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The Impact of Implementing Hypofractionation Prescription Regimens and Modernizing Delivery Technique on Treatment Resources in Breast Radiotherapy

S. Quirk

Kundan Thind

L. Van Dyke

K. Long

T. Phan

See next page for additional authors

Authors

S. Quirk, Kundan Thind, L. Van Dyke, K. Long, T. Phan, P. Grendarova, K. Martell, W. L. Smith, L. Barbera, and M. Roumeliotis

Abstract 2247 — Table 1

Score	Description
5: Use as-is	Clinically acceptable, could be used for treatment without change.
4: Minor edits are not necessary	Stylistic differences, but not clinically important. The current contours are acceptable.
3: Minors edits are necessary	Edits are clinically important, but it is more efficient to edit the automatically generated contours than start from scratch.
2: Major edits	Edits are required to ensure appropriate treatment and sufficiently significant that the user would prefer to start from scratch.
1: Unusable	The automatically generated contours are unusable.

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2248

Developing Dosiomics Models for the Prediction of Postoperative Radiotherapy-Induced Esophagitis in Patients with Non-Small Cell Lung Cancer

Z. Ma,[1] B. Liang,[1] R. Wei,[1] Y. Liu,[1] B. Yongxing,[1] M. Yuan,[1] X. Yang,[1] Y. Men,[2] J. Wang,[1] L. Deng,[1] Y.R. Zhai,[1] N. Bi,[1] L. Wang,[1] J. Dai,[1] and Z. Hui[2]; [1]*Department of Radiation Oncology, National Cancer Center/ National Clinical Research Center for Cancer/Cancer Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China,* [2]*Department of VIP Medical Services & Radiation Oncology, National Cancer Center/National Clinical Research Center for Cancer/Cancer Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China*

Purpose/Objective(s): Symptomatic postoperative radiotherapy-induced esophagitis (RE) (Grade≥2) develops in up to 31% of patients undergoing thoracic radiotherapy, lowering the quality of life and sometimes leading to treatment interruption, which negatively affects overall survival. We adopted the common omics and convolutional neural network (CNN) methods to extract dosiomics features to predict RE in patients with non-small cell lung cancer (NSCLC), and compared them with the dosimetric features-based model.

Materials/Methods: Patients with histologically confirmed pIIIA-N2 NSCLC who underwent resection followed by postoperative radiotherapy from 2011 to 2015 were enrolled. The endpoint was Grade≥2 RE according to Common Terminology Criteria for Adverse Events (CTCAE v4.0). Dosiomics features were extracted from the 3D dose distribution within the esophagus using the common omics and convolutional neural network (CNN) methods. The extracted features were screened using an entropy-based method and further selected using the minimum redundancy maximum relevance (mRMR) method. Prediction models were built with machine learning algorithms using these selected features as input. The area under the curve (AUC), accuracy, sensitivity, specificity, and F1 score were used to evaluate the performance of prediction models. The prediction model using dosimetric features as input was also built for comparison.

Results: A total of 189 patients were eligible. Models were trained and hyper-tuned on 80% (n = 151) of the dataset and validated on the remaining 20% (n = 38). In total, 107 and 4096 features were derived with the common omics and CNN methods, respectively. Four common omics features were selected, including glcm_ClusterShade, shape_MinorAxisLength, firstorder_Kurtosis, Shape_Flatness. Three CNN-extracted features were selected, while the features were not interpretable. Four dosimetric features were selected, including the maximum dose (Dmax), equivalent uniform dose (EUD), percentages of esophagus volume receiving >20 Gy (V20), >60 Gy (V60). The AUC, accuracy, sensitivity, specificity, F1 score were 0.74, 0.70, 0.70, 0.62, 0.80 for common omics features-based model, and 0.79, 0.77, 0.78, 0.68, 0.85 for CNN-extracted features-based model, and 0.64, 0.58, 0.58, 0.62, 0.70 for dosimetric features-based model, respectively.

Conclusion: Both dosiomics prediction models outperformed the dosimetric features-based model. The CNN-extracted features were more predictive but less interpretable than the common omics features.

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2249

The Impact of Implementing Hypofractionation Prescription Regimens and Modernizing Delivery Technique on Treatment Resources in Breast Radiotherapy

S. Quirk,[1] K. Thind,[2] L. Van Dyke,[3] K. Long,[4] T. Phan,[1,5] P. Grendarova,[1] K. Martell,[1,6] W.L. Smith,[1] L. Barbera,[7] and M. Roumeliotis[1]; [1]*University of Calgary, Calgary, AB, Canada,* [2]*Henry Ford Health Systems, Detroit, MI,* [3]*Alberta Health Services, Calgary, AB, Canada,* [4]*Department of Radiation Therapy, Tom Baker Cancer Centre, Calgary, AB, Canada,* [5]*Tom Baker Cancer Centre, University of Calgary, Calgary, AB, Canada,* [6]*Department of Radiation Oncology, Tom Baker Cancer Centre, Calgary, AB, Canada,* [7]*Division of Radiation Oncology, University of Calgary, Tom Baker Cancer Centre, Calgary, AB, Canada*

Purpose/Objective(s): To determine the change in treatment resources due to the implementation of hypofractionated prescription regimen

Materials/Methods: All patients between January 1, 2012 and December 31, 2021 receiving curative intent breast radiotherapy at a tertiary cancer center were included. Plan and patient data were extracted from the patient database with the treatment planning system and direct database query. Treatment plan categorization was completed using data elements to include only curative intent. Treatment plans for seroma boost or supraclavicular irradiation were excluded to ensure this analysis did not double-count regional nodal irradiation contribution or confound boost with hypofractionation. Treatment delivery time is recorded in the database for each patient treatment delivered. Average patient treatment time per year was estimated by multiplying the average fractions each year by average time in the same year. The standard fractionation regimens (95% of patients) are 42.56 Gy in 16, 40 Gy in 16, 27 Gy in 5 (accelerated partial breast irradiation), and 26 Gy in 5 (FAST-Forward). In the analysis, implementation milestones are indicated for new prescription regimens and delivery technique changes including deep inspiration breath hold (DIBH) for left-sided patient treatments and daily verification imaging.

Results: A total of 6505 patients were included. Table 1 details the total number of patients per year, the average number of fractions treated per patient, and the average treatment time of each patient plan. The average total fractions per treatment decreased from 17.5 in 2012 to 10.9 in 2021. The average treatment delivery time increased from 12.9 minutes to 21.4 minutes.

Conclusion: In considering total treatment resources, the interplay between hypofractionation and modernization delivery techniques is complex. The impact of hypofractionation reduced the average number of fractions but total treatment resources are offset with the implementation of modern treatment delivery techniques. Hypofractionated prescription regimens reduce the time and travel commitment required of patients on an individual basis, contributing to person-centered care.

Abstract 2249 − Table 1

Year	Patients	Average fractions per patient	Average treatment time (minutes)	Total treatment resources (minutes)	Patients treated in DIBH (%)
2012	537	17.5	12.9	225.8	0%
2013	537	17.5	14.1	246.8	10%
DIBH implemented					
2014	516	17.4	14.8	256.5	38%
2015	608	17.0	13.8	234.6	37%
APBI (5-fraction) implemented					
2016	627	16.1	15.4	247.9	33%
2017	647	15.6	17.8	277.7	51%
2018	706	15.4	18.5	284.9	45%
2019	732	16.1	18.0	289.8	48%
Fast forward (5-fraction)					
Daily verification imaging					
2020	730	14.3	19.7	281.7	46%
2021	865	10.9	21.4	233.3	54%

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2250

Iterative Refinement to Improve Data Quality and Label Consistency by Synergizing Parsimony Model Guidance and Physician Interaction

H. Zhou,[1] J. Xiao,[2] Z. Fan,[2] and D. Ruan[1]; [1]*University of California, Los Angeles, Los Angeles, CA,* [2]*University of Southern California, Los Angeles, CA*

Purpose/Objective(s): Clinical data and labeling are usually noisy and uncertain. Modeling based on such inconsistent data risks overfit and may generate faulty insight on prominent features and regression relationships. We hypothesize inter-sample consistency serves as a rational surrogate for data quality and can be used to guide improvement, in the absence of an absolute ground-truth. To this end, we aim to synergize a deep-learning setting and an iterative interactive refinement procedure for label refinement.

Materials/Methods: We proposed a novel approach by guiding physician-approved label perturbation with parsimonious deep network modeling. The proposed procedure alternates between fitting a parsimonious deep network model to human labels and guiding the human observer to review the labels to identify ill-fitted examples to perform label refinement when appropriate. Convergence is claimed when further iteration stops to produce clinically pronounced improvement, as defined from a statistical equivalence test. To evaluate the efficacy of the refinement, input-output agreement index (IOAI) based on partial ranking consistency is also calculated. We took as a use case in segmenting the lumen and vessel wall from MR vessel wall imaging (VWI) from 80 patients with intracranial atherosclerotic disease, on four locations with high likelihood of plaque presence: the intracranial internal carotid artery, the middle cerebral artery, the intracranial vertebral artery, and the basilar artery. Each segment contained 30 contiguous 2D cross-sectional slices with 0.55 mm slice thickness and 0.10 mm in-plane resolution. A lightweight 2.5D segmentation network was used as the low-dimensional model, and equivalence criterion was defined by one-sided superiority threshold of 0.03 in Dice similarity coefficient (DSC) based on reported performance from existing study. Clinical soundness was further assessed with the variation in normalized wall index as a quantitative imaging index, expected to low if segmented structures were piecewise smooth conforming to clinical insight.

Results: 5-fold cross validation based on the 80*4*30 slice samples showed enhanced modeling performance and better conformality to clinical insight with the final labels. In this use case, DSC improved from 0.893±0.108 to 0.938±0.078 for lumen, from 0.806±0.086 to 0.879±0.072 for vessel wall, the total variation in normalized wall index decreased from 0.757±0.181 to 0.586±0.182, and the input-output agreement index increased from 0.523 to 0.556 by the proposed refinement procedure.

Conclusion: This study demonstrates that inconsistency in clinical labels and physiological limitations can be addressed with an iterative interactive process with parsimonious modeling, taking advantage of flexibility from deep networks. The rationale generalizes to other label settings and tasks.

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2251

A Prospective Evaluation of Individualized CONstraints for Radiation Therapy Planning in Prostate Cancer (ICON-P)

S. SAHA, M. Arunsingh, S. Prasath, A. Balakrishnan, S.J. Kalita, N. Elavarasan, and I. Mallick; *Tata Medical Center, Kolkata, India*

Purpose/Objective(s): Present planning practices for radiation therapy are based on generic dose-constraints for organs-at-risk (OAR) extrapolated from those defined in the QUANTEC guidance. We have developed a web-based dashboard to determine individualized dose constraints based on summary estimates of achieved doses in prior approved plans in prostate cancer. In this study, we prospectively evaluated the feasibility and improvements achieved in doses to OARs with this approach.

Materials/Methods: A set of 24 cases previously planned using generic constraints to a dose of 60 Gy in 20 fractions was de-identified and replanned using individualized constraints derived from summary statistics of a subset of cases with similar target, OAR and overlap volumes from a reference library of 94 approved plans on a web-based dashboard. From the similar case subset for each study patient, the 25th and 50th percentile of achieved V59 Gy, V56 Gy, V53 Gy, V47 Gy, V40 Gy for the rectum and bladder and V57 Gy for the planning target volume (PTV) were defined as the ideal and acceptable set of individualized dose-constraints. The goal was to assess the improvement in mean doses and the specified dose volumes. Planners were blinded to the prior achieved doses and penalties. Sample size estimation was based on an estimated 3 percentage point improvement in V53 Gy for rectum and bladder with a paired evaluation using Wilcoxon sign-rank test. Python v3.7 was used for creating the dashboard and statistical comparisons.

Results: The differences in reference and replanned cases using individualized dose constraints are charted in table 1. There was a numerically robust and statistically significant reduction of mean doses and percentage volumes of all the discrete dose points for both bladder and rectum, including a 4% and 6.8% reduction in the primary endpoint of V53 Gy. All the plans generated had a D95 of at least 95% for the PTV.

Conclusion: Treatment planning based on individualized dose constraints is feasible and leads to improvement at clinically important dose volumes in prostate cancer treatment planning.

Abstract 2251 − Table 1

	Bladder			Rectum		
	Reference Plan (Generic Dose-constraints)	Study plan (Individualized dose-constraints)	Improvement	Reference Plan (Generic dose constraints)	Study Plan (Individualized dose-constraints)	Improvement
Mean Dose	37.62 Gy	30.07 Gy	7.55 Gy (p value 0.000003)	38.72 Gy	33.16 Gy	5.55 Gy (p value 0.002)
V59 Gy	5.91%	4.91%	1% (p value 0.004)	7.11%	2.49%	4.63% (p value 0.00001)
V56 Gy	9.77%	7.27%	2.5% (p value 0.004)	13.2%	8.06%	5.14% (p value 0.00003)
V53 Gy	13.03%	9.01%	4.02% (p value 0.002)	17.94%	11.1%	6.84% (p value 0.000008)
V47 Gy	21.09%	12.77%	8.32% (p value 0.0002)	27.74%	16.34%	11.39% (p value 0.00003)