

Development of a liver gel-dosimetry motion phantom for real-time image guided radiotherapy verification

Intrafraction motion during radiotherapy is an important challenge to address due to its blurring of the dose delivered to the treatment target, which decreases target dose and increases surrounding healthy tissue dose. Real-time image guided radiotherapy (IGRT) methods have been developed to monitor target intrafraction motion and adjust treatment delivery accordingly. The American Association of Physicists in Medicine (AAPM) Task Group (TG) 76 recommends that image guidance systems should undergo end-to-end validation using a physical measurement phantom. Current motion phantoms lack a combination of three traits: compatibility with a variety of imaging modalities, 3D dosimetry for robust testing of systems, and deformability to better mimic intrafraction human anatomy motion. This work developed a deformable abdominal motion phantom which incorporates 3D polymer gel dosimetry to address these shortcomings. A protocol for in-house fabricated DEFGEL dosimeters paired with a magnetic resonance imaging (MRI) data acquisition was developed, which resulted in dose uncertainties of 5% or lower for the dose ranges characteristic of tumor doses. A deformable abdominal motion phantom was manufactured from polyvinyl chloride plastisol (PVCP) with internal PVCP organs fabricated using molds based on anonymized patient imaging data. The phantom and organs were designed such that they resulted in realistic CT and ultrasound images. Deformable DEFGEL dosimeters were placed within the liver to represent a tumor. The motion of the in-phantom dosimeter was shown to be repeatable within 0.30 mm on average in all directions and resultant average Dice coefficients exceeded 0.98. DEFGEL dosimeter measurements of a liver stereotactic body radiotherapy (SBRT) treatment in the phantom were found to match closely to the planned dose distribution, ion chamber measurements, and radiochromic film measurements. As a proof-of-principle study, the phantom was used to measure the dosimetric benefits of a novel ultrasound transducer and tracking system for real-time IGRT. Overall, this phantom shows promise as a tool for the verification of real-time IGRT systems before their use in clinical trials, improving patient safety during radiotherapy treatment.