Report on “Radiation Disaster Recovery Studies”

Course: Radiation Disaster Medicine
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○ **Radiation Disaster Recovery Studies**

Nowadays, applications of nuclear technology in different areas have largely expanded worldwide and various types of nuclear or radiological accidents are always a possibility. Many Member States are currently not adequately prepared to respond to nuclear and radiological emergency situations. An analysis of the lessons from past accidents, including the Fukushima, Chernobyl and Goiania accidents, have shown us how lack of crucial components in the emergency response system could result in major radiological and non-radiological consequences at the national level [1]. For instance, after the Fukushima Daiichi Nuclear Power Plant accident, the evacuation procedures did not work for some vulnerable groups of people, such as those who were in need of nursing care. As the result, many deaths occurred during the evacuation procedures, which could have been prevented with better preparedness and response [2]. Thus, the radiation disaster medical system should be strengthened worldwide, especially in developing countries. In my native country of Mongolia, an adequate medical system for radiation emergencies is not established. There is a lack of specialists in radiation disaster medicine in Mongolia. If any radiological or nuclear accident happened, we as radiation oncologists, must respond to the accident according to the National Radiation Emergency Response Plan. Although radiation oncologists have the knowledge and awareness about the applications of radiation in medicine and its impact on human health, we are still not fully ready to respond to a radiation disaster or to function as experts within radiation emergency medicine. Thus, I joined the PLEP in order to further my expertise beyond radiation oncology and to become a specialist in radiation disaster medicine.

I have gained broad knowledge and practical skills in Radiation Disaster Recovery Studies through interdisciplinary professional subjects, including radiation oncology, radiation disaster medicine and radiobiology; phoenix leader common coursework; cross-disciplinary common subjects; and also fieldwork and internships. Furthermore, I have developed a vision on how to conduct research in the radiation disaster field and how to prevent further issues in case of another nuclear accident in the future.

My research interests include both radiation oncology and radiation disaster medicine.

My doctoral thesis is in the field radiation oncology; focused on the ability of functional image (gadoxetate disodium enhanced hepatic MRI) guidance liver SBRT planning with IMRT technique to spare functional liver in order to reduce risk of radiation induced liver disease. Our results demonstrated that this novel method could significantly reduce the low dose area in normal liver tissues. Although this study is not directly related to radiation disaster medicine, its outcome is applicable for radiation disaster victims with liver cancer and the method could be used for improvement in health care for such individuals. According to a report by the Radiation Effect Research Foundation, a significant increase in liver cancer risk with radiation dose has been observed in both the mortality study and cancer incidence study [3].

During my long-term internship at the Incident and Emergency Centre of the International Atomic Energy Agency, I have been given an opportunity to write a review on medical overexposure in radiation therapy under the supervision of Dr. May Abdel-Wahab, IAEA. Over the last decades, new diagnostic and therapeutic radiation techniques have developed rapidly and contributed to improvements in health care. Along with the greater realization of the benefits of these advances in healthcare came a greater recognition of the impact of medical accidental overexposures as well as the importance of preventive measures to avoid or minimize their occurrence.

Recent publications suggest that overexposure during radiation therapy was the leading cause of radiation-related acute health effects and deaths in the period between 1980 and 2013 [4,5]. The objective of our review manuscript is to examine medical overexposure accidents related to new technologies in radiation therapy during the period 2000-2009. A total of 24 of the most serious radiation therapy overexposure accidents were reviewed. The result showed that the accidents occurred most frequently in patients treated with 3-D conformal radiation therapy or stereotactic radiosurgery. The main causes of accidents were related to human error – 62.5% (15); equipment -29.2% (7); system - 8.3% (2). This review aims to emphasize that with proper preparation and availability of resources, including sufficient number of staff members, adequate staff training, as well as risk audit of new technology, and enhanced safety culture and quality-assurance, the number of accidents related to the use of new radiation therapy technologies can be greatly reduced. The manuscript has been accepted for publication in Journal of Radiation Oncology.

I have also studied the adverse events caused by radiation therapy for atomic bomb survivors with breast cancer. This study concluded that the standard radiation dose can be administered to ABS with breast cancer.

References:

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4. Coeytaux K , Bey E, Christensen D, et al, "Reported Radiation overexposure accidents worldwide, 1980-2013: A systematic Review"
5. UNSCEAR. Source and effects of ionizing radiation. Volume II. Annex C: Radiation exposures in accidents. Report to the General Assembly; 2008. pp 1–43.

○**Title of Doctoral Thesis:**

Functional image-guided stereotactic body radiation therapy planning for patients with hepatocellular carcinoma

○ **Summary of Doctoral Thesis**

Introduction: Recent technological advances in the planning and delivery of stereotactic body radiotherapy (SBRT) have provided the means to treat hepatocellular carcinoma (HCC) in safer, and more effective than previously. However, challenges of HCC treatment include limited liver function in some patients; in previous studies, non-classic radiation-induced liver disease (RILD) was more common in patients with poor liver function (hepatitis B infection and Child–Pugh classes B and C) . Therefore, SBRT to the liver should be cautiously planned to prevent RILD. Moreover, the incidence of RILD is strongly correlated with irradiated liver volumes and mean liver doses. Hence, precise assessments of the current level of liver function are critical in the radiation treatment (RT) of HCC to minimize irradiate volumes and mean doses to functional liver tissues. Functional imaging techniques are used during RT planning and treatment to minimize irradiated volumes and mean doses to functional tissues while delivering highly conformal doses to the tumor. Recent studies have suggested that gadoxetate disodium (EOB; EOB Primovist; Bayer Yakuhin Ltd., Osaka, Japan)–enhanced magnetic resonance imaging (EOB-MRI) is effective for detecting hepatic lesions and may indicate hepatic function. Therefore, we believe that the EOB-MRI–guided liver functional imaging modality can be applied to SBRT for liver cancer to spare the functional liver region using intensity modulated radiation therapy (IMRT) technique and lead to safer and more efficacious treatment.

Purpose: The present simulation study aimed to evaluate the ability of EOB-MRI–guided

SBRT planning by using IMRT technique in sparing the functional liver tissues during SBRT for HCC.

Methods: In this study, 20 patients with HCC were enrolled and EOB-MRI was performed before planning. Functional liver tissues were defined according to quantitative liver–spleen contrast ratios ≥ 1.5 on a hepatobiliary phase scan. Functional images were fused with the planning computed tomography (CT) images, which were obtained during the arterial phase, in the treatment planning system. Gross tumor volumes (GTVs) were defined as those carrying residual lipiodol from transarterial chemoembolization and early enhancement during the arterial phase of dynamic CT. A clinical target volume (CTV) margin of 0–5 mm was added to the GTV for subclinical invasions, and a planning target volume (PTV) margin of 5–8 mm was added to the CTV based on the reproducibility of respiratory motions and setup errors. Eight ports were selected in all patients, including four coplanar and four non-coplanar static beams, which were established in directions that avoided the stomach, intestine, gall bladder, and spine if possible. The total prescribed dose was 48 gray (Gy) in four fractions; the prescription dose comprised 95% of the PTV. The following two SBRT plans were designed using a "step-and-shoot" static IMRT technique for each patient: 1) an anatomical SBRT plan (plan A) optimization uses based on the total liver; and 2) a functional SBRT plan (plan F) based on the functional liver. Dosimetric parameters of plan A and plan F were investigated by: 1) PTV doses to 95% of the prescription dose (PTV $D_{95\%}$) and mean PTV dose; 2) calculating mean doses to total and functional liver minus GTVs (MLD and fMLD) ; 3) expressing percentages of total and functional liver volumes, which received doses from 5 to 30 Gy [V5 to V30, fV5 to fV30]; 4) calculating mean doses, doses to 0.5cc and to 5cc volumes (D0.5cc and D5cc) of stomach, duodenum and intestine; and 5) calculating monitor units.

Results: Dosimetric parameters including PTV $D_{95\%}$ (mean: plan A, 48.0; plan F, 48.0 Gy; $p = 0.78$) and mean PTV doses (mean: plan A, 54.6 Gy and plan F, 54.8 Gy; $p = 0.11$) did not differ significantly between the two plans. Compared with anatomical plans, functional image-guided SBRT plans reduced MLD (mean: plan A, 5.5 Gy and plan F, 5.1 Gy; $p < 0.0001$) and fMLD (mean: plan A, 5.4 Gy and plan F, 4.9 Gy; $p < 0.0001$), as well as total and functional liver V5 to V30 and fV5 to V30. Mean dose, D0.5cc and D5cc of stomach (***mean:*** plan A, 0.82 Gy; plan F, 0.78 Gy; $p = 0.19$; ***D0.5cc:*** plan A, 6.0 Gy; plan F, 5.8 Gy; p=0.34 ; ***D5cc:*** plan A, 4.5 Gy; plan F, 4.4 Gy; p=0.36), duodenum (***mean:*** plan A, 0.59 Gy; plan F, 0.62 Gy; $p = 0.09$; ***D0.5cc:*** plan A, 2.2 Gy; plan F, 2.4 Gy; p=0.07 ; ***D5cc:*** plan A, 0.96 Gy; plan F, 0.98 Gy;

p=0.4) and intestine (***mean:*** plan A, 0.68 Gy; plan F, 0.66 Gy; p = 0.29; ***D0.5cc:*** plan A, 4.5 Gy; plan F, 4.7 Gy; p=0.36 ; ***D5cc:*** plan A, 3.1 Gy; plan F, 3.1 Gy; p=0.45) were not significantly different between the two plans. However, monitor units (mean: plan A, 2437; plan F, 2495; p = 0.01) and conformity indexes (mean: plan A, 0.99; plan F, 1.01; p = 0.003) differed significantly between the two plans.

Conclusions: This simulation study demonstrates the ability of functional imaging with EOB-MRI for SBRT planning in patients with HCC. EOB–MRI-guided SBRT planning using the IMRT technique may improve functional liver preservation in patients with HCC.

This study has been accepted for publication in “Medical Dosimetry” journal.

○ Other thesis published in academic research journals

1. ***Title of thesis:*** Accidental overexposure related to new radiation therapy technologies

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Title of journal: Journal of Radiation Oncology (with peer review), 2017, in press