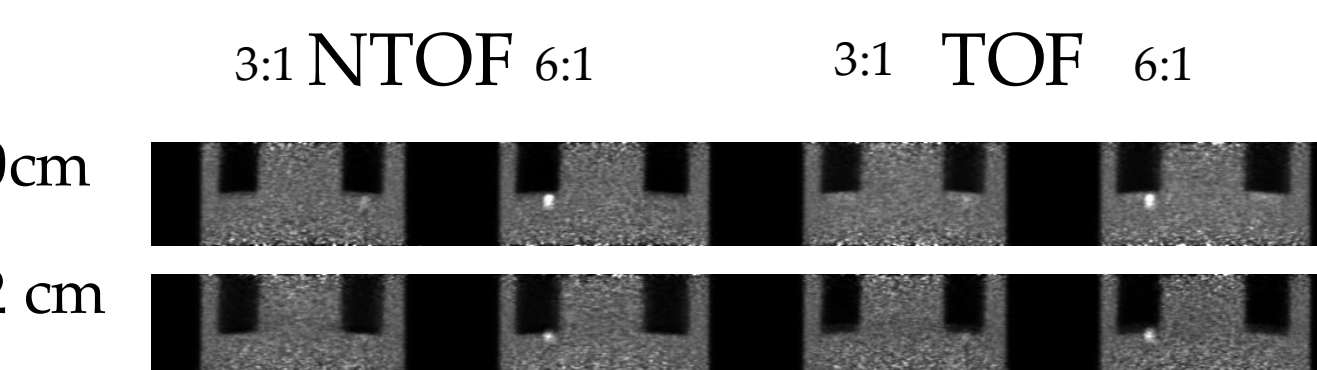


Illustration of phantom movement during scans

Results showed worsening detectability of the hot spheres with increasing displacement, which worsened when compounded with motion during the PET and with the lack of TOF capabilities.



Top to bottom: Axial slices of lung insert phantom, coronal slices, intensity profiles across axial slices



Coronal images for blurred PET scan

Summary

- Sphere discernability degrades with displacement between PET and CT
- This effect is worsened with displacement during the PET

Retrospective Study with Human Data

- Developed code in Linux to extract anonymized image data from Duke Health PET archive with IRB exemption.
- Developed code in Python to determine the transition point between lung tissue and liver tissue in NAC PET and CT by finding the largest average positive gradient across 3 slices

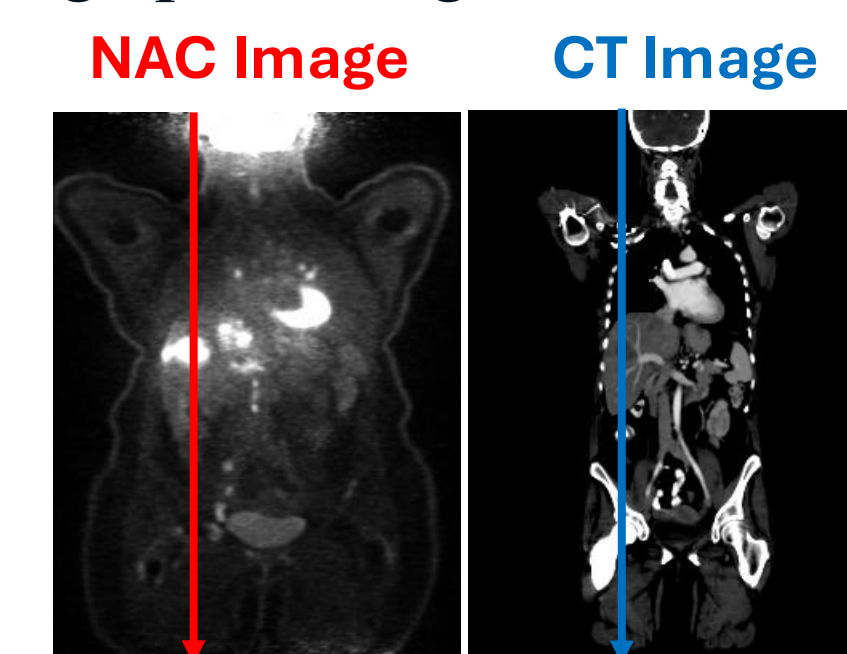
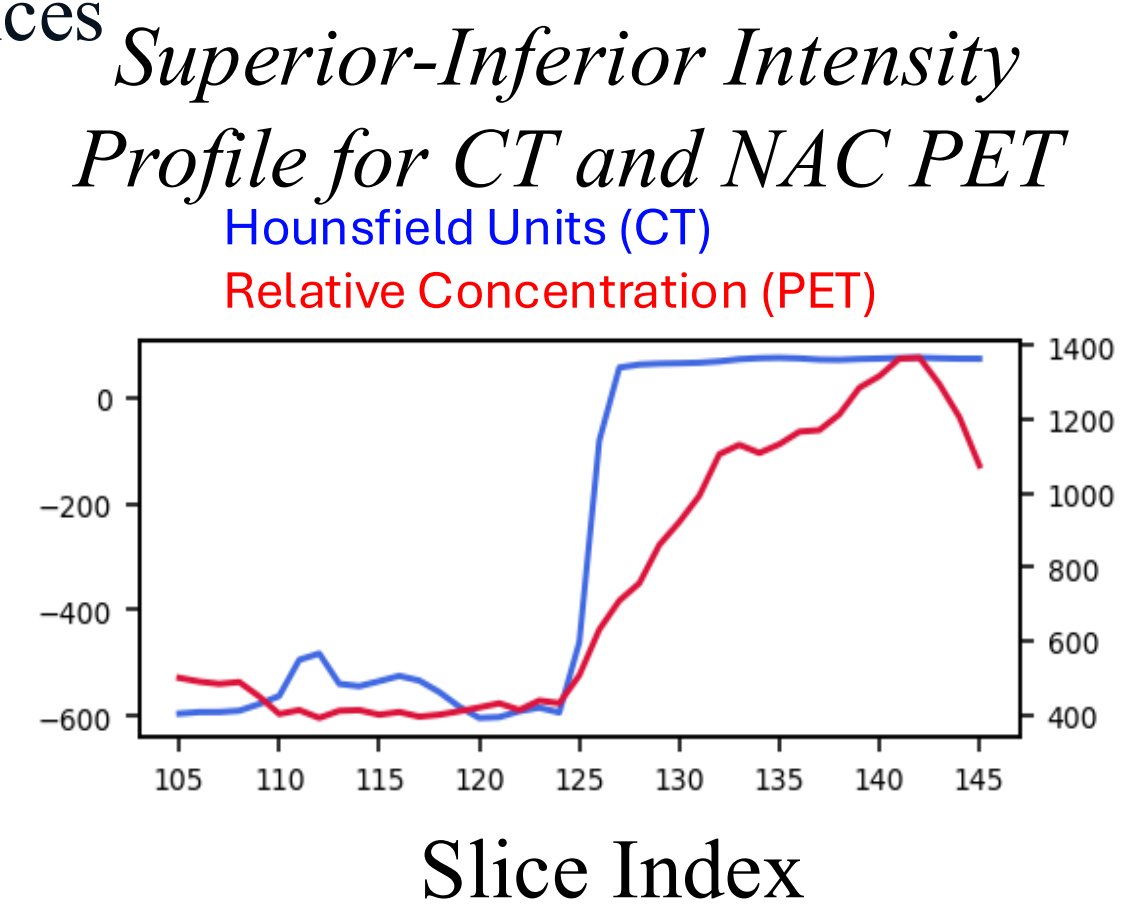
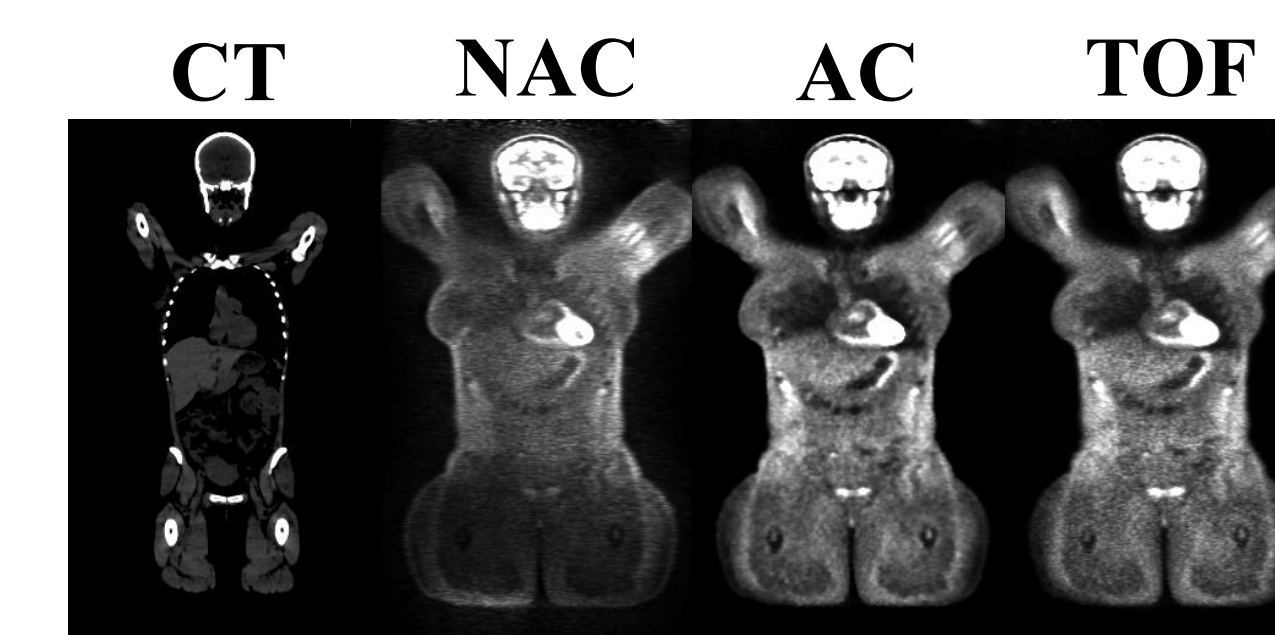


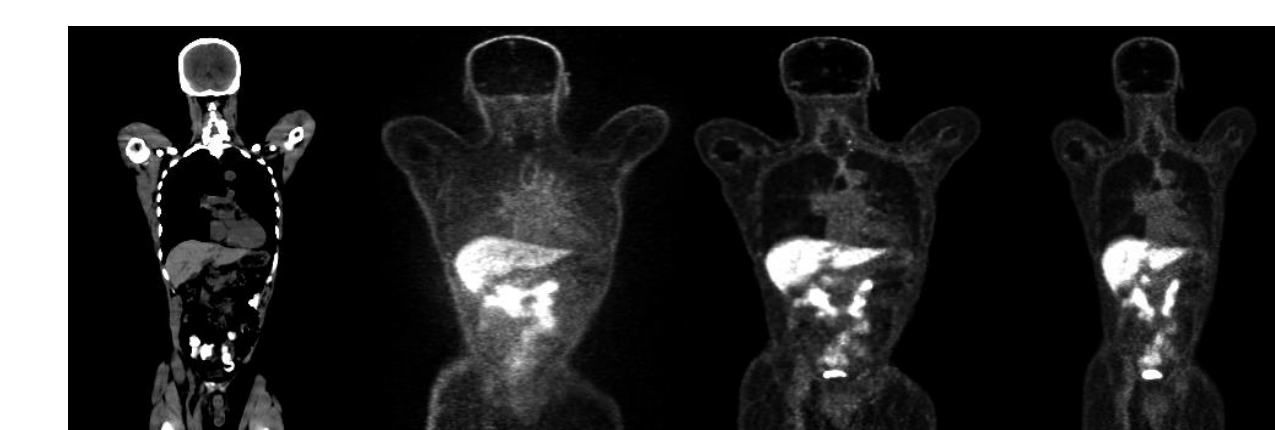
Illustration of transition algorithm



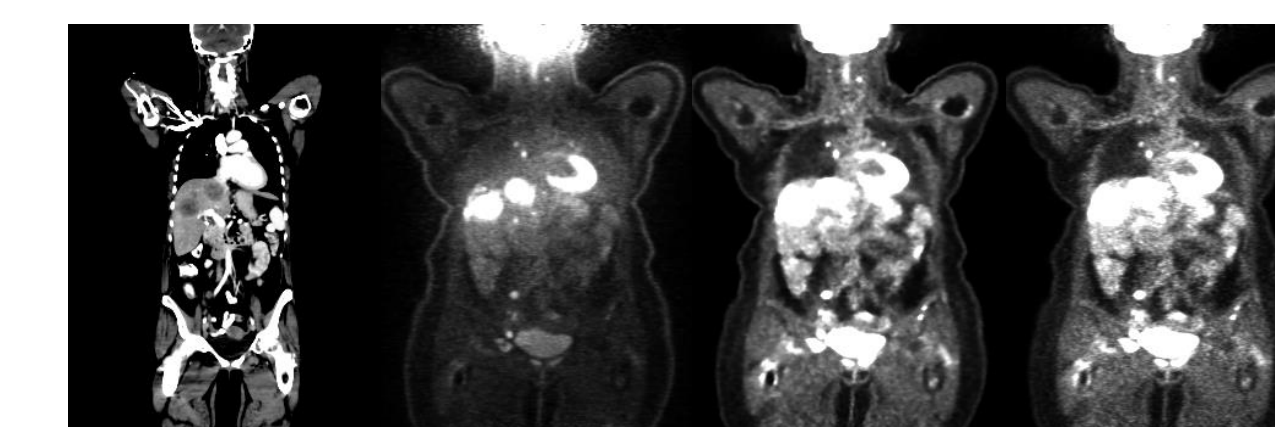
Patient Coronal Images



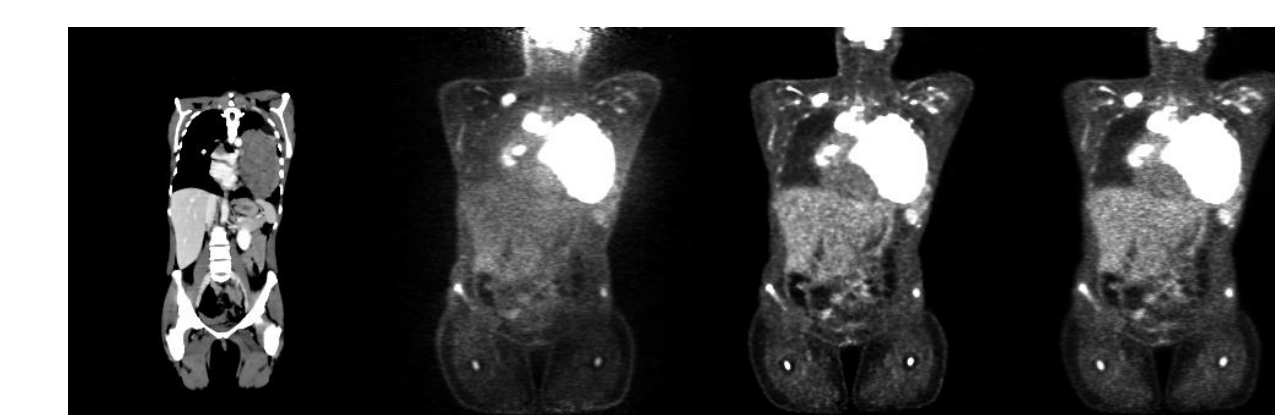
Extreme displacement—no match



No displacement—match



Positive displacement—match



No determination made