Abstract

Preclinical radiation biology studies serve as a basis for developing new treatments for radiation therapy. As in clinical radiation therapy, accurate and traceable dose measurements are essential to establishing reproducible and translatable dose-response relationships. In the past decade, there has been an increasing awareness of gaps in the methodology between small animal research and human clinical treatments, especially in the accuracy of delivered dose using kilovoltage x-ray sources. This has led to uncertainty in the reproducibility and efficacy of results. The development of conformal small animal x-ray irradiators has allowed for sophisticated treatment delivery that aims to mimic clinical practice, yet dose calculation typically relies on manufacturer-supplied calibrations. While dose calculation protocols exist for kilovoltage x-rays, the applicability for radiobiology irradiators has not been investigated and radiation detectors that may be used for dose verification exhibit large energy responses in this energy range. The main goal of this work was to investigate NIST-traceable measurement techniques in radiobiology x-ray irradiators.

Kilovoltage dosimetry protocols, such as AAPM's TG-61 report, are based on air-kerma rate measurements and tabulated factors to convert to dose to water. In this work, beam quality and air-kerma rate measurements were investigated in a large-field and conformal x-ray irradiator. Dose-to-water rates were calculated in a reference water phantom using both simulated and TG-61-tabulated factors. A direct conversion between the air-kerma rate and dose to water rate was also determined and found to be consistent with TG-61 methods. This showed that TG-61 can be used to estimate the dose to water in reference conditions in these irradiators.

Dose to water measurements were also explored in non-reference conditions, as the setups in radiobiology differ from full scatter conditions defined in TG-61. It was found that protocol-defined reference dose rates overestimated the delivered dose to the specimen. Measurements in a representative mouse phantom were characterized to estimate the corrections needed when comparing dose estimates in experimental conditions. This included determining the energy response of common detectors in-phantom. The University of Wisconsin M-series NIST-matched x-ray beams were used in conjunction with the previously determined dose to water rates in the large and small field irradiators to characterize the in-phantom energy response of detectors. The in-phantom response for the radiobiology irradiators agreed within uncertainty to the M-series x-ray beams. These characterized detectors were then used to compare dose estimates from a small animal treatment planning system.