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Estimation of Radiation Therapy Induced Carcinogenesis: X-Ray vs. Proton Therapy

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Abstract. The purpose of this study is to compare the risk of the radiation induced carcinogenesis between x-ray radiotherapy and proton beam therapy. In this comparison study, the intensity modulated radiotherapy (IMRT) and scattering mode were chosen for x-ray therapy and proton therapy, respectively. For diseases of lung and liver cancer, the results show that the secondary cancer risk using proton beam therapy is either significantly lower than the cases in IMRT treatment or, at least, does not exceed the secondary doses induced by conventional IMRT treatment.

Keywords: Carcinogenesis, radiation therapy, proton therapy

1. Introduction

Protons are used in radiotherapy because of their advantageous physical properties. These include a near-zero exit or distal dose just beyond the target volume, resulting in reduced proton doses to normal tissue, with better conformation of the dose to the target volume. There have been many measurements and calculations of secondary neutron doses resulting from clinical proton beams [1,2]. The neutron dose associated with proton beam therapy (PBT), however, is highly facility dependent and is based on various factors, including initial beam, field-shaping devices, aperture, and treatment volume [3].

Calculations of secondary cancer should also include intermediate dose–induced carcinogenesis, because the risk of radiation-induced carcinogenesis due to intermediate doses in the beam path (in-field) may be much higher than that due to low doses in the out-of-field region. The risks of proton therapy may therefore not exceed those of conventional intensity-modulated radiotherapy (IMRT) treatment, because the intermediate dose of the former will be generally lower than that of the latter. In this study, we compared the **s**econdary cancer risk induced by advanced radiotherapy modalities, IMRT and PBT, for the treatment of lung and liver cancers.

2. Methods and materials

We randomly selected the lung and liver cancer patients, who were treated with IMRT and PBT at National Cancer Center Korea. The treatment beams were delivered to phantom and corresponding secondary doses during irradiation were measured at various points from 20 cm to 50 cm apart from the beam isocenter using ion chamber and CR-39 detectors for IMRT and PBT, respectively.

In each distance, CR detectors were positioned with three different orientations (Superior to inferior, Lateral, Anterior to Posterior) to minimize the directional dependency. Top surface was radiated directly, vertical and parallel surfaces were arranged with standard of the couch direction and radiated. Considering the internal neutron effect, measurement was performed without phantom and compared with phantom.

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Organ-specific radiation-induced cancer risk was estimated by applying organ equivalent dose (OED) to dose distributions.

3. Results

Fig 1 shows that the average secondary doses of proton therapy for lung and liver cancer patients, measured 20 to 50 cm from the isocenter, ranged from 1.73 mSv/Gy to 0.86 mSv/Gy, the average secondary doses of IMRT for lung patients, however, ranged between 5.8 mSv/Gy and 1.0 mSv/Gy, approximately three times higher than for proton therapy. Although there were small fluctuations, this trend held at various distances from the isocenter.

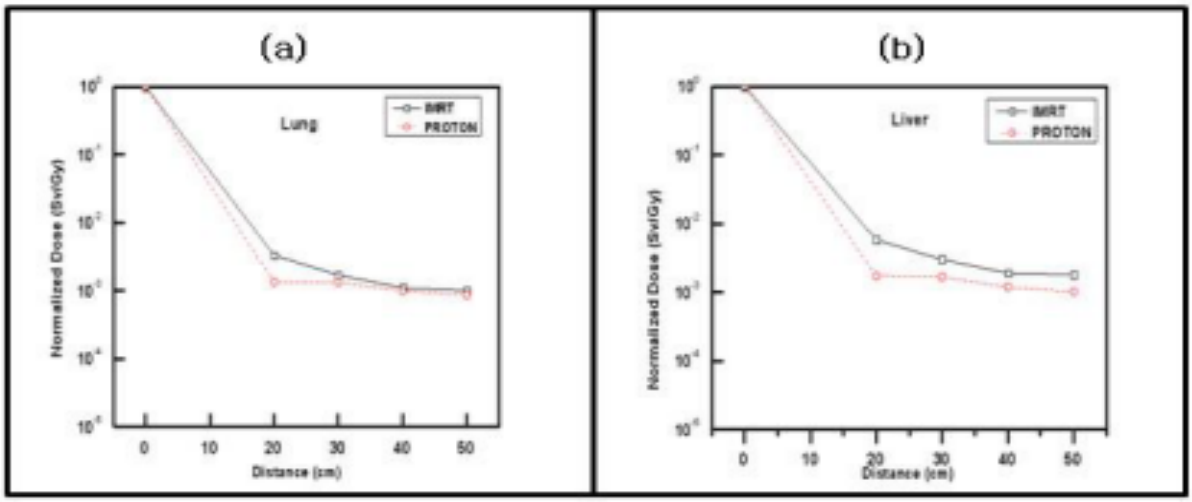

Fig. 1: Comparison of secondary doses resulting from IMRT and PBT of patients with (a) lung cancer and (b) liver cancer

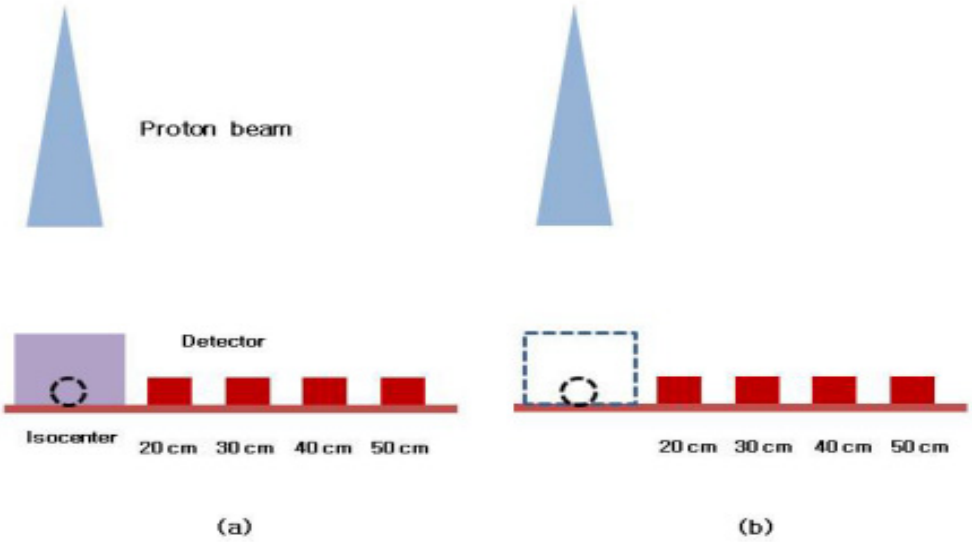

Fig. 2: The schematic of proton beam setup (a) with phantom (b) without phantom

Fig 2 shows that schematic of proton beam setup with phantom or without phantom to consider the effect of internal neutron dose produced by proton interaction in the body. Here, we assumed that the neutron dose without phantom is caused *only* by external neutron from beam modulating equipment. Fig 3 shows that the

average internal neutron doses of proton therapy for lung and liver cancer patients, measured 20 to 50 cm from the isocenter, ranged from 0.21 mSv/Gy to 0.08 mSv/Gy at all orientations.

The result shows that internal neutron dose produced by proton interaction in the body is generally much less than external neutron dose produced by proton interactions in the scattering elements of the passively modulated beam line.

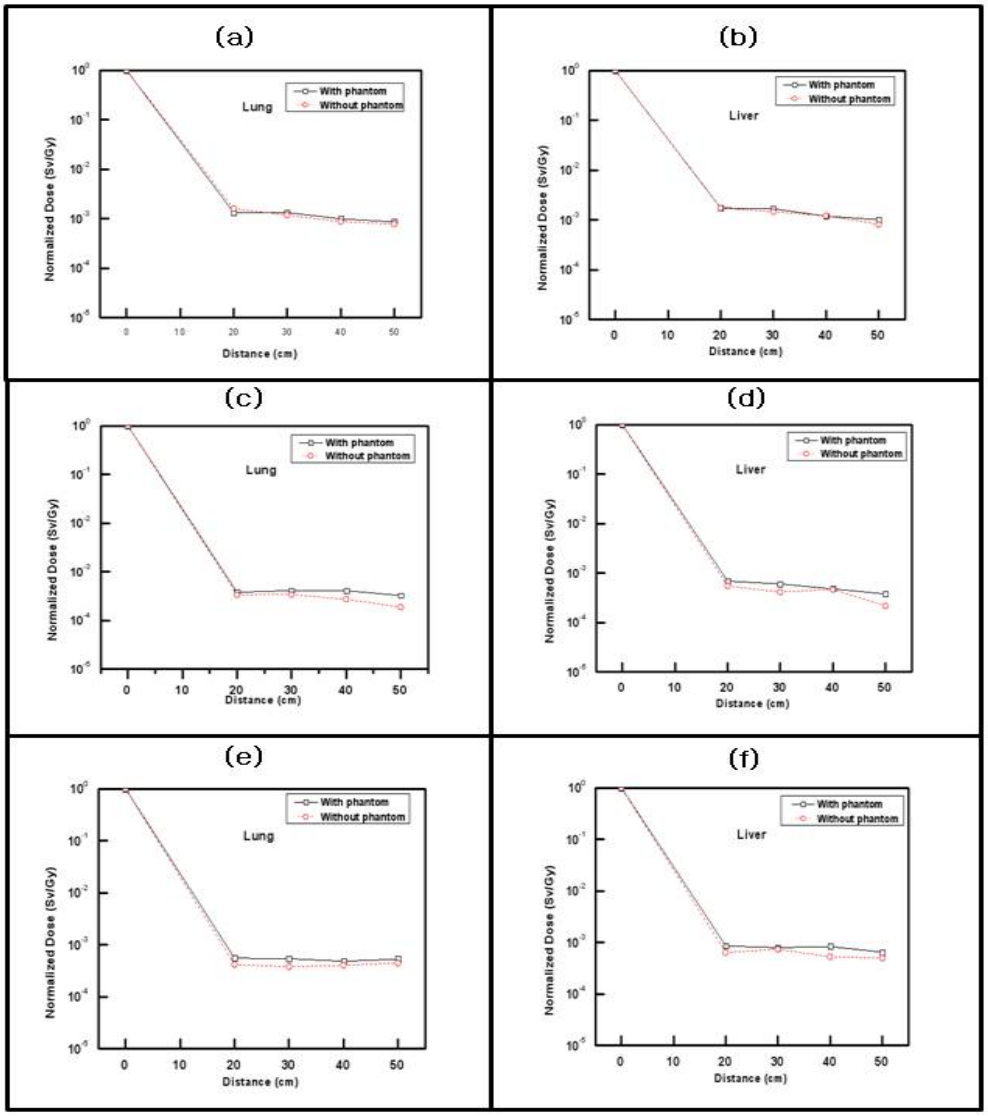

Fig. 3: Comparison of secondary doses with phantom and without phantom for three directions. (a) lung cancer (b) liver cancer in anterior to posterior, (c) lung cancer (d) liver cancer in lateral direction, (e) lung cancer (f) liver cancer in superior to inferior direction

4. Conclusion

By a comparison between passive proton beam therapy and IMRT for diseases of lung and liver cancer, it was shown that the secondary cancer risk using scattering mode in proton beam therapy is either significantly lower than the cases in IMRT treatment or, at least, does not exceed the secondary doses induced by conventional IMRT treatment. Our measurement also suggests that the neutron dose in proton treatment is mainly caused by the external neutron implying the negligible internal neutron doses from body.

5. References

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