Report on ESTRO Technology Transfer Grant (TTG)

Information on the TTG

- *ESTRO travel grant*
- *30.6.2019 - 21.7.2019*
- *Host institute: UMCG, the Netherlands*

Proton therapy treatment for lung cancer patients: the use of deformable image registration for dose accumulation

With proton therapy, high dose conformity to the target can be achieved while sparing normal tissue. This makes it especially suitable for tumours with many nearby organs at risk (OARs). Patients with non-small-cell lung cancer (NSCLC) in particular could benefit from this modality due to the critical structures that surround the tumour (lung, heart, oesophagus and spinal cord). On the other hand, the anatomy of NSCLC patients typically changes during treatment, not only within a fraction (e.g. due to breathing motion) but also between fractions (tumour growth/shrinkage, weight changes) and the proton dose is sensitive to density changes in the beam path. This means that collection of regular control images and careful dose accumulation are particularly important for these patients.

Dose accumulation maps the dose observed in the on-treatment CT back to the planning CT. It is useful to evaluate overall treatment dose in the presence of anatomical variations, to compare it with the planned dose and to make treatment decisions, for example, whether adaptation is necessary. To collect this dose-accumulation data in the lung, deformable-image registration (DIR) is necessary. Several DIR algorithms have been implemented in treatment planning systems. However, different DIRs give different results [1–3]. As it is very difficult to define a ground truth in a real patient image, the achievement of quality assurance of these algorithms remains challenging. Nowadays, in most clinics, only one DIR algorithm is available and it is impossible to quantify its error. At University Medical Center Groningen (UMCG) and the Paul Scherrer Institute (PSI), we have access to six commonly used DIRs: one from Mirada medical imaging software, two from RayStation (Anaconda and Morpheus), one from Velocity and two from Plastimatch (B–spline and Demon). This huge variety of algorithms enables us to investigate the variations between different DIRs.

In a previous project (also kindly supported by the European SocieTy for Radiotherapy and Oncology (ESTRO) travel grant) we investigated the dosimetric effects of 4D dose calculations using different DIRs for liver-cancer patients [4]. We could show that none of the evaluated DIRs matched the ground truth perfectly. The latter had been previously generated using the motion extracted from 4D MRI data applied to static CT images. In this follow-up study we have focused on the inter–fractional changes in NCSLC patients, for which we have a deep-inspiration breath-hold (DIBH) planning CT and a set of nine on-treatment DIBH CTs per patient.

The application of six algorithms enabled us to investigate their differences in results (geometrically and dosimetrically). Preliminary results show remarkable changes between the same CT pair. Gross tumour volume (GTV) structures propagated with different DIR algorithms differ between each other and do not match the re-contoured GTV on the on-treatment CT (Figure 1).

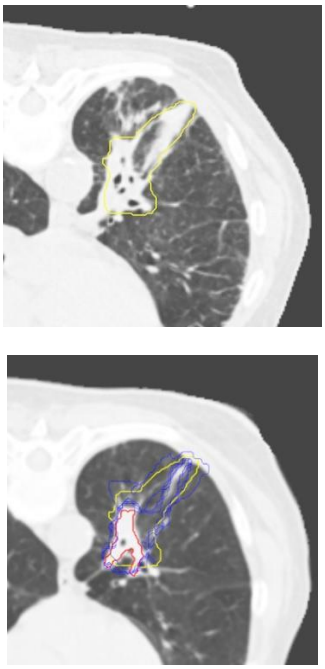

Figure 1: On-treatment CT (at the end of treatment course) of one example patient with GTV contours: initial GTV contour is shown in yellow; manual re-contour in this CT is shown in red; and deformable propagated GTV contours obtained with five different DIR algorithms are shown in blue.

Also, the recalculated dose on the same on-treatment CT, mapped back to the planning CT, differs between DIR algorithms (Figure 2).

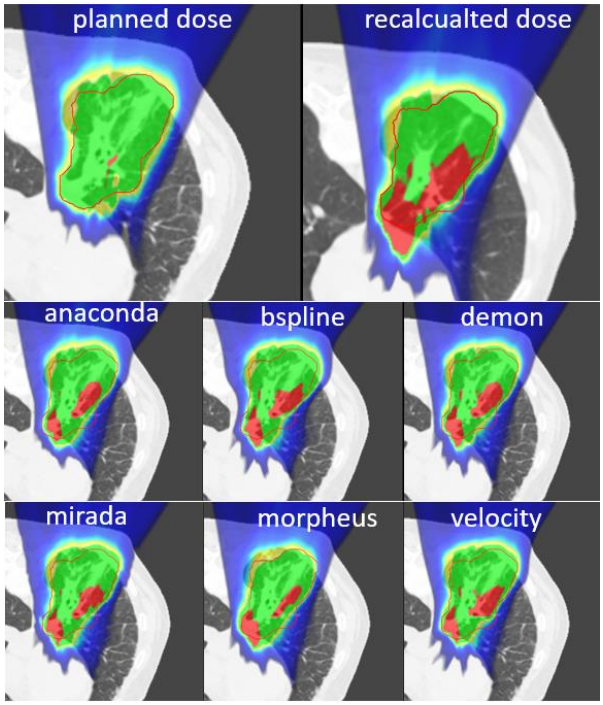

Figure 2: Top: planning CT with planned dose and on-treatment CT with recalculated dose. Centre and bottom: the recalculated dose mapped back to the planning CT and shown in six different DIR algorithms.

Results will now be systematically evaluated to produce an estimate of the error caused by the DIR algorithm.

The ESTRO travel grant enabled us not only to extend the number of DIR algorithms that were included in our study, but also to exchange ideas and challenges regarding DIR, how to quantify its errors, and most importantly, how to use this information in clinics (Figure 3).

Figure 3: Important meeting for brainstorming and the exchange of ideas.

[1] Zhang L, Wang Z, Shi C, Long T, Xu XG. The impact of robustness of deformable image registration on contour propagation and dose accumulation for head and neck adaptive radiotherapy. J Appl Clin Med Phys 2018;19:185–94. doi:10.1002/acm2.12361.

[2] Kadoya N, Nakajima Y, Saito M, Miyabe Y, Kurooka M, Kito S, et al. Multi-institutional Validation Study of Commercially Available Deformable Image Registration Software for Thoracic Images. Int J Radiat Oncol 2016;96:422–31. doi:10.1016/j.ijrobp.2016.05.012.

[3] Miura H, Ozawa S, Nakao M, Furukawa K, Doi Y, Kawabata H, et al. Impact of deformable image registration accuracy on thoracic images with different regularization weight parameter settings. Phys Medica 2017;42:108–11. doi:10.1016/j.ejmp.2017.09.122.

[4] Ribeiro CO, Knopf A, Langendijk JA, Weber DC, Lomax AJ, Zhang Y. Assessment of dosimetric errors induced by deformable image registration methods in 4D pencil beam scanned proton treatment planning for liver tumours. Radiother Oncol 2018;128:174–81. doi:10.1016/j.radonc.2018.03.001.

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