



PHYSICS

3rd ESTRO Physics Workshop: Science in Development

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Workshop: computational methods for clinical target volume definition

Among the three radiotherapy target volume concepts – gross tumour volume (GTV), clinical target volume (CTV) and planning target volume (PTV) - the definition of the CTV has arguably made the least progress over the past decades. Definition of the GTV has improved through use of novel imaging techniques, and improved image guidance has led to smaller PTVs. CTV definition is particularly complex as the CTV, which accounts for microscopic extensions of the tumour beyond the GTV, is by its nature invisible. Thus, CTV delineation does not amount to an image segmentation problem alone but requires knowledge of the patterns of tumour progression. CTV definition has attracted relatively little attention in the medical physics community and is left to the radiation oncologist to work out. However, medical physics can contribute through the development of computational methods with the goal of automating current guidelines, improving consistency in delineation, and ultimately improving definition of the CTV.

The workshop brought together an international group of medical physicists and radiation oncologists working in the field of CTV definition. The initial goal was to discuss prior and ongoing work on computational methods for CTV definition. Additional goals were to initiate collaborations, identify areas of future research, and raise awareness within the European Society for Radiotherapy and Oncology (ESTRO) of the role that medical physics plays in CTV definition.

In the first session, CTV definition for gliomas was discussed. Glioblastomas are known to infiltrate the brain that appears normal, far beyond the GTV visible on MRI. However, microscopic tumour invasion is not isotropic but is influenced by anatomical barriers such as the falx, ventricles and major sulci. Previously, phenomenological tumour growth models were developed, which effectively defined a geodesic distance from the GTV. Use of these in combination with automated segmentation of relevant brain anatomy using convolutional neural networks (CNN) can lead to automated GTV-to-CTV expansion that is consistent with the complex neuroanatomy. In collaboration with RaySearch, a first module for CTV delineation support is being developed.

CTV definition for head & neck cancer was the topic of the second session. The session started with an invited presentation by Vincent Grégoire, Head of the Radiation Oncology Department Centre Léon Bérard, Lyon, France and Professor in Radiation Oncology at Université Catholique de Louvain, Brussels, Belgium. He provided a summary of current clinical practice and challenges in head & neck cancer. In addition to a primary tumour CTV to account for tumour infiltration of adjacent tissues, the CTV includes electively irradiated lymph-node levels that are at risk of harbouring occult metastases. During the participant pitches, recent work on use of CNN was discussed, both for automatic segmentation of the GTV as well as to learn the complete CTV contour from examples using CT and GTV contours as input. In addition, work was presented on the modeling of lymphatic progression and the estimation of the probability of microscopic involvement of lymph-node levels using Bayesian networks.

In the third session, challenges in CTV definition for other sites including oesophageal and lung cancer were discussed. For lung cancer, CTV definition in the context of adaptive therapy represents an additional challenge. It remains unclear whether a shrinking GTV implies a shrinking CTV. Esther Troost, chair of the Department of Radiotherapy and Radiation Oncology at University Hospital Carl Gustav Carus, Dresden, Germany, presented oesophageal cancer as the primary tumour site, in which the CTV prior to treatment and following neoadjuvant radiochemotherapy could be assessed. Moreover, the results of a contouring challenge were presented. The challenge focused on the GTVs and CTVs before and during treatment of non-small-cell lung cancer (NSCLC) and head & neck squamous-cell carcinoma (HNSCC). The participants decided to create a prospective database on patients who had undergone treatment adaptation and to discover the sites of potentially recurrent tumour in these patients.

The final session was dedicated to the question of how uncertainty in the extent of the tumour can be accounted for in treatment planning. Currently, the definition of the CTV is binary. Typically, treatment planning aims to deliver a prescribed dose to all parts of the CTV while minimising dose outside the CTV. However, in the example of glioblastoma, tumour infiltration is continuous. The tumour-cell density decreases with distance from the GTV, but tumour cells may be found anywhere in the brain. This appears to contradict the binary nature of CTV definition. In the example of head & neck cancer, the probability of microscopic involvement varies continuously between lymph-node levels.

In summary, all participants perceived the workshop as highly stimulating. As a result of the workshop, testing of a first module for automated CTV definition in gliomas across multiple institutions is planned. In the domain of head & neck cancer, collaborations to build larger data sets to model lymphatic progression and to train on and validate segmentation models have been discussed. We are convinced that CTV definition deserves more attention as a research topic and that, within a multi-disciplinary effort, medical physics can make a significant contribution to automated, more consistent, and eventually improved CTV definition. If you think so too and would like to join our collaborative efforts, please get in touch!

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