Automated 3D PET/CT-based Detection of Suspect Central-Chest Lesions

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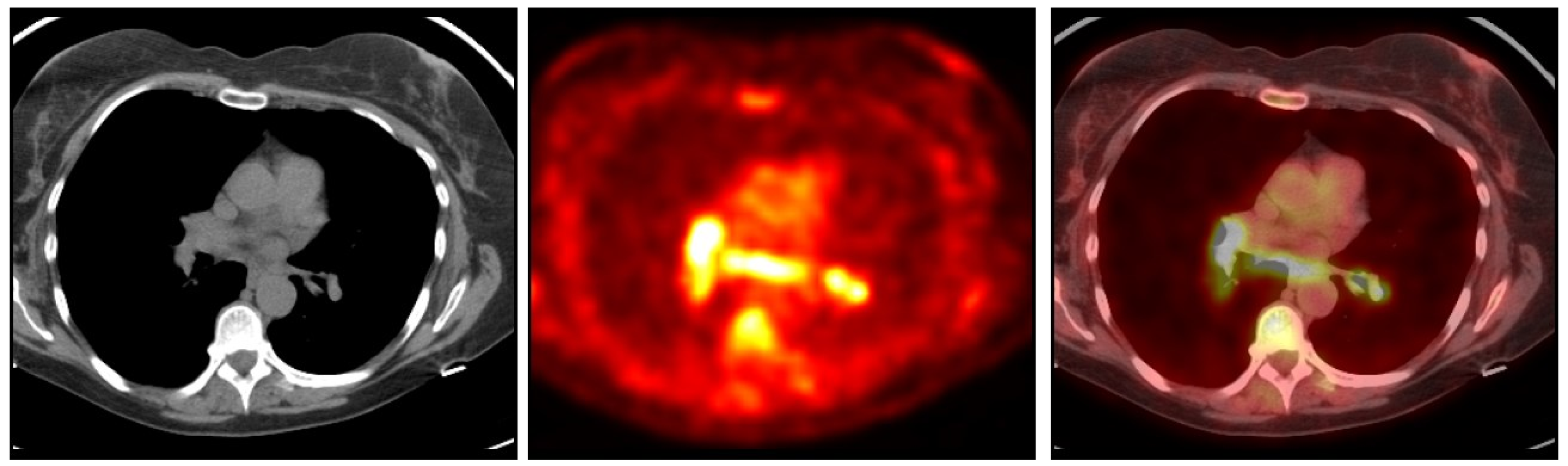
1. Background

Integrated PET/CT scanners give 3D multimodal information that not only highlights suspect lesions but also provides detailed anatomical information (PET = positron emission tomography; CT = computed tomography) – see Figure 1.[1,2] Unfortunately, tedious interactive image scrolling is generally used to identify suspect lesions. We present a feasibility study considering the use of automated computer analysis of PET/CT scan data for detecting suspect lesions.



Axial CT section | Corresponding PET section | Fused PET/CT section

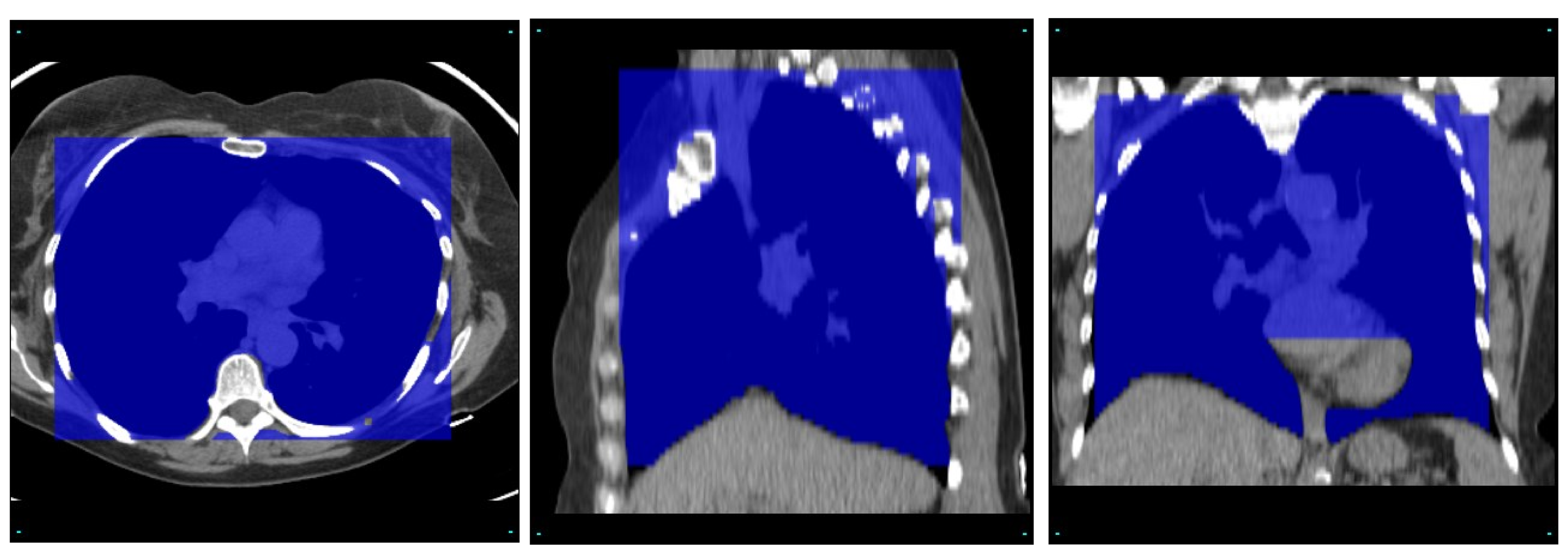
Figure 1. The high-resolution CT data ($\Delta x = \Delta y = 0.88$ mm) clearly shows detailed anatomical relationships, while the lower-resolution PET ($\Delta x = \Delta y = 4.0$ mm) highlights suspicious lymph nodes. Data fusion combines the strengths of the two modalities (case 21405.98).

2. Materials and Methods

Four patients underwent a PET/CT scan with a Philips True Flight Gemini PET/CT scanner. We manually identified a total of 26 central-chest lesions on the fused PET-CT versions of the four scans to establish a ground-truth database (range of lesions per scan: 2-11). We next applied a series of fully automatic image-analysis methods to each PET/CT study. These methods involved the following functions:

1. 3D CT analysis:
   a. Extract the lungs and define a 3D bounding box enclosing the lungs.
   b. Digitally subtract out the bones and lower diaphragmatic tissue regions contained in the bounding box – this gives a final 3D central-chest mask (Figure 2).
2. Apply the CT-based central-chest mask to the PET scan.
3. Apply Otsu's iterative thresholding algorithm to the masked 3D PET scan to find a suitable $SUV_{threshold}$ for candidate lesions (SUV = standard uptake value).[3]
4. Identify regions > 100 mm^3 in volume – these regions represent the final lesion detections.

Figure 3 depicts results of steps 2-4. After automated lesion detection, we examined the results using our custom multimodal PET/CT visualization system (Figure 4).



Axial section | Sagittal section | Coronal section

Figure 2. 2D axial, sagittal, and coronal slices with the extracted central-chest mask (blue) obtained from automated 3D CT analysis (case 21405.98).

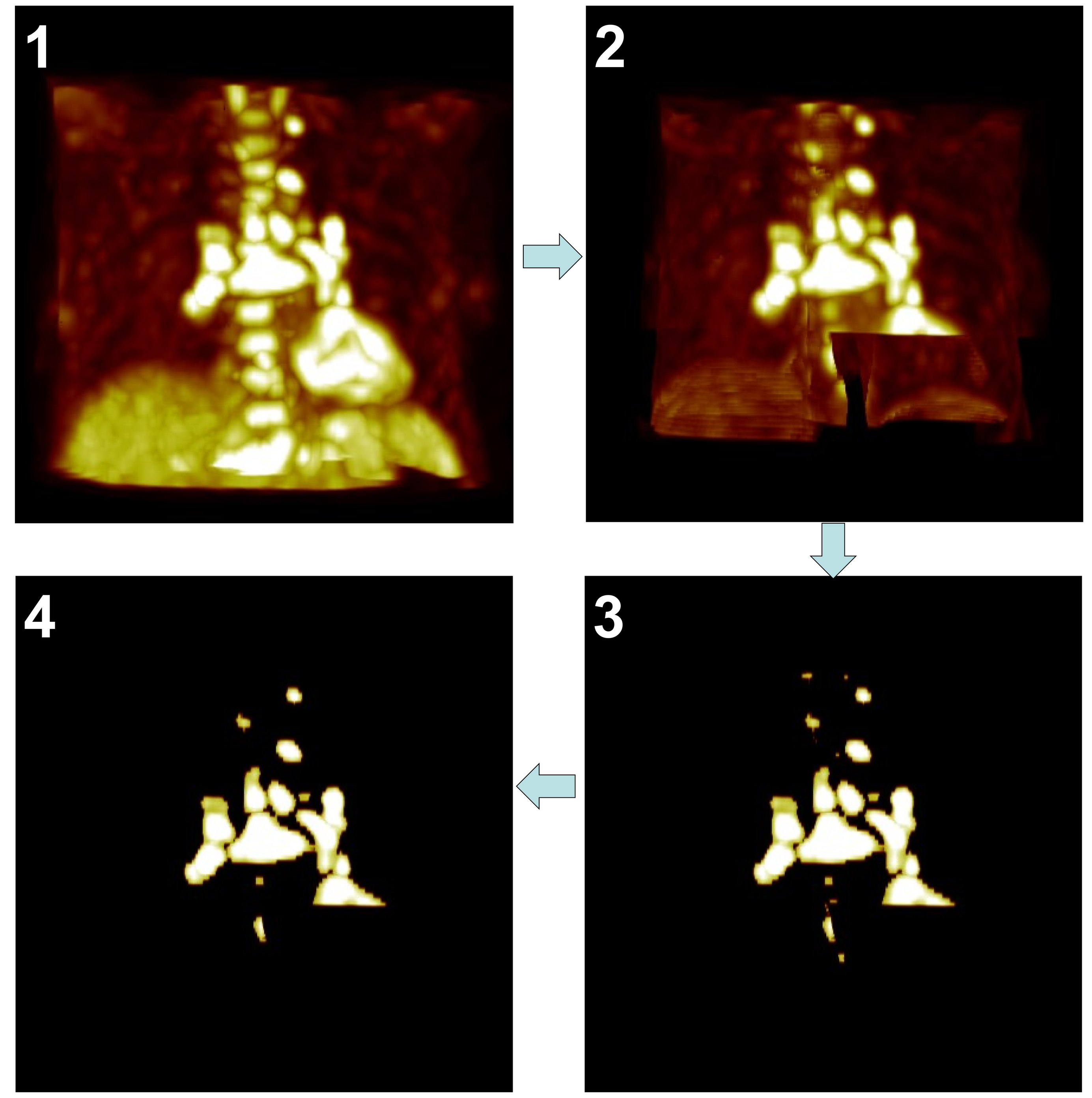


Figure 3. (1) Original 3D PET volume. (2) Masked 3D PET volume after applying CT-based central-chest mask. (3) Segmented 3D PET volume using automatically obtained $SUV_{threshold}$ = 3.38. (4) Final detected lesions after small regions removed (case 21405.98).

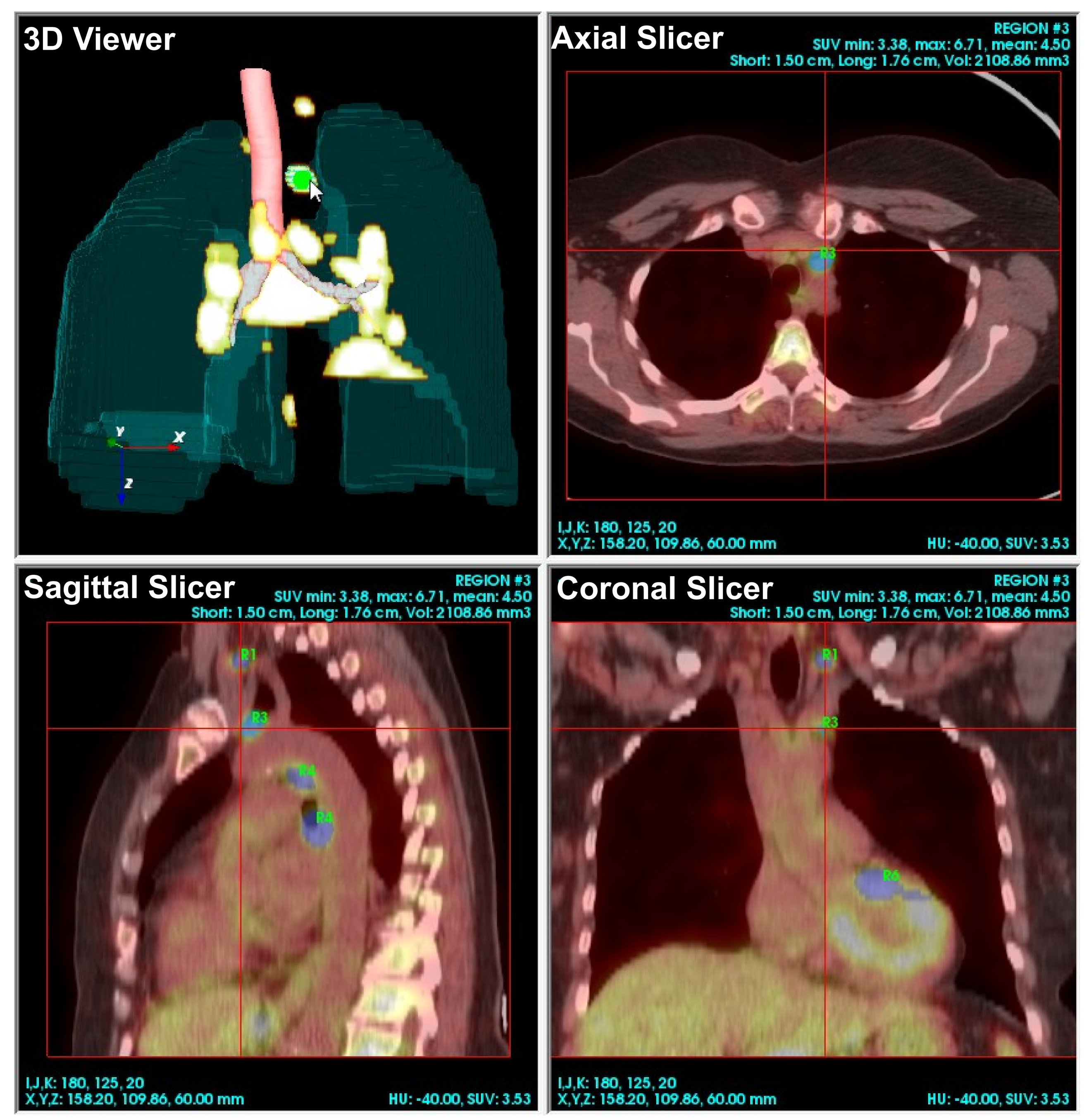


Figure 4. Example display from our multimodal PET/CT visualization system. The final detected region #3 is selected and highlighted by a single click in the 3D viewer. All slicers simultaneously show the following visual and quantitative region information: location, SUV_{min}, SUV_{max}, SUV_{mean}, short and long axis lengths in cm, and volume in mm^3. Each detected region is annotated with a letter 'R' followed by an ordinal number (case 21405.98).

3. Results

The table below shows the detection results we achieved over the four test cases and 26 ground-truth lesions. Figure 5 depicts graphical results for one case.

Data Used	Mean SUV Threshold*	False-Detection Rate (%)**
PET only* **	3.01 (range: 2.58 – 3.55)	71 (range: 50-88)
PET/CT	3.29 (range: 3.12 – 3.39)	44 (range: 0 – 61)

*SUV threshold = lowest SUV that enables 100% sensitivity to ground-truth lesions.
**A false detection represents a detected region not corresponding to a ground-truth lesion.
*** "PET only" situation involved only applying steps (3-4) of the automated analysis to the complete unmasked 3D PET scan. Hence, this results in different SUV thresholds than those derived by the full automated PET/CT analysis.

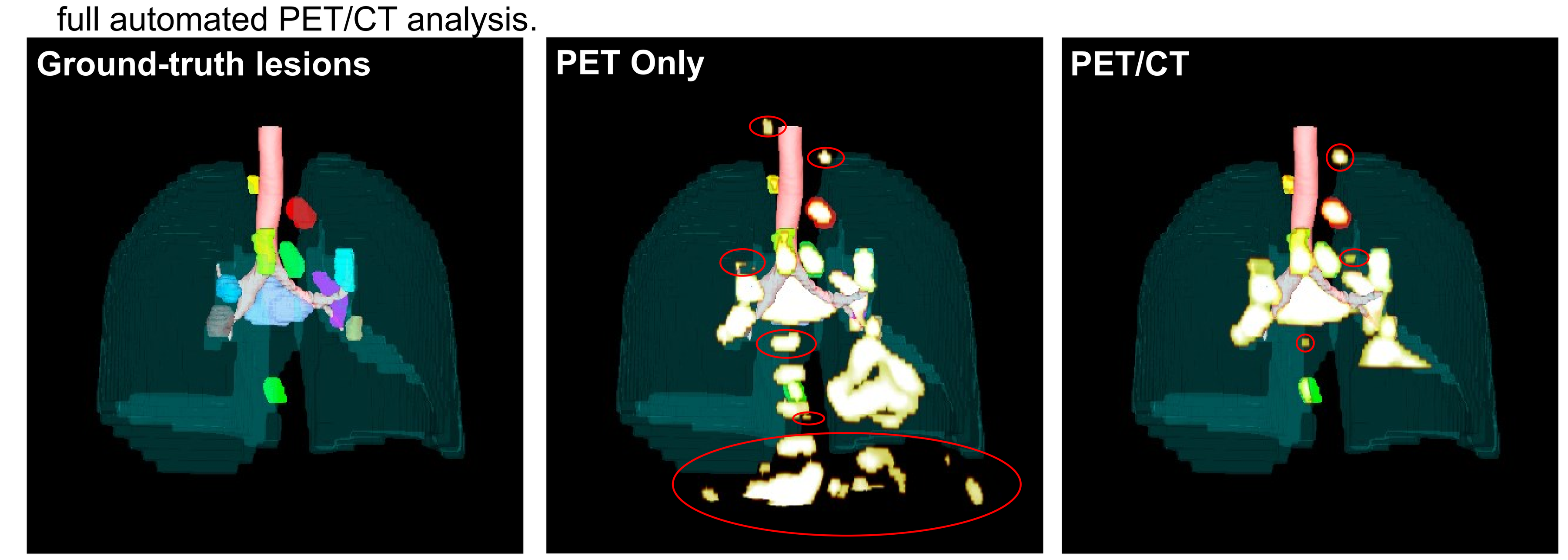


Figure 5. The above figures show 11 ground-truth 3D lesions and final regions detected using PET only and using PET/CT together. Falsely detected regions are highlighted by red ellipses. We can see from the figures that PET/CT has a smaller number of falsely detected lesions as compared to using PET only (case 21405.98).

For all cases, the automated PET/CT analysis derived an SUV threshold enabling 100% sensitivity, while lowering the false-detection rate over PET-only analysis. The results demonstrate that combined PET/CT analysis lowers the false-detection rate by 38%. In addition, PET-only analysis placed all 26 ground-truth lesions in only 14 detected regions (i.e., 12 lesions merged with others), while PET/CT analysis better distinguished the lesions, using 18 detection regions.

4. Conclusion

Automated 3D multimodal image-analysis methods show potential for effectively identifying suspect central-chest lesions depicted in PET/CT studies.

References

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2. T. M. Blodgett, C. C. Meltzer, and D. W. Townsend, "PET/CT: form and function," *Radiology*, vol. 242, no. 2, pp. 360-385, Feb. 2007.
3. N. Otsu, "A threshold selection method from gray-level histograms," in *IEEE Trans. Sys., Man., Cyber.*, vol. SMC-9, pp. 62-66, 1979.

Acknowledgments

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