PATIENT-SPECIFIC TISSUE MODELS FOR HIGH FIELD MRI ACQUISITION DESIGN

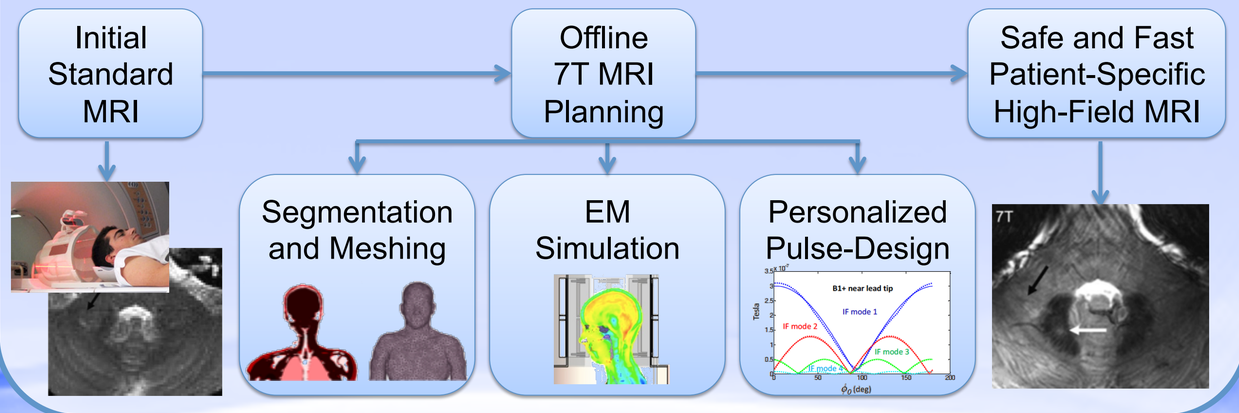
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Abstract

When using High-Field MRI scanners, the specific absorption rate (SAR) or the power deposited in patients may cause unsafe tissue heating, thus restricting the application of these systems[1]. Several studies have used head and shoulder tissue models based on MRI and CT to simulate SAR[2], which could be used to improve the safety of high-field MRI by adapting the pulse sequences to each specific patient. However, CT images require the use of ionising radiation and additional costs and time. We propose a pipeline for creating patient-specific tissue models based only on MRI and "a priori" whole brain CT data that could enable patient-specific pulse design in high-field MRI. In this work, we have focused on head-only tissue segmentation models, as the torso does not require a very precise segmentation when simulating SAR in brain MRI studies[3]. To the best of our knowledge, no complete automatic segmentation methods for head and neck have been previously implemented.

High-Field MRI Planing



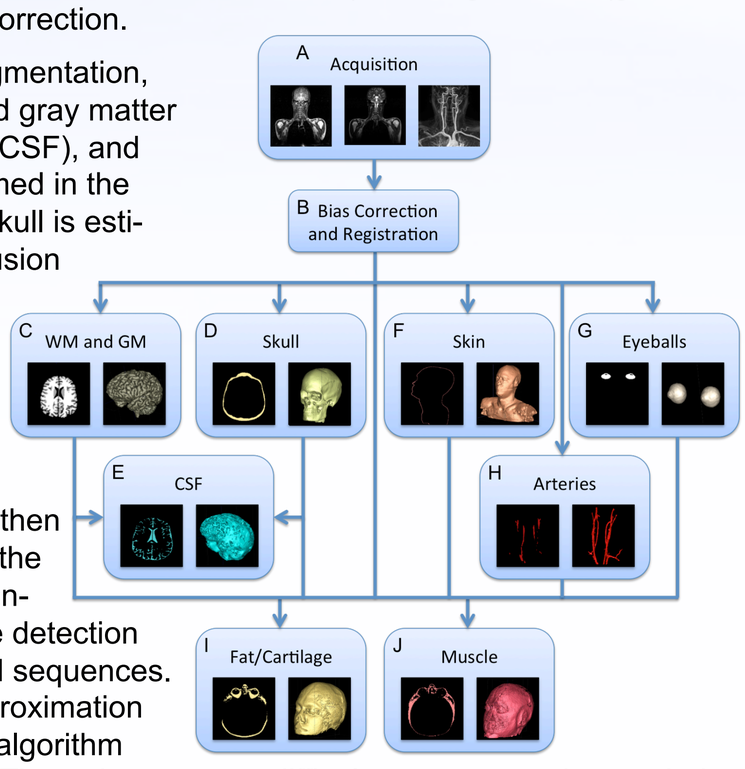
Patient-Specific Tissue Model Segmentation

We propose a pipeline for creating patient-specific tissue models based only on MRI images of the subject[4]. Additionally, previous works have proved that only head segmentation models are good enough to simulate the SAR[3], so we have centered in the head segmentation.

Data Acquisition: Images of the head and torso were acquired on a GE Signa HDxt 3.0T MR scanner using the body coil for excitation and an 8-channel quadrature brain coil (head imaging) and the body coil (torso imaging) for reception. Three volumes were acquired: an isotropic 3DT1w SPGR, an IDEAL sequence (water and fat volumes), and a Time Of Flight (TOF) volume.

Data Preprocessing: Image preprocessing was carried out using the 3D Slicer built-in modules for MRI bias correction (N4 ITK MRI bias correction) and registration (general registration BRAINS) for movement correction.

Segmentation Pipeline: Cortical segmentation, including brain white matter (WM) and gray matter (GM), ventricular cerebrospinal fluid (CSF), and cerebellum WM and GM, was performed in the T1-w volume using FreeSurfer. The skull is estimated using a multi-atlas and label-fusion based approach[5]. Remaining CSF is computed as the residual of the skull and brain. To segment the skin we have developed an algorithm that estimates the background noise variance, and thresholds the anisotropic filtered volume; gaussian smoothing is then applied to reduce aliasing artifacts in the skin surface. The eyeballs are segmenTed by applying a threshold and edge detection algorithm to the IDEAL in-phase head sequences. We have also obtained a smooth approximation of the main arteries applying an E-M algorithm to the median filtered TOF images. These images are difficult to segment due to their inherent low SNR. The remaining tissue is classified into muscle and fat/cartilage using an expectation-maximization algorithm on the IDEAL fat and water images.

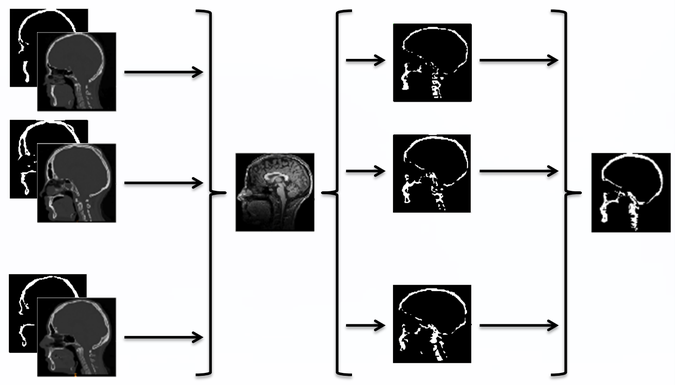


Meshing: The resulting models are automatically converted to a 3D tetrahedral finite element (FE) mesh using the iso2mesh 3D surface and volumetric mesh generator.

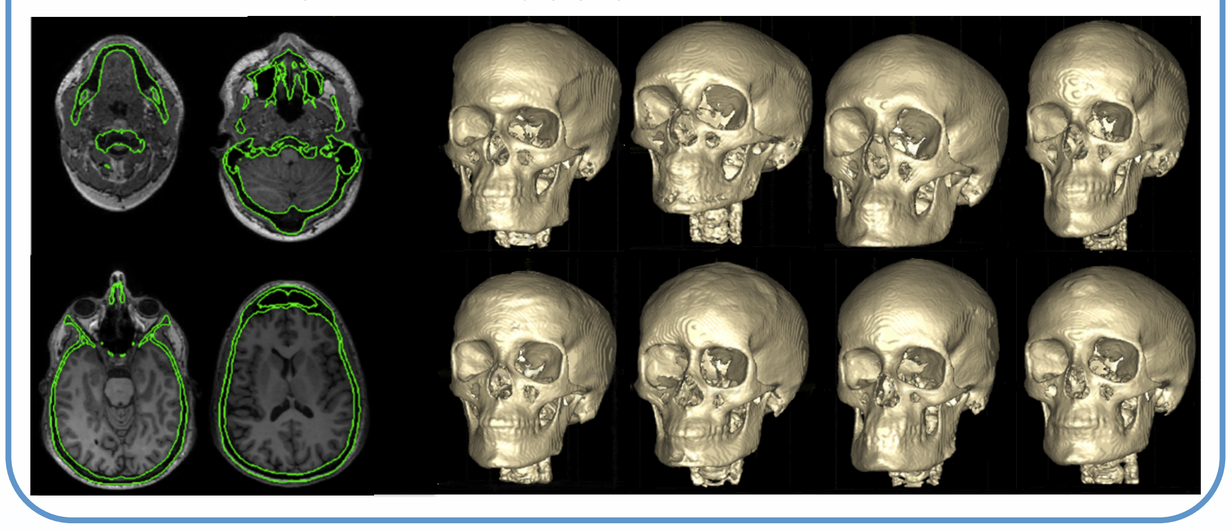
Skull Segmentation in MRI

The skull is estimated using a multi-atlas segmentation and label-fusion approach[5]. We consider the CT volumes from a whole head CT-scan database. These CTs are registered to the patient T1-weighted image using affine and non-rigid transformations (see scheme).

The final patient-specific skull is estimated using label fusion techniques; we have compared Majority Voting, the Simultaneous Truth and Performance Level Estimation (STAPLE), and the Selective and Iterative Method for Performance Level Estimation (SIMPLE) algorithms.



The figure show the skull estimation over several slices of a single subject, where we can appreciate the differentiation between bone and air (left) and the reconstruction of the skull for 8 subjects in the study (right).

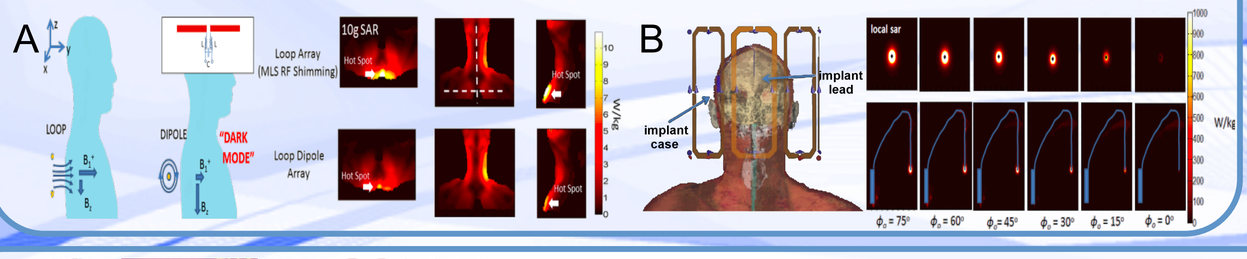


The complete pipeline has been implemented as a Python scripted module for 3D Slicer. It takes about 10 hours running over Ubuntu Precise (12.04.3 LTS) on an Intel(R) Core(TM) i7-2600 CPU @ 3.40GHz with 8GB RAM. The method was tested in 12 healthy subjects (4 males/ 8 females) aged 22-57. An expert radiologist considered all the segmentations as accurate. We are now measuring the real accuracy in CT-MR pairs.

Use of the models

The head/torso models can be used to model electromagnetic fields to calculate SAR and excitation B_1^+ patterns generated by conventional loop arrays and loop arrays with added electric dipole elements. For example:

- The use of an array element, which is intentionally inefficient at generating spin excitation (a "dark mode") to attempt a partial cancellation of the electric field from those elements that do generate excitation[6] (Panel A).
- A method where the implant friendly modes, determined empirically from the B1+ artifact visible in low-SAR scanning is used to lower SAR at the implant[7,8] (Panel B).



References

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Acknowledgements

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