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Investigating passive B_0 shimming for spinal cord imaging at 7T

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Introduction

- fMRI of the human spinal cord holds great promise from a clinical perspective to delineate pathological mechanisms in disorders such as multiple sclerosis and chronic pain.
- One of the challenges of spinal cord fMRI is the strong magnetic field variations [1] which are especially prominent at higher field strength.
- A possible way to mitigate the field variations arising from air-tissue interfaces at the neck is to employ passive B_0 shimming.
- At lower field strengths, such implementations have been demonstrated for neck imaging [3,4] and a number of spinal fMRI studies [5,6] have employed this technique.
- Here, we evaluate the effects of a commercially available device for passive B_0 shimming on 7T cervical spinal cord imaging using pads filled with liquid perfluorocarbon.

Methods

- Seven healthy volunteers were measured on a 7T MAGNETOM Terra scanner (Siemens Healthcare, Erlangen, Germany) equipped with a custom-built 24-channel neck coil for cervical spinal cord imaging (MRI.TOOLS, Berlin, Germany).
- Images were acquired **with**/**without** the pads (SatPad Inc., West Chester, USA), with the acquisition order counterbalanced across volunteers.

SCT Spinal Cord Toolbox

FSL

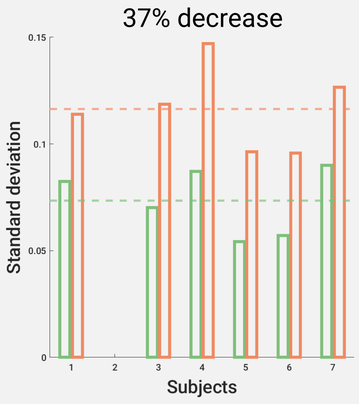
The following image types were acquired:

- **Field map of the entire cervical spinal cord**: GRE field mapping; voxel size: 2×2×2mm^3; assessment of field homogeneity
- **T1-weighted image of the entire cervical spinal cord**: 3D VIBE; voxel size: 0.8×0.8×0.8mm^3; assessment of signal-to-noise ratio (SNR)
- **T2*-weighted image of the cervical cord** (segments C5-C7): 2D multi-echo GRE; 5 echoes (echo range and spacing: 4.5ms-19.26ms, 3.65ms); voxel size: 0.4×0.4×3 mm^3; assessment of gray/white matter contrast-to-noise ratio (CNR)
- **fMRI time-series** (segments C5-C7): GE-EPI; TR: 1120ms; TE: 23ms; voxel size: 0.8×0.8×3mm^3; positioned like ME-GRE; assessment of temporal-signal-to-noise-ratio (tSNR) as well as image quality and motion

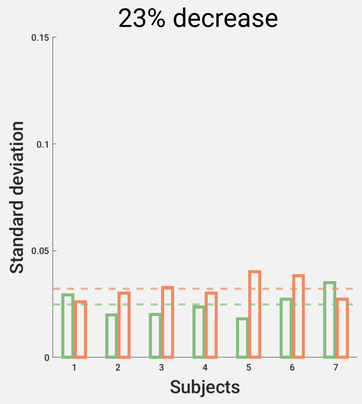
Results

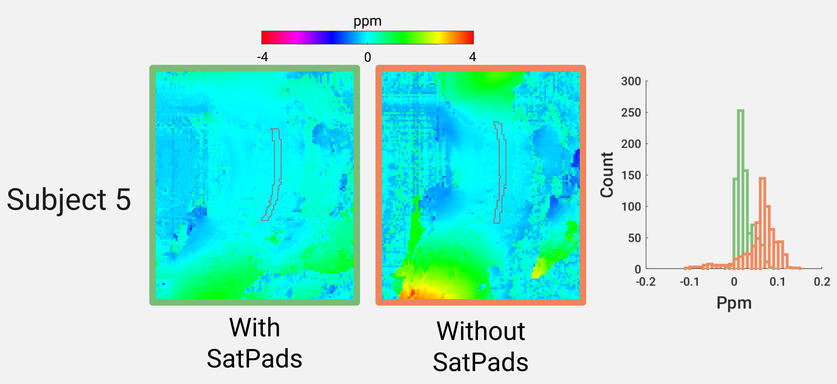
Field map

Tune-up shim
37% decrease



Active shim
23% decrease

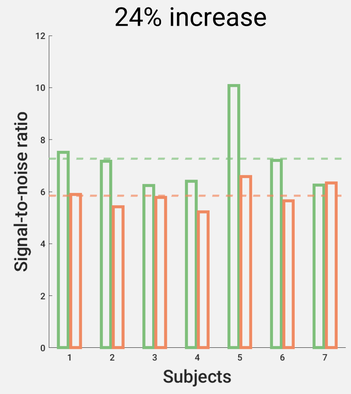




ROI

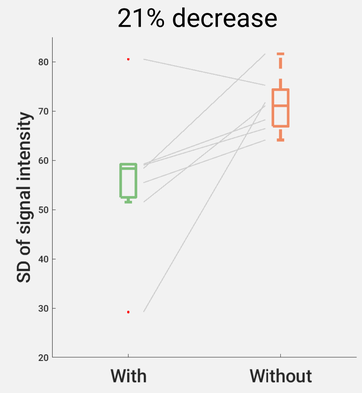
T1-weighted

Whole cord SNR
24% increase

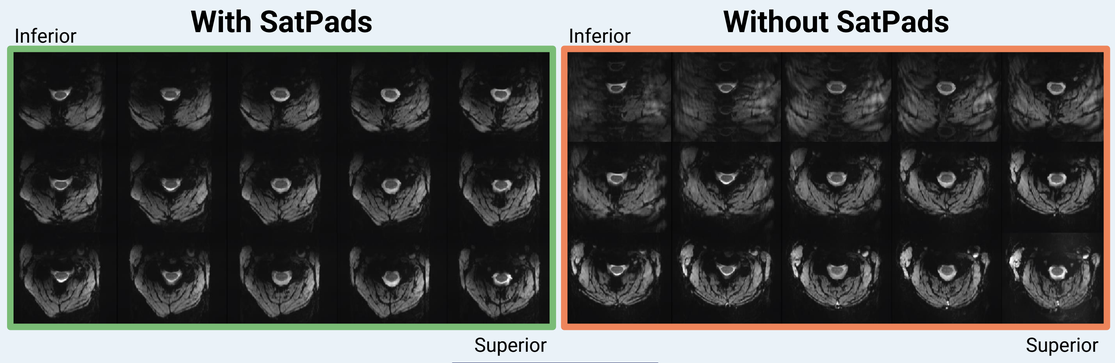


No change in slice-wise SNR

Across-slice SD
21% decrease



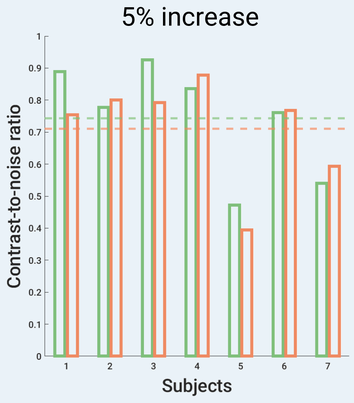
fMRI time series (GE-EPI)



No change in tSNR

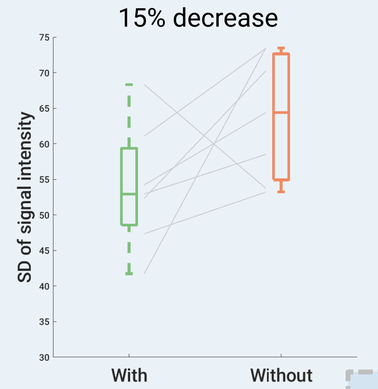
Multi-echo GRE

CNR
5% increase

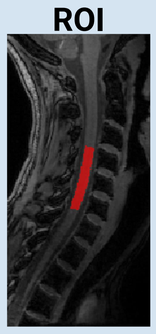


No change in slice-wise CNR

Across-slice SD
15% decrease

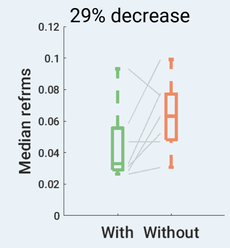


ROI

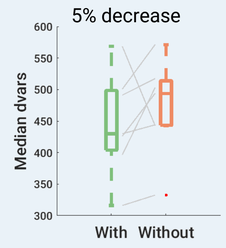


Subject movement

RefRMS
29% decrease

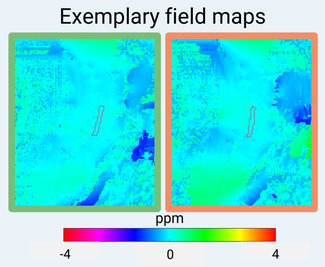


DVARS
5% decrease

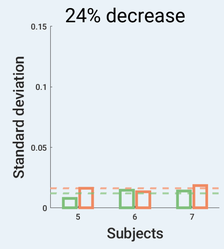


Field variation

Exemplary field maps

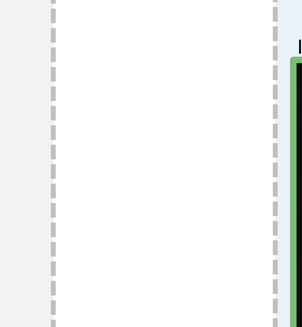


Active shim
24% decrease



Gray & white matter segmentations

Dice coefficient (ME-GRE and EPI)
8% increase



Summary

- We investigated the impact of passive B_0 shimming via a commercially available product on cervical spinal cord acquisitions at the field strength of 7T.
- Building on previous observations at lower field strength [3,4], the use of a susceptibility-matched material around the neck strongly improved the field homogeneity with robust effects across different shimming options.
- While the use of SatPads did not lead to increased slice-wise SNR in T1-weighted or CNR in T2* weighted structural images, it led to increased signal homogeneity across slices in both acquisitions and improved visual appearance.
- Although we did not observe an increase in fMRI data quality in terms of tSNR when using SatPads, we observed a strong reduction in both ghosting artifacts and subject movement. Additionally, we observed an increased similarity between (distortion-free) ME-GRE and EPI acquisitions, suggesting improved spatial fidelity.
- The use of passive shimming thus offers modest benefits for 7T spinal cord MRI and seems without any apparent draw-backs. Future research avenues might include investigating the effects of passive B_0 shimming when a larger EPI slice-stack is acquired.

References

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