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# An AP/PA Recumbent Technique for Total Body Irradiation Using IMRT at Extended SSD

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## INTRODUCTION

The Total Body Irradiation (TBI) has long been successfully used for the treatment of hematologic malignancies to irradiate the blood-related cancer cells like leukemias, lymphomas, and myelomas [1]. The goal is to deplete patient's bone marrow and suppress the immune system by delivering uniform dose to the entire body with megavoltage photon beams [2]. It was traditionally carried out with patient positioned at extended SSD (~ 400 cm) in a ***large*** linac room using a single photon beam from two opposing directions. It was necessary to fabricate customized compensators and/or partial transmission blocks to accommodate patient geometry and organ shielding. Previous studies have shown that AP/PA TBI technique performs better in critical organ protection than bilateral technique [3]. More and more institutions have pursued advanced techniques into TBI treatment by using computerized treatment planning system which have been validated to be feasible in calculation for extended SSD TBI treatment [4-6].

## AIM

- Develop a novel **AP/PA TBI technique using IMRT at extended SSD** that can be performed in ***any linac room*** and meet clinical criteria of dose uniformity, organ shielding, and absorbed dose rate.
- Provide **adequate sparing of lungs and kidneys** by using dynamic MLC to reduce the complexity of customized compensators and partial transmission blocks.
- Develop **an optimization algorithm** for the IMRT TBI treatment to deal with dose homogeneity improvement, critical organ shielding, and skin flash.

## METHOD

- **Geometry and setup:** A polycarbonate platform was constructed and placed under the gantry as close to the floor as possible with typical **SSD at ~200 cm**. Patient cranial-caudal axis is in the gantry rotation plane. Two (2) abutting fields with same external isocenter at **gantry angles of ±21˚**, **collimator angle of 90˚**, and **field size of 25×40 cm²** are employed (Figure 1). Field size could be extended to 32×40 cm² for **maximum treatment coverage (190cm L × 70cm W)**. Patient is treated in both **supine and prone** positions.
- **Optimization and dose evaluation:** To generate uniform dose at the **patient mid-plane with adequate shielding to the lungs and kidneys**, an iterative optimization algorithm was developed and interfaced to the Eclipse treatment planning system (TPS). The optimal fluence for each beam was input to TPS for MLC leaf sequencing, final dose calculation, plan evaluation and quality assurance (QA). This technique was applied to both phantom and patient CT images for the treatment planning. Dose measurement were performed in phantom and QA was done with portal dosimetry.
- **Prescription and dose verification:** The prescription for the treatment plan was **800 cGy in total with four (4) fractions delivered twice daily**. **Lungs and kidneys received 25% of prescription dose (200cGy).** For patient treatment, the absorbed dose rate is recommended to be **< 15 cGy/min** to reduce the radiotoxicity and late effects[7]. A **CR film placed** under the platform could be used to verify the patient setup, field shape and organ shielding. **OSLD** could be placed on the patient surface under bolus for dose measurement.

## RESULTS

- **In phantom**, the dose uniformity at mid-plane *before optimization* was over **±20%**. *After the 1st iteration*, it became less than **±10%**; however, the dose profile still showed a descending trend in the inferior part (Figure 2). The dose uniformity after 2nd iteration reduces to less than **±5%**. Except for the fluctuations near the center, the overall profile has been smoothed and became more closer to the prescription dose. The dose profile after the 3rd iteration did not improve significantly.
- To verify the dose delivery accuracy, one longitudinal mid-line dose profile and two transverse dose profiles, going through lungs and upper legs respectively, are measured and shown (Figure 4). The measurement was **performed at Truebeam linear accelerator** on **solid water phantom** and **farmer chamber and parallel plate chamber**. Since AP and PA beams were symmetric, measurement was done only for AP beams (Field AP1 and Field AP2).

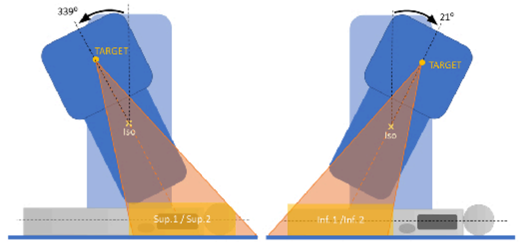


*Figure 1* *Illustration of the setup for Novel AP/PA Recumbent Position IMRT TBI.*

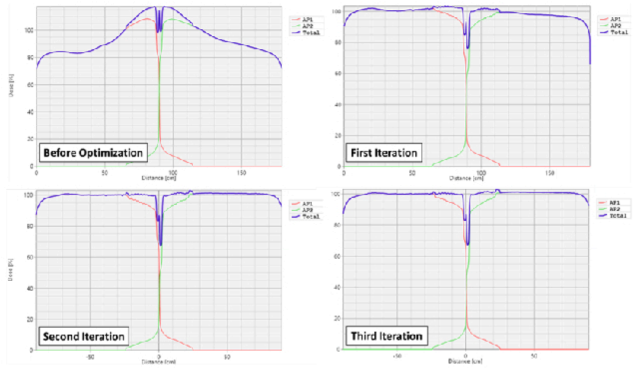


*Figure 2* *Dose profiles for phantom before and after optimization. The fluctuation in dose profiles near the central regions were affected not only by the scatter from the abutting fields (green lines and red lines) but also by the difference of transmission factors between the optimal fluence and the actual fluence.*

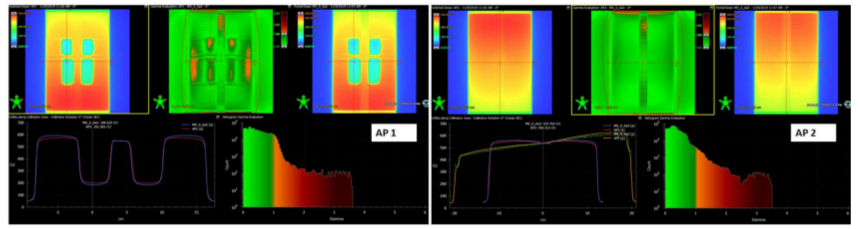


*Figure 3* *The gamma evaluation from Portal Dosimetry in Eclipse. EPID was used for IMRT TBI treatment QA. All fields in the phantom study pass the gamma evaluation (3% dose difference, 3 mm DTA, 5% threshold).*

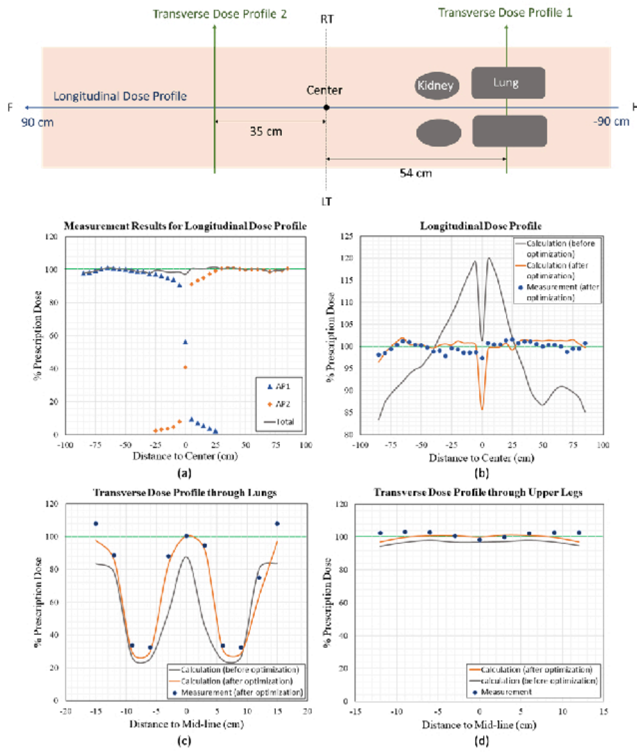


***Figure 4*** *The measured dose profiles for phantom. The green lines on each graph show the 100% prescription dose. Calculation and measurement agree well in both longitudinal and transverse direction.*

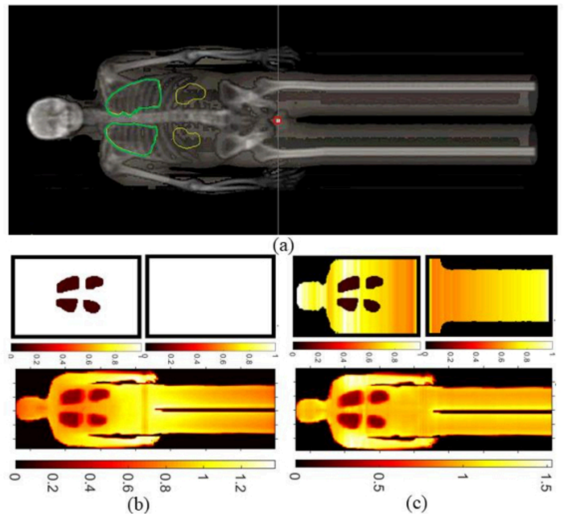

***Figure 5*** *(a) Projection of patient CT image with extended legs in AP direction, with lungs outlined in green and kidneys in yellow. (b) initial fluence map (left) and patient effective mid-plane dose (right) (c) final fluence map (left) with skin flash and patient effective mid-plane dose. Much improved dose uniformity in (c) than (b).*

- **For patient**, ***the effective mid-plane*** was first determined based on patient CT and body contour, so that AP/PA beam can deliver equal dose to the patient. The optimization reduced the transmission factor gradually when getting closer to the center of the patient and compensate for the beam divergency effect (Figure 5). The dose homogeneity improved after optimization. The homogeneity of dose profiles with skin flash for both superior and inferior fields also reduce to less than **±5%** prescription dose except for the field junction area in the center (Figure 6).
- To account for the patient movement during TBI treatment and reduce the unnecessary irradiation, a **3 cm skin flash** was applied to the TBI patient treatment plans. Surface dose computed in Eclipse for patient was between **96% to 98%** prescription dose, though the calculation may not be precise for surface region.

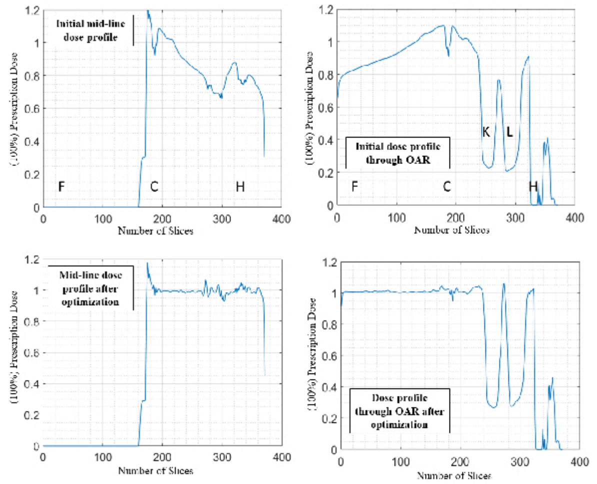


***Figure 6*** *The dose profile extracted from the effective mid-plane dose matrix through patient mid-line and OARs. The relative position of head (H), center of patient (C), feet (F), and the shielding to lung (L) and kidney (K) were labeled. Two dose profiles after optimization were around 100% prescription dose with small dose difference.* ***Kidneys and lungs dose were kept at around 25% to 30% prescription dose.***

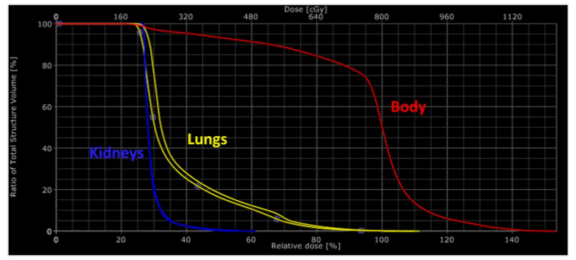


***Figure 7*** *The dose volume histogram (DVH) curves for lungs (left lung and right lung), kidneys (left kidney and right kidney), and body . Lung dose distribution had larger variation compared with kidney dose. To irradiate the supraclavicular region, part of the lungs received 100% prescription dose, while kidneys were all under shielding.*

## CONCLUSIONS

- We have developed a promising TBI technique using abutting IMRT fields at extended SSD which can achieve excellent dose uniformity within patient body.
- Effective CT simulation and treatment planning **reduce the treatment complexity**.
- Patient is in a comfortable recumbent position with **good reproducibility** and less motion during treatment, compared to current standing position.
- The technique allows **excellent sparing of lungs and kidneys** and can be executed in **any linac room**.
- It provides **3D dose distribution** inside patient body for better plan evaluation and clinical study.

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