Dosimetric impact of patient motion on occurrence of radiation pneumonitis

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INTRODUCTION

Radiation pneumonitis (RP) is a major dose-limiting toxicity in patients receiving thoracic irradiation and substantially affects the therapeutic ratio of radiotherapy. The time to onset of RP is usually several months after radiotherapy [1]. In clinical practice, various dosimetric factors have been used widely to limit radiation toxicity in order to prevent the development of RP, including mean lung dose (MLD), percent of lung volume receiving a dose of 5Gy or more (V5), or 20Gy or more (V20), and total dose [2]. However, radiation pneumonitis still develops in about 50% of the breast and esophageal cancer patients in our clinic, even with satisfactory planned dose distributions. This study is motivated to investigate the impact of patient motion on the occurrence of RP.

AIM

- To develop a Monte Carlo dose calculation module based on open source TOPAS and VMC++ as an independent dose calculation tool for various dosimetric study purposes.
- To incorporate the patient motion based on cone beam computed tomography (CBCT) images prior to treatment of breast and esophageal cancers.
- To thoroughly investigate the impact of patient motion on the occurrence of RP by calculating the actual dosimetric factors (MLD, V5,V20, and total dose).

METHOD

1. Retrospectively investigate 42 breast cancer patients and 45 esophageal cancer patients several months post radiation therapy, and respectively 9 and 7 were diagnosed with radiation pneumonitis.

2. Divide those patients into two groups in terms of with or without concurrent chemotherapy.

3. Calculate the dose distribution by incorporating the patient motion information that is captured by CBCT before each fraction.

3a. The dose calculation was performed by Eclipse TPS.

3b. Monte Carlo (MC) software VMC++ and TOPAS was used as an independent verification.

4. Integrate the fractional dose distributions to evaluate the overall dosimetric factors of radiation pneumonitis such as V20 and mean dose of lung for both groups of patients.

- VMC++ is a C++ re-implementation of the VMC [3] and XVMC [4] and incorporates a variety of improvements in the modeling of the underlying physical processes and incorporates several new variance reduction techniques [5]. The workflow to test VMC++ as a Monte Carlo dose calculation module is shown in Figure 1.
- TOol for PArticle Simulation (TOPAS) is an innovative proton Monte Carlo platform for research and clinical applications [6]. In TOPAS, the IAEA phase space data was used as the source to simplify the calculation, which include all the particle information including the position, direction, charge, energy, history and so on.
- On-Board Imager (OBI) CBCT was used before each fraction for acquiring patients patient motion information.

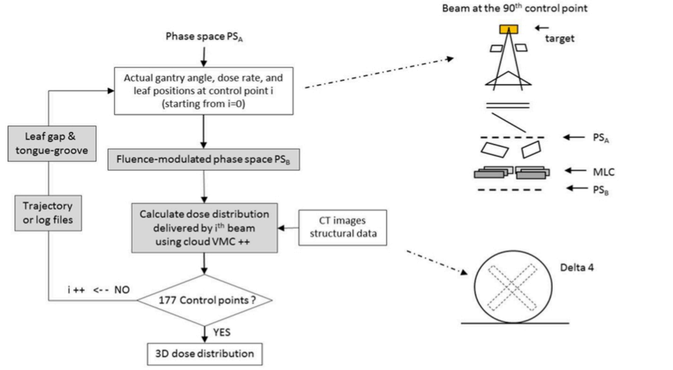

Figure 1. The workflow to test VMC++ for dose calculation.

RESULTS

- Within 42 breast cancer patients and 45 esophageal cancer patients, respectively 9 and 7 were diagnosed with radiation pneumonitis. RP of a patient with breast cancer is shown in Figure 2.
- The MC module is validated as a reliable and independent Monte Carlo dose calculation tool. The comparison of dose distribution from Eclipse and VMC++ based on Delta 4 Phantom+ (Oncology Imaging Systems) is shown in Figure 3.

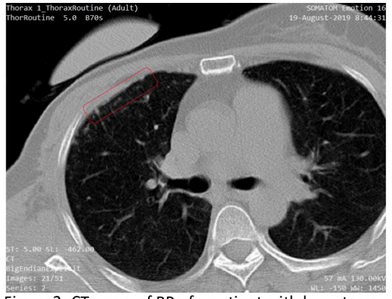

Figure 2. CT scans of RP of a patient with breast cancer three months post radiation therapy.

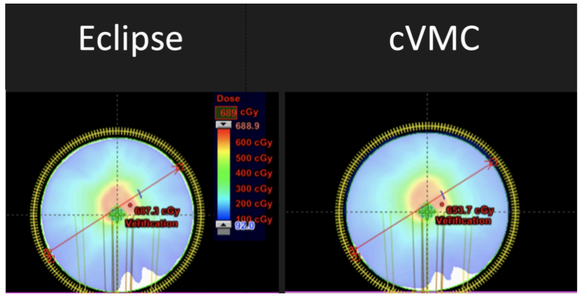

Figure 3. Comparison of dose distributions between Eclipse and VMC++.

Future plans include

- validating TOPAS for dose verification.
- calculating the dose distribution based on Eclipse and MC codes by incorporating the inter-fractional patient motion information from CBCT.
- integrating the fractional dose distributions to evaluate the overall dosimetric factors of RP (MLD, V5, V20, and total dose) for both groups of patients.

CONCLUSIONS

- The Monte Carlo codes VMC++ could be used as an independent dose verification tool.
- In addition to dosimetric factors, accurate and repeatable patient setup and correction of motion play important roles on the development of radiation pneumonitis for radiation therapy of thoracic regions.

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REFERENCES

1. **Hope AJ et al**. Modeling radiation pneumonitis risk with clinical, dosimetric, and spatial parameters. International Journal of Radiation Oncology* Biology* Physics. 2006 May 1;65(1):112-24.
2. **Kim TH et al.** Dose-volumetric parameters for predicting severe radiation pneumonitis after three-dimensional conformal radiation therapy for lung cancer. Radiology. 2005 Apr;235(1):208-15.
3. **Kawrakow I et al.** 3D electron dose calculation using a Voxel based Monte Carlo algorithm (VMC). Medical physics. 1996 Apr;23(4):445-57.
4. **Fippel M**. Fast Monte Carlo dose calculation for photon beams based on the VMC electron algorithm. Medical physics. 1999 Aug;26(8):1466-75.
5. **Kawrakow I**. VMC++, electron and photon Monte Carlo calculations optimized for radiation treatment planning. InAdvanced Monte Carlo for Radiation Physics, Particle Transport Simulation and Applications 2001 (pp. 229-236). Springer, Berlin, Heidelberg.
6. **Perl J et al**. TOPAS: an innovative proton Monte Carlo platform for research and clinical applications. Medical physics. 2012 Nov;39(11):6818-37.

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