Using second order statistic analysis of images to quantify and optimize parallel acquisition strategies for 3He MRI of human lung

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Motivation

The parallel MR-imaging acquisition techniques (**PAT**) being used for ^{3}He lung MRI may significantly gain the signal-to-noise ratio (SNR) of images and shorten the acquisition time by reducing the amount of phase encodings (**PE**) and the capability of using a higher flip angle (FA) [1]. However, because of the irreversible magnetization losses in each rf-excitation the energy of the k-space in ^{3}He MRI is always weighted by the PE-trajectory and the slice acquisition ordering (**SAO**). The strong k-space weighting leads to the reducing of SNR or to the broadening of the image point spread function (PSF) that appears like an image blurring due to the mutual contamination of nearby pixels (Fig 1 left)[2]. In general, such a "contamination" in an arbitrary direction and pixel distance can be described by the image textures analysis i.e. second order statistic parameters (**SOSP**) of the images morphology [3]. Particularly, the blurring effect appears as a "pixel leakage" in the Gray Level Co-occurrence Matrix (**GLCM**) (Fig 1) and the effect can be quantified by changes of GLCM statistical parameters e.g. *Contrast*, *Energy*, standard deviation (*GLCM-SD*), etc. The example of the simulation of k-space filter effect on *GLCM-Energy* and *Contrast* is shown on Fig 1 right. In this work we performed the GLCM-based analysis of the ^{3}He images acquired using PAT under condition of the optimized flip angle to get maximal SNR while restricting the PSF broadening factor P_{ksf} to be <0.2[2].

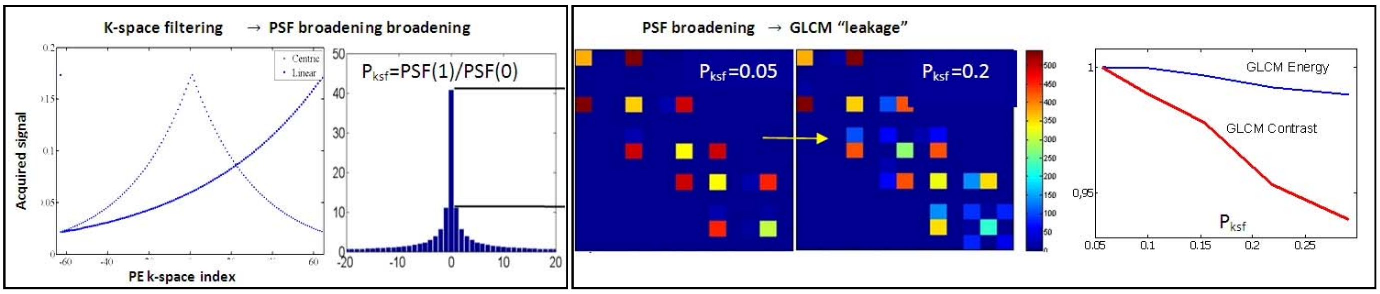

Fig 1 (left) The k-space weighting in the ^{3}He acquisition (depending on the phase encoding trajectory) leads to the broadening of the image PSF that appears like a blurring effect in the image due to the mutual contamination of the nearby pixels. This "contamination" can be described by changes in the Gray Level Co-occurrence Matrix of the image and could be quantified by the GLCM statistical parameters like Contrast, Energy, Standard deviation etc. On the right plot the results of the simulation of the k-space filtering on GLCM parameters are shown.

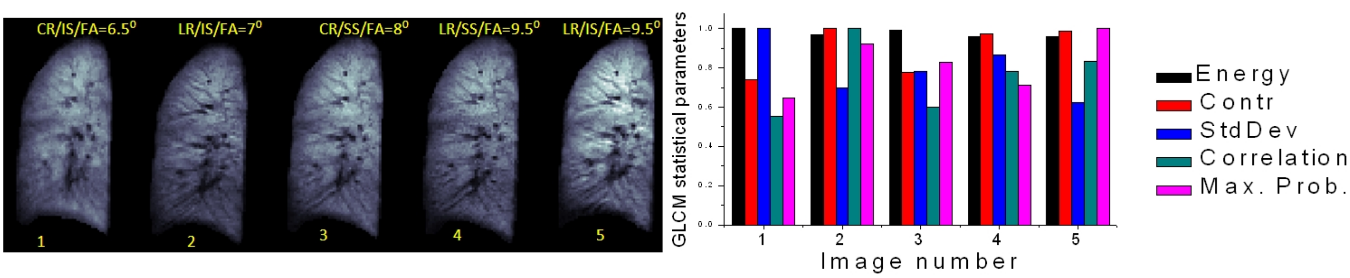

Fig 2 The GLCM statistical parameters can be used to characterize and optimize the quality of the ^{3}He images for the parallel acquisition and to choose an optimal strategy for the slices sampling order and for the k-space trajectory. The GLCM statistic is sensitive both to the image SNR/CNR and resolution. The MR images 1-5 were acquired with optimization of FA for maximal SNR and keeping the k-space filtering parameter P_{ksf} <0.2. This keeps Energy of GLCM nearly constant while the Contrast, standard deviation, covariance and maximal probability are statistically significant correlated with image blurring and contrast changes.

Material and Method: The ^{3}He MRI acquisitions were performed on 5 healthy volunteers using mixture (200/800ml $^3He/N_2$) with permission of local Ethic Committee. The acquisitions were done with 32-TX/RX in-house built phased array coil [1] on Avanto Tim scanner (Siemens, Erlangen, Germany). Slice selective SGRE sequence with TR/TE=7.6/3.6 ms, 15 slices (10mm thickness) were used. 72 PE lines + 16 ACS lines, GRAPPA acceleration Acc=2 were sampled. Five acquisitions were done with different SAO (sequential (*SS*)/ interleave (*IS*)) and PE- trajectories (centric (**CR**) and linear (**LR**) PE-lines reordering). Depending on phase encoding and slice order trajectory the flip angle (FA) is calculated to keep optimal SNR and P_{ksf} <0.2 as described in [2]. The exception is additional LR image #5 acquired with uses FA optimized for « SNR only» according to [4] and , therefore, has increased theoreical P_{ksf} value compared to others.

Results and Discussion

Fig 2 (left) shows the exemplary slice in posterior part of the right lung. The CR images both with sequential and interleave slice order have, in general, higher k-space filtering and, therefore, are more blurred. However, because the P_{ksf} <0.2 was the boundary condition for the SNR optimization, the GLCM-*Energy* remains nearly unchanged that is in agreement with simulations (Fig (1) right). In the same time, the *GLCM-Contrast* parameter is well correlated with blurring effect being on 15-20 % less for blurred CR images in comparison with more sharp LR ones as it is also predicted (qualitatively) by simulations (Fig 1). The *GLCM-Maximal Probability*, *GLCM-SD* and *GLCM-Correlation* are, in contrast, generally superior for the less blurred images #2, #3 and #5. Additionally, these parameters obviously are correlated with image CNR. This could be seen if one compare the "intensity-optimized" image #5 acquired with FA=9.5^0 with "P_{ksf}-optimized" image #2 (FA=7^0).

Thus, the image SOSP are able to quantify the ^{3}He MR-images quality in terms of resolution, SNR and image contrast in the same time, and can be used to improve the optimization strategy for the parallel ^{3}He MRI when developing the optimal k-space trajectories in 2D and 3D. Particularly, by constructing a corresponding GLCM, the k-space trajectories could be then optimized for preserving of the certain shapes and structures in the image (stripes, grain structure, etc).

Refrences: [1] Meise F. et al 63:456-464, (2010) MRM; [2] Rivoire J et al (2009) Proceedings of ISMRM#2139; [3]Risse F. et al NMR Biomed. (wileyonlinelibrary.com) DOI: 10.1002/nbm.1725, [4] Mugler JP III (1998) Proceedings of ISMRM #1904.

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