Ph.D. Thesis Title: Using Machine Learning to Predict Gamma Passing Rate Values and to Differentiate Radiation Necrosis from Tumor Recurrence in Brain

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ABSTRACT:

A major concern in radiation therapy has always been to deliver the prescribed dose to a tumor volume while keeping the surrounding organs at risk (OAR) safe. This is significantly important for cases of using Intensity Modulated Radiosurgery (IMRS) with a single isocenter to treat multiple brain lesions. In these cases, small and wide spread-out tumors in the brain are irradiated with larger doses while sparing OAR is critical but significantly more challenging.

It is common to perform pre-treatment verification to make sure the accurate treatment dose is delivered. Numerous applications including predictive modeling of treatment outcomes in radiation oncology, treatment optimization, error detection, and prevention have been developed and are now accessible. Typically, patient-specific QA compares dose distribution generated by the treatment planning system (TPS) with the delivery of that patient's treatment plan to an array of detectors. In other words, patient-specific QA (pre-treatment verification) compares the dose distributions between measured and predicted. This process compounds numerous potential sources of error, including dose calculation, data transfer, linac performance, device setup, and dosimeter response among others. Consequently, the cumulation of errors may cause the results to fail. Several reports show that common pre-treatment verification measurements are insensitive to delivery errors and unable to predict the acceptability of plan delivery. Therefore, by using machine learning, we plan to devise an algorithm to achieve a higher level of understanding and insight to improve each patient's treatment plan and safely deliver precise radiation to tumors while minimizing the radiation dose to the surrounding normal tissues. The results of this part of the study indicate that machine learning can predict the gamma passing rate (3%/2mm with a 10% threshold) with an error of less than 3%.

Another crucial task is the differentiation of Radiation Necrosis (RN) from recurrence tumors. RN is one of the common adverse effects resulting from irradiation to the brain, nevertheless, RN is hard to diagnose and manage. Differentiating treatment-induced necrosis from tumor recurrence remains the main challenge. They appear similarly in conventional follow-up imaging studies and make it difficult for physicians to characterize a new contrast-enhancing lesion appearing on a patient's follow-up imaging. It is critical to differentiate them because these two have different outcomes and treatments. Using deep learning offers a useful and powerful computational tool for the differential diagnosis between recurrent tumors and necrosis. This study demonstrates that the use of machine learning with radiomics can differentiate RN from tumor recurrence with an accuracy greater than 80%. Moreover, using edge enhancement filters can improve the results significantly.

References to author publications that relate specifically to the dissertation:

1. **Salari, E;** Parsai, EI; Shvydka, D; Sperling, NN; Evaluation of Parameters Affecting Gamma Passing Rate in Patient-Specific QAs for Multiple Brain Lesions IMRS Treatments Using RayStation Treatment Planning System. J Appl Clin Med Phys. 2022;23(1): e13467. **DOI: 10.1002/acm2.13467**

2. **Salari, E;** Xu, K.S; Sperling, N.N; and Parsai, E.I; Using Machine Learning to Predict Gamma Passing Rate in Volumetric Modulated Arc Therapy Treatment Plans. J Appl Clin Med Phys. 2023;24(2): e13824. **DOI: 10.1002/acm2.13824.**

3. **Salari, E**; Elsamaloty, H; Ray, A; Hadziahmetovic, M; Parsai, E.I; Differentiating Radiation Necrosis and Metastatic Progression in Brain Tumors Using Radiomics and Machine Learning. American Journal of Clinical Oncology. 2023; **DOI: 10.1097/COC.0000000000001036**