Report on “Radiation Disaster Recovery Studies”

Course: Radiation Disaster Medicine.

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○ Radiation Disaster Recovery Studies

The incident of Great East Japan Earthquake happened on March 11, 2011 was regarded as a triple disaster because of the quake itself caused a tsunami and a nuclear power plant accident. The accident of hydrogen explosions from Fukushima Daiichi Nuclear Power Plant followed by the released of radioactive materials caused the towns in the vicinity of the power plant became radiation hazard areas. Although Japan experienced atomic bombings in more than half a century ago and Ukrainian had a similar nuclear power plant accident that released radioactive materials into the atmosphere in 1986; the acute radiation effects from a cohort of casualty were known, but the stochastic effects of a long-term low-dose radiation exposure was lack of data [1,2]. Therefore, a long-term health monitoring namely “Fukushima Health Management Survey” was conducted soon after the accident. It was an effort of the radiation disaster recovery, to estimate individual radiation dose, perform health checkup, study the effects of long-term low-dose radiation exposure and promote future well-being.

The past experiences inculcate people a concept that the consequence of radiation accident is horrible. Without sufficient knowledge and proper understanding about radiation, people anxious and fear of the risk of being exposed to radiation, because they do not understand the relationship of radiation-induced cancer diseases with radiation dose and dose rate. I was interested to study the radiation-induced cancer diseases. My research study focused on the delivery of radiation treatment for liver cancer. Although my research study did not directly related to the radiation accident; my work was considered as a contribution on reducing the risk of radiation-induced cancer disease. In radiotherapy, cancer cells have to be treated with tumoricidal dose, however a conflicting priority is that the doses to the adjacent healthy tissues must be kept as low as possible, to reduce the risk of secondary cancer. The tolerance of normal liver tissues to radiation is low and are at risk to develop radiation-induced liver disease [3]. The fact is, during the radiation treatment, normal tissues that are regarded as an out-of-field region are also exposed to radiation, but at very low doses. Therefore, my research study proposed a technique of radiation delivery (split-VMAT) that can be clinically implemented for hepatocellular carcinoma and the doses subjected to the normal liver tissues were lower than the conventional technique of radiation delivery.

References

1. Shimizu Y, Kodama K, Nishi N, Kasagi F, Suyama A, Soda M, Grant EJ, Sugiyama H, Sakata R, Moriwaki H, Hayashi M, Konda M, Shore RE. Radiation exposure and circulatory disease risk: Hiroshima and Nagasaki atomic bomb survivor data, 1950-2003. *BMJ*. 2010;340:b5349.
2. Cardis E, Howe G, Ron E, Bebeshko V, Bogdanova T, Bouville A, Carr Z, Chumak V, Davis S, Demidchik Y, Drozdovitch V, Gentner N, Gudzenko N, Hatch M, Ivanov V, Jacob P, Kapitonova E, Kenigsberg Y, Kesminiene A, Kopecky KJ, Kryuchkov V, Loos A, Pinchera A, Reiners C, Repacholi M, Shibata Y, Shore RE, Thomas G, Tirmarche M, Yamashita S, Zvonova I. Cancer consequences of the Chernobyl accident: 20 years on. *J Radiol Prot.* 2006;26:127-40.
3. Emami B, Lyman J, Brown A, Coia L, Goitein M, Munzenrider JE, Shank B, Solin LJ, Wesson M. Tolerance of normal tissue to therapeutic irradiation. *Int J Radiat Oncol Biol Phys.* 1991;21:109-22.

○ **Title of Doctoral Thesis**

Split-VMAT technique to control the expiratory breath-hold time in liver stereotactic body radiation therapy

○ **Summary of Doctoral Thesis**

Introduction

Most of the hepatocellular carcinoma (HCC) cases are unresectable due to the hepatic dysfunction associated with cirrhosis. The alternative treatments available for the unresectable HCC are transcatheter arterial chemoembolization, percutaneous ablation and radiotherapy. Recently, the efficacy of using stereotactic body radiation therapy (SBRT) for HCC has been extensively reported. However, the challenge is that the liver is a moving organ, and there is a need to reproduce the tumor position for such a highly localized tumor control treatment. Expiratory breath-hold is one of the methods to improve the reproducibility of tumor position. In Japan, three-dimensional conformal radiation therapy (3D-CRT) is a common technique of radiation delivery for unresectable HCC, so far. However, 3D-CRT requires long total treatment time and prone to increase intra-fraction motion of tumor. Volumetric modulated radiation therapy (VMAT) is an advanced form of radiation delivery with an advantage that the total treatment time is short. This is because the radiation beam is delivered simultaneously with the gantry motion. As the result, VMAT can make the intra-fraction motion of tumor smaller than 3D-CRT.

Since the delivery time of VMAT is dependent on the angular velocity (e.g., degrees of gantry rotation per second) of a linear accelerator, we demonstrate the feasibility of using split-arcs in VMAT, tailored for expiratory breath-hold in SBRT for HCC. This split-arcs in VMAT technique was compared with 3D-CRT and continuous-VMAT, for ten randomly selected hepatocellular carcinoma cases.

Methods

The reproducibility of tumor position was confirmed within 5 mm using *Acuity* X-ray fluoroscopy simulator. *Abches* was used as a monitor to self-control the respiratory motion. Radiation treatment planning images were taken, using a CT *Lightspeed RT16* scanner. Radiation treatment plans were created using the *Pinnacle*^{3} *Planning System Version 9.6*, which was commissioned with the 5 mm MLC *TrueBeam* linear accelerator. Four coplanar and four non-coplanar beams were used for the 3D-CRT plans. The beam angle selection was case dependent and the position of the MLC was manually adjusted in order to fit the prescribed isodose line to the planning target volume. A pair of partial arcs, chosen using a back-and-forth rotating motion, were used for the continuous-VMAT plans. Split-VMAT plans were created using the same arc range as the continuous-VMAT plans, but were split into smaller arcs (< 90°), to simulate an expiratory breath hold of < 15 s. The prescription was 48 Gy/ 4 fractions, to the 95% of the planning target volume, using 10 MV flattening filter free X-ray beams.

Dose distribution was measured using an *EBT-eXtended Dose Gafchromic* film on an *I'mRT* phantom. The dose difference, between the measured and the planned, was analyzed using a *DD System*. All VMAT plans were evaluated with a gamma criteria of 3% dose difference; and a 3 mm distance-to-agreement, at a threshold of 10% to the maximal dose. The acceptance level of the gamma index was 95%.

The total treatment time was the summation of the patient-setup time, beam-on time, and intermediate time. In this study, every patient-setup time was assumed to be the same, regardless of the technique of delivery. Times were measured using a stopwatch with an estimated uncertainty of 1 s. Since

no MLC segment movement was needed in the 3D-CRT planning, the dose rate was assumed to be relatively constant over the period of the 3D-CRT delivery. Therefore, the beam-on time for 3D-CRT was calculated using the obtained MU, divided by the applied dose rate 2400 MU/min.

Dosimetric indices for normal tissues were evaluated. The dose distribution, treatment delivery efficiency, and patient specific quality assurance of the VMAT, were verified, to ensure that the outcomes were equal, or better than, those for 3D-CRT and continuous-VMAT.

Results

The mean dose of the normal liver was significantly lower in the split-VMAT compared with that of 3D-CRT. The percentage of dose to the normal liver exceeding 5 Gy and 20 Gy, the mean dose of stomach, the mean dose of spinal cord were not significantly different between the split-VMAT and 3D-CRT. These dosimetric indices were observed to be similar between split-VMAT and continuous-VMAT. The conformity index was significantly higher for split-VMAT than that of 3D-CRT. The values of MU obtained by 3D-CRT, continuous-VMAT and split-VMAT showed no significant difference, although split-VMAT was trended lower. The total treatment time for split-VMAT was shorter than that of 3D-CRT. All VMAT plans passed the gamma acceptance test.

Conclusion

The continuous-VMAT had similar dosimetric outcomes as split-VMAT, but less efficient in controlling the beam-on time, due to the continuous gantry rotation. The 3D-CRT could not predetermine a comfortable breath-hold duration like what the split-VMAT could do. We have shown that the split-VMAT in conjunction with the expiratory breath-hold, is a feasible clinical implementation for liver SBRT. Split-VMAT is effective and does not compromise the quality of the plan compared with 3D-CRT and continuous-VMAT. The main advantages are that VMAT has a shorter total treatment time, which facilitates ease of practice, and is more patient and therapist friendly for HCC SBRT.

○ **Other theses published in academic research journals**

Not applicable.