Results: There was a strong correlation between the consistency metrics and the true accuracy ($r = 0.85$ and $r = 0.70$ for DSC and DTA, respectively), indicating that the new method is suitable to automatically infer contour propagation accuracy. In addition, a simple threshold on the consistency metrics enabled accurate automatic identification of introduced errors (fig 1E).

Conclusion: The presented workflow enables the accuracy of a propagated contour to be tested automatically for any patient, and for errors to be identified. This method can be used as part of an online ART protocol, to automatically detect contour propagation issues that require manual review and contour editing.

EP-1899
Evaluation of SEMAC MRI metal artifact reduction for orthopaedic implants in radiotherapy planning
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Purpose or Objective: Many commonly used metallic orthopaedic implants cause artifacts in MR and CT images and are a serious challenge for obtaining high quality anatomical images for radiotherapy (RT) planning. We investigate the utility of SEMAC (Slice Encoding for Metal Artifact Correction [Ai et al. Invest Radiol 47: 267-76, 2012]) in patients with hip replacements and spine fixation devices, and consider the impact of metal artifacts on the registration of MR and CT images for RT planning.

Material and Methods: This study was approved by the Ethics Committee. MRI was undertaken on a 70 cm bore system (1.5T MAGNETOM Aera, Siemens) adapted with a home-built flat bed. SEMAC fast-spin-echo (FSE) pulse sequences were developed to approximate the coverage, image quality and contrast of the conventional FSE protocol (WARP works-in-progress software package, Siemens Healthcare). MR and CT images were registered using standard RT software (Pinnacle, Philips); conventional FSE and SEMAC FSE pulse sequences were compared on a purpose-built test object (spine fixation device suspended in gelatine) and on clinical examinations. Six patients with bilateral hip replacements and two patients with metallic fixation devices on the spine were scanned. For the spine fixation devices the visibility of the spinal canal was assessed. For the hip replacement patients, the internal surface of the pelvic girdle was scrutinised. Conventional and SEMAC FSE images were compared to detect relative geometrical distortion.

Results: The conventional FSE protocol shows extensive areas of signal loss and signal pile up around the spine fixation device test object. Signal loss volume was reduced from approximately 16.0 ± 0.5 cm3 to 12.9 ± 0.5 cm3 when the SEMAC FSE protocol was used. The two spine patients were shown to have metallic implants adjacent to the spine canal, which was partially affected by signal loss in three separate slices for conventional FSE protocols. Using the SEMAC FSE protocol, areas of signal loss and signal pile up are significantly reduced; the spinal canal is visible throughout the scanned volume (Figure 1). Geometrical distortion and signal loss were visible in all of 12 hip replacements scanned, but the metal artifacts do not reach the prostate, bladder and the seminal vesicles. In 8 of those hip replacements the signal loss extended to the internal surface of the acetabulum with conventional FSE protocols. Using SEMAC FSE techniques the signal loss is reduced and for only four of the hip replacements it was not possible to visualise the complete internal surface of the pelvic bones.

Conclusion: This work demonstrates improvement in geometric accuracy and reduction in signal loss around common metallic implants using SEMAC FSE sequences, with a positive impact on CT-MR registration. This technique will enable better contouring confidence in the location of target volumes and organs at risk which are close to metallic implants.

EP-1900
Geometric accuracy of MRI for stereotactic radiosurgery planning of Acoustic Neuromas at 3 Tesla
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Purpose or Objective: MR-CT co-registration is a mandatory requirement to accurately plan Stereotactic Radiosurgery (SRS) for Acoustic Neuromas (AN). MRI scans are subjected to susceptibility-related magnetic field inhomogeneity in the proximity to air spaces and this effect is enhanced at higher magnetic fields. We investigate the geometric distortion of anatomical MRI head images acquired at 3 Tesla (3T), and consider protocol requirements for SRS.
Material and Methods: This work was approved by the Research Ethics Committee and undertaken at 3T (Skyra, Siemens). 3D MR images of a structured test object were obtained (500 Hz/pixel, 1 mm³ isotropic resolution) and displacements from the true position were estimated over the head volume. High resolution magnitude and phase images were acquired for field mapping on five volunteers after shimming over the entire head volume; (TE1/TE2/TR = 2.46/7.38/12 ms, 800Hz/pix, approximately 1mm³ isotropic, sagittal 3D acquisition, standard head coil). The phase images were processed off-line to produce field maps (in-house software, IDL 8.2, USA). Field maps were assessed over the whole head and over the area surrounding the ear canal for range of magnetic field values and accuracy of phase unwrapping algorithm. In addition, field mapping was performed with the same sequence on a uniform test object with the phase encoding direction both head/foot and anterior/posterior to evaluate the effect of eddy currents on field map accuracy. From the volunteer field maps, the displacement of any signal from its true origin was calculated for the anatomical MRI pulse sequences used in SRS (SRS Planning Protocol: 900Hz/pix bandwidth, 1mm³ isotropic voxel size).

Results: Geometric displacements assessed with a structured test object were found to be under 1 mm within a central volume of 20 x 20 x 20 cm³. From images of a uniform test object, the field mapping errors were estimated to be under 0.30 ppm over that volume. In all five subjects a macroscopic gradient was observed along the head/foot direction (Fig1a). The total range of magnetic field values is under 7 ppm over the head for all subjects, including the oral cavity. However, steep field gradients were detected adjacent to air spaces in the ear canal (Fig 1b). The maximum field change in this area is under 3.5 ppm for all subjects. For the SRS Planning Protocol displacements associated with susceptibility-related field inhomogeneity are therefore under 1 mm for the head and 0.5 mm around the ear canal. For MRI examinations undertaken with lower receiver bandwidth (and thus lower readout gradients) the geometric accuracy can be compromised by susceptibility effects.

Conclusion: It is possible to maintain geometric accuracy at 3T by using high readout gradients. SRS planning MRIs benefit from the superior image quality achieved at 3T with careful setting of the receiver bandwidth. These finding have implications for SRS and MR-guided Radiotherapy in general.

EP-1901
Patient-specific deformable image registration quality assurance based on feature points
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Purpose or Objective: Despite high prevalence of DIR, the lack of patient-specific quality assurance method poses challenge to truly integrate the DIR into clinical practice. We addressed this problem by developing a DIR-QA platform that quantifies geometrical error in registration based on stable feature points

Material and Methods: Our DIR-QA software uses a scale-invariant feature transform algorithm to identify feature points on diagnostic images within a specified volume (e.g. liver).

Results: Over a thousand unique feature points were identified within the liver volume, and 100 feature points were tested for inter-operator variability in the QA process. This correspondance served as the gold standard for point-by-point assessment of DIR, and provided measurements of the inter-operator variability. The intra-operator variability was measured using 3 preselected feature points that were randomly presented to the operator 3 times during the task of finding the machine-generated feature points.

Conclusions: We generated feature points on reference CT images (full-exhale) from 4DCT scans of the abdomen and measured correspondence of the feature points on the target CT image (full-inhale) by having three radiation oncologists and four medical physicists to identify 100 corresponding feature points. This correspondance served as the gold standard for point-by-point assessment of DIR, and provided measurements of the inter-operator variability. The intra-operator variability was measured using 3 preselected feature points that were randomly presented to the operator 3 times during the task of finding the machine-generated feature points.