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Quality assessment for images obtained using 3D printed stereotaxic frame

Lucy Liang[1], David J Schaeffer[1], Tales Santini[1], Isabela Zimmermann Rollin[1], Elvira Pirondini[1]

[1]University of Pittsburgh

ASAP Collaborative Research Network

Lucy Liang
University of Pittsburgh

ABSTRACT

This protocol describes the steps taken to assess whether MR signal noise and distortion is introduced by utilization of a 3D printed plastic stereotaxic frame.

The computer-aided design files and engineering drawings for the frame used in this protocol are publicly available, with the modular design allowing for low cost and manageable manufacturing.
You can find it here: https://github.com/SchaefferLab/Macaque-Stereotax

This protocol is supplementary to the manuscript:
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We use this protocol and it's working

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PROTOCOL REFERENCES

3D printable stereotaxic frame: https://github.com/SchaefferLab/Macaque-Stereotax

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GUIDELINES

The geometric phantom used in this assessment was chosen to match the size of a macaque monkey head, with internal geometric structure the size of a typical monkey brain, our target imaging structure. This protocol can be used also for other imaging targets, but the phantom should be adjusted to obtain accurate assessment results.

MATERIALS

Imaging Equipment

- Siemens 7T whole body MRI scanner (Magnetom, Siemens Healthcare, Erlangen, Germany)
- 2nd generation Tic-Tac-Toe radiofrequency (RF) system (Sajewskiet al., 2023; Santini et al., 2021)
- small animal CT scanner (Si78; Bruker BioSpin GmbH, Ettlingen, Germany), with software package ParaVision-360 (version 3.2; Bruker BioSpin Corp, Billerica, MA)

Materials

- 3D printed stereotaxic frame (https://github.com/SchaefferLab/Macaque-Stereotax)
- Bruker BioSpin MRI GmbH phantom ($CuSO_4$ x $2H_2O$ 1g/L, Agar/Agar 10g/L, model no. 1P T11170, Ettlingen, Germany)

Geometric phantom (radius = 35 mm and height = 190 mm)

Image Processing Software

- FSL: fsleyes, flirt, fslmaths (Smith et al. 2004)
- MATLAB 2022b

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Image Acquisitions

1 Acquire MRI using gradient-echo sequences in the 7T MRI scanner (Magnetom, Siemens Healthcare, Erlangen, Germany) with the following parameters:
- TE/TR=8.16/40 ms
- resolution 400 µm isotropic (same as what you will acquire for your target structure)
- matrix size=176×384×384
- flip angle=15°
- acceleration factor (GRAPPA)=2

1.1 Without stereotaxic frame: place the geometric phantom in the center of the coil, acquire images as described

1.2 With stereotaxic frame: center the geometric phantom in the stereotaxic frame in the same orientation as without the frame, place the stereotaxic frame in the center of the coil, acquire images with same parameters as before

2 Next, acquire CT images of the same phantom in a small animal CT scanner (Si78; Bruker BioSpin GmbH, Ettlingen, Germany) with the following parameters:
- resolution 200 µm isotropic, FOV: 79.6×199 mm
- Low Dose 1 mm aluminum filter, “step and shoot” method (0.6-degree gantry step)
- reconstruct using filtered back projection algorithm equipped with the software package ParaVision-360

Signal to Noise Ratio (SNR) Assessment

3 In MATLAB, calculate the SNR maps for MRI of the phantom (with and without frame) by dividing the signal in the image by the standard deviation of the background noise.

4 Compare the average SNR value of the entire image stack, calculated for each of the two MRIs. They should be very similar. This allows us to assess the overall signal quality.

5 In FSL, visualize (fsleyes) and coregister the SNR maps of the MRIs with and without stereotaxic frame using rigid transformation (flirt).

6 Overlay the SNR maps (with and without frame). The hyper/hypo-intensities should match well if there are no spatial distortions introduced by the frame.

Geometric Distortion Assessment

7 In FSL, visualize (fsleyes) and coregister the MRIs with the CT image using rigid transformation (flirt).

8 Binarize the phantom (include only internal geometric structure) CT image using thresholding with fslmaths or any equivalent software/function.

9 Overlay the binarized image with the MR SNR maps. Check conformity of the rectilinear geometric structure between the two.