generating sCTs which could be used for EBRT treatment planning for glioblastoma. Additional improvements of MRI protocols and patient fixation may reduce dosimetric differences between CT and sCT even further.

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Feasibility of generating mid-position CT from 4DCT using commercial deformable registration systems

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**Purpose or Objective:** Publications have shown the benefit of motion compensation (MC) of 4D CT to create a mid-position CT for planning of lung tumours. The MC process creates a single sharp image in which all information of the 4D scan is combined, improving signal to noise ratio, while the absence of motion blurring improves the identification of tumour and organ-at-risk boundaries compared to a maximum intensity or average scan. Furthermore, margins to account for the residual respiration motion relative to the mid-position scan can be small. Unfortunately, there are as yet no commercial solutions available to create such scans and their use is limited to a few hospitals. The aim of this work is to apply two commercial deformable registration systems, combined with open source software, to create mid-position scans, and to evaluate their performance for potential clinical use.

**Material and Methods:** 4D phase sorted CT scans (Philips Brilliance, 10 frames) of 8 patients were selected. Tumour peak to peak motion had to exceed 8 mm and there was no selection on scan quality. Deformable registration between all frames and the first was performed using Elekta’s Admire and Mirada’s RTx. The deformation vector fields (DVFs) were exported in DICOM format. Using the open source Conquest DICOM server, the DVFs and 4D CT were converted into Nifti format. A script in the DICOM server then called open source command tools of NiftyReg to first calculate the average DVF. Subsequently for each frame, the average DVF was subtracted from the frame DVF and the CT frame was deformed with this DVF to the mid-position. The resulting MC 4D data was written out for analysis. To provide a measure of quality of the MC process, the overall standard deviation of the difference of each MC CT frame with the average MC CT was calculated.

**Results:** The quality of the MC scans made with the two commercial systems is evaluated in Fig. 1 both quantitatively (frame by frame) and visually (average scans). Because post-processing was identical for both systems, only the quality of the DVF affects the results. Overall there is very little performance difference between the systems, with the average residual SD for both systems being within one hourglass field unit. It is furthermore visible that certain frames (particularly 1, 2, 7 and 10) have a larger residual. These lie in- and exhale and show a higher motion speed of the anatomical structures leading, on average, to more blurring and artefacts.

**Conclusion:** Using a combination of commercial and open source software, mid-position CT scans were created. The performance of both commercial deformable registration packages was similar. For some motion compensated frames, registration performance is poorer. For practical implementation of the mid-position scan in our clinic, we propose to exclude such frames, likely leading to a more robust performance.

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Integration of 7T MRI into image-guided radiotherapy of glioblastoma: a feasibility study


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**Purpose or Objective:** 7 Tesla (7T) MRI has recently shown great potential for high-resolution soft-tissue neuroimaging and visualization of micro-vascularisation in glioblastoma (GBM). Its value for the delineation of GBM in radiation
therapy planning (RTP) has not yet been established. We hypothesize that 7T MRI allows for improved GTV delineation over 1.5T or 3T MRI and have designed a clinical study to investigate this. However, increases in power deposition, susceptibility artefacts and geometrical distortions could significantly compromise the quality and interpretability of 7T MR images. In this study we aim for qualitative and quantitative assessment of these effects when incorporating 7T MR images into the neurosurgical navigation and RTP software.

Material and Methods: MR images were acquired with a Siemens Magnetom 7T whole-body scanner and a Nova Medical 32-channel head coil. 7T MRI pulse sequences were selected to visualize both intracranial anatomy and tumour (MP2RAGE) and perilesional edema (T2-SPACE, SPACE FLAIR). Moreover, multi-echo gradient recalled echo (GRE) T2*-weighted images were selected to visualize microvascularisation. A pilot study with 3 healthy volunteers was performed to optimize the anatomical image contrast by tuning the pulse sequences and scan protocols. Subject tolerability and side effects were assessed after each scan. A new anthropomorphic 3D phantom (CIRS Model 603A) was used to assess the geometrical image accuracy. A study-specific workflow for the transfer and processing of the 7T MR images from the scan facility to the RTP and neurosurgical navigation software was developed to enable integrating these images.

Results: Images from the four pulse sequences could be acquired within 50 minutes. The scans were well tolerated. All three volunteers reported slight vertigo while being moved in and out of the scanner. No other side effects of the 7T field were reported. Increased geometrical distortion was observed in the cortex in close proximity to air-filled cavities (fig 1). Regional loss of signal and contrast could be minimized by placing dielectric pads between the head and the coil. Regions of increased signal were identified in the occipital and temporal lobes caused by residual B1-inhomogeneities. Flow-artefacts were observed near major intra-cranial vessels. Image transfer and processing did not degrade image quality. Overall system-related geometrical distortion was 2 mm. Detailed results of the geometrical distortion analysis are reported in the phantom study by Peerlings et al.

Conclusion: Integration of high quality and geometrically reliable 7T MR images into neurosurgical navigation and RTP software is technically feasible. Quantification of object-related geometrical distortion needs further analysis before clinical implementation.