COMPARATIVE RISK ASSESSMENT OF RADIATION INDUCED SECOND CANCERS IN PATIENT WITH PROSTATE CANCER AFTER INTENSITY MODULATED RADIATION THERAPY AND STEREOTACTIC BODY RADIATION THERAPY

SAWANEE SUNTIWONG 5436424 RAMP/M

M.SC. (MEDICAL PHYSICS)

THESIS ADVISORY COMMITTEE : VIPA BOONKITTICHAROEN, Ph.D., MANTANA DHANACHAI, M.D., M.Sc., CHOMPORN SITATHANEE, M.D.

ABSTRACT

This study aimed to assess the risks of second primary cancer (SPC) for prostate cancer patients treated by intensity-modulated radiation therapy (IMRT), CyberKnife stereotactic body radiation therapy (CK-SBRT) in comparing to three-dimensional conformal radiation therapy (3D-CRT). The SPC risks expressed as excess absolute risk (EAR) were determined for organs in or near the treatment fields, out-of-field and those involved in the image-guided procedures. Organ equivalent dose (OED) using a mechanistic model incorporating a dose fractionation effect, dose-volume histogram and organ-specific cancer risk parameters were employed for calculation of EAR^{org} for the primary beam component. Treatment plans for six prostate cancer patients were generated using the Eclipse treatment planning system (TPS) for both 3D-CRT and IMRT, Multiplan TPS for CK-SBRT. Ten-MV photon with 7-fields and 6-MV photon with 9-fields were delivered according to 3D-CRT plan and IMRT plan, respectively, in 39 fractions of 2 Gy; 6-MV photon with 184-289 beam orientations for CK-SBRT plan was delivered in 5 fractions of 7.25 Gy. An image-guided dose and scatter/leakage radiation for each treatment plan were measured using an Alderson radiotherapy (ART) phantom and thermoluminescent dosimeters. Associated EARs were calculated using a linear model. Ratios of OED for a certain organ site allowed a relative assessment of SPC risks (RR) between treatment modalities.

The EAR^{org} of an organ was observed as a function of organ specific carcinogenic susceptibility and OED which is dependent of the shape of dose-risk curve (bell-shaped or plateau), dose fractionation, and the organ dose-volume histogram. A hypofractionated regimen yielded a smaller area under the risk equivalent dose (RED) curve than that of conventional fractionation. Risks of SPC for all organs in or near the treatment fields of CK-SBRT were less than those from 3D-CRT and IMRT with an average RR of 0.446 ($p < 0.0001$). Comparing the dose distributions; the IMRT plan generated an RR of 0.99 for risk at the pelvic soft tissue, an inferior dose profile with a higher rectal risk (RR = 1.02, $p = 0.002$) and superior dose distribution with a lower pelvic bone sarcoma risk (RR = 0.72, $p < 0.0001$). For organs distal to the field edge, like the thyroid and brain, CK-SBRT in relation to 3D-CRT, generated an average RR of 4.46 ($p < 0.002$). Minimal patient scatter in CK-SBRT resulted in a decreasing RR from lungs (2.81) to kidneys (0.83). For IMRT, in relation to 3D-CRT, the average RR was 2.39 ($p < 0.001$). Image-guided procedures contributed much less radiation doses to organs in or near the treatment fields and also those organs receiving scatter/leakage radiation.

In conclusion, OED from the primary beam component was the major contributor of EAR^{org}, followed by scatter/leakage radiation and doses from the image-guided procedures. Overall, IMRT was associated with a highest EAR of 9.93 excess cases per 10^4 PY, 3D-CRT 8.25 per 10^4 PY and CK-SBRT 7.10 per 10^4 PY.

KEY WORDS: SECOND CANCER / RISK ASSESSMENT / ORGAN EQUIVALENT DOSE / IMRT / SBRT

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