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Guest Editorial

It is time to integrate MRI deformable registration into image-guided radiotherapy and margin analysis: using prostate cancer radiotherapy as a model?

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THE NEED TO INTEGRATE MRI DEFORMABLE REGISTRATION INTO RADIATION TREATMENT PLANNING OF PROSTATE CANCER

Recent advances in mono-modal[1,2] and multi-modal[3] deformable registration have for the first time to allow accurate mapping of prostate cancer from magnetic resonance imaging (MRI) onto treatment MRI or computed tomography (CT). This technology can also propagate the information from the treatment planning CT to daily CT used for image-guided radiotherapy (IGRT). Prostate cancer radiotherapy is used as a model because deformable registration is arguably most advanced in this field with the recent addition of multi-modal solution of using human *a priori* knowledge, i.e., prostate and prostate cancer contours.[3] It has been long advocated to improve the prostate cancer treatment outcome by increasing radiation dose;[4,5] to decrease clinical side effects, the 'nominal' treatment margins have been shrinking so that the normal tissue complication probabilities of rectum[6] and bladder[7] could be controlled. This is largely based on the ability of image guidance[8,9] to aim at the targets. Some centres are now using very tight 3–5 mm margins arguably without deep understanding of our current knowledge of errors inherent in deformable registration, although organ motions have now been well considered.[10–18] Three millimetre margins may be enough because of organ motion and thus the dose smearing effects.[13] However, there seems to be a hidden layer of knowledge behind the choice of 'nominal' margins. The gap of knowledge at this point is the deformable registration accuracy that needs to be further explored to ensure the knowledge from academic centre should flow to the community. Many of the nuances implicitly understood when academicians treat cancers with tight margins are not easily written down in manuscripts so that they are omitted. This needs to be and could easily be corrected with an update of this field.

MRI-GUIDED PROSTATE RADIOTHERAPY

Tumour response during the course of radiation is neither currently monitored nor used in determining radiation treatment plan and the final dose given. MRI could potentially provide the response data when combined with optical tomography.[19,20] This area has an enormous potential for individualization of radiation treatment and improvement of outcome. This is particularly true when radiation sensitization is used. As prostate cancer is known to be heterogeneous, molecular response data of the intraprostatic tumour foci may allow targeted dose escalation to these areas without irradiating the entire prostate, thus limiting the surrounding normal tissue irradiation.[19] Furthermore, normal tissue response monitoring by MRI may help to guide the development and use of targeted therapeutics that may lower normal tissue toxicity.

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THE CHALLENGE AND SOLUTION OF USING MRI IN PROSTATE RADIATION TREATMENT PLANNING

Because of the large deformation introduced by an endorectal probe, registering diagnostic MRI with a probe to the treatment planning MRI without a probe has been intractable until recently[3]. Some investigators have suggested using hardware solution to by-pass performing deformable registration involving a large deformation. This has prompted the use of 3T MRI with a body coil for both diagnosis and radiation treatment planning. However, the signal increases only linearly with magnetic field strength. On the other hand, in the distance between the probe and prostate decreases, the signal strength increases in a power of 2. In other words, 3T MRI cannot replace the endorectal coil.[21] Alternatively, some researchers have used an endorectal balloon to stabilize the prostate each day during the course of about 8 weeks of treatment.[22] This strategy is associated with patient discomfort and an increase in acute rectal toxicity. Furthermore, the prostate can still have a measurable movement due to variable positioning of the endorectal balloon[23] requiring image guidance for daily treatment.[20] Taken together, these strategies may only complement the use of deformable registration of prostate MRI rather than replacing it. We have shown that the deformed MRI and non-deformed MRI could mismatch more than 5–10 mm. We urge caution, despite the vast utility of MRI in guiding prostate cancer treatment planning; without an accurate multimodal deformable registration program, the treatment margin will need to be considerably increased to account for mis-registration. We have deposited critical parts of our codes in Matlab implementation in open source Matlab Central (http://www.mathworks.com/matlabcentral/fileexchange/authors/37883) including codes to register MRIs, quantify the mis-registration and compute the additional margin needed to account for the image registration error. However, using a priori expert contours of the prostate and prostate cancer, the deformable registration could be as accurate as 1 mm. This could be done on a desktop from contouring to final result I about 40 minutes.[3] This is the first time, accurate MRI deformable registration could be achieved at a clinical feasible time frame. I suggest that it is time to start thinking about using MRI information in our prostate cancer planning and guidance.

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