# Segmented Multislice Acquisition for Motion-Insensitive Super Resolution Multislice T2-Weighted Fast-Spin-Echo Imaging

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## INTRODUCTION

T2-weighted fast-spin-echo (T2 FSE) imaging using a two-dimensional (2D) multislice acquisition is one of the most commonly used pulse sequences in clinical MRI. However, T2 FSE continues to be limited by spatial resolution in the slice select direction, typically 3-6× coarser than the in-plane resolution. Although three-dimensional (3D) fast-spin-echo approaches have been developed and used in various applications to offer improved slice resolution, they have yet to routinely replace 2D multislice T2 FSE. Direct 3D T2 FSE has limited contrast and spatial resolution. Obtaining high through-plane resolution of multi-slice T2 FSE imaging has been a long-standing challenge. Recently, methods have been developed for providing improved through-plane resolution using overlapped slices, allowing, for example, high quality sagittal and coronal reformats from axial acquisition. However, subtle slice-to-slice motion during acquisition causes objectionable scalloping artifact.

## AIM

Previously we have shown improved through-plane resolution in T2 FSE prostate MRI by acquiring overlapped slices and accounting for the slice profile in the reconstruction [1]. The purpose of this work is to describe how the overlapped slices required for super resolution can be acquired using a modified, segmented, multislice acquisition. We hypothesize that the modified approach substantially reduces the scalloping artifact seen in reformats while retaining overall image quality.

## METHOD

Subtle transverse motion of the prostate during a 4-6 minute-long T2 FSE scan is observed to be primarily driven by peristaltic motion in the rectum. With no motion the stack of axial slices accurately portray a presumed superior/inferior edge of some object. However, slight motion in-plane leads to step-wise scalloping owing to data for the different passes being collected at different times (Fig.1). In the proposed method the acquisition of the $k_Y$-lines in each pass is divided into multiple segments. Each segment comprises the acquisition of some subset of the $N_{REP}$ repetitions required for full sampling (Fig.2). The new acquisition causes the data acquisition of all passes to have substantial temporal overlap, leading to improved pass-to-pass consistency of object position but at the possible expense of in-plane blurring. The new segmented sequence was evaluated using a motion-controlled resolution phantom to assess possible loss of in-plane resolution vs. the original sequence (Fig.3-4). To assess performance *in vivo*, the new segmented and original multislice sequences were compared in 14 male patients under an IRB-approved protocol. Super-resolution axial images and sagittal reformats were evaluated by 3 experienced uroradiologists (Fig.5-7).

## RESULTS

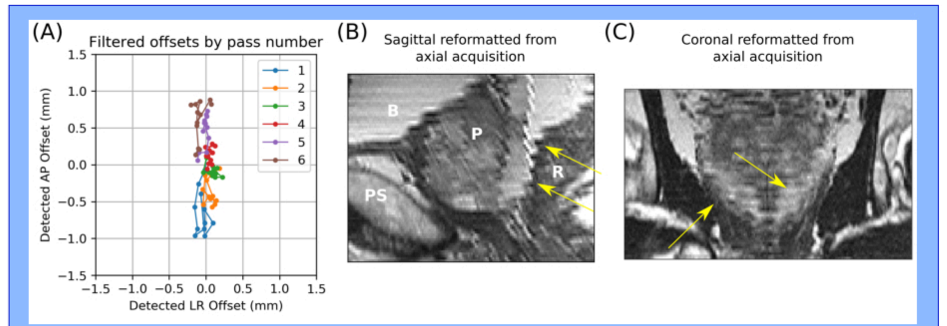


*Figure 1. Example of scalloping and plot of displacement*

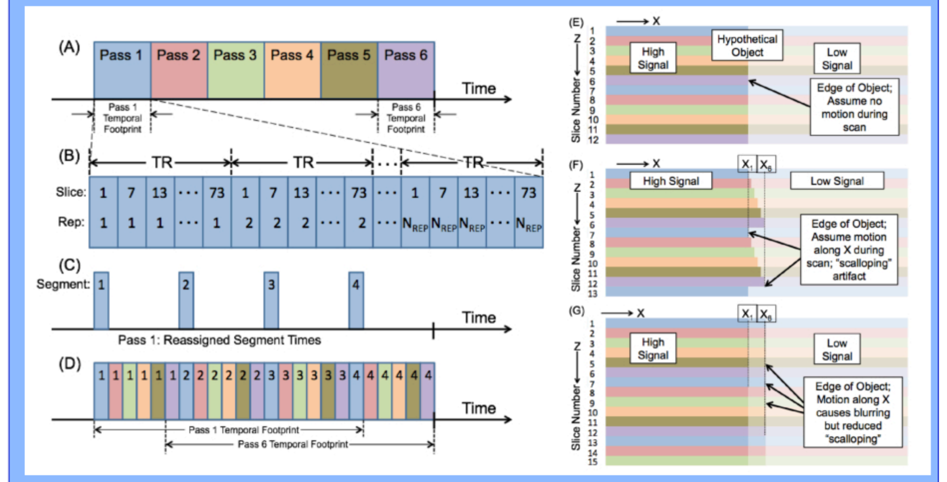


*Figure 2. Schematic comparing the timing diagrams of the original multislice sequence (A-B) and the modified, segmented sequence (C-D). (E) depicts an object in a sagittal reformat of axial images acquired with no motion. (F) and (G) depict the object for assumed X-going motion, (F) for the original axial acquisition and (G) for the new segmented axial acquisition.*

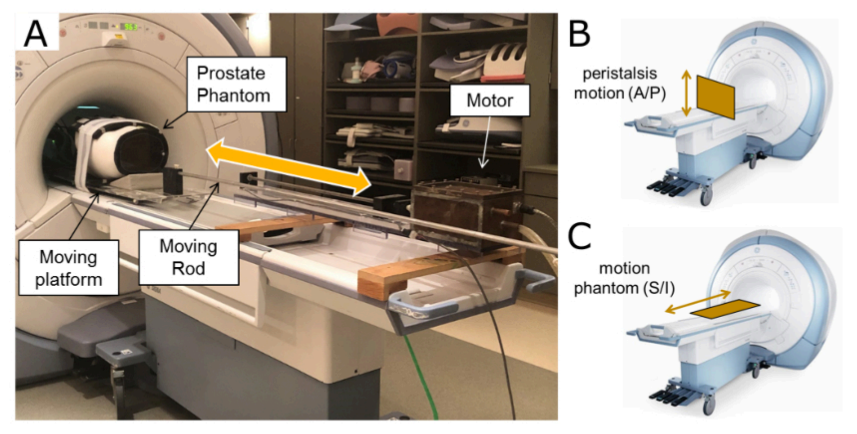


*Figure 3. (A), Setup of computer-controlled mechanical motion assembly within the MRI scanner bore. (B), Orientation of peristaltic-induced motion in the A/P (in-plane) direction within the patient for axial acquisition. ©, Orientation of the (coronal) acquisition plane in the phantom studies to simulate in-plane motion.*

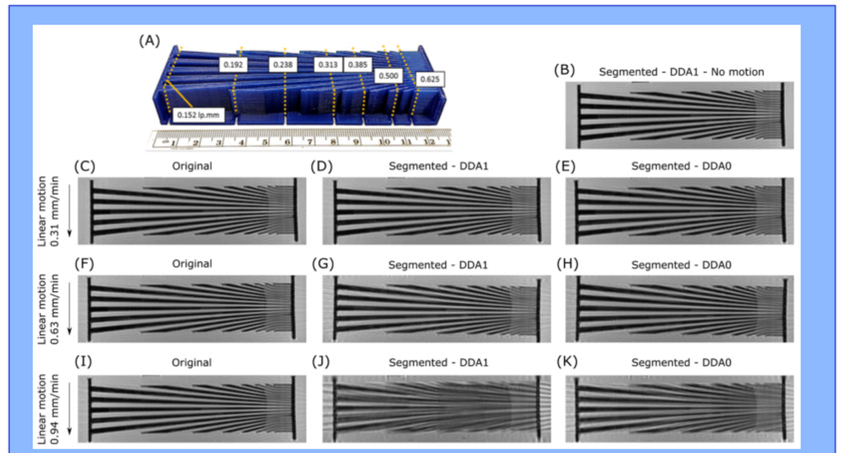


*Figure 4. (A) Photograph of resolution phantom. (B-K) Images of the resolution phantom in the plane of acquisition for no motion (B) and different levels of in-plane motion (C-K). Level and direction of motion are shown for (C, F, I).*

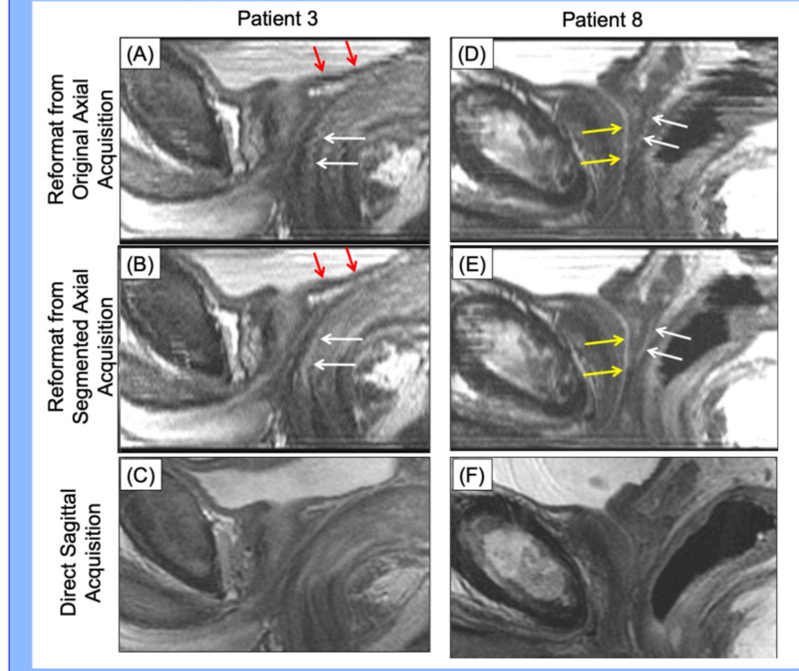


*Figure 5. Sagittal reformats from original (A) and segmented (B) multislice axial acquisitions in Patient 3 with history of cryoablation therapy. Reviewer scores for artifact were +1, 0, +1 in favor of (B) versus (A). Although (A) has very slight scalloping artifact of anterior rectal wall (white arrows), (B) is superior in artifact reduction. The wall of the posterior bladder base (red arrows) is better delineated on (B) than (A). Corresponding direct sagittal FSE image is shown in (C). Sagittal reformats from original (D) and segmented (E) multislice axial acquisitions in Volunteer 8. Reviewer scores for artifact were +2, +1, +1 in favor of (E) versus (D). Slight scalloping modulates signal of the urethra (D, yellow arrows) and prostatic wall (D, white arrows) but are absent in (E). Corresponding direct sagittal FSE image is shown in (F).*

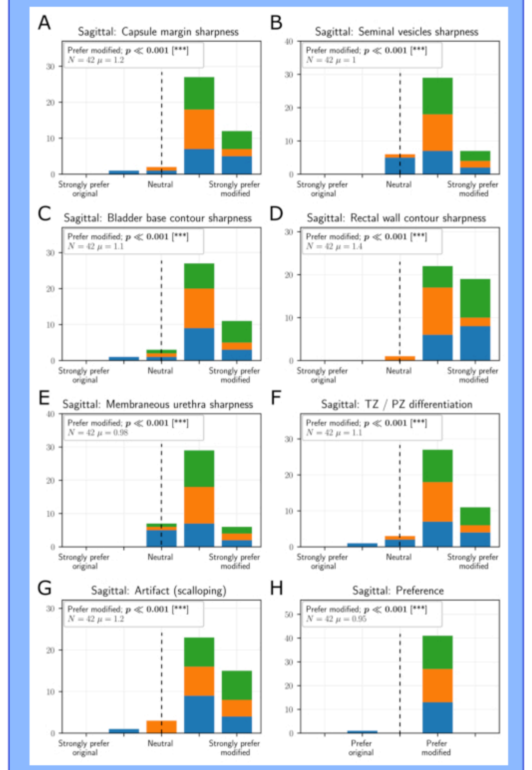


*Figure 6. Results of the clinical evaluation for the comparison of sagittal images using the original and segmented multislice sequences. Results from each of the three radiologists are shown in a different color.*


*Figure 7. Overall Image Quality scores of the axial images formed from the original and the new segmented sequence.*

## CONCLUSIONS

We have shown within the context of axial prostate T2 FSE MRI how segmenting the multiple repetitions of the multiple passes typically used to acquire overlapped slices can significantly reduce the scalloping artifact observed in sagittal or coronal reformats while retaining image quality in the acquired axial orientation. In this work we first assessed the degree of involuntary peristaltic motion typically encountered in prostate axial T2 FSE, next showed how the standard acquisition can be modified by segmenting the multiple repetitions across the acquisition time for all passes, evaluated the level of in-plane resolution loss due to the increase in temporal footprint, and finally showed significant improvement in the sagittal reformats while maintaining image quality in the native axial images.

In conclusion, we have shown how segmenting the 2D T2 FSE multislice acquisition provides considerable reduction in the level of scalloping artifact observed in sagittal and coronal reformats from (through-plane) SR axial images of the prostate while retaining image quality within the acquired axial images.

## ACKNOWLEDGEMENTS

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## REFERENCES

[1] Kargar S, Borisch EA, Froemming AT, et al. Use of $k_Z$-space for high through-plane resolution in multislice MRI: application to prostate. Magn Reson Med. 2019;81:3691-3704.

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