Real Time Velocity-Based Navigator triggering in the abdomen: Initial results

G. Beck[1], J. Stout[1], V. Denolin[2], K. Coenegrachts[3], and G. Herigault[1]
[1]Philips Healthcare, Best, Netherlands, [2]Philips Healthcare Benelux, Brussels, Belgium, [3]Department of Radiology, AZ St.-Jan, Brugge, Belgium

Introduction

In abdominal applications, Respiratory-Belt Triggering (RBT) and Preparation-Based Navigator Triggering (PBNT) techniques typically use information from the beginning of the scan to provide subsequent motion control and adjustment of the acquisition window to the end expiration phase. Both techniques require prior knowledge on the optimal trigger delay time and PBNT further requires additional information on the trigger level. However, the end expiration timing and level often varies throughout the scan with the consequence that trigger moments may either be missed or acquisitions may not be performed in the calm end expiration phase but in between inspiration and expiration states. Immediate consequences are image blurring and prolonged scan time especially with PBNT methods. A recent approach has incorporated velocity encoding in projection navigators to identify calm breathing periods in PRF Thermometry [1]. Here we present a novel Navigator triggering method that relies on the real-time analysis of breathing states and velocities to detect the calm end expiration phase. The Velocity-Based Navigator triggering (VBNT) method includes slice tracking to correct for end expiration level variations. The goal of this study is to compare VBNT, PBNT and RBT approaches and report on the impact on scan efficiency and image sharpness in abdominal imaging.

Methods

Navigator triggering use repetitive Navigator acquisitions until an end expiration state is detected. In VBNT a motion velocity is determined from these successive motion states and is checked using the following steps:

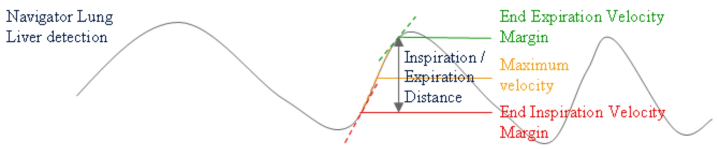

Figure 1: Navigator triggering principal using a motion velocity regulator

Passing an end inspiration phase, the end inspiration breathing state is stored. After a maximum velocity is reached the motion velocity is checked with respect to a velocity margin and a minimum inspiration / expiration distance criterion. Triggering is enabled when the velocity is below a specified end expiration velocity margin and the inspiration / expiration distance is larger than the minimum noise distance criteria.

All experiments were performed on Philips 1.5T and 3.0T clinical scanners using a 16-channel Torso coil. A volunteer study including 10 subjects was carried out to compare PBNT and VBNT, both using slice tracking. Both approaches were validated on state of the art body sequences (T2W-TSE, DW-EPI). The patient study was performed on 14 subjects comparing RBT and VBNT techniques. In this study the comparison was performed using a DW-EPI sequence with the following parameters: 38 axial slices covering 190 mm, FOV 305 mm (RL) x 290 mm (AP), voxel size 1.9 mm x 2.4 mm, , diffusion b = 10 s/mm^2, scan time 3:15.

Results

Navigortor trace results: Illustration of problems (PBNT) and solution (VBNT)

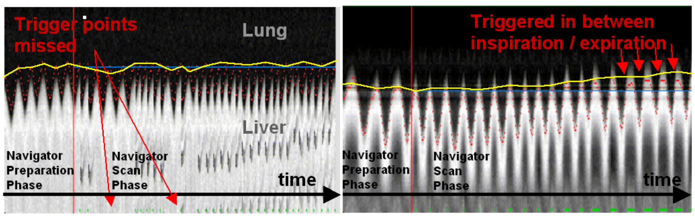

Figure 2: 3T Navigator examples of the Preparation-based Navigator triggering technique.

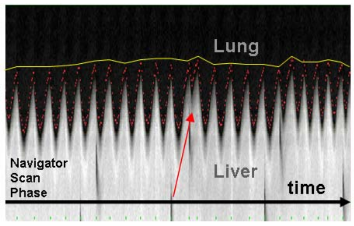

Figure 3: Examples of the VBNT approach. Note that end expiration states are consistently detected also in case of short respiratory cycles (red arrow).

Figure 2 demonstrates the difficulties with PBNT. Due to variations in the breathing pattern, the trigger level (blue line) determined during the preparation phase does not always match with the subsequent end expiration levels. As a result trigger points are missed as illustrated by the missing green dots at the bottom of the Navigator display (left example, red arrow). In the right example, breathing variations result in acquisitions triggered in between inspiration and expiration as indicated by the red arrows resulting in motion blurring.
Figure 3 illustrates the Navigator signal with VBNT. Trigger moments and respective acquisition points are consistently detected in the end expiration state as illustrated by the green dots.

Imaging results

In all 10 volunteers the quality of VBNT was either equal (n=6) or better (n=4) than PBNT. Scan time was significantly reduced in 8 out of the 10 volunteers, with up to a factor 2 in scan-time reduction. In the 14 patients, the quality of VBNT was either equal (n=5) or better (n=9) than RBT.There was no statistical differences in scan-time between the two techniques. Figure 4 shows DWI data obtained on one of the patients with RBT (left) and VBNT (right) and the respective coronal MPRs (lower row). VBNT provides better image sharpness allowing to better visualize a small lesion in the liver (red arrow). MPR reconstructions show better signal homogeneity in the slice direction when VBNT is used, likely to be a direct benefit of slice tracking which provides more accurate coverage.

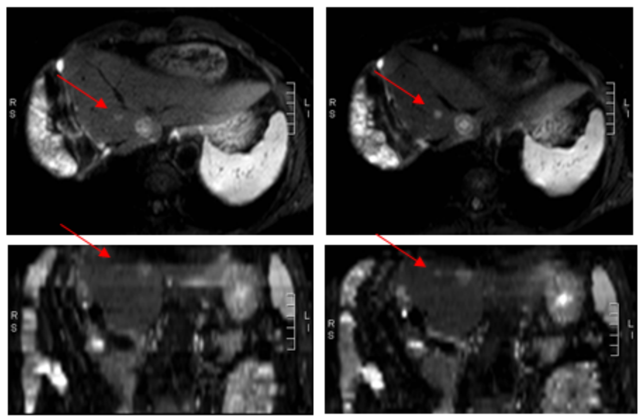

Figure 4: Slices (upper row) and MPR (lower row) acquired with a DWI sequence on 1.5 T using RBT (left) and VBNT (right).

Conclusion

Our novel velocity based Navigator triggered method was succefully applied on volunteer and patient abdominal examinations providing robust, accurate and time efficient motion correction. VBNT outperformed the standard respiratory-belt trigerring approach with respect to image sharpness and homogeneity, and was faster than the conventional preparation-based navigator method.

References

[1] Maier F et al., ISMRM Proceedings 2010: Velocity Navigator Triggering for Motion Compensated PRF Thermometry