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Calibration of EBT3 radiochromic films with machine learning: development of a dose predictive model

Victor Daisuke Araqui[1], Aline Aparecida da Costa Granja[1], Paula Cristina Guimarães Antunes[1,2]

[1] Faculdade Israelita de Ciências da Saúde Albert Einstein, Hospital Israelita Albert Einstein, São Paulo, SP, Brazil.

[2] Instituto de Pesquisas Energéticas e Nucleares, São Paulo, SP, Brazil.

Corresponding authors

Academic: Victor Daisuke Araqui - victor.daraqui@einstein.edu.br

Mentor: Paula Cristina Guimarães Antunes - pacrisguian@gmail.com

Category: Biomedical engineering

Victor Daisuke Araqui – https://orcid.org/0009-0008-0481-9394
Aline Aparecida da Costa Granja – https://orcid.org/0009-0002-4480-0985
Paula Cristina Guimarães Antunes – https://orcid.org/0000-0001-9751-6174

Introduction: Radiochromic films have been widely used in radiation therapy for nearly 30 years, valued for their high spatial resolution, self-developing nature, and tissue-equivalent composition. Among them, the Gafchromic EBT series, especially the EBT3 model, is commonly employed for quality assurance and dose verification. Despite these advantages, accurate dosimetry still demands careful calibration and control of variables such as film uniformity, scan quality, and environmental conditions. To address these limitations, a Python-based software was developed, integrating artificial intelligence to automate key steps-optical density reading, calibration curve creation, and dose prediction-using polynomial regression and machine learning. This solution reduces human error, increases reproducibility, and streamlines workflows. Compared to other dosimeters, such as ion chambers and diodes, radiochromic films uniquely offer 2D dose mapping without electrical connections, minimizing interference. Their growing clinical and research adoption has been supported by recommendations from institutions like the AAPM, reinforcing their role in modern radiotherapy.

Objectives: The objective of this project is to develop software in Python with artificial intelligence algorithms to automate the calibration and analysis of radiochromic films, increasing accuracy, reducing manual errors and optimizing time in the dosimetry process in clinical and research applications.

Methods: This project presents an advanced Python software for calibrating EBT3 radiochromic films, integrating image processing, data analysis and dose prediction using conventional and machine learning (ML) methods. The graphical interface, developed with Tkinter, organizes functionalities in intuitive menus, allowing image upload, calculation of optical density (OD), generation of calibration curves and dose distribution, as well as dose simulations and predictions.

The conventional method applies filters (median and Gaussian) for noise reduction and uses the Lambert-Beer Law to calculate the OD, based on the average of the RGB channels of the image. The calibration curve is adjusted by polynomial regression and used to simulate doses. The spatial dose distribution is displayed with colored maps, facilitating qualitative and quantitative analysis.

In the ML method, images with labeled dose in the name are processed with PCA for dimensionality reduction and modeled with polynomial regression. The model is evaluated with metrics such as MAE, MSE and R^2, in addition to cross-validation. A margin of error of 0.05 Gy is used to reflect the accuracy of the system. The code also includes resource monitoring to ensure stability during intensive tasks.

Results: Radiochromic film images irradiated with a Co-60 beam across 0-2 Gy were analyzed to assess dose estimation in a challenging low-dose region. The conventional method, using the mean of RGB channels for optical density (OD) estimation, achieved an R^2 of 0.94162 through second-degree polynomial regression. The largest relative errors (REs) occurred at the lowest doses (e.g.,>350% at 0.05 Gy and>100% at 0.1 Gy), reflecting minimal OD changes and high noise influence. Errors decreased and stabilized below 25% from 0.15 Gy to 2 Gy, indicating a more reliable estimate in the mid-to-high dose range. A predictive model using PCA (Principal Component Analysis) and polynomial regression significantly improved performance. Using three principal components, the model reached an R^2 of 0.99871 over 1250 images (125 per dose level), demonstrating excellent accuracy and generalization. REs were consistently low above 0.2 Gy, often under 5%. The elbow plot analysis indicated that three components captured over 96%

of the variance, optimizing the tradeoff between performance and dimensionality. Fewer than three components led to underfitting, while more than three introduced noise and overfitting. Empirical elbow plots confirmed consistent performance across all test and cross-validation sets, with maximum accuracy in three components. Errors remained higher (between 10 and 40%) at very low doses (0.05-0.15 Gy), where the film response is weaker, but were significantly reduced compared to the conventional method. From 0.2 Gy onwards, predictions were robust and accurate, suitable for clinical applications. These results underscore the advantage of multichannel analysis combined with PCA, offering a reliable, generalizable model for dose prediction, especially in the intermediate to high dose ranges where clinical precision is crucial.

Conclusion: A predictive model using second-degree polynomial regression and PCA was developed to estimate Co-60 absorbed doses (0-2Gy) from EBT3 film images. By treating RGB channels independently and reducing dimensionality, the model achieved high accuracy, outperforming traditional methods, especially in clinically relevant low-dose regions (≥0.2Gy).

Keywords: Dosimetry, Calibration, Radiotherapy Dosage, Principal Component Analysis, Machine Learning

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Assessment of regional pulmonary aeration by electrical impedance tomography in infants with bronchiolitis using high-flow nasal cannula

Priscila Monteiro de Souza[1], Graziele Garcia Pires De Campos Domingues[2], Patricia Angélica de Lima Silva[2], Milena Siciliano Nascimento[2]

[1] Faculdade Israelita de Ciências da Saúde Albert Einstein, Hospital Israelita Albert Einstein, São Paulo, SP, Brazil.

[2] Hospital Israelita Albert Einstein, São Paulo, SP, Brazil.

Corresponding authors

Academic: Priscila Monteiro de Souza - souza.montepri@gmail.com

Mentor: Milena Siciliano Nascimento - milena.nascimento@einstein.br

Category: Physiotherapy

Priscila Monteiro de Souza – https://orcid.org/0009-0008-8262-3776
Graziele Garcia Pires De Campos Domingues – https://orcid.org/0009-0000-2946-830X
Patricia Angélica de Lima Silva – https://orcid.org/0009-0001-1635-2794
Milena Siciliano Nascimento – https://orcid.org/0000-0002-0515-3933

Introduction: High-flow nasal cannula is a relatively recent therapy that has been changing outcomes in the treatment of respiratory failure in infants with bronchiolitis. However, the absence of clinical improvement reflects the need to escalate care, such as the use of non-invasive ventilation and orotracheal intubation, which impacts Intensive Care Unit length of stay, overall hospitalization time, and, consequently, costs. Currently, there is a growing need to understand the mechanisms by which HFNC reduces the work of breathing and improves gas exchange. The use of electrical impedance tomography allows for real-time mapping of changes in ventilation distribution and lung aeration. Recently, studies using EIT have evaluated functional residual capacity through end-expiratory lung impedance (EELZ) at different flow rates in an attempt to support the hypothesis that HFNC therapy contributes to an increase in functional residual capacity.

Objectives: The aim of this study is to analyze the variations in anterior and posterior end-expiratory lung impedance (EELZ) values in patients with bronchiolitis, in order to investigate potential regional differences in ventilation distribution according to the applied flow rate.

Methods: A prospective clinical study is being carried out in the Pediatric ICU of Hospital Israelita Albert Einstein, from January 2024 to December 2025. Infants