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# INDIVIDUALIZED MARGINS IN 3D CONFORMAL RADIOTHERAPY PLANNING FOR LUNG CANCER: ANALYSIS OF PHYSIOLOGICAL MOVEMENTS AND THEIR DOSIMETRIC IMPACTS

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**Abstract—In conformal radiotherapy planning for lung cancer, respiratory movements are not taken into account when a single computed tomography (CT) scan is performed. This study examines tumor movements to design individualized margins to account for these movements and evaluates their dosimetric impacts on planning volume. Fifteen patients undergoing CT-based planning for radical radiotherapy for localized lung cancer formed the study cohort. A reference plan was constructed based on reference gross, clinical, and planning target volumes (rGTV, rCTV, and rPTV, respectively). The reference plans were compared with individualized plans using individualized margins obtained by using 5 serial CT scans to generate individualized target volumes (iGTV, iCTV, and iPTV). Three-dimensional conformal radiation therapy was used for plan generation using 6- and 23-MV photon beams. Ten plans for each patient were generated and dose-volume histograms (DVHs) were calculated. Comparisons of volumetric and dosimetric parameters were performed using paired Student t-tests. Relative to the rGTV, the total volume occupied by the superimposed GTVs increased progressively with each additional CT scans. With the use of all 5 scans, the average increase in GTV was 52.1%. For the plans with closest dosimetric coverage, target volume was smaller (iPTV/rPTV ratio 0.808) but lung irradiation was only slightly decreased. Reduction in the proportion of lung tissue that received 20 Gy or more outside the PTV (V20) was observed both for 6-MV plans (−0.73%) and 23-MV plans (−0.65%), with $p = 0.02$ and $p = 0.04$, respectively. In conformal RT planning for the treatment of lung cancer, the use of serial CT scans to evaluate respiratory motion and to generate individualized margins to account for these motions produced only a limited lung sparing advantage.** 

*Key Words:* **Movements, Lung tumor, Radiation therapy.**

## INTRODUCTION

Lung cancer, 80% of which are non-small cell lung carcinoma (NSCLC), is the leading cause of cancer mortality in both women and men in North America. In 2006, the estimated incidence of lung cancer in the United States was 174,470 cases and the estimated mortality was 162,460 deaths.[1] The corresponding lung cancer incidence and mortality in Canada was 22,700 cases and 19,300 deaths.[2]

Thoracic irradiation is an integral treatment modality for patients with non-metastatic NSCLC. However, many patients continue to experience local-regional failure after treatment.[3] Distinct from other anatomical sites like cervix or head-and-neck carcinomas, local control and survival of lung cancer remain modest despite technological advances in radiation therapy and systemic therapy use.[4] These outcomes support the need for continued efforts to improve the quality and accuracy of radiation delivery.

The evaluation of the movements induced by respiration[5–11] and cardiac motions[9,12] confirms that thoracic tumors may move significantly, impacting on tumor localization. This movement is considered unpredictable by some authors.[13] To include tumor movement, the simple use of a margin by expansion of the contoured volumes may not only produce geographical misses but may also include excessive healthy lung parenchyma.[14] This could lead to increased toxicity without improving local control. Various approaches have been evaluated to improve the evaluation and inclusion of cardiorespiratory motion in treatment planning and delivery for lung cancer.[5,6,14–18] These approaches have included respiratory correlated planning data acquisition and systems to track tumor mobility during treatment. For most of these methods, delay between position acquisition and radiation delivery remains a challenge. Synchronized Moving Aperture Radiation Therapy (SMART) using dynamic multileaf collimation is under development, based on the concept of the average tumour trajectory.[19] While these strategies have the potential to improve precision in lung cancer treatment delivery, clinical data supporting their use in routine clinical practice have remained limited.

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In modern radiation oncology practice, computed tomography (CT) is a widely available modality for image-based treatment planning and dose distribution calculations. However, CT imaging provides only a static image of a dynamic organ in motion. Cardiorespiratory movements will therefore have an impact on the dose delivered to a moving target compared to the planned dose distribution. The current analysis examines the use of serial CT scans to evaluate physiologic motion and to generate individualized margins in target volume definition for lung carcinoma. In this report, comparisons of volumetric and dosimetric parameters using multiple vs. a single CT scan are performed to identify any advantages that may be associated with treatment planning for lung cancer.

## METHODS

*Patient subjects*

This explorative and feasibility study was developed with consideration of available institutional resources. Fifteen patients with non-metastatic NSCLC undergoing CT-based planning for radical radiation therapy were accrued between November 2003 and April 2004. Patients with previous thoracic surgery, with allergies to contrast product, with distant metastases, or palliative treatment intent were excluded from study enrolment. The study was approved by the institutional research review board. The mean patient age was 66.5 years, ranging from 51 to 79 years. The ratio of males to females was 10:5 (Table 1).

*Planning CT acquisition*

Each subject underwent 5 CT scans using a Siemens Somatom Emotion™ CT single-slice helical scanner (Siemens Medical Systems, Palo Alto, CA). CT data were acquired in the same session to avoid interfractional motion component in this intrafractional study. Scan speed was 1.25 rotations per second. Patients were immobilized in Vac-Lok™ system (MEDTEC, Orange City, IA) with arms raised and instructions to breath normally during the scanning procedure. The first 3 scans were performed with 3-mm contiguous slices to reduce x-ray exposure to the patients, speed up the process, and limit heating of the tube, a potential problem with repeated acquisition. The fourth scan was performed with 2-mm slices and served as the reference scan for this study. The fifth and final scan was performed using 2-mm slice thickness and contrast enhancement using Visipaque™ (Iodixanol, Amersham Health, Piscataway, NJ) intravenous injection. The information from the contrast-enhanced scan was used for tumor and normal tissue contouring and to identify nodal disease and extension to adjacent structures.

Table 1. Patient characteristics

| Patient | Sex | Age (years) | Stage | Primary Site |
|---|---|---|---|---|
| 1 | M | 69 | IIIB | RUL |
| 2 | M | 60 | IIIA | LEFT HILAR + LLL |
| 3 | M | 67 | IIB | LUL |
| 4 | M | 69 | IIIA | RUL |
| 5 | M | 73 | IIIB | RIGHT HILAR |
| 6 | M | 68 | III | LUL |
| 7 | M | 68 | IIIA | LUL |
| 8 | M | 62 | III | LUL |
| 9 | F | 79 | IIIB | LUL |
| 10 | F | 58 | IIIA | RUL |
| 11 | F | 70 | IIIA | LUL |
| 12 | F | 76 | IIIA | RUL |
| 13 | M | 51 | III | RUL |
| 14 | F | 59 | IIIA | RUL |
| 15 | M | 69 | III | RIGHT HILAR |

RUL = right upper lobe; LUL = left upper lobe; LLL = left lower lobe.

*Delineation of GTV and expansion to CTV and GTV*

A single physician contoured the gross target volume (GTV) on all 5 scans in the same session for each patient. During contouring, efforts were made to ensure consistency in volume definition to include and reproduce each structure on each scan, but no attempt was made to correct artefacts due to scanning moving objects.[20] Volumetric reconstruction and comparison of tumor surface were done to increase accuracy. Tight contours were drawn for visible GTV, including suspicious lymph nodes, using the radiologist's description and the contrast-enhanced structures. A preset lung window setting was used for the lung tumor and a preset thoracic window setting for nodes was used for the mediastinum. All image sets of each patient were merged with the reference scan using the structure fusion tools in Philips/ADAC Pinnacle 3® 6.2b radiotherapy planning system (ADAC Laboratories, Milpitas, CA) using the best fit on vertebral bodies at the level of GTV.

For the present study, an 8-mm conformal expansion on each GTV was used as clinical target volume (CTV) to encompass microscopic invasion.[20] The CTV had no correction on anatomic limiting structures (such as bone, blood vessels, pericardium, trachea) to avoid any manual modifications and to maintain the consistency of the volumes. A reference planning target volume (PTV) (rPTV) from the reference CT scan was created using an expansion of 10 mm of the CTV of the reference CT scan (rCTV). While some authors have suggested that smaller margins may be used,[21] in the current analysis, the same margin was used for mediastinal nodes to establish consistency and to maintain automatic expansion.

*CT fusion: "common" and "sum" volumes*

With the fusion process, contours performed on all scans were superimposed on the reference scan, allowing a visual approximation of the excursion of the tumor and the associated volumes through the respiratory cycle. Two new volumes were created (Fig. 1). The "COMMON" volume is defined as the intersection of the individual volumes of