Contrast-oriented seed based automatic segmentation algorithm: minimizing effect of lesion heterogeneity on algorithm response.

M. Carles[1,2], T. Fechter[2], U. Nestle[2], A. Schaefer[3]

1 Department of Nuclear Medicine, Hospital Universitario y Politecnico La Fe, Spain.
2 Department of Radiation Oncology, University Medical Center, Freiburg, Germany.
3 Department of Nuclear Medicine, Saarland University Medical Center, Homburg, Germany.

montserrat.carles@uniklinik-freiburg.de

AIM: To investigate the impact of tumor heterogeneity on the performance of a contrast oriented (COA) segmentation algorithm for tumor delineation on PET image and preliminary evaluation of an extended version of the algorithm (2I-A), accounting for lesion heterogeneity

INTODUCTION

➢ Taking into account the background around the target has been proved to be necessary in order to derive correct volume information. The **contrast oriented algorithm** (**COA**) is based on this approach [1]:

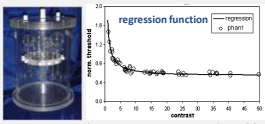
$$TS = a \times mI_{70} + b \times BG \qquad eq.\ (1)$$

Where

TS is threshold intensity for volume delineation , **BG** is mean background, mI_{70} is mean intensity of all pixels with intensities above 70% of Imax and **a** and **b** were derived from **calibration procedure [1] [2] in previous work**:

- TS was determined based on the a-priory knowledge of volumes
  - -Spheres were auto-contoured in the attenuation-corrected slices varying the **TS in steps of 0.1**.
  - -Using the resulting optimum threshold values, a **regression function** was calculated (*a* and *b*).

Inserts filled with homogeneous uptake solutions.



Phantom and results from calibration procedure by Schaefer et al [1]

How significant is the **impact of heterogeneous lesions on COA?**

How **could** it **be minimized?**

MATERIALS & METHODS

Data

8 non-small lung cancer patients

75 ± 3 years old

previously injected (60min)

with FDG (344±17MBq)

PET/CT Philips System GEMINI TF TOF (64)

- **Retrospectively gated (4D-)PET/CT imaging**
- Number of phases:10
- **10min** (PET) and 36 s (CT).
- BLOB-OSEM-TOF
  2 iterations & 3 subsets
- Image voxel volumes CT: 1.17x1.17x3 mm³
  PET: 4x4x4 mm³

Proposed algorithm

- **Two iteration algorithm (2I-A)**

COA was extended by a second iteration :

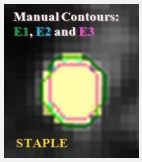
mean intensity derived from the segmented volume by COA (mI_{COA}) was the input value for **mI_{70} in a second TS computation** by equation (1).

- This proposed method was an attempt to better account for uptake heterogeneity not considered by the calibration procedure, which uses homogeneously filled inserts.
- Computation time is around 3 s.

Analysis

For each of the 80 PET images (10/patient) lesions were manually contoured by 3 experts:

Their **STAPLE [3] consensus** was established as the **ground truth (GT)**. For voxel intensities within GT, **heterogeneity was quantified** by **COV_T**=(SD/mean)



Dice **S**imilarity **C**oefficient

$$DSC = \frac{2(A \cap B)}{(A+B)}$$

Being A and B two segmented volumes

In order to measure volume accuracy:

DSC_A	DSC_E	DSC_{2IA}
COA vs **GT**	Average over 3 pairs of Experts	2IA vs **GT**

Accuracy of COA (DSC_A) was compared with respect to inter- observer variability (DSC_E) as a **measure of the level of accuracy**: DSC_A /DSC_E

RESULTS

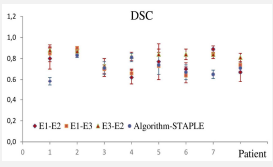
– COA Accuracy: dependence on lesion heterogeneity.

I. COA algorithm accuracy is within the variability obtained among the 3 experts.

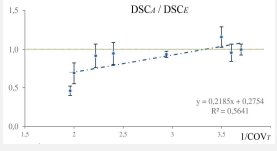
	Vol. (ml)			COA vs STAPLE		Average Experts	
	SUV_{max}	STAPLE	COA	%Vol.	DSC_A	%Vol.	DSC_E
Total Mean ± SD	11 ± 9	5 ± 4	4 ± 2	40 ± 30	0.71±0.08	50 ± 20	0.78±0.07

II. Non-negligible **volume underestimation for some patients.**

➢ **Significant linear correlation between level of accuracy and lesion heterogeneity**



(r=0.751, p=0.032)



– 2I-A volume accuracy for lesions with COV_T>0.3.

For patients with GT COV_T> 0.3, segmented volumes by initial COA and by 2I-A were compared with respect to GTS.

STAPLE VERSUS COA AND 2I-A.

VOLUME (ml)

	Patient1	Patient2	Patient5	Patient6	Patient7
COA	5.4 ± 0.2	8.0 ± 0.3	1.6 ± 0.3	1.8 ± 0.2	5.8 ± 0.4
2I-A	9.2 ± 0.2	10.12 ± 0.12	2.5 ± 0.3	2.8 ± 0.2	8.0 ± 0.3
STAPLE	13.4 ± 1.3	9.1 ± 0.4	2.8 ± 0.3	2.6 ± 0.5	9.7 ± 0.6

DSC

	Patient1	Patient2	Patient5	Patient6	Patient7
COA	0.58 ± 0.04	0.83 ± 0.02	0.74 ± 0.09	0.67 ± 0.09	0.65 ± 0.4
2I-A	0.76 ± 0.07	0.89 ± 0.02	0.85 ± 0.02	0.81 ± 0.03	0.79 ± 0.3

➢ **Volume accuracy was improved by 2I-A.**

CONCLUSIONS

✓ **Lesion uptake heterogeneity** has shown **significant impact on** the level of accuracy of **COA**.

✓ **In lesions with heterogeneous tracer uptake**, COA seed based algorithm with a second iteration (**2I-A**) accounting for lesion heterogeneity **is recommended**.

✓ Future work:

Evaluation with larger cohort of patients & Investigation of the best trigger for 2I-A application (texture features)

REFERENCES

[1] A. Schaefer et al.,*" A contrast-oriented algorithm for FDG-PET-based delineation of tumour volumes for the radiotherapy of lung cancer: derivation from phantom measurements and validation in patient data. "*, Eur. J. Nucl. Med. Mol . Imaging, 35(11):1989–1999, November 2008.

[2] A. Schaefer et al.,"*Multi-centre calibration of an adaptive thresholding method for PET-based delineation of tumour volumes in radiotherapy planning of lung cancer. "*,Nuklearmedizin, 51(3):101–110, March 2012.

[3] S. K. Warfield et al. "*Simultaneous truth and performance level estimation (STAPLE): An algorithm for the validation of image segmentation. "*,IEEE Trans Med Imaging, 23(7):903–921, July 2004.