Purpose: To minimize radiation delivery time for a novel 4D-Volumetric Modulated Arc Therapy (4D-VMAT) system.

Methods: 4D-VMAT enhances radiation sparing of organs at risk (OARs) in breathing patients by preferentially exposing the tumour when it moves away from the OAR. To maximize treatment plan quality, our preliminary implementation of the 4D-VMAT algorithm placed little constraint on the maximum deliverable MU/control point (arc sample). However, the maximum time allowed/control point/arc is restricted as gantry rotation is synchronized to patient respiration. Consequently, to deliver the full MU of a few selected control points, multiple arcs were required resulting in 4D-VMAT radiation delivery times that were 3-5 times greater than 3D-VMAT.

To decrease 4D-VMAT radiation delivery time, a maximum MU/control point constraint was incorporated into our algorithm and the resulting DVHs were compared against the unconstrained 4D-VMAT results. The maximum MU constraint is dependent on tumour motion amplitude, respiratory period, dose rate and fraction size. MU modulation flexibility can be increased by increasing the number of breathing periods in the optimization (i.e. increase gantry rotation time). Our new 4D-VMAT algorithm was tested on a combination of tumour motions (1-2 cm), respiratory periods (2.5-5.5 s) and treatment fractions (2, 15, 20 Gy). Dose rate was 1000 MU/min and prescription was 60 Gy.

Results: For tumour motion of 1 cm, 4D-VMAT can match the fastest 3D-VMAT radiation delivery times without significantly affecting DVHs (2 Gy: 1-2 min, 15 Gy: 5-6 min, 20 Gy: 7-8 min). For 2 cm motion and higher fractional doses of 15 Gy and 20 Gy, 4D-VMAT treatment times were approximately 2 minutes longer than 3D-VMAT (8 min and 10 min respectively). Total plan MU also decreased by 5-30% compared to the unconstrained 4D-VMAT algorithm.

Conclusions: 4D-VMAT can improve treatment plan quality over 3D-VMAT without significantly extending the radiation delivery time.