Purpose: We propose to overcome the limitations of conventional helical 4D computed tomography (4DCT) using a volumetric 4DCT approach with a 320-slice scanner. This scanner is able to acquire image volumes with 16 cm of superior-inferior coverage with a single gantry rotation and no couch translation, preventing artifacts caused by retrospective image slice sorting. Image volume datasets over multiple breathing cycles can be acquired using this technique.

Methods: A respiration motion phantom containing a cube and two sphere objects was scanned on a 320-slice scanner using a volumetric approach and on a 16-slice CT scanner using a helical scan technique. An irregular breathing pattern taken from a previous patient scan was programmed into the phantom. Volumes and centroid positions of these objects were segmented for volume and displacement measurements. A model was developed which predicted the number of samples of peak-to-peak displacement of a target that could be obtained with a conventional or volumetric scan technique.

Results: Using a volumetric 4DCT scan technique to scan an irregular breathing pattern reduced the percent error in the measured volumes relative to the ground truth volumes of the cube and spheres by as much as 81%. No sorting artifacts or missing slices in these object volumes were present using the volumetric technique, unlike the conventional approach. The model predicted that the helical scan technique was limited to measuring 1-2 displacement samples. This limitation was not present with the volumetric scan technique, with which multiple samples of peak-to-peak displacement can be acquired.

Conclusions: Volumetric 4DCT is a superior scan technique to the conventional helical approach, and its ability to acquire target volumes and displacements more accurately for irregular breathing patterns than the helical approach could help to improve internal target volume definitions for radiotherapy treatment planning.