Coronary Magnetic Resonance Angiography using non Spatially Selective Navigator Excitations at 3T

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INTRODUCTION: Real-time navigator technology is commonly used for respiratory motion suppression in high spatial resolution cardiovascular magnetic resonance imaging (MRI). For the estimation of respiration induced cardiac motion, one class of navigators excites a pencil beam shaped volume (2D selective excitation) that is typically localized at the dome of the right hemidiaphragm (RHD) [1]. For this approach, multicenter experience at 1.5T exists [2] and 2D selective excitations with shallow tip angles support localization of the navigator not only at the RHD, but also directly at the lung-heart interface [3]. However, localization of this 2D selective excitation is user dependent, extra time for localization of the navigator has to be accounted for, and at high magnetic field strength, magnetic field inhomogeneity at tissue interfaces poses extra challenges to the performance and reliability of such 2D selective navigators. For these reasons, we have aimed at implementing a real-time navigator that is less susceptible to magnetic field inhomogeneity, and that minimizes the need for user interaction, therefore maximizes the 'ease-of-use' of navigators for the suppression of respiratory motion.

METHODS: To remove the need for a pencil beam excitation [4], we have replaced the 2D selective excitation with a single RF block pulse (Figure 1). However, this non-spatially selective RF pulse excites the entire thorax, and the resulting compound signal confuses respiratory estimators. To counter this, the individual coil sensitivities of the phased array cardiac coil were exploited and the source of the navigator signal was spatially constrained by selecting the coil element closest to the heart for navigator signal reception. To further minimize unwanted signal from the chest, both a saturation band localized at the anterior chest and fat saturation preceded the non-selective navigator. While both saturation band and fat saturation are commonly used in coronary MRA and are typically performed after the navigator, we have implemented the navigator after both of these sequence elements (Figure 2). With this implementation, the navigator is closer to the imaging part of the sequence. After non-selective excitation, the 1D navigator signal is obtained with a flow-compensated gradient in foot-head direction, and this signal can be used for both navigator gating and real-time motion correction. To test whether this technique can be used in vivo, coronary MRA of the left coronary arterial system was performed in a healthy adult subject during free breathing on a 3T clinical MR scanner (Achieva, Philips Medical Systems, Best, NL). The system was equipped with a 6-element cardiac phased array surface coil and vector ECG technology [5]. The 3D imaging sequence (FOV = 360mm; matrix = 560×560; TR = 11ms; TE = 2.7ms; α = 20°; acquisition window = 68.5ms; acquired slice thickness = 3mm; reconstructed slice thickness = 1.5mm; adiabatic T2Prep (TE = 50ms [6]), navigator gating window = 5mm; fat saturation; saturation band localized at the anterior chest wall) was performed with the non-spatially selective navigator and was repeated with the conventional 2D selective navigator localized at the dome of the RHD for comparison. Images were reformatted using the 'Soapbubble' tool for visualization [7].

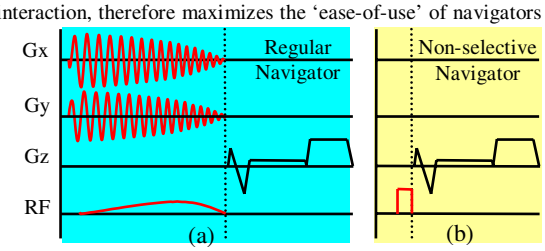

Figure 1: Pulse sequence diagram for a) conventional and b) non-selective navigator.

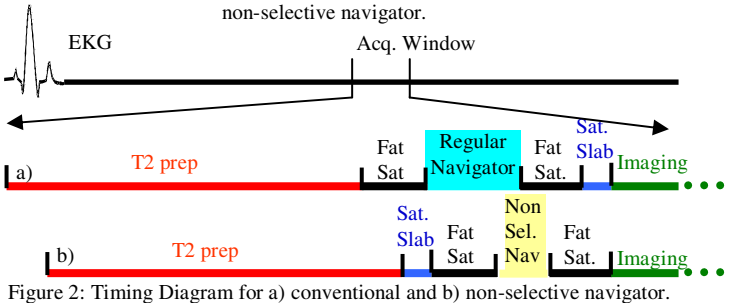

Figure 2: Timing Diagram for a) conventional and b) non-selective navigator.

RESULTS: Free-breathing coronary MRA of the left coronary arterial system could successfully be obtained with both the new, non-spatially selective and the more conventional 2D selective navigator. In Figure 3, the signal of the non-spatially selective navigator on the y-axis is displayed as a function of time on the x-axis. The respiratory pattern can easily be recognized and a high visual signal and contrast for navigator interface detection is observed. As a result, this navigator interface could easily be detected by the navigator cross-correlation algorithm and was successfully used for respiratory gating. The navigator efficiency and total scanning time were 52% and 8 min for the non-spatially selective navigator vs. 88% and 5min for the 2D selective navigator. Reformats of the 3D coronary MRA obtained with both techniques are displayed in Figure 4. In Figure 4a), the image obtained with the 2D selective navigator is displayed while that from the non-spatially selective navigator is shown in Figure 4b). On both the images, the left main (LM), the left anterior descending (LAD) and even a diagonal branch can easily be identified with high visual contrast. On the image obtained with the 2D selective navigator, a higher level of motion artifacts can be observed originating from chest wall motion. In contrast, no major motion artifacts are seen on the image obtained with the new navigator technique which leads to a better delineation of the coronary vessel and an improved visualization of smaller-diameter branching segments (dotted arrows D1 and M1).

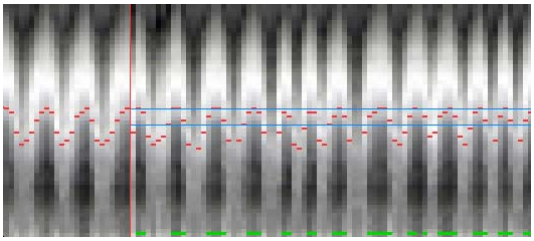

Figure 3: 1D projection obtained from non-selective navigator and the estimated motion (shown as tick marks).

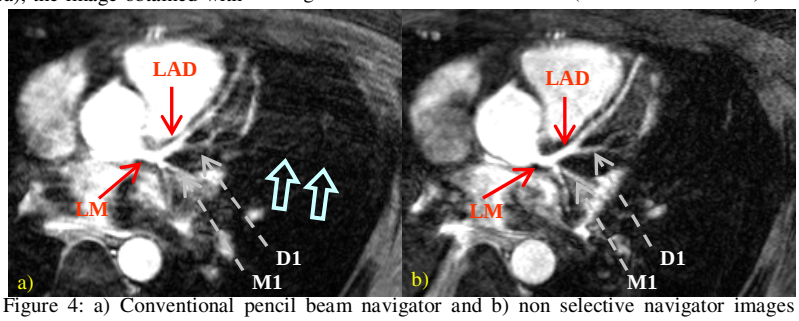

Figure 4: a) Conventional pencil beam navigator and b) non selective navigator images reformatted using 'Soapbubble' tool displaying the left coronary artery (Left main (LM), Left Anterior Descending (LAD) and First diagonal branch (D1) and First Marginal branch (M1)). Motion artifacts are shown by empty arrows in a).

DISCUSSION: We have successfully implemented and tested a navigator technique that makes use of non-spatially selective excitation in conjunction with single surface coil navigator signal reception. With the use of this technique, respiratory motion was effectively suppressed in a human in vivo experiment. Simultaneously, motion artifacts were reduced when compared to the images obtained with the more conventional navigator technology. While this led to a better visibility of smaller-diameter vessels in our experiment, a thorough side-by-side *in vivo* comparison including multiple human subjects is now needed. B0 inhomogeneity, reduced T2* and off-resonant fat excitation often adversely affect the performance of the 2D selective navigator technology, particularly at higher magnetic field strength. Furthermore, localization of a 2D selective navigator is user dependent and time consuming. We were able to circumvent these issues by the use of non-selective excitation. In summary, we have implemented a navigator technology which has the potential to improve the 'ease-of-use' of free-breathing coronary MRA particularly at higher magnetic field strength. However, further in vivo studies are now needed.

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