Voxel-wise tumour response estimation from functional imaging and radiobiological model

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Purpose

To implement biologically guided radiotherapy, multiple tools must be developed to utilise the information contained in functional images. We have developed a script integrated in one of the most widely used TPS to predict the evolution of tumour cell density using a radiobiological model that includes information from functional images, such as diffusion-weighted imaging (DWI) and dynamic contrast-enhanced imaging (DCE).

Methods

An Eclipse Scripting Application Programming Interface (ESAPI) script of ARIA (Varian Medical Systems, version 15.1) was developed in C# for individualised calculation of tumour response. For a selected patient, the program works with data from ARIA (images, plans, dose distributions, contours...) or any DICOM file. In the case of importing new DICOM images, they must be previously registered to an image set registered to the planning CT in ARIA.

The programme obtains a voxel-wise estimate of the tumour cell density and the apparent diffusion coefficient (ADC) maps, seizing the correlation between ADC values and cellularity [1]. An initial ADC map (obtained from a low-distorted DWI sequence), a DCE K_{trans} map, the dose distribution and the treatment schedule are required (Fig. 1). The cell response was calculated based on the linear quadratic model (LQ) modified by oxygenation and proliferation. Parameters can be configured individually (Fig 2). Vascularisation was considered proportional to the value of K_{trans} and oxygenation modellable as a function of K_{trans}.

The parameters of the LQ model were obtained from the literature [2], but they can be tailored to available data.

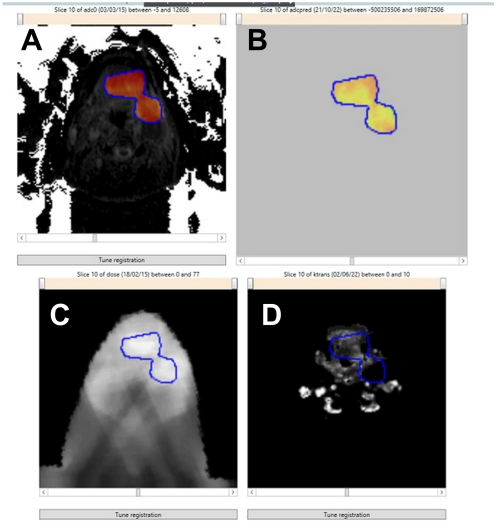

Figure 1. Programme window. (A) Initial ADC corrected by RG, (B) predicted tumour cell distribution within volume, (C) dose distribution, (D) K_{trans} distribution

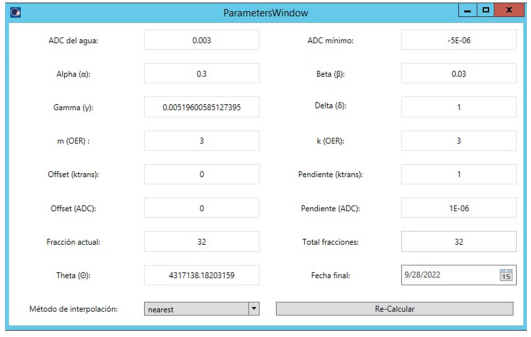

Figure 2. Programme window showing editable parameters to perform prediction

Results

Fig. 3 shows an example of a calculated patient, recruited during the ARTFIbio project, treated with 68.16 Gy in 32 fractions. Initial ADC map was calculated with b = 0, 1000 and distortion corrected by reversed-gradient method (RG).

The ADC for different stages and the tumour cell density within the treatment was computed. As seen in Fig. 3, hypoxic areas of the tumour (poorly vascularised) show lower response to the treatment at all the fractions.

The inhomogeneous response of the tumour due to poor oxygenation can be observed (Fig. 3).

Conclusion

We have developed software suitable for use in a widely deployed environment (Eclipse-ARIA), which allows the integration of relevant biological information into functional images for tumour response prediction in a routine workflow.

The use of such tools can be very useful in order to design a voxel-wise personalized treatment

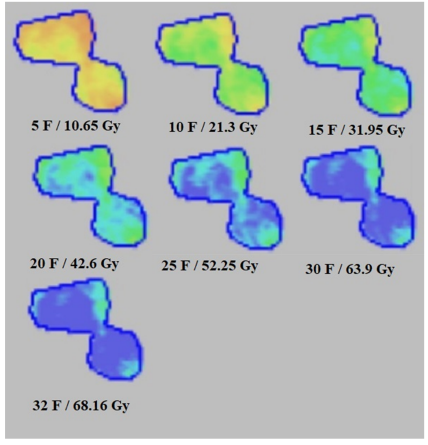

Figure 3. Evolution of tumor density during RT, showing fractions and prescribed dose. Patient with head and neck tumor prescribed with 68.16 Gy in 32 fractions.

Acknowledgments

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