Background

Radiotherapy is a curative treatment of non-small cell lung cancer, and for stage II-III disease is typically delivered in 20-30 fractions. Improving its spatial accuracy and precision is challenging for lung tumours, which move with respiration. Residual uncertainties in tumour position during treatment are accounted for by irradiating tumours and surrounding safety margins to the prescription-dose. The safety margins contain healthy tissues, and if they could be narrowed, tumour doses could be escalated, or toxicity levels reduced in the absence of escalation.

To improve tumour targeting, medical images are required which accurately capture the respiratory motion envelope, and have sufficient soft tissue contrast to differentiate between tumour and healthy tissue. Diagnostic-quality 4D computed tomography (4D-CT) is currently the preferred modality, but its high radiation dose limits it to a single use, one week before treatment. For tumour localization immediately before radiotherapy delivery, cone-beam CT images are used instead, but provide poor image quality.

4D magnetic resonance imaging (4D-MRI) may offer an improvement. MRI has good soft tissue contrast, and unlike CT delivers no radiation dose. Imaging times can therefore be lengthened to provide a more complete representation of tumour motion. New technology enables 4D-MR images to be collected in the treatment room, allowing the tumour position to be monitored before and during each treatment session, potentially enabling treatment beams to track the moving tumour.

Aim

To improve the precision and accuracy of high-dose radiotherapy delivered to stage II-III non-small cell lung cancer using new 4D-MRI techniques. Specifically, I hypothesize that 4D-MRI will allow –

a) More accurate determination of the maximum extent of respiratory motion than achievable using 4D-CT.
b) Consequent reduction of the safety margin when using daily 4D-MRI before treatment.
c) Real-time on-treatment localization of the tumour, facilitating tracked radiotherapy techniques which will result in a useful reduction of margins and safe escalation of prescription doses.

Methods

Initial Development

4D-MRI protocols have been developed to capture tumour movement. Their spatial accuracy, precision and signal-to-noise properties will initially be characterized by collecting images of anthropomorphic phantoms programmed with respiratory-like motion patterns.

Patient data

20 patients will be imaged using MRI, each for two sessions before and during radiotherapy and separated by at least a week (figure 1). To allow comparison with current practice, routine 4D- CT images will also be analysed. Radiotherapy will be standard-of-care.

Work packages and timelines

WP1) Testing of tumour delineation and image quality (0-10 months).

WP2) Quantification of tumour motion (10-16 months).

WP3) Determination of tumour tracking accuracy (16-23 months).

WP4) Planning studies exploring feasibility of dose intensification, using dose accumulation to account for dosimetric effects of residual uncorrected movement throughout treatment delivery (23-31 months).

Anticipated impact and dissemination

I will use 4D-MRI to improve the effectiveness of radiotherapy, and disseminate results through conference presentations and peer-reviewed journals. Findings will form the evidence-base for a phase I/II clinical trial.