

A method for automatic segmentation of ^{18}F PET signals for target volume delineation

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Introduction

Positron Emission Tomography (PET) is increasingly used not only for staging but additionally for target volume assessment. Several publications have shown, that PET data reduce inter-observer variability. Yet, the visual impression of PET images is dependent on window and level settings. Thus a standardization is essential.

Material and Method

A **model-based method** was developed to determine a **relative threshold level (Th_{rel})** from the **background subtracted image** for volume delineation. Measurements were made using cylinders (diameter 4.5mm to 45mm) filled with ^{18}F activities ranging from 0.001MBq/ml to 0.15MBq/ml. These were placed in a tank filled with ^{18}F water of different activities to simulate various signal to background ratios from 3:1 to 20:1. All measurements were performed on a combined PET/CT scanner (Discovery LS, GE Medical Systems, Waukesha, WI). From these measurements Th_{rel} was derived (Fig. 2).

Software (SW) was generated to **automatically delineate PET activity volumes** based on this threshold. For the target volume delineation a point within the tumour is defined and another point for the background nearby. SW then automatically finds the maximum signal and the background surrounding the signal. With these values, a first GTV in 3D is contoured. This first contour may include non-target structures. With a mouse click the SW automatically excludes these structure in 3D resulting in an automatically defined GTV ready for manual refinement if necessary (Fig. 4).

The SW was **validated *in-vitro* and *in-vivo***. *In-vitro* validation was done with spherical sources (diameter 16mm to 36mm; Fig 3). *In-vivo* validation was done using patient data. Specially designed PET/CT marker (Isotopes Products Laboratories, California) were used to verify the fusion and if necessary to adjust the data sets. Tumour volumes derived with the automatic SW were compared with CT based clinician derived volumes.

Results:

The Th_{rel} best representing the source diameter was **$41 \pm 2.5\%$ of the background-subtracted signal**. The Th_{rel} was constant for diameters $\geq 12.5\text{mm}$. In an *in-vitro* set-up the SW was capable of segmenting solitary PET volumes to within 1.4mm (1SD).

In-vitro measurements using spheres confirmed the background subtracted threshold method at $Th_{rel} = 41\%$ (Fig. 3).

For non-homogeneous signals in a **clinical set-up** minimal manual intervention is presently required to separate target from non-target signals (Fig. 4). Matching accuracy between PET and CT data sets was 2mm. Examples of automatically generated GTV are presented in Fig 5. The **PET-based automatically derived volumes fitted the CT-based clinician drawn volume in $> 2/3$ of the cases**. Manually adaptation to define the ultimate target volume is possible. In Fig. 1 the GTV was cranially and caudally extended.

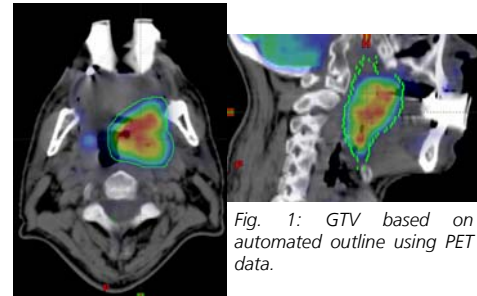


Fig. 1: GTV based on automated outline using PET data.

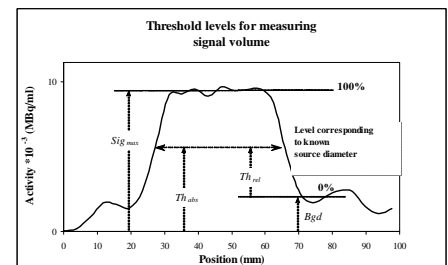


Fig. 2: To find the best threshold phantom measurements were made using cylinders and spheres. After subtracting the background signal the relative threshold best representing the physical diameter was 41%. The threshold was constant after the image was scaled.

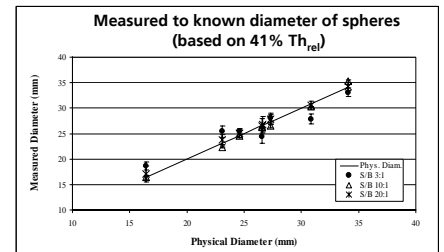


Fig. 3: Measured diameter of spheres using the fixed background subtracted threshold of 41%. No dependence of signal to background ratio was observed.

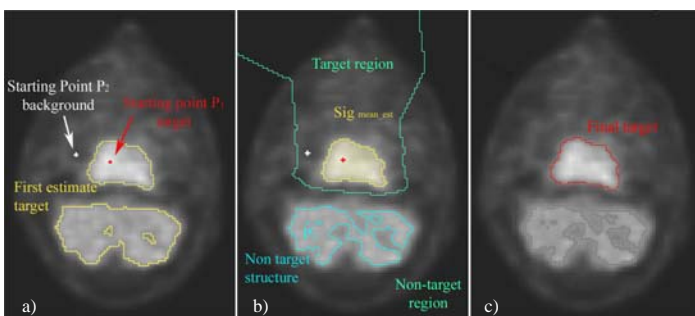


Fig. 4: Process of automatic GTV outlining: a) A point within the GTV (high uptake) and one in the background nearby are defined. A first approximation of the GTV volume is delineated. This may include non-target structures. b) With a mouse click in the non-target structure the SW excludes this volume automatically. c) The final GTV is outlined.

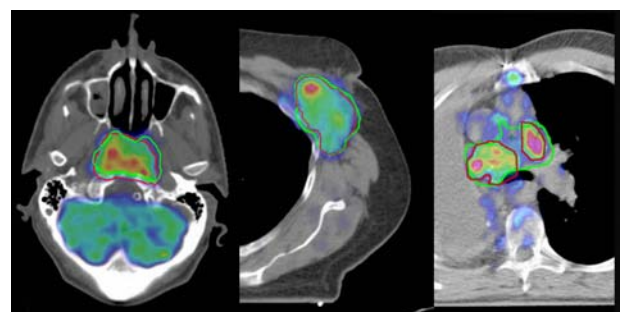


Fig. 5: GTV definition for three different sites: green the outline defined by the clinician based on CT, in red the outline automatically defined by the software based on PET data only.

Conclusion:

SW-based automatic delineation of the volume of ^{18}F activity is feasible and highly reproducible. If necessary, volumes can be subsequently modified by the clinician to produce the ultimate target volume. This approach will increase the efficiency and reproducibility of the planning process.