Prediction of metastasis-free survival in patients with localized prostate adenocarcinoma using delta radiomics from pre-treatment PSMA-PET/CT scans and dosiomics

Graphics Group

UNIVERSITY of MARYLAND SCHOOL OF MEDICINE

A. Singh, PhD[1], W. Mendes, MD[1], S. Oh, MD[1], O.C. Guler, MD[2], A. Sawant, PhD[1], P.T. Tran, MD, PhD[1,4], H.C. Onal, MD[2,3*] and L. Ren, PhD[1*]

[1]Department of Radiation Oncology, University of Maryland School of Medicine, Baltimore, MD, USA

[2]Baskent University Faculty of Medicine, Adana Dr Turgut Noyan Research and Treatment Center, Department of Radiation Oncology, Adana, Turkey

[3]Baskent University Faculty of Medicine, Department of Radiation Oncology, Ankara, Turkey

[4]Department of Genitourinary Radiation Oncology, The University of Texas MD Anderson Cancer Center, Houston, TX, USA

INTRODUCTION

Purpose: To develop prognostic models integrating delta radiomics from prostate-specific membrane antigen positron emission tomography/computed tomography (PSMA-PET/CT) and dosiomics with clinical variables to predict metastasis-free survival (MFS) in patients with localized prostate adenocarcinoma treated with androgen-deprivation therapy and external-beam radiotherapy.

Cohort: Delta radiomics analysis included 43 patients. Radiomics features were extracted from the primary tumor on pre-and post-treatment PSMA-PET/CT and delta features were calculated as relative changes. Dosiomics analysis included 48 patients. Dosiomics features were extracted from the planning target volume receiving 86 Gy dose.

METHODS

- Z-score normalization was performed on the pre-treatment, delta radiomics and dosiomics features.
- Eight high-variance features were selected from delta radiomics and pre-treatment radiomics were selected and combined with clinical variables (age, Gleason score, initial PSA, PSA relapse).
- Data was split 70:30 with training set imbalance correction.
- Predictors significant on univariate Cox regression ($p < 0.05$) were entered into multivariate Cox models. Five-year MFS was classified using a quadratic support vector machine.
- Dosiomics and pre-treatment radiomics and clinical variables were modeled using the same framework.

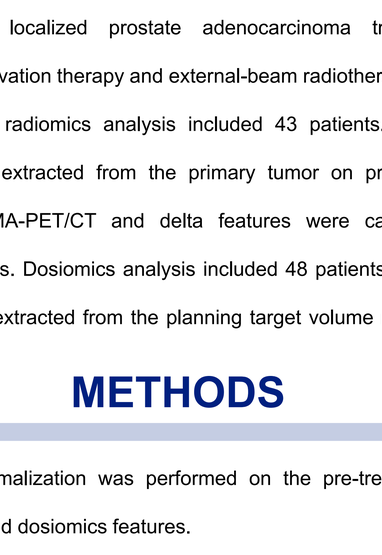

Figure 1. Representative PSMA-PET/CT images showing the gross tumor volume of the prostate (GTVp) delineated on (a) pre-treatment and (b) post-treatment registered scans in a patient included in the delta radiomics analysis.

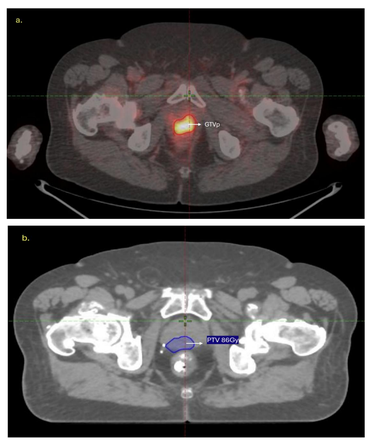

Figure 2. Representative images for the dosiomics analysis showing (a) the GTVp contoured on pre-treatment PSMA-PET/CT and (b) the corresponding intra-prostatic region (planning target volume (PTV) receiving 86 Gy) on the planning CT.

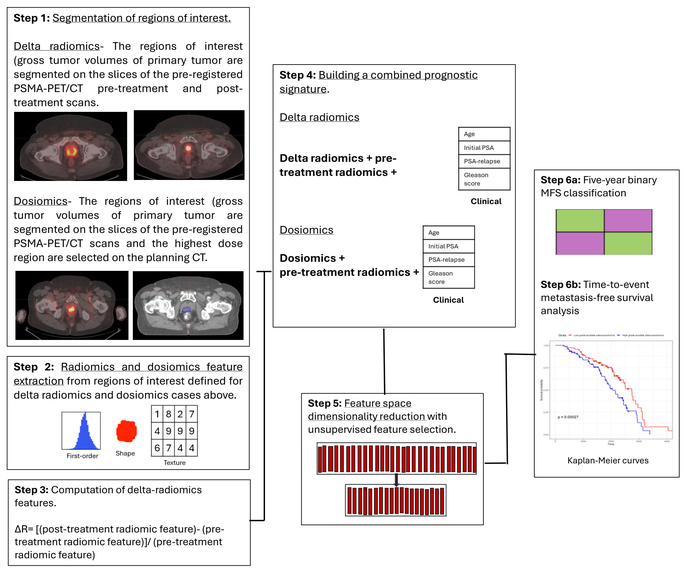

Figure 3. Workflow illustrating the methodological pipeline for delta radiomics and dosiomics analysis. Step 1: segmentation of regions of interest (ROIs). Step 2: extraction of radiomics and dosiomics features. Step 3: computation of delta radiomics features. Step 4-5: integration with clinical variables, dimensionality reduction. Step 6a-6b: evaluation.

RESULTS

Model	Description	Train (c-scores, 95% CI)	Test (c-scores, 95% CI)
	Delta radiomics analysis		
Model 1_delta	Delta + pre-treatment + clinical	0.64 [0.58 - 0.65]	0.58 [0.53 - 0.59]
Model 2	Pre-treatment+ clinical	0.62 [0.57 - 0.63]	0.56 [0.52 - 0.58]
Model 3	Clinical	0.57 [0.51 - 0.58]	0.51 [0.50 - 0.55]
	Dosiomics analysis		
Model 1_dose	Dosiomics + pre-treatment + clinical	0.60 [0.56 - 0.61]	0.56 [0.54 - 0.59]
Model 2	Pre-treatment + clinical	0.58 [0.55 - 0.60]	0.55 [0.52 - 0.57]
Model 3	Clinical	0.55 [0.51 - 0.56]	0.50 [0.50 - 0.55]

Table 1 : Cox-regression analysis results for delta-radiomics and dosiomics models showing concordance indices (c-scores) with 95% confidence intervals for training and test cohorts.

Model	Description	(Sensitivity, Specificity, AUC)	(Sensitivity, Specificity, AUC)
	Delta radiomics analysis		
Model 1_delta	Delta + pre-treatment + clinical	[70.1%, 78.5%, 0.76]	[65.1%, 71.2%, 0.70]
Model 2	Pre-treatment + clinical	[65.2%, 70.3%, 0.71]	[58.2%, 63.5%, 0.65]
Model 3	Clinical	[56.4%, 65.6%, 0.63]	[52.1%, 60.4%, 0.56]
	Dosiomics analysis		
Model 1_dose	Dosiomics + pre-treatment + clinical	[67.5%, 75.2%, 0.73]	[62.4%, 68.5%, 0.67]
Model 2	Pre-treatment + clinical	[63.4%, 68.1%, 0.68]	[55.1%, 60.2%, 0.62]
Model 3	Clinical	[54.1%, 62.4%, 0.60]	[51.3%, 57.1%, 0.54]

Table 2: Five-year metastasis-free survival (MFS) binary classification results for delta radiomics and dosiomics models, including sensitivity, specificity and area under the curve (AUC) for both training and test data sets.

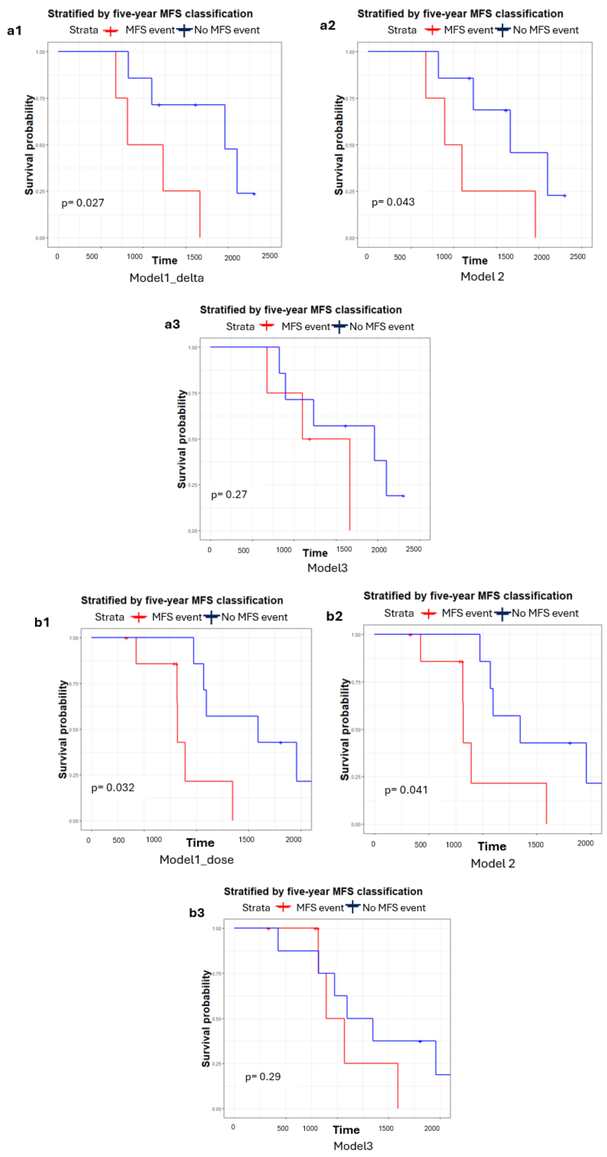

Figure 4. Kaplan–Meier survival curves stratified by five-year metastasis-free survival (MFS) classification (MFS event vs no event). Panels a1–a3 show the delta-radiomics models: (a1) Model 1_delta = delta radiomics + pre-treatment radiomics + clinical; (a2) Model 2 = pre-treatment radiomics + clinical; (a3) Model 3 = clinical only. Panels b1–b3 show the dosiomics models: (b1) Model 1_dose = dosiomics + pre-treatment radiomics + clinical; (b2) Model 2 = pre-treatment radiomics + clinical; (b3) Model 3 = clinical only).

CONCLUSIONS

1. This study demonstrates that integrating delta radiomics and dosiomics features with pre-treatment PSMA-PET/CT radiomics and clinical variables significantly enhances the prediction of MFS in patients with localized PCa.
2. By capturing both temporal biological changes and spatial dose heterogeneity, these spatiotemporal imaging biomarkers provide complementary prognostic information beyond conventional clinical parameters.
3. The findings support the potential of PSMA-PET–based radiomics and dosiomics as non-invasive tools for personalized risk assessment, enabling more precise patient selection for treatment intensification or adaptation.
4. Future prospective, multi-institutional studies with standardized imaging protocols are warranted to validate these results and advance the integration of such biomarkers into clinical RT practice.

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