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Comparing VMAT with IMRT and 3D-CRT for stereotactic body radiotherapy in early lung cancer.

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Introduction: Stereotactic body radiotherapy(SBRT) for early lung cancer results in excellent local control and potentially improved survival,but demands high levels of dose conformality. To achieve this with 3D-conformal radiotherapy(3D-CRT) and intensity modulated radiotherapy (IMRT) large numbers of beams, and non-coplanar techniques are often required. Hence treatment times are long, increasing the risk of patient motion. Volumetric arc therapy(VMAT) may result in improved dosimetric outcomes, and reduce treatment time. We report on a planning study comparing VMAT to coplanar (CP) and non-coplanar (NCP) 3D-CRT and IMRT, and our initial clinical results.

Materials and Methods: Pinnacle VMAT, and CP and NCP 3D-CRT and IMRT plans for delivery on Elekta Linacs of 5 patients were compared.The following dosimetric characteristics were assessed: target coverage(coverage with the prescribed dose and 98% coverage of the PTV), dose conformality (100% conformity indices, D2cm and volume of tissue outside PTV receiving high dose, defined as >105% of prescription dose) and V20 (volume of lung receiving 20 Gy). A minimum of 10-12 beams were used for IMRT and 3D-CRT plans. VMAT plans were single arc with 4 degree spacing. Plans aimed to deliver the prescription dose to at least 98% of the volume, with a V20 ≤ 8% . All patients had peripheral tumours and received 48 Gy in 4 fractions.

Results:

Dosimetric Outcomes

VMAT achieved equivalent radiotherapy target coverage to 3D-CRT and IMRT (>98.2%). However, 3D-CRT plans had a large volume of surrounding normal tissue receiving a high dose (24.0% and 21.3% of the PTV volume for CP and NCP respectively) when compared to VMAT and IMRT plans (3.9% and 4-5% of the PTV volume respectively). 100% conformity indices were lowest for VMAT and NCP IMRT (1.1 for both) and highest for 3D-CRT (1.5 and 1.4 for CP and NCP respectively). D2cm was also lowest for VMAT and NCP IMRT (26.1 Gy and 25.3 Gy) and highest for 3D-CRT plans (29.4 Gy and 28.7 Gy for CP and NCP respectively). V20 was between 4.4 and 6.1% for all plans.

Clinical outcomes

Clinical VMAT treatment time takes 35 minutes, and beam-on time is 8 minutes. With short follow-up (range 4 weeks to 6 months), 1 patient has developed worsening dyspnoea, due to a chest infection. No other Grade 2 or greater toxicity was seen in the other 4 patients.

Conclusions: Clinical implementation of VMAT was successfully demonstrated, and has resulted in fast treatment times for our SBRT lung patients. VMAT plans are similar in quality to NCP IMRT, but are much faster to deliver due to reduced gantry and couch movements. 3D-CRT plans were unable to deliver equivalent dose conformality, and a much larger region of normal tissue was exposed to a high dose when equivalent PTV coverage was achieved.

Parameter	VMAT	3D-CRT CP	3D-CRT NCP	IMRT CP*	IMRT-CP*
PTV Coverage	98.2%	98.2%	98.3%	98.4%	98.4%
V20	4.82%	5.1%	3.9%	5.4%	4.6%
Mean Lung Dose	4.3 Gy	3.9 Gy	4.2 Gy	4.2 Gy	4.4 Gy
High dose Spillage (% PTV volume)	3.9%	24.02%	21.3%	5.2%	4.6%
D2Cm	26.1 Gy	29.4 Gy	28.7 Gy	30.7 Gy	25.3 Gy

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Fiducial markers for liver SBRT using helical tomotherapy MVCT

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Purpose/Objective: To assess the visibility of various fiducial markers for the application in stereotactic body radiation therapy of colorectal liver metastases. Breathing dynamics were mimicked with a 4D phantom and evaluated with helical tomotherapy MVCT.

Materials and Methods: Initially, fifteen types of markers were imaged in a static water environment with MVCT. Poor visible markers on MVCT were eliminated leaving six markers for further evaluation in dynamic conditions.

A 4D motion phantom was developed and validated to perform these measurements. A repetitive motion on the studied markers was applied in a water environment. Peak-to-peak amplitude and frequency was varied to analyze the effect of dynamic conditions on the marker detectability on MVCT of a helical tomotherapy system. A conventional 4D kVCT unit was used as reference.

The detectability was quantified by analyzing the contrast of the fiducial markers on the obtained images. Also, the artifacts on the images caused by the moving markers were analyzed with respect to the amplitude and frequency of the movements.

Results: Best contrast on MVCT was generated by the 'gold sphere' marker, but this marker generated unacceptable artifacts on kVCT. The ‘gold anchor’ marker provided the least artifacts on kVCT; however, visibility on MVCT was limited. All studied fiducial markers had good agreement between the average geometric position and the observed position on MVCT under the studied conditions.

The size and number of the observed artifacts on MVCT were dependent on type of marker and specific dynamic conditions. Artifacts on MVCT improved the marker detectability and helped the observer to determine the center of the markers.

Conclusions: Good detectability of all observed fiducial markers was obtained for the studied dynamical conditions. Good agreement was observed between the geometrical average position of the moving markers with respect to the observed position on MVCT. Artifacts generated by the MVCT-image processing can help in determining the position of the markers.

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Multi-atlas fusion methods for segmentation of head and neck lymph nodes for radiotherapy planning

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Purpose/Objective: Intensity Modulated Radiotherapy (IMRT) treatment planning for head and neck (H&N) cancer requires accurate delineation of target volumes, and these volumes could include several lymph node levels. Manual contouring of lymph nodes, in each CT slice, is a laborious and time consuming task; instead, it is more efficient to first perform automated segmentations and then followed by manual corrections if needed. It is shown in many recent works that the automated segmentations obtained by merging segmentation results obtained from multiple atlases are more accurate and robust than the results from a single atlas. In this work, we evaluate state-of-the-art atlas fusion methods and our recently proposed fusion method for H&N lymph nodes segmentation.

Materials and Methods: The fusion methods compared in this work are: (i) Majority Voting (MV), (ii) Global Weighted Voting (GWV), (iii) Local Weighted Voting (LWV), (iv) Shape Based Averaging (SBA), (v) Simultaneous Truth And Performance Level Estimation (STAPLE), and (vi) a Markov Random Field (MRF) based LWV method that we have proposed recently, which performs simultaneously both fusion and smoothing (LWV+MRF). In this evaluation, we consider 10 lymph node structures for automated segmentations: (i) IB-Left, (ii) IB-Right, (iii) IIA-Left, (iv) IIA-Right, (v) IIB-Left, (vi) IIB-Right, (vii) III-Left, (viii) III-Right, (ix) IV-Left and (x) IV-Right. The dataset contains 12 atlas images and 8 patients' images to be segmented. For each image to be segmented, results obtained from 12 atlases are merged using all the above methods.

Results: The quantitative evaluation is performed over the entire dataset, using two metrics; (i) Dice Similarity Measure (DSM): This is a commonly used metric that computes the measure of overlap (in %) between the ground truth and automated segmentations. (ii) Number of connected regions per label: The output segmentations of each lymph node should ideally contain a single contiguous region. Hence, we evaluate the fusion algorithms also based on the number of connected regions it creates per structure. Figure 1 presents box plots of average DSM computed across all lymph nodes. Among all fusion schemes, our LWV+MRF method provided the best results followed by LWV, GWV, MV, SBA and STAPLE respectively. Table 1 presents the average values of number connected regions per structure. Notice that LWV+MRF provided the best results, in terms of both these metrics. We also performed Wilcoxon signed rank test, and it is found (with p= 0.05) that the improvements in DSM from LWV+MRF when compared to the rest of the methods are statistically significant.