Partial Volume Correction (PVC) in Quantitative ^{18}F-FDG PET/CT Imaging on Intratumoral Dose Response Assessment

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INTRODUCTION & OBJECTIVES

Intratumoral heterogeneity fosters therapeutic resistance that causes treatment failure [1]. Using serial FDG-PET/CT imaging feedback [2] has been suggested to assess intratumoral dose response and used to guide adaptive dose painting by number (DPbN) [3, 4], i.e. prescribing and delivering a nonuniform dose to the target. Previous studies have demonstrated the clinical feasibility and the possibility of improving the therapeutic ratio using DPbN [5, 6]. However, the PET imaging and processing induced uncertainty on quantitative response assessment, particular at the tumor voxel-level, remain largely unknown and need to be determined for the reliable implementation of tumor response guided adaptive DPbN.

One of the major uncertainties is partial volume effect (PVE) caused by the limited spatial resolution of the imaging system and the relatively small scale of tumor morphology/biology spatial heterogeneity. This study aim to investigate the impacts of PVE on tumor voxel dose response assessed using serial FDG-PET/CT imaging feedback.

MATERIALS & METHOD

FDG-PET/CT images were obtained at pretreatment and weekly during chemoradiotherapy of 30 head and neck cancer patients. PET images were reconstructed using blob-ordered-subsets time-of-flight algorithm with a voxel size of 4×4×4 mm^3.

Two iteratively deconvolution-based PVE correction algorithms, Richardson-Lucy (RL) [7] and reblurred Van-Citter (VC) [8], were applied on each PET image with different full width at half maximum (FWHM), respectively. For each patient, the weekly PET/CT images were registered to the pretreatment PET/CT image voxel-by-voxel to construct a tumor voxel dose response matrix (DRM). The DRM value represents the average metabolic change ratio, used as a surrogate of cell killing and growth ratio in the tumor voxel during the treatment; 0 < DRM < 1 implies that cell killing in the voxel is bigger than tumor growth, otherwise ≥ 1.

Resistant subvolume (RV)s = $\{v \mid \mathrm{DRM}(v) \geq a \cdot \mathrm{SUV}_0(v)^b + c\}$ were calculated with and without PVE correction respectively and used to predict local tumor failure/control using Receiver operating characteristic (ROC) test. The true positive/negative is defined as a tumor will recur/control locally if its has an RV larger/smaller than a cutoff. The parameters a, b and c were determined by maximizing the area under the curve (AUC). The mean and standard deviation (SD) of tumor voxel SUV_0 and DRM discrepancies induced by PVE correction were also calculated on individual tumors.

RESULTS

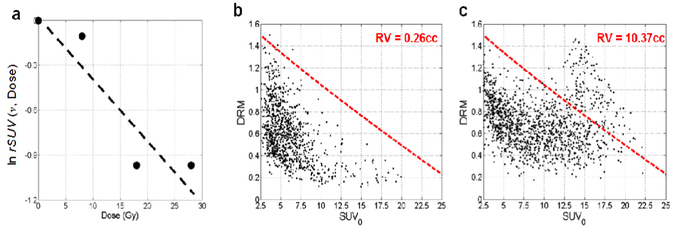

Figure 1 (a) an illustration of DRM construction for a tumor voxel; **(b)** and **(c)** illustrations of the RV, defined on the tumor voxel (SUV_0, DRM) domain, for a local control and a failure tumor, respectively. The red dashed line show the resulting function of $\mathrm{DRM}(v) = a \cdot \mathrm{SUV}_0(v)^b + c$

Table 1 Predictive value of the RVs and the tumor volume on local tumor failure or control (5 of the 30 patients had experienced biosy-proven local failure. The median followup time was 22.5 (7 ~ 52) months)

	AUC	p	Sensitivity	Specificity	Cutoff (cc)
RV-PVC	0.96	< 0.001	1.0	0.96	0.38
RV-Non PVC	0.96	< 0.001	1.0	0.96	0.19
Tumor Volume	0.72	0.066	1.0	0.52	32.32

AUC = area under the curve; p was calculated using the Mann-Whitney U-test (null hypothesis: AUC = 0.5); tumor volume was defined on the pretreatment PET/CT image; RV-PVC and RV-Non PVC are the resistant sub-volumes that calculated with and without partial volume correction, respectively

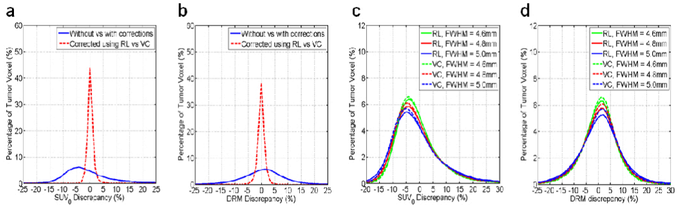

Figure 2 (a) and **(b)** histograms of the tumor voxel SUV_0 and DRM discrepancies that calculated without *vs* with using the RL PVE correction algorithm as well as the discrepancies calculated using the RL *vs* VC correction algorithms; **(c)** and **(d)** histograms of the tumor voxel SUV_0 and DRM discrepancies that calculated without *vs* with different PVE correction algorithms/FWHMs (bin size = 1%)

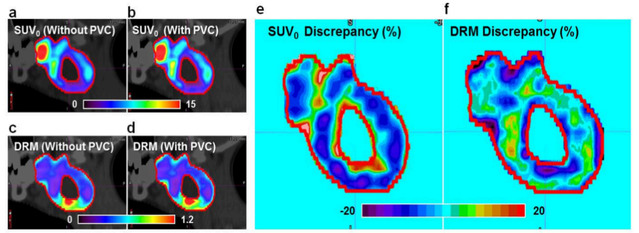

Figure 3 (a) and **(b)** the SUV_0 calculated without and with SUV and DRM distributions, with and without PVE correction, as well as the distributions of the discrepancy for a tumor with large heterogeneous FDG uptake

CONCLUSIONS

Local tumor failure/control could be equally well predicted with using FDG-PET/CT imaging feedback with or without PVC. However, discrepancies of 9.3% and 8.8% (1 SD) for tumor voxel baseline SUV measurements and dose response DRM quantification were identified. This could imply the reliability of the prediction method needs more clinical followup to confirm.

REFERENCES

[1] M. Renovanz and E.L. Kim, Intratumoral Heterogeneity, Its Contribution to Therapy Resistance and Methodological Caveats to Assessment, Front Oncol 4(June), 1–4 (2014)

[2] D. Yan, S. Chen, D.J. Krauss, P.Y. Chen, P. Chinnaiyan, and G.D. Wilson, Tumor Voxel DoseResponse Matrix and Dose Prescription Function Derived Using 18 F-FDG PET/CT Images for Adaptive Dose Painting by Number, Int J Radiat Oncol Biol Phys 104(1), 207–218 (2019)

[3] C.C. Ling, J. Humm, S. Larson, et al., Towards multidimensional radiotherapy (MD-CRT): biological imaging and biological conformality, Int J Radiat Oncol Biol Phys 47(3), 551–560 (2000)

[4] S.M. Bentzen, Theragnostic imaging for radiation oncology: Dose-painting by numbers, Lancet 24 Oncol 6(2), 112–117 (2005).

[5] F. Duprez, W. De Neve, W. De Gersem, M. Coghe, and I. Madani, Adaptive dose painting by numbers for head-and-neck cancer, Int J Radiat Oncol Biol Phys 80(4), 1045–1055 (2011).

[6] E. Gronlund, S. Johansson, A. Montelius, and A. Ahnesjo, Dose painting by numbers based on retrospectively determined recurrence probabilities, Radiother Oncol 122, 236–241 (2017)

[7] W. Richardson, Bayesian-based iterative method of image restoration, J Opt Soc Am **62**(I), 55–59 (1972)

[8] A. Carasso, Linear and Nonlinear Image Deblurring: A Documented Study, SIAM J Numer Anal **36**(6), 1659–1689 (1999)