Evaluation of the Stereotaxis Radiosurgery effects using MRI

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INTRODUCTION: Stereotactic radiosurgery (SR) is a highly precise form of radiation therapy used primarily to treat tumours and other abnormalities in the brain. This technique uses a few highly focused x-rays beams usually delivered in a single high-dose. To maximise the radiation dose in the tumour, and to minimise the damage in collateral healthy areas, the treatment uses a helmet-like device that keeps the head completely still and a three-dimensional computer-aided dose planning software that gives the location and strength for each x-ray beam using as input a tomographic image of the tumour. The dose planning softwares are validated using physical models, phantoms or radiosensitive gels [1], however they are not rigorously calibrated using *in vivo* tests. Some sequences of MRI have been used to detect metabolic changes associated with ischemic damage and irradiated tissue [2-3]. We propose to use T2-weighted MR images to evaluate *in vivo* the precision of the dose planning software. The method consists in estimating the irradiated tissue from T2w images obtained pre and post SR and compare the results with the previous planning. This evaluation can be extremely useful to calibrate parameters of the dose planning model mainly in SR that uses multiple doses.

METHOD: Three different patient cases treated with brain SR were analyzed, where two of them were patients with brain metastases and the third corresponded to a primary brain tumor. The SR planning was done from a CT scan (Fig. 1) using the FastPlan® software (version 5.5 2007, Varian), considering a single dose. Patients were subject to a brain MRI scan one week before and four weeks after the SR (in average), using identical T2w sequences (Turbo Spin Echo, TR/TE = 4.4/0.1 s, resolution 4.5x4.5 mm, slice thickness 5mm, scan matrix 460x345, 22 slices). The image segmentation over equivalent slices was automatically done using the *Active Contours without Edges* technique [4], which was implemented in a home-made software using Matlab (The Mathworks, Natick, 2007). Although images were not registered mathematically, anatomical markers were identified to select equivalent slices. The results of the analysis applied to one of the patients with cerebellar metastasis are shown in Figs. 2-5.

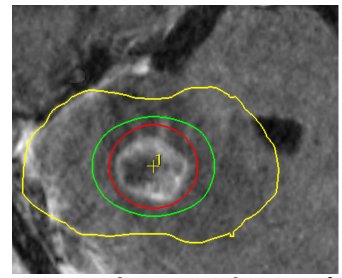

Fig1. Radiosurgery planning of cerebellar metastasis using FastPlan® software a CT scan

RESULTS: Figure 1 shows the SR planning on a CT scan. The inner line represents the isodose at 70% of the maximum, the intermediate line the 35% and the external one the 10%. As can be seen in Fig. 1 and 2, a good morphology correlation of the tumour was obtained between CT and MRI scans. In all the analysed cases the planned inner dose level set (Fig 1) have a good correspondence with the T2w image post SR (Fig 4). In Fig 4 it can be observed that the image contrast given by the T2w sequence is produced by two effects the physiological characteristics of the tumour itself (Fig 2) and the changes induced by the SR. However, we believe that the morphological change of the hyperintensity regions between the pre and post RS T2w images is mainly due to the radiotherapy effect, since the images were acquire within a short period of time. Similarly, the T2w images show the effects caused by the SR in the peritumoral areas (Fig. 5); however, in all the cases the planned outer dose level set (Fig 1) showed a considerable difference with the resulted segmented area in the T2w image (Fig. 5). These differences could be explained by: movement of the patient during the treatment, accuracy of the planning software, quality of the treatment equipment, among others. Further evaluations needs to be done to identify their causes.

Fig2. Automatic segmentation of the central area of the metastasis before radiosurgery

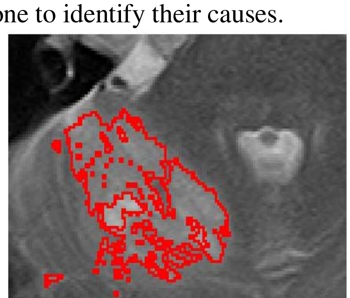

Fig3. Automatic segmentation of the peritumoral area of the metastasis before radiosurgery

Fig4. Automatic segmentation of the central area of the metastasis after radiosurgery

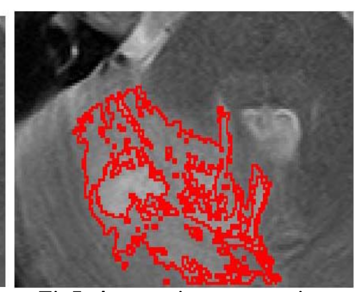

Fig5. Automatic segmentation of the peritumoral area of the metastasis after radiosurgery

CONCLUSION: An *in vivo* evaluation for dose planning software used in SR has been proposed. This evaluation was done using T2w MRI images by detecting metabolic changes associated with irradiated tissue. The analysis pre and post radiotherapy showed that there are some differences between effectively irradiated tissue and what was estimated by the planning software, and therefore a more accurate calibration of the model after radiotherapy is needed. The changes detected post SR may also include effects due to the extracellular liquid diffusion from irradiated to healthy tissue (i.e. edema). A further validation of our method will be done by acquiring sequential images at different periods of time after intervention, which will allow a better discrimination between the changes associated with the actual irradiated tissue and other kind of physiological effects. We believe that the proposed method is of great use in supplying feedback information to the dose planning software and it can be extended to evaluate the effects of radiotherapy in others organs such as breast, prostate and bone lesions.

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