3D/2D Hybrid PR for Single Dose Acquisition of Dynamic and Breath-held Hyperpolarized He-3 Ventilation Imaging

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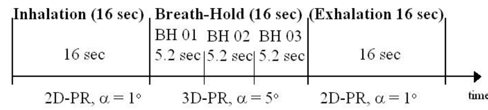
Introduction

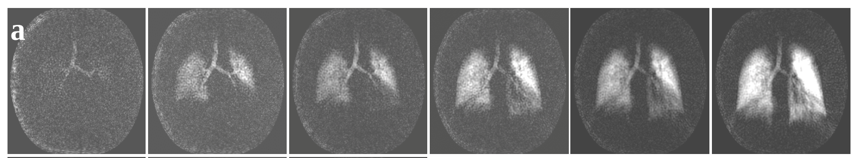
Hyperpolarized gas has raised the promise of true 3D imaging of lung function. However work is still needed to implement these methods clinically. Specifically, there is a need to reduce costs and accommodate patients with decreased lung function who have difficulty holding their breath. Work has been demonstrated for 2D and 3D dynamic imaging in separate inhalations of gas [1]. In angiographic applications, Hybrid-PR has been shown to yield high temporal and spatial resolution imaging [2]. We hypothesize that a 3D/2D Hybrid-PR acquisition will enable both high temporal resolution dynamic and high spatial resolution static ventilation imaging during a single acquisition. We have developed a single acquisition technique that depicts changes in ventilation during inhalation and exhalation of hyperpolarized gas and high spatial resolution 3D image of the lung volume during a breath-hold. Previous methods have relied on 2 separate scans to independently examine dynamic and static phases, at the cost of twice the He-3 usage and imaging time.

Figure 1. 3D/2D Hybrid PR acquisition sequence showing inhalation and breath-hold phases in time.



Methods

Imaging was performed using a standard clinical 1.5T MRI system with broadband capabilities (GE Health Care, Milwaukee WI) coupled with a vest coil(IGC Medical Advances, Milwaukee WI) tuned to 48 MHz. All volunteer studies were approved by the University of Wisconsin IRB. Lung functional measures indicated that volunteers exhibited >80% predicted FEV1. Subjects were asked to inhale a 3.4 mM dose of He-3 and Nitrogen gas mixture for 16 seconds, then maintain a breath-hold for 16 seconds, and finally perform a forced exhale. During the course of the procedure, three separate imaging phases occurred. During the dynamic phases, a 2D-PR acquisition was performed allowing high temporal resolution. Imaging parameters for the dynamic phase included TR/TE = 6.1/2.7 msec, FOV = 46 cm, BW = 15.63 KHz, 128 sampled points, 60 projections, 1 deg flip angle, while during the breath-hold phase, 3D Hybrid-PR was performed to obtain high spatial resolution. Imaging parameters for the 3D breath-hold were the same except for a partial NEX in the slice encoding direction (Z), 24 x 8 mm slices in Z, and the flip angle was increased to 5 deg. During the breath-hold, three full 3D volumes with offset angles are acquired. Dynamic data was reconstructed to achieve a temporal resolution of 366 msec. Data were zero-filled to provide a 256x256 matrix. Two separate 3D volumes acquired during breath-hold were combined to create a single 120 projection angle image volume. Breath-hold static data was reconstructed to 256 x 256 x 48 matrix using homodyne in the slice select direction (Z) to achieve a spatial resolution of 1.8 mm in-plane and 4 mm in Z. A static 2D Cartesian multi-slice acquisition was also performed for a 5.4 mM He-3 dose using TR/TE = 7.7/1.3 msec, FOV = 46 cm, BW = 15.63 KHz, 9 deg. flip angle, 15 x 10 mm x slices, and 128 x 128 matrix.



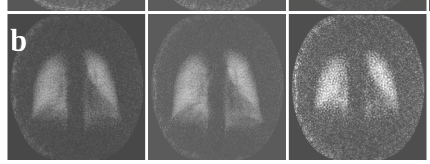


Figure 2. 3D/2D Hybrid PR dynamic ventilation images produced using 60 projection angles over a 40 cm FOV at a temporal aperture of 366 msec showing high temporal resolution during the 2D-PR phase of the acquisition, a) inhalation b) and forced exhalation.

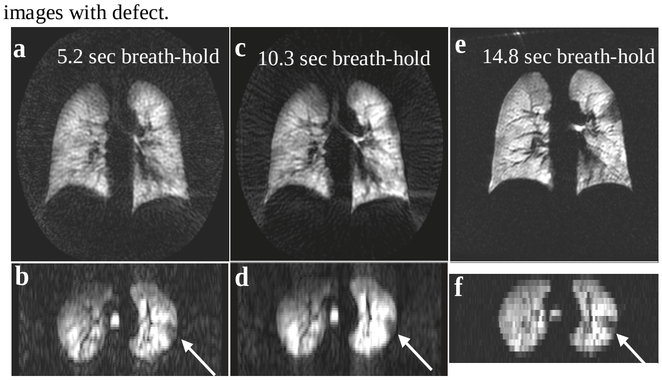
Results and Discussion

Dynamic images of the inhalation and exhalation phases are shown in Figure 1 a and b respectively. Several stages of both inhalation and exhalation are depicted allowing detection of any potential gas trapping. Slices of the 3D volume are shown in Figure 2 for a single 5.2 sec acquisition volume and for 2 combined 3D volumes acquired over 10.3 sec demonstrating the high resolution attained during the breath-hold. The volunteer moved prior to completion of the full 16 sec breath-hold making combining of the third 3D volume impossible. Ventilation defects are depicted with arrows. Decreased signal in the anterior of the axial images is shown in agreement with previous work and is likely due to a combination of gravity effects and RF saturation[3].

Conclusions

We have demonstrated a combined acquisition for both high temporal resolution during the dynamic phases and high spatial resolution during the breath-hold. This enables simultaneous acquisition of valuable information about static ventilation defects as well as the ability to detect dynamic events such as gas trapping. This reduces both costly hyperpolarized He-3 and clinical time by a factor of two. Additionally, the use of 3D Hybrid-PR ensures acquisition of a full 3D image set in only 5.2 sec if the patient is not capable of completing the full 16 sec breath-hold. Future work will include increasing receiver bandwidth to reduce off resonance blurring and decrease acquisition time. Also, the flexibility allowed by this 3D/2D Hybrid PR technique enables further optimization of the breath-hold phase. The current implementation includes a 16 sec breath-hold during which 3 complete 3D volumes are acquired. This can allow averaging if the patient has completed the full 16 sec hold, or ensure an image is acquired if patients are unable to complete the full 16 sec hold. Offsetting the PR angles between 3D volumes will allow combining of data sets for increased in-plane resolution in patients capable of longer breath-holds. A ramped RF-pulse implementation of the sequence is under development to compensate for RF saturation in the anterior regions of the right and left lungs.

Figure 2. a) 3D Hybrid PR 5.2 sec in of breath-hold coronal slice demonstrating ventilation defect (arrow) b) axial slice showing defect. 3D hybrid PR combining 10.3 sec of breath-hold data showing same c) coronal and d) axial slice with defect. 2D Cartesian acquisition acquired in 14.8 sec with comparable spatial resolution showing matching e) coronal and b) axial images with defect.



References

[1] Wild et al. MRM, 49;991-997 (2003).
[2] Vigen et al. MRM, 43;170-176 (2000).
[3] Wild et al. MRM, 52:673-678 (2004).

Acknowlegements

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