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Surface-Guided Radiotherapy for Motion Management - from Conventional to Ultra-High Dose Rate Treatments

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Approximately half of all cancer patients receive radiotherapy, with external beam radiotherapy being a cornerstone of treatment. The objective is to deliver radiation with high precision to achieve tumor control while minimizing exposure of surrounding healthy tissue. Despite major technological advances, some radioresistant tumors remain incurable with conventional methods.

Microbeam Radiotherapy (MRT) is a promising experimental technique that may overcome these limitations. At synchrotron facilities, low-divergence X-ray beams can be spatially fractionated into arrays of extremely narrow (≈50 μm) microbeams separated by ≈400 μm. These beams deliver extremely high doses (hundreds of Gray) and dose rates (hundreds to thousands of Gy/s), while sparing normal tissue in between. This unique dose distribution has demonstrated potential to improve tumor control and could provide curative treatment options in diseases where current approaches are palliative. However, the very high precision of MRT also demands strict patient positioning and robust motion management.

Patient and tumor motion remain major challenges in radiotherapy. While intracranial tumors move very little, thoracic and abdominal tumors are significantly affected by respiration. Furthermore, patients may move during treatment due to nervousness, discomfort, or involuntary actions, compromising treatment accuracy.

We are, for the first time to our knowledge, investigating the role of optical surface scanning for motion management in a microbeam radiotherapy setting. Surface-guided radiotherapy (SGRT) provides a non-ionizing solution through optical surface scanning. SGRT monitors the patient's position continuously, in real time, with sub-millimeter accuracy and high update frequency. Unlike other imaging systems used in radiotherapy, SGRT enables immediate detection of even the smallest deviations, can automatically interrupt beam delivery, and can guide breathing to optimize tumor positioning relative to nearby organs. We are presenting QA strategies using SGRT for advancing microbeam radiotherapy toward clinical application.

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