Impact of motion on PET texture features: evaluation with heterogeneous phantoms.

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AIM: To evaluate with experimental heterogeneous phantoms the current use of PET texture analysis for heterogeneity characterization in lesions affected by respiratory motion.

INTRODUCTION

- An increasing interest is focusing on **intratumoral FDG heterogeneity characterization** by image features (IF) for its use in **prognosis** and **monitoring** of radiotherapy treatment response.
- In **lung cancer**, quantification by PET/CT imaging presents **additional challenges due to respiratory movement**.

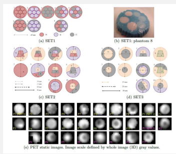
Could the compensation of motion implied by **4D PET/CT minimize the variability of image features in** lesions following different **movements**?

MATERIALS & METHODS

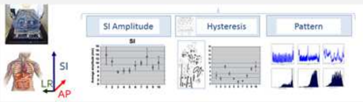
Experimental phantom measurements

- **Heterogeneous (COV>0.3) phantoms alginate** [1] and **^{18}F-FDG**

On image:
$I_0=6I_3$ $I_1=3.5I_3$ $I_2=2I_3$
$I_3=17$ kBq/ml $Bg=I_3/10$



- **Respiratory movement** [2]



Movement	Phantom	Image	Segmentation Method	Study
Typical.HP $A_p(LR)=3$ mm and $A_p(SI)=18.3$ mm	SET1 M.Q. Platform	Gated Ungated	$VOI_{40\%}$	Effect of repeated measurements for the same movement
$A_p(SI)=(18.3, 15.7, 12.6, 9.4$ and 6.3 mm) Typical.HP and $A_p(LR)=0$.	SET 2 M.Q. Platform	Gated Ungated	$VOI_{40\%}$	Effect of SI amplitude
$A_p(LR)=(10.5, 8, 5, 3$ and 0 mm) Typical.HP and $A_p(SI)=18.3$ mm	SET3 M.Q. Platform	Gated Ungated	$VOI_{40\%}$	Effect of Hysteresis(LR amplitude)
3 Typical (HP, MP, LP), 1 Atypical Normal and 1 Atypical Irregular $A_p(LR)=0$ and $A_p(SI)=18.3$ mm	SET3 M.Q. Phantom	Gated Ungated	$VOI_{40\%}$	Effect of waveform

A_p: peak-to-peak amplitude; SI: superior-inferior; LR: left-right; TF: texture features; M.Q.:Medical Quasar; VOI: volume of interest and H(M/L)P: high(middle/low) peak

Tumor segmentation

- **PET volume ($VOI_{40\%}$)** [3]: contouring lesions by a fixed threshold of 40% of the lesion maximum intensity.

4D- PET/CT acquisition

Philips System GEMINI TF TOF (64)

- PET and CT acquisitions **synchronized to the breathing cycle.**
  - Pressure sensor belt: *Mayo Clinic Respiratory Feedback System*
- Data processing results in 10 **phases**.
- 10 min (PET) and 36 s (CT)
- BLOB-OSEM-TOF
  - 2 iterations & 3 subsets
- Image voxel volumes
  - CT: 1.17x1.17x3 mm^3
  - PET: 4x4x4 mm^3

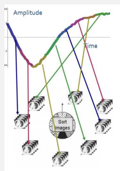


Image Features (11 metrics) [4]

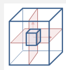
- **1st order**

coefficient of variance **COV** (σ/μ),
kurtosis (**KT**),
skewness (**SK**) and
width of the volume-activity histogram (**WH**).

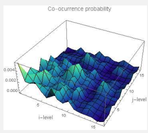
- **2nd order**:

gray-level co-ocurrence matrix

GLCM (16x16, d=26, r=1)



Energy (**ENG**),
local homogeneity (**LH**),
contrast (**CONT**) and
entropy (**ENT**).



RESULTS

Comparison of IF derived from 3D-PET (IF^U) with respect to values derived from 4D-PET (IF^G).

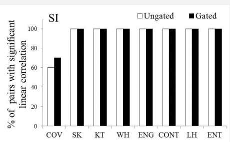
Relative deviation ($\delta^{GU}(\%)=100(IF^G-IF^U)/IF^G$)

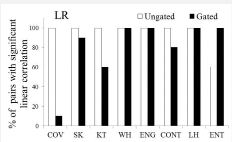
Vol	C_{max}	COV	SK	KT	WH	ENG	CONT	LH	ENT
-20±9	9±18.	-2±3	8±40	3±10	10±8	-14±30	0±20	-8±12	-5±17

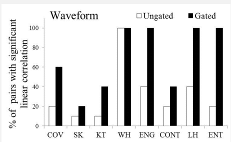
- Wilcoxon Signed Rank test showed **significant differences** for **C_{max}, volume, COV** and **WH**.

Comparison of IF variability for different movements with 3D-PET and with 4D-PET.

- Our set-up permitted to study the effect of the three main characteristics of respiratory movement on heterogeneity quantification: **amplitude along SI**, **hysteresis along LR** and **waveform**. IF values derived from G- and U-image were analyzed in terms of linear correlations (LCs) for 10 possible combinations of the 5 movements applied to the phantoms in each study.







- Overall, ideal performance, i. e. significant LC for all pairs of movements (30/30), was obtained for:
  - WH on U-image and
  - WH, ENG, LH and ENT on G-image.

- For a given waveform, to increase the amplitude along SI did not translate in significant differences between IF variability on G- and U- image.
- Hysteresis did not compromised variability on U-image, but for G-quantification by first order IF (FOS) poorer variability was observed.
- For different waveforms, U-image quantification had poor correlation for IF, both 1st and 2nd order. This effect was minimized using G-image.

CONCLUSIONS

✓ This work presented the **first evaluation of the impact of motion in IF variability with heterogeneous experimental phantoms**.

✓ For some IF, the use of 4D-PET instead of 3D-PET for IF computation would not translate to a significant difference on their values. However, the use **4D-PET for IF computation** should be **recommended** in order **to minimize IF variability** in lesions following different movements.

REFERENCES

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