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A comparison between radiation therapists and medical specialists in the use of kilovoltage cone-beam computed tomography scans for potential lung cancer radiotherapy target verification and adaptation

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Target volume matching using cone-beam computed tomography (CBCT) is the preferred treatment verification method for lung cancer in many centers. However, radiation therapists (RTs) are trained in bony matching and not soft tissue matching. The purpose of this study was to determine whether RTs were equivalent to radiation oncologists (ROs) and radiologists (RDs) in alignment of the treatment CBCT with the gross tumor volume (GTV) defined at planning and in delineating the GTV on the treatment CBCT, as may be necessary for adaptive radiotherapy. In this study, 10 RTs, 1 RO, and 1 RD performed a manual tumor alignment and correction of the planning GTV to a treatment CBCT to generate an isocenter correction distance for 15 patient data sets. Participants also contoured the GTV on the same data sets. The isocenter correction distance and the contoured GTVs from the RTs were compared with the RD and RO. The mean difference in isocenter correction distances was 0.40 cm between the RO and RD, 0.51 cm between the RTs, and RO and 0.42 cm between the RTs and RD. The 95% CIs were smaller than the equivalence limit of 0.5 cm, indicating that the RTs were equivalent to the RO and RD. For GTV delineation comparisons, the RTs were not found to be equivalent to the RD or RO. The alignment of the planning defined GTV and treatment CBCT using soft tissue matching by the RTs has been shown to be equivalent to those by the RO and RD. However, tumor delineation by the RTs on the treatment CBCT was not equivalent to that of the RO and RD. Thus, it may be appropriate for RTs to undertake soft tissue alignment based on CBCT; however, further investigation may be necessary before RTs undertake delineation for adaptive radiotherapy purposes.

Introduction

The treatment of lung cancer is a complex process that is influenced significantly by treatment and patient uncertainties, such as respiratory motion, target volume motion, tumor size changes, and daily setup variations.[1] Improving the methods for identifying and correcting these errors would aid in improving precise treatment delivery.[2]

Image-guided radiation therapy for lung cancer has undergone significant advances, moving from traditional 2-dimensional (2D) orthogonal imaging to Kilovoltage cone-beam computed tomography (kVCBCT). A 2D treatment verification involves daily pretreatment alignment of 2D port films with planning port films (or digitally reconstructed radiographs) using bony anatomy structures for alignment. Uncertainty is inherent in 2D treatment verification owing to the uncertainty of using 2D images to position a 3D tumor volume, using bony anatomy as a surrogate for the tumor. kVCBCT is a useful image guidance tool that can be used for the verification of treatment position for lung tumors as it provides 3D visualization of the gross tumor

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volume (GTV) and provides soft tissue information.[3] The study by Yeung *et al.*[3] concluded that localizing the tumor for treatment verification resulted in improved accuracy of 2 to 5 mm than using bony anatomy as a surrogate for the tumor volume. The study also demonstrated that tumor localization provides improved target coverage and decreased dose to critical structures.

A study by Galerani *et al.*[4] investigating the dosimetric effect of online kVCBCT soft tissue image guidance for lung cancer radiotherapy concluded that soft tissue correction improves the accuracy of treatment delivery. This study demonstrated that without soft tissue verification using cone-beam computed tomography (CBCT), the overall target dose coverage would be reduced on the treatment plan.

In Australia, radiation therapists (RTs) are responsible for the simulation, planning, and treatment of all radiotherapy patients, including treatment verification without radiation oncologist (RO) supervision. To enable a workflow where soft tissue matching based on identification of the tumor on CBCT can be used daily, RTs need to perform the soft tissue alignment without immediate review by a RO. The aims of this study were to determine (1) whether the RTs' abilities were equivalent to those of an RO and a radiologist (RD) in alignment of the CBCT with a simulation computed tomography (CT), based on the RO-defined GTV outline, (2) whether RTs' abilities were equivalent to those of an RO and an RD in the delineation of lung cancer GTV, and (3) if choice of window level affected either result.

Methods and Materials

Patient data

The kVCBCT data sets for the first fraction of treatment of 15 patients who had completed a radical course of radiotherapy for lung cancer were selected. To be included in the study, patients should have had a clinical diagnosis of lung cancer, received a radical course of radiotherapy, had no surgical intervention, and had a kVCBCT verification image acquired on the first fraction of treatment. All patients' were treated using an Elekta Synergy linear accelerator (Elekta, Sweden) with kVCBCT capability (X-ray Volumetric Imaging). The kVCBCT was reconstructed on 2-mm slices to match the planning CT scan. The data sets were deidentified and given a unique study code. This study was approved by the hospital ethics committee.

Participant selection

Overall, 13 RTs were recruited by circulating a department-wide e-mail requesting expressions of interest for participation in the study. Of the 13 participants, 10 completed the study. Participants were chosen based on their level of experience to ensure representation across all experience levels. The details of the RT participants have been summarized in Table.

An RO lung specialist and an RD were also recruited to the study to provide expert baselines for comparison. The RD was a specialist in thoracic region cases with radiotherapy contouring experience.

Tumor alignment and correction

The RTs, RO, and RD were asked to align the CBCT to the RO-defined GTV that was outlined during treatment planning. The CT scan including the planning structures was initially fused with the kVCBCT before participant involvement to enable the tumor alignment and correction. Only the GTV and not the planning CT scan itself was able to be viewed during the alignment and correction process. To perform the alignment, the RTs were instructed to manually manipulate the image by adjusting the window width (W) and window level (L) values of the CBCT to produce an optimal viewing platform for them to perform the alignment. The alignment was performed using the simulation and review system Focal (Elekta, Sweden) as it mimicked treatment conditions. The alignment was performed with only translational isocenter corrections to simulate the process on the treatment machine. The magnitude of the distance of the resulting correction was calculated and has been referred to throughout this article as the "isocenter correction value." Both window-level and isocenter correction values were recorded on a data record sheet.

Table 1
Details of the RT participant group

Radiation therapist grade	
Lowest	2
Highest	4
Years of experience	
Minimum	3
Maximum	20
Average	6.5

GTV delineation

The GTV delineation was carried out using the Focal Contouring System. The kVCBCT scans acquired for treatment verification were transferred from the X-ray Volumetric Imaging system to Focal Contour System. All participants were asked to contour the GTV as defined in The International Commission on Radiation Units and Measurement Report 50.[5] All participants were supplied with a guide on using the Focal Contouring System.

Each participant was instructed to use the same window values as they used in the tumor alignment process. Each participant was allocated a unique contour code. Participants were blinded to the contours generated by the other participants. Once the participants completed their contouring, they were asked to record the window-level settings they had used during the process.

In total, 180 contours were generated by the 12 participants. There is no standard set of metrics available for use in comparing radiotherapy lung contours; however, 3 metrics that have been commonly used in previous studies[6] include the centre of volume (COV), volume, and concordance index (CI). CI is defined as the ratio of the intersection and union volume of 2 delineated structures.[7,8] The CI is a measure of the agreement between 2 structures, in this instance, the GTV, defined as the ratio of intersection volume and the union volume. A CI of 1.0 indicates that full overlap exists, and hence there is perfect agreement between the 2 volumes being compared. A CI of 0.33 is an indication that only half of the volumes intersect with one another. These metrics were calculated for each kVCBCT data set using Computational Environment for Radiotherapy Research (Washington University, St Louis) and in-house software using MATLAB (The MathWorks Inc. 2007).

Window level correlation

To determine whether window level was associated with differences in tumor alignment and correction or GTV delineation, the differences in window level (W and L) between the RTs, RO, and RD were correlated with these differences.

Statistical analysis

For the isocenter correction and CI measurements, a 5-mm tolerance margin was applied to the error range between the RO and RD measurements (referred to as "RO and RD reference error range" throughout this article). This clinical margin was applied to these measurements as 5 mm is the clinical expansion of the internal target volume to the planning target volume used for treatment planning. This margin accounts for setup error and other delivery uncertainties and is therefore the tolerance for soft tissue verification. The differences between the RTs, RO, and RD were then calculated for each of these measurements.

For tumor alignment and correction analysis, 95% CIs were constructed for each participant and patient for all metrics. Mixed models with crossed random effects (using participants and patients as the random effects) were used to obtain an overall average of differences between the RTs, RO, and RD. If the upper bound of the 95% CI was lower than the RO and RD reference error range, then this was deemed as equivalent.

A log transformation of the differences was utilized for the COV measurements to achieve normality of the differences in the polarity of the values. This was not necessary for the other measurements.

Linear regression models were performed for each patient separately to analyze window level. In all models, the dependent variable was the measurement and the independent variable was the difference in the W and L values between the RT, RO, and RD. Two models were run for each patient, the first including only W and L in the model. The second model included W, L, and an interaction between W and L (W*L) to determine whether the W and L values were dependent on each other.

Results

Tumor alignment and correction

The difference between isocenter corrections was determined in Focal Contouring System for each RT participant relative to the RO and RD, and this isocenter correction distance was compared with the RO and RD reference error range. This difference expressed as the isocenter correction for each kVCBCT patient data set has been summarized in Fig. 1. The mean error in isocenter corrections was 0.40 cm between the RO and RD,