Target volume delineation with PET: two case studies

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Objective
The objective of the study is to evaluate the accuracy of different approaches for target volume delineation on amino acid PET images in clinical studies.

Methods
Three different approaches for target delineation were compared:
• Manual contouring by an experienced nuclear medicine physician
• An algorithm based on absolute SUV thresholds or SUV thresholds based on maximum tumor uptake
• A source/background algorithm.

Parameters of the two automated approaches were optimized in the first patients to be studied. The impact of high-resolution PET reconstruction techniques using 2 mm slices on target volume delineation was compared with T2-weighted MRI. Trajectories of stereotactic biopsies were fused with PET/CT images and the intensity profile along the trajectory was correlated with histopathologic findings.

Illustrative case
A 47-year-old female patient with suspected recurrence of a grade II oligodendroglioma was studied by FET PET and MRI (Figure 1a). There was markedly increased FET uptake in the cingulate cortex (white arrows) without a clear corresponding abnormality in the T2-weighted MRI. Conversely, there is an area of increased T2 signal (red arrows) in the MRI without increased FET uptake.

Case 1: Recurrent oligodendroglioma demonstrated by amino acid (FET) PET

Background
Several studies have indicated that PET imaging with radiolabeled amino acids such [11C] methionine (MET) or [18F]fluorothalidrine (FET) can improve the detection and characterization of gliomas. Amino acid PET can detect tumor tissue in areas that show no or unspecific abnormalities on MRI [1]. Conversely, abnormalities on amino acid PET are more specific for tumor tissue than contrast enhancement or edema on MRI [2]. Based on these data, amino acid PET is increasingly used to define tumor extension for planning radiation therapy or surgical interventions [3]. However, validated algorithms for automatic delineation of tumor extension on amino acid PET are currently lacking.

The trajectory of the stereotactic biopsy was projected onto the maximum intensity projection of the PET scan (Figure 1b) and the intensity of the PET signal was measured along the trajectory. Biopsies taken close to the target point all demonstrated the presence of recurrent oligodendroglioma.

Conclusion
Amino acid PET is more specific for tumor tissue than contrast enhancement or edema on MRI. There is a close correlation between the intensity of the PET signal and the presence of tumor tissue, as confirmed by biopsy. Based on the data obtained to date, amino acid PET offers an effective method for target volume delineation for planning radiation therapy or surgical interventions.
Case 2: Planning stereotactic radiotherapy of lung metastases with PET

Background
Stereotactic radiotherapy is increasingly used for treatment of lung metastases and small primary lung tumors [4,5]. However, radiation treatment planning on routine CT scans is limited by the respiratory motion of the metastases.

Objective
The objective of the study is to evaluate the use of PET for definition of target volumes for stereotactic radiotherapy of lung cancer and lung metastases, and compare the results with CT.

Methods
Patients underwent an ungated PET scan followed by a respiratory gated CT (Figure 2: A1 and B1).

Tumor volumes were delineated on all gates of the CT scan (Figure 2: A2, A3) using a threshold method combined with manual corrections to eliminate vessels and other structures. The combination of all respiratory gates represents the volume which was covered by the lung lesion during the whole respiratory cycle (VBT).

Tumor volume on PET (VPET) was calculated by a thresholding technique (50% of background corrected maximum FDG uptake, Figure 2: B2, B3). The sum of volumes of all respiratory CT gates provides a map (VPM) of the probability of tumor location during the breathing cycle (Figure 2: A/B4, upper part).

The coverage of VPM by the PET-based volume delineation was calculated by integrating the VPM encompassed by VPET (Figure 2: A/B4, lower part). In addition the volume of VPET which does not overlap with VBT is calculated (VPET-O). For comparison, tumor volume on the mid-inspiratory CT scan, plus a safety margin of 5 mm, was determined (VCT). The latter approach represents the current standard for target volume delineation.

Illustrative case
A 74-year-old female with known metastases, who was scheduled for stereotactic radiation therapy, was examined by ungated PET and respiratory gated CT (Figure 2).

During the respiratory cycle 10 studied metastases encompassed a volume of 5.8 ± 6.0 ml (0.6-16.5 ml, VBT). Tumor volume calculated on the PET images (VPET) was 5.7 ± 5.8 ml (0.9-17 ml) and covered 87% of the tumor location during the respiratory cycle (VPM). 0.5 ± 0.4 ml of VPET (22% of VBT) did not include tumor tissue.

Tumor volume calculated from the CT images (VCT) covered a comparable percentage of the tumor location (93%), but a much larger percentage did not include tumor tissue (6.3 ± 4.7 ml, 160% of VBT).

Conclusion
FDG-PET study can improve target volume delineation for stereotactic radiotherapy of lung metastases [6]. The smaller target volumes provided by PET may reduce the toxicity of stereotactic radiotherapy and may thus allow more patients to become eligible for this non-invasive therapy.

References