# 3-Dimensional Navigators for Motion Tracking and Correction in 3D Radial Imaging

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## INTRODUCTION

Radial acquisitions have inherent navigation properties; however, in practice, motion correction using projections is relatively difficult due to trajectory errors from eddy currents, electronic delays, and gradient non-linearities [1]. As an alternative, many authors utilize pencil beam navigators in conjunction with radial sampling for data rejection during free breathing [2]. While navigators have proven effective, they still maintain relatively low acquisition efficiency, and can disrupt the acquisition, perturbing the signal steady state and introducing eddy currents, particularly in cine acquisitions. For radial exams, we instead propose to replace the traditional pencil beam navigator with three orthogonal projections, without modifying the RF pulse. This allows for greater control over data rejection, offers the possibility of Center Of Mass (COM) corrections, and allows for a combination of both rejection and correction.

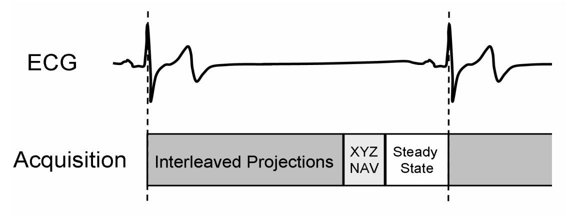


*Figure 1. Acquisition timing diagram showing shown positions of interleaved projections, the xyz projection set used as a navigator, and steady state recover.*

## METHODS

All experiments were performed on a 3.0T clinical scanner (GE Signa EXCITE2 Twinspeed). Initial experiments were designed to explore the motion detection ability of a three projection navigator. A sequence was designed with a single projection played repetitively along the S/I direction. Using a 31.25 kHz readout BW, 256 readout points, and a 30 cm FOV, projections were acquired of a volunteer during 20 s breath held and free breathing exams. Cardiac and respiratory monitoring signals were acquired throughout the exam, and stored for comparison. A simple spoiled-gradient echo free-breathing CINE 3D radial (VIPR [3]) sequence was implemented with prospectively gated acquisition with consisting of a long acquisition period, a short three projection navigator, and dead time in which pulses are played to maintain steady state but no data is collected. Phantom images were acquired with this sequence with a simulated cardiac signal: with no motion, with motion in the S/I direction by continuous table rocking. Images were acquired using a 22x22x22 cm FOV, 320x320x320 matrix, 31.25 kHz readout BW, and an artificial 60 bpm cardiac trigger signal. Images acquired with and without the navigator were compared for image quality and distortions. Images with motion were corrected using offsets determined by the COM at echo time, as interpolated between 3-projection navigators. .

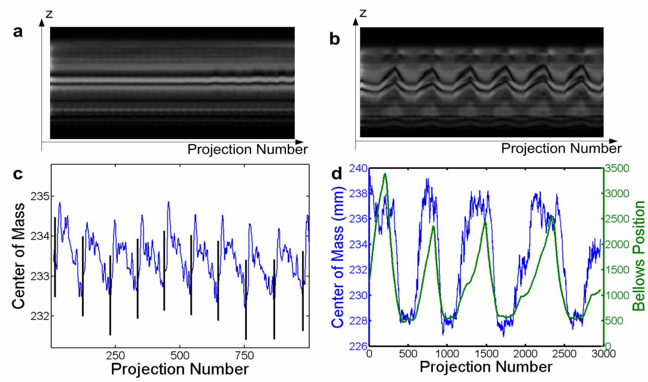


*Figure 2. Motion tracking scan with PC VIPR.. The top row shows the magnitude of unsubtracted projection data during breathhold (a) and free breathing (b). The bottom row plots the COM location of segments of (a) and (b). During breathhold (c), the COM varies with the cardiac cycle (black bars indicate location of R-wave). During free breathing (d), the COM tracks well with a bellows*

## RESULTS

Results of the motion detection ability test, are shown in Figure 2. During the breath hold scan, cardiac ECG triggers locations are correlated with rapid changes in the position of the center of mass. A similar approach has been used by others for self-gating of 2D radial cine acquisitions [4] During free-breathing, the center of mass also tracks the respiratory bellow well as it has been exploited for navigation for the imaging of the coronary arteries [5]. Some disagreement is seen during periods of inspiration, likely due to the non linear relationship between the bellows reading and S/I motion. Results also show that it is rather implausible to detect both respiratory and cardiac motion simultaneously from this signal. Phantom images, with and without motion are shown in Figure 3. Images with motion are heavily corrupted, but can be corrected to nearly motion free conditions (Fig. 3b,c), using the measured COM location as shown in Figure 4.

## DISCUSSION

We have shown the ability of 3-projection navigators to both detect motion in volunteers and correct translational motion in volunteers. This approach allows for motion tracking in three orthogonal spatial dimensions with very little penalties in scan time and no distortions of the steady state. The ability to correct for motion will be more limited in actual imaging due to the complexity of motion; however, this may be overcome using a local analysis of each projection and different shifts for each coil. Currently, this method is limited to low frequency motion correction because COM measurements are obtained once every heartbeat only. However, it may be possible to use the inherent navigation properties of the radial acquisition to provide better interpolation between measurements.

## REFERENCES

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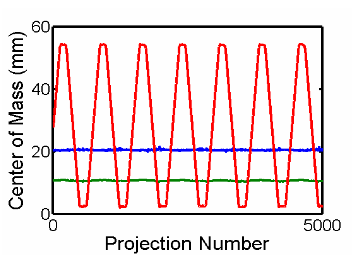


*Figure 4.Measured COM, during programmed table motion, along the S/I (red), L/R(blue), and A/P(green). Values are interpolated, with a navigator projection set every 90 projections.*

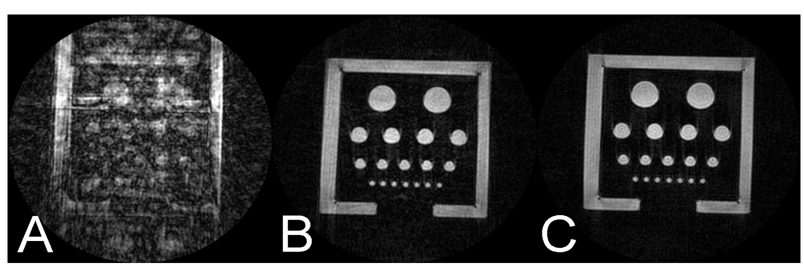


*Figure 3. Reconstructed VIPR mages acquired with motion (A), with motion corrections (B), and a reference image acquired without motion*