PhD Thesis Title: Quantitative methods for improved error detection in dose-guided radiotherapy

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ABSTRACT:

With the increasing complexity of radiotherapy, it has become increasingly important to verify that the desired radiation dose is delivered as planned. This thesis focuses on Dose-Guided Radiotherapy (DGRT) using portal dosimetry with the Electronic Portal Imaging Device (EPID) as a method for treatment verification. Automatic error detection and consequently patient selection for adaptive radiotherapy using portal dosimetry remains difficult. This is due to the unknown uncertainty of the portal dosimetry methods, as well as the lack of objective triggers for adaptation and the use of simple decision protocols (often consisting of an action threshold on a single metric) that cannot take the multidimensionality of the EPID dose distributions into account.

The overall aim of this thesis was to investigate and improve the error detection capabilities of portal dosimetry methods. The first part of the thesis concerns uncertainties and sensitivity of portal dosimetry methods. A framework for analyzing uncertainties of portal dosimetry methods was developed,[1] and factors influencing the uncertainty,[2] and the sensitivity and specificity of portal dosimetry[3] were investigated and quantified. It is important to incorporate this quantitative knowledge in decision protocols for adaptive radiotherapy.

The second part focuses on advanced methods for error detection and classification, applying Artificial Intelligence (AI) to portal dosimetry. Several AI methods and classification problems were investigated to show the potential of AI-based error detection for portal dosimetry. First, it was shown that it is possible to relate 2D portal dosimetry results to differences in dose-volume histogram metrics by using Convolutional Neural Networks (CNNs);[4] a relationship that is notoriously difficult to find with traditional action threshold-based classification methods. Second, it was demonstrated that deep learning is a promising powerful tool for identifying types of treatment errors with portal dosimetry.[5] Errors can be identified to a high level of detail, and this approach can provide additional information not currently available from portal dosimetry. Third, external validation of a machine learning model for classifying anatomical changes showed that it is difficult to use such a model directly on clinical data from a different institute due to differences in data acquisition and clinical interpretation.[6]

Overall, portal dosimetry for DGRT can greatly benefit from improved error detection methods. This thesis has contributed to this improvement, by providing a framework for uncertainty analysis of portal dosimetry methods, by examining the sensitivity and specificity for action threshold-based classification methods for various portal dosimetry methods, and by investigating various advanced AI algorithms and error classification problems.

References to author publications that relate specifically to the dissertation:

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