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Impact of lung density on the lung dose estimation for radiotherapy of breast cancer

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ABSTRACT

Background and purpose: To investigate the impact of the clinical implementation of a deterministic particle transport method on the lung dose evaluation for radiotherapy of breast cancer focusing on dosimetric effects of the lung density.
Material and methods: Fourteen patients with left sided breast cancer having both deep inspiration breath hold (DIBH) and free breathing CT scans were studied. Lung density variations for 157 patients treated under DIBH were quantified and the cases with the lowest lung densities for breast and for loco regional treatment added to the study. Dose calculations were performed with the class-b type algorithm AAA and the deterministic algorithm Acuros XB. Monte Carlo method was utilized as reference. Differences in the dose distributions were evaluated by comparing DVH parameters.
Results: Lung density variations between 0.08 and 0.3 g/cm^3 and between 0.02 and 0.25 g/cm^3 were found for loco-regional and tangential breast treatments under DIBH, respectively. Lung DVH parameters for patients with medium and high lung density obtained by the different algorithms agreed within 3%. Larger differences were observed for low lung density cases where the correction based algorithm underestimated V_{10Gy} and overestimated V_{40Gy} by up to 5%. The least affected parameter, V_{20Gy}, deviated by less than 2% for all cases and densities.
Conclusions: Dosimetric constrains for lung based on V_{20Gy} required minimum changes due to implementation of the new algorithm regardless of breathing technique or type of treatment. Evaluation criteria utilizing V_{10Gy} or V_{40Gy} needed reconsideration, especially for treatments under DIBH involving low lung density.

1. Introduction

Radiotherapy of breast cancer involves complex anatomy and regions of highly different densities; soft tissue, lung and bone, surrounding air. The lung density may substantially decrease when utilizing respiratory gating technique such as deep inspiration breath hold (DIBH) in order to limit the radiation dose to the heart. An accurate determination of the dose distribution in lung requires advanced dose calculation algorithms. Type-a algorithms, using inhomogeneity corrections along the ray direction only, have been gradually replaced by type-b algorithms capable to approximate the lateral electron transport. Both use dose kernels calculated in water and handle different tissues by density based corrections.

More advanced methods explicitly model the interaction of radiation with matter solving the Linear Boltzmann Transport Equation (LBTE). Monte Carlo (MC) is well established stochastic method indirectly obtaining the LBTE solution. Because of the relatively long computational time and the statistical noise of the result, it is mostly used as a reference method when evaluating dose distributions from the treatment planning systems. An alternative approach has been recently applied to address medical physics problems utilizing a deterministic method for numerical solution of the LBTE [1]. The accuracy of the new algorithm has been fundamentally investigated [1–6] and found to be comparable to MC.

Important step toward the clinical implementation of the new method is to ensure the validity of the old treatment planning criteria or to reconsider them. Dosimetric predictors of radiation induced lung complications involved in the plan evaluation are currently related to dose distributions produced by correction

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based algorithms. The impact of the algorithm change on the dose parameters needs to be investigated in order to take advantage of previous clinical experience. Whether type-b algorithms over- or underestimate dose was shown to depend on field size, beam energy and electron density [3,7,8]. Thus, results from comparative dosimetric studies for diverse radiation treatments cannot be automatically translated to dose distributions in lung tissue for breast cancer treatment.

Studies for breast cancer treatments confirmed the impact of the lung density on the accuracy of the dose determination [7,9]. Deviations between lung dose distributions determined by the explicit and correction based algorithms were larger in cases of DIBH compared to FB for tangential 6 MV beams [9]. Dosimetric differences for commonly used field in field techniques utilizing different beam energies as well as for treatment techniques of more advanced breast cancer including lymph nodes were not examined.

In this work a comparative dosimetric study was performed of the impact of the clinical implementation of the deterministic radiation transport algorithm on the lung dose estimation for tangential as well as loco-regional treatment of breast cancer. The effect of the lung density on the dose determination was investigated by considering clinical plans for FB as well as DIBH. The lung density in DIBH CT scans for a large population was evaluated in order to quantify the variations. The cases with lowest lung density were identified and the corresponding dose distributions studied in detail with MC method as a reference.

2. Method and materials

2.1. Clinical material

Fourteen patients with left sided breast cancer having both DIBH and FB CT scans were included in the dosimetric study. The scans were acquired with 3 mm slice separation on a Toshiba Aquillion LB CT-scanner (Toshiba Medical Systems). The double scans were motivated clinically by the newly installed breathing adaptation system, the Varian real-time position management system (RPM, Varian Medical Systems). The FB CT scan were supposed to enable treatment without adaptive breathing in case of system failure. Five out of fourteen patients underwent loco-regional (LGL) treatment with tangential fields covering the breast tissue and anterior-posterior fields covering supraclavicular lymph nodes. Rest of the patients underwent radiotherapy of breast cancer by tangential fields covering the breast tissue.

The tumor was delineated by physicians and lung tissue was automatically defined by the clinical segmentation wizard in Eclipse treatment planning system. The prescribed dose was 50 Gy at 2 Gy per fraction with at least 95% isodose covering the PTV. The treatments were planned with 6 MV and 15 MV photon beams delivered by Varian accelerator with a static multileaf collimator (MLC). Two treatment plans, one on the FB CT scan and one on the DIBH CT scan, were prepared for each patient.

The lung tissue densities were evaluated for the fourteen patients with double CT scans as well as for a large population of 157 breast cancer patients treated with DIBH technique during one year. The two cases of lowest lung density identified in the large population, one for LGL treatment and one for breast treatment, were added to the dosimetric study.

2.2. Evaluation of lung density variations

The lung density was determined for each CT scan as the average lung density in a two dimensional rectangular region of interest (ROI) in a transversal plane. The ROI was placed within the 15% isodose line and the size was at least 20 $\times$ 20 pixels (1 mm resolution). The ROI was placed in the isocenter plane of both the LGL and breast treatment plans. For the LGL cases the isocenter plane was located at the junction between the tangential fields (covering

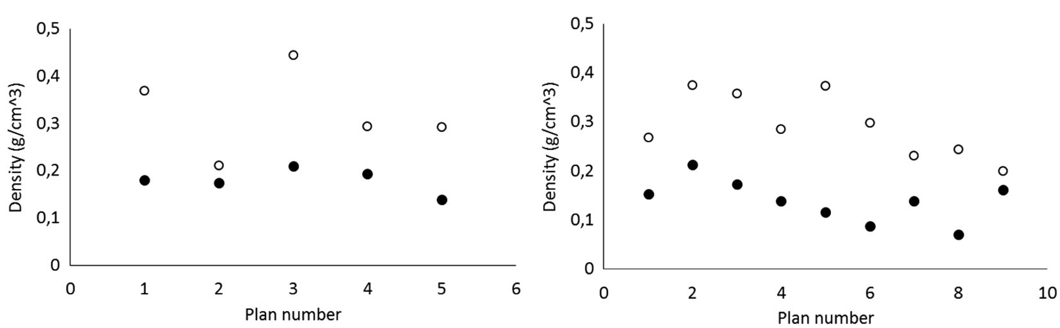

Fig. 1. The lung density in the isocenter plane for the patients given LGL (left) and tangential breast (right) treatments with plans for FB (open circles) and DIBH (filled circles).

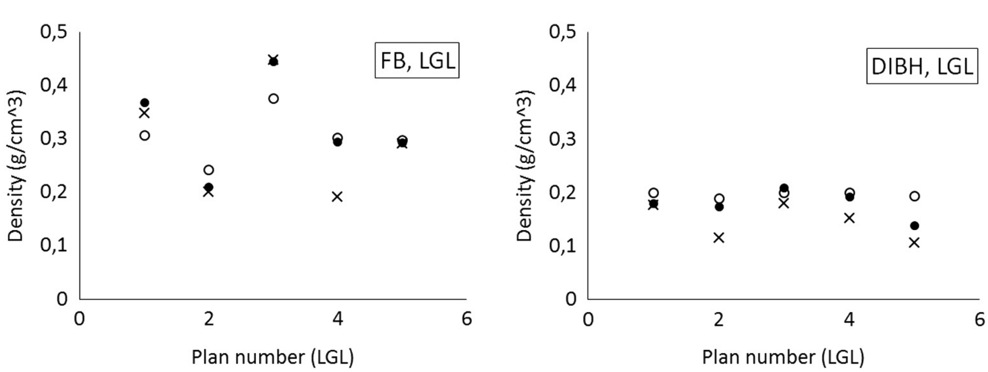

Fig. 2. The lung density for the 5 LGL cases, FB (left) DIBH (right), measured at three different planes: isocenter (filled circles); caudal plane across tangential fields (crosses); cranial plane across anterior/posterior field (open circles).