(様式 4)

学位論文の内容の要旨

Daniel Scott Bridges

(学位論文のタイトル)

Probabilistic dose distribution from interfractional motion in carbon ion radiation therapy for prostate cancer shows rectum sparing with moderate target coverage degradation

(前立腺癌の炭素イオン線治療において照射毎の動きを考慮した確率線量分布はターゲットのカバーの若干減少と直腸線量が減少することを示す)

(学位論文の要旨)

Purpose: This observational study investigates the influence of interfractional motion on clinical target volume(CTV)coverage, planning target volume (PTV) margins, and rectum tissue sparing in carbon ion radiation therapy (CIRT). It reports dose coverage to target structures and organs at risk in the presence of interfractional motion, investigates rectal tissue sparing, and provides recommendations for lowering the rate of toxicity. We also propose probabilistic DVH based on cone-beam computed tomography (CBCT) table shifts from photon therapy for consideration in bone-matching CIRT treatment planning to represent probable dose to our CIRT patient population.

Methods: At Gunma University Hospital intensity-modulated x-ray therapy (IMXT, aka IMRT) prostate cancer patients are positioned on a table which is shifted twice based on CBCT to align bones and then align prostate tissue to isocenter. These shifts thereby contain interfractional motion. A total of 1306 such table shifts from 85 patients were collected. Normal probability distributions were fit to the difference between bone-matching and prostate-matching CBCT-to-planning CT table shifts (i.e. interfractional motion). Between 2011 and 2016 CIRT prostate patients were treated with three beams to PTV1 (lateral-opposing and anterior) one per day for 9 fractions and two beams for a boost PTV2 (lateral-opposing) one per day for 7 fractions for a prescribed total of 57.6 Gy(RBE) as follows: PTV1 extends the prostate contour by 10/10, 5/10, 6/6 mm in the right/left, posterior/anterior, and superior/inferior directions, respectively, and the proximal seminal vesicles contour by 5 mm superiorly and inferiorly, 3mm right and left. PTV2 reduces PTV1 posteriorly along a straight line to exclude the rectum and reduces the superior and inferior margins by 6 mm. Probable interfractional motion for 40 patients was simulated using each patient's own beam data as follows: The previously fit normal probability distributions were randomly sampled 2000 times per patient, and the five beams were shifted and summed with the same relative weighting as in the 16-fraction regimen. The resulting dose distribution was then scaled back down by 16/2000 to match the prescribed number of fractions. We then analyzed the resulting doses to contoured structures.

Results: Probable dose to rectum is substantially less than planned: For example, mean+-standard deviation D2% for planned and probable DVH is 51+-1.9 and 45+-2.4, respectively. Cumulative DVH show mean CTV fraction receiving a given probable dose is

less than the mean fraction receiving the corresponding planned dose for doses larger than 52 Gy(RBE), up to 19% less at 57.4 Gy(RBE). Our PTV1 margins generally cover 95% of interfractional motion but seminal vesicles and inferior prostate receive less dose than planned due to insufficient PTV2 margins.

Conclusion: Assuming rigidly shifting interfractional motion around the prostate region and neglecting minor changes in soft tissue stopping power, interfractional motion resulted in target underdosing but better tissue sparing in all cases. Given our low rates of relapse and recurrence, it appears less curative dose is needed than previously thought or else current planning target margins may be excessive: Planning target volumes should be reconsidered with the adoption of dose verification methods. Our probable dose distributions quantify expected dose for future dose verification studies.