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A novel quantitative metrics for assessing IMRT plan complexity: A virtual phantom study

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Introduction: In IMRT treatment planning, there has been little interest in defining parameters to assess the quality of the treatment plan using quantitative metrics. This work was carried out for the first time to develop a series of virtual phantom to assess the IMRT planning complexity. Methods: A series of virtual phantoms were designed by using MATLAB® software (MathWorks, Natick, MA, United States), simulating a cylindrical-shaped planning target volume (PTV) surrounded by two cylindrical-shaped organ-at-risk (OARs). The separation of PTV-OARs was designed to have variable distances. Three different IMRT techniques were investigated: step-and-shoot IMRT (SSIMRT), volumetric modulated arc therapy (VMAT) and helical tomotherapy (HT). Later, there were two complexity metrics being established to quantify the complexity of an IMRT treatment plan. The first was the wiggliness of dose profile for treatment plan. This was chosen as an approach to represent the complexity of a treatment plan and it was quantified as spatial complexity matrix (SCM). Both the dose profile and 3-D surface plot for 120 IMRT plans were plotted and analysed by using MATLAB® software. The second, the metric of spatial frequency ratio (SFR) was established. The proportion of rapidly varying dose with distance in a treatment plan was used to predict the complexity of a plan. The 1-D power spectral density (1D PSD) for the dose surface was generated to characterise the high and low frequency components of the dose surface. Results: For SCM analysis, the dose profiles and 3-D plots for 7-field SSIMRT plans presented a noticeable seven dose peak with higher value of maximum dose compared with VMAT and HT. The planning complexity in SSIMRT was decisive in the outcome of comparison against VMAT and HT. The calculated SCM value for SSIMRT is found to be higher than VMAT and HT. For SFR analysis, HT was having the highest SFR, followed by VMAT and SSIMRT. The higher SFR indicated that the high frequency dose was varying rapidly with the distance. This was then considered a good surrogate to represent the level of complexity for a treatment plan. Conclusion: This study has demonstrated the complexity assessments on all the IMRT plans generated using the virtual phantoms. The 3-D surface plots and 1D PSD plots generated in this study clearly presented a landscape view of the dose surface roughness and the spatial variation of high frequency dose component. The results of these studies have shown for the first time, the feasibility of using the self-developed metrics of SCM and SFR on virtual phantoms for assessing plan complexity.

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