On the influence of scanner vibrations on ADC in apparent exchange rate measurements

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Target audience: Researchers interested in vibration artifacts and apparent exchange rate measurements in diffusion MRI

Purpose: Diffusion MRI is sensitive to particle motion on a micrometer scale. Thus small phantom motions can lead to significant artifacts in the apparent diffusion coefficient (ADC). One reason for such movements are vibrations caused by the strong and fast switching gradients [1], which are needed to be sensitive to diffusion. For the measurement of the apparent exchange rate (AXR) via filter exchange imaging, one needs a second diffusion weigthing [2], which can cause additional vibrations. The aim of this work was to evaluate the influence of scanner vibrations on AXR experiments.

Material and Methods: Images were acquired with an in-house developed filter exchange imaging sequence [3] with a field of view of 345x345 mm² and a single slice of 10 mm thickness, an acquisition matrix of 80x80 pixels, an effective echo time of 136 ms and 5 repetitions. The b-values in the first weighting were $b_1 = 0$ and 0.9 ms/µm² and in the second $b_2 = 0$ and 0.5 ms/µm². Phantoms were used that consisted of a suspension of yeast in tap water with a mass ratio of 1:1 filled in 500 mL plastic bottles. The phantoms were measured once lying on the bottom of the head coil and once being held by an in-house constructed wooden frame (Fig. 1), which provides a good decoupling of from scanner vibrations. Both diffusion weightings were applied along six different directions with 10 mixing times ranging from 30 to 620 ms. Because of the low signal to noise ratio, the images were averaged before calculating ADC values. ADC values corresponding to the second diffusion weighting were determined from the mean signal of a ROI in the center of the bottle. Standard deviations of the ADC over the six directions were calculated for each mixing time. The experiments were performed on a 1.5 T Symphony and a 3 T Biograph (both Siemens Healthcare, Erlangen, Germany).

Fig. 1: Wooden frame used for decoupling. The phantom was fixed on the bar, so that the effect of scanner vibrations was minimized.

Results: The standard deviation is approximately reduced by a factor of 2 when using the wooden frame (Fig. 2). The standard deviation is in general higher when applying both diffusion weightings in comparison to applying only the second one. This difference almost vanishes if the phantoms are placed on the wooden frame. Considering the mean and standard deviation over all mixing times and directions, without the first weighting, the ADC is slightly lower when measured directly in the head-coil (1.447 ± 0.009 µm²/ms) than on the frame (1.469 ± 0.004 µm²/ms). The ADC maps are more homogenous when the phantoms were placed on the frame (Fig. 3). The influence of the vibrations varies for different diffusion directions. All experiments presented here showed the same behaviour on both machines, while there seem to be greater eddy current artifacts on the 3 T MRI, as there were larger image distortions (data not shown).

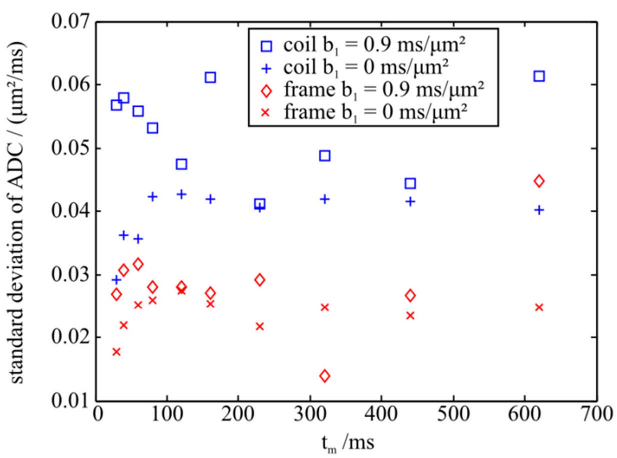

Fig. 2: Standard deviation of the ADC (measured with the second diffusion weighting with the 1.5 T scanner) over six directions. For all mixing times, the standard deviation is lower if the phantom is placed on the wooden frame instead of directly in the coil.

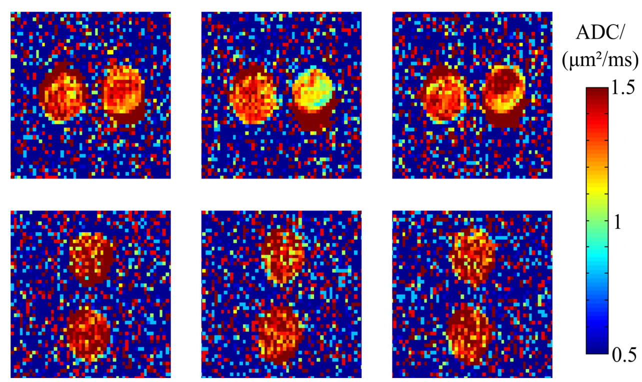

Fig. 3: ADC maps for different diffusion directions. In the upper row, the phantoms were placed directly in the head coil, in the lower row they were mounted on the wooden frame and fixated by tape above and below the batten, which explains the different arrangement. The maps are more homogeneous when the wooden frame is used. Data acquired with the 3T scanner.

Discussion: The findings of Hiltuunen et al. that scanner vibrations [1] are a cause of uncertainties in diffusion MRI are confirmed here. This is especially true when performing AXR experiments of fluids as this is an approach with technical demands close to the limits of currently available hardware and which involves fitting procedures that can be quite sensitive to uncertainties. The stabilization achieved by vibrational decoupling appears thus as a first important step on the path to reliably estimate quantitative values of apparent exchange rates and filter efficiencies in validating phantom experiments.

Conclusion: Increasing stability and reproducibility of AXR measurements can be achieved by vibrational decoupling. Phantom studies using other diffusion MRI methods could also benefit from reducing vibration artifacts. Wooden frames, such as the one used here, are a straightforward, cheap and easily usable approach to achieve vibrational decoupling.

References: 1. Hiltuunen *et al*. Neuroimage 32:93-103 (2006) 2. Lasič *et al*. Magn. Reson. Med. 66:356-365 (2011) 3. Mueller *et al*. Proc. Intl. Soc. Magn. Reson. Med. 22:4412 (2014)