Computational analysis of interfractional anisotropic shape variations of the rectum in prostate cancer radiation therapy

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論 文 名：Computational analysis of interfractional anisotropic shape variations of the rectum in prostate cancer radiation therapy
（前立腺癌放射線治療における照射間の非等方的直腸形状変化の解析）

区　　分：甲

論 文 内 容 の 要 旨

The quality of radiation therapy in prostate cancer treatments is determined by many factors including the dose delivered to the organs at risks (OARs) such as the rectum, which could be affected by the uncertainties of the rectum. The rectal position uncertainties, which could cause toxicities (e.g., rectal bleeding, fecal incontinence), mainly comes from the rectal motion due to the changes in rectal filling. Currently, the two common methods used to study the rectal motion were tracking the changes in rectal volume and evaluating the translation and rotation errors of the rectum. However, the more complex problem of internal organ motion involve changes in the shape (shape variations) of the organ especially along the anterior direction of the rectum. Therefore, the shape variations of the rectum, especially along the anterior direction, need to be investigated.

This study is aimed to analyze the uncertainties of the rectum and the regions in which the rectum overlapped with the planning target volume (PTV) along the anterior wall (referred to as the rectum-overlap PTV (ROP) region) due to the anisotropic shape variations by using a statistical point distribution model (PDM) for prostate cancer radiation therapy. The idea was to apply the PDM to the rectum contours that were delineated on planning computed tomography (CT) and cone-beam CT (CBCT) images of the patients and calculate the standard deviations (SDs) of systematic and random errors of the whole rectum and the ROP regions. The application of the proposed method was assessed by comparing the dose evaluation indices between the original plan and the plan which used a planning risk volume (PRV) margin to the rectum, derived from the results of the proposed method.

The population SDs of the random errors for the whole rectum along all directions obtained by the proposed method were larger than 1.0 mm. On the other hand, the population SDs of the systematic errors for the whole rectum were smaller than 1.0 mm along the posterior, left and right directions. The deviations along the superior direction was largest for the systematic errors, while the deviation along the inferior direction was largest for the random errors. The population SDs of systematic error for the ROP regions were larger than 1.0 mm along the superior and inferior directions, while the population SDs of random errors for the ROP regions were larger than 1.0 mm except along the right and posterior directions. The dose evaluation study showed that the V_{75} for the rectum in PRV-based plans was significantly smaller ($p < .001$) than those of the original plans. However, the V_{40} for the rectum in PRV-based plans were significantly larger ($p < .001$) than those of the original plans. On the other hand, the D_{98} to the CTV showed no statistical significant difference between original and PRV-based plans ($p > .001$).

In conclusion, the anisotropic shape variations analysis, especially in the ROP regions, should be considered in the analysis of rectum uncertainties and the determination of PRV margins for the rectum associated with the acute toxicities.