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Time-Resolved 4DMRI

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Introduction

4D imaging is an important tool for respiratory motion quantification and, among others, finds its application in radiotherapy treatment planning. To date, most 4D imaging techniques rely on prospective or retrospective stacking of partial image data and binning [1]. The result is a respiratory-correlated 4D image representing a mean breathing cycle. However, such binning methods lack the ability to reveal respiratory variabilities which are crucial for the validation of treatment plans or motion mitigation strategies in radiotherapy [2]. We present a novel 4D MRI approach which relies on a sophisticated k-space sampling strategy and motion compensation via spatial core alignment [3]. The presented method is truly time-resolved in the sense that it does not depend on respiratory binning but it provides a continuous 4D image while capturing motion variabilities.

Materials and Methods

The amount of time required for full Cartesian k-space sampling often exceeds the time frame where moving structure can be imaged without suffering from major motion artifacts in the final reconstruction. Thus, we have developed an MR sequence which alternately samples the k-space core and a peripheral patch of the k-space (Figure 1a). The acquired k-space cores allow the monitoring of the motion which happens during the acquisition of the peripheral patches. Peripheral patches are corrected for the motion by using the spatial image alignment of the cores. For each acquired core the spatially aligned peripheral patches are accumulated to a full and consistent time-resolved k-space [3].

Results

We modified a product sequence for a radio-frequency spoiled gradient echo acquisition with short repetition time and low flip angle in order to alter the sampling of the k-space. Considering 1500 time points, the acquisition time was 11.1 min and the reconstruction time 2h. Six volunteers have been scanned under free-breathing on a 3T clinical scanner. In Figure 1b, we compare sample slices of reconstructions where no motion has been considered (*static*) with the reconstructions where the *non-rigid* motion has been compensated.

Conclusions

By visually comparing the static and non-rigid reconstruction (Figure 1b), the motion-corrected images are superior and look reasonable. As for each acquired k-space core, a full image can be reconstructed, our method yields a time-resolved 4D image. The quantitative validation of this method using an anthropomorphic phantom with repeatable respiratory motion is planned for the future.

Acknowledgments

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References

[1] Stemkens et al. (2018), PMB(63); [2] Krieger et al. (2019), ESTRO38; [3] Jud et al. (2018), MICCAI18

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