Editors' pick

A biomechanical finite-element model to generate a library of cervix CTVs

Chris Beekman, Suzanne van Beek, Jikke Stam, Jan-Jakob Sonke, Peter Remeijer

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What was your motivation for initiating this study?

Various organs in the pelvic region such as the bladder, the cervix-uterus and the rectum are subject to substantial daily anatomy changes. This poses a challenge for accurate external beam radiotherapy of these sites. Without daily adaptation, large planning target volume (PTV) margins would be required in order to obtain adequate coverage, and these large PTVs would cause considerable toxicities. Therefore, the library of plans (LoP) strategy, which is based on a series of clinical target volumes (CTVs), has been devised. For cervical cancer, the patient is scanned twice: once with a full bladder and again on an empty bladder. The series of CTVs is currently generated by the scaling of a deformation vector field that maps the anatomy of the bladder from full to empty. However, this method often results in physiologically implausible intermediate shapes.

Therefore, in this study a new method to construct a library of cervix CTVs was proposed. Variations in the shape and position of the cervix CTV are primarily caused by variation in bladder filling, while variations in rectal filling also play a role. In this study we approximated these inter-organ dependencies by application of a biomechanical model. Our final goal was to use this model to generate a series of anatomically plausible cervix CTVs, which could be used for the LoP strategy.

What were the main challenges during the work?

The main challenge of this work was the translation of the patient's anatomy to a robust biomechanical model that accurately reproduced observed cervix CTV deformations. In particular, the magnitude of the deformation posed challenges. For example, to obtain realistic deformations, we had to allow for sliding interfaces between the modelled organs. This introduced nonlinearities to the model, which could impede convergence.

What is the most important finding of your study?

We created a biomechanical model that can be used to generate anatomically plausible intermediate shapes that form between empty and full bladder anatomy for a LoP strategy in cervical cancer radiotherapy. The validity of the model was tested on an independent dataset that consisted of a series of MRI scans that covered empty to full bladder anatomy. With respect to the current method, the proposed biomechanical method reduced residual errors by up to 3mm on average. For individual cases, regional residual error reduction could be as large as 8mm.

What are the implications of this research?

A reduction in residual errors means improved coverage of the observed CTV by the library CTV. This potentially allows for PTV margin reduction while adequate target coverage is maintained. Since the CTV volume is quite large in cervical cancer, even a relatively small margin reduction could translate into quite a large volume reduction and thus potentially reduce toxicity of the treatment. Furthermore, the biomechanical model tracks volumetric deformations, and this feature could be used to calculate dose accumulation in a LoP setting.

Chris Beekman
Department of Radiation Oncology
The Netherlands Cancer Institute
Amsterdam, The Netherlands.
c.beekman@nki.nl