PET TUMOR SEGMENTATION: VALIDATION OF A GRADIENT-BASED METHOD USING A NSCLC PET PHANTOM

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Background

FDG-PET image volumes typically have increased contrast for tumor identification as compared to other modalities. Activity levels in PET volumes are related to regional tissue perfusion and tumor glycolysis and in many instances are not constant throughout the tumor. Constant threshold methods (THRESH) cannot accurately define tumor boundaries when there are significant differences in activity levels. Previous studies with constant activity in sphere phantoms have demonstrated that constant threshold methods require different thresholds based on several factors including sphere volume and ratio of sphere activity relative to background[1]. Gradient methods, such as PET Edge (GRAD), detect structure edges based on a change in activity levels near the structure edge. Sphere phantom studies have demonstrated that accurate volumes can be obtained with gradient based methods for clinical activity levels, acquisition and reconstructions[2]. In order to more accurately simulate tumor activity patterns found in patients, Monte Carlo lung phantoms were created and processed[3].

Purpose & Objectives

Reproducible, accurate PET segmentation methods are needed for assessing therapy response and aiding in creation of target volumes for Radiation Oncology. Our goal is to evaluate the accuracy of GRAD and THRESH on realistic, simulated PET phantom data for target volume definition and quantitative assessment of tumor activity.

Methods & Materials

Twenty-five realistic digital PET phantoms of the thorax were obtained with 31 simulated tumors of varying size, shape and location. An observer segmented each tumor with GRAD and THRESH. THRESH was performed using thresholds of 15-50% of maximum counts at 5% increments. Tumor volumes for each method were compared to known volumes from digital phantoms. Total Glycolytic activity (TGA), SUVmean * volume, was calculated for each method. Tumors were grouped by size into <60ml, 60-120ml, and >120ml. Mean absolute % difference was calculated for the volume (Vdiff%) and TGA (TGAdiff%) for each group using all methods.

Results

GRAD achieved greater accuracy than any THRESH method. For tumors <60ml, 60-120ml, and >120ml, the Vdiff% using GRAD was 14.2%, 8.0%, and 6.2%, respectively. Vdiff% for the best THRESH was 35.8%, 27.3%, and 18.6%, respectively (see Table 1). TGAdiff% for GRAD was 7.7%, 3.3%, and 1.5%, respectively. TGAdiff% for the best THRESH was 27.0%, 13.8%, and 15.7%, respectively. (see Table 2).

Figure 1

Threshold Method: Impact of Threshold on Relationship Between Actual and Measured Lesion Volume

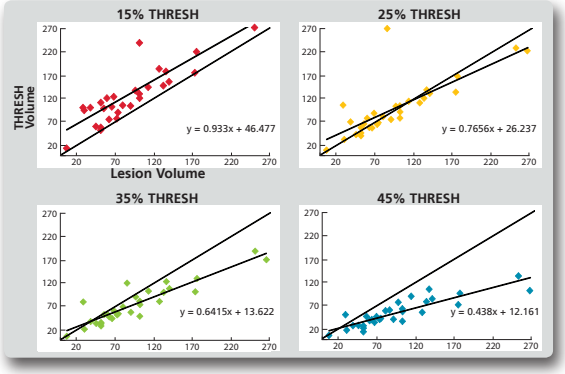


Figure 2

Gradient Method : Relationship Between Actual and Measured Lesion Volume

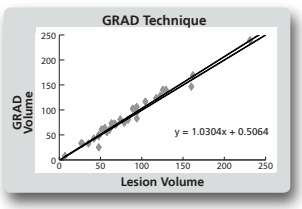


Table 1

Mean Absolute % Difference in Volume

Technique	<60mL	60-120mL	>120mL	Overall
GRAD	14.2	8.0	6.2	**9.5**
15% THRESH	106.3	56.8	17.8	**62.7**
20% THRESH	70.3	34.9	5.5	**38.7**
25% THRESH	49.7	26.9	10.1	**29.9**
30% THRESH	38.8	27.3	18.6	**28.8**
35% THRESH	35.8	24.5	27.4	**28.9**
40% THRESH	43.3	29.4	36.7	**35.8**
45% THRESH	43.4	39.4	47.0	**43.3**
50% THRESH	62.9	48.5	57.3	**55.4**

Table 2

Mean Absolute % Difference in Total Glycolitic Activity

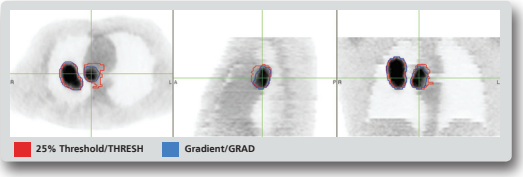
Technique	<60mL	60-120mL	>120mL	Overall
GRAD	7.7	3.3	1.5	**4.2**
15% THRESH	53.7	26.4	7.2	**30.3**
20% THRESH	44.0	19.3	2.5	**22.9**
25% THRESH	36.3	15.2	4.5	**19.3**
30% THRESH	30.4	15.7	9.5	**18.8**
35% THRESH	27.0	13.8	15.7	**18.6**
40% THRESH	30.5	14.6	23.3	**23.3**
45% THRESH	33.0	25.8	32.8	**29.9**
50% THRESH	36.9	34.3	43.3	**37.5**

Discussion

Constant threshold methods have been developed which attempt to iteratively optimize threshold level based on measured tumor volume and tumor to background activity ratios[1] . These methods fail when background is not constant in the region of the tumor and activity levels are not constant in the tumor. In the present study the optimum threshold for these 31 lesions was 25%. This is smaller than results in spherical phantoms which are generally in the range of 36-44%[1]. Since the simulated phantoms appropriately include regions of lower activity a lower threshold provides better results for this group of phantoms. A different optimum threshold would be obtained based on different experimental conditions. GRAD, however, is based on relative changes in activity levels near the structures edge helping to provide a robust method across many different conditions.

Figure 3

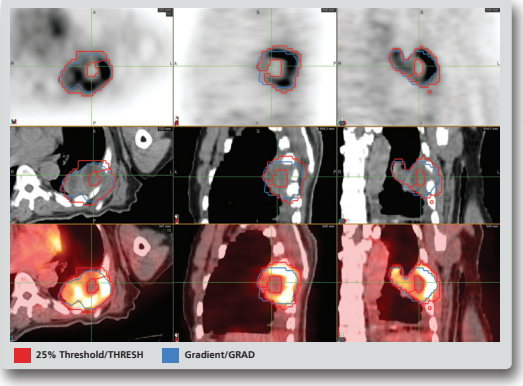
Phantom Image



For cases where the tumor is in the center of lung (i.e. high source-to-background) and fairly homogeneous, 25% THRESH performs fairly well, however, in the mediastinum with lower source-to-background 25% THRESH performs poorly. GRAD produces more accurate segmentations in both of these scenarios.

Figure 4

Patient Image



Case illustrates limitations of constant threshold in cases of heterogeneous tumor metabolism and areas of decreased SBR (adjacent to chest wall) while GRAD produces more accurate segmentations in both of these scenarios.

Conclusions

GRAD resulted in more accurate tumor volumes and TGA statistics than THRESH for all lesions. Through more accurate tumor volume segmentation and statistics, GRAD may play an important role in prognosis, therapy response assessment, and creating target volumes in Radiation Oncology. Ongoing research includes multi-observer, multi-institutional validation of the gradient-based method using this data set[4] and pathological confirmation[5].

References

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Abstract accepted tos Journal of Nuclear Medicine 2009.