Whole-Heart Magnetic Resonance Coronary Angiography with Visual Feedback

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Introduction

Whole-heart magnetic resonance coronary angiography (WH MRCA) [1] can be used to depict the courses of the coronary arteries over the entire heart and is a promising method for the diagnosis of ischemic heart disease [2]. The WH MRCA method most commonly employed at this time is performed under free breathing while monitoring the position of the diaphragm. However, as the scan time is rather long, the patient's breathing pattern may change during scanning.

In such cases, the scan time is prolonged even further and scanning may sometimes not be completed. An abdominal band can be applied to the patient in order to limit movement of the diaphragm, but this cannot completely eliminate changes in breathing pattern, and in large patients, it may not even be possible to apply an abdominal band. There is another method in which the FOV is divided into multiple slabs and WH MRCA is performed during multiple breath-holds [3]. However, in this method, patients cannot hold their breath at exactly the same level each time, and misregistration therefore occurs between slabs. As a result, continuity of blood vessels is lost in volume rendering. These problems can basically be attributed to the fact that patients cannot recognize their breathing level and therefore cannot adjust it.

In order to reduce scan times and improve throughput, we have developed a Visual Feedback (VFB) system that visually displays the breathing level to the patient, thus permitting the patient to adjust his or her breathing level. The present study was undertaken to investigate the usefulness of the VFB system in WH MRCA studies.

Methods

All studies were performed using a standard 1.5-T clinical MRI system. A 3D SSFP pulse sequence was used in combination with Realtime Motion Correction (RMC), which detects the position of the diaphragm and performs correction to compensate for the effects of respiratory motion. Scanning was performed with TR/TE = 5.2/2.6, matrix size = 168 x 256, and number of segments = 4 to 6. A total of 75 to 80 slices were obtained and then interpolated to 150 to 160 slices. The spatial resolution was 0.75 x 0.75 x 0.75 mm^3. Spectral Fat Suppression was also employed.

The VFB system converts the NMR signals from an ROI set on the diaphragm and information concerning the specified breathing level threshold into NTSC signals and then converts these NTSC signals into optical signals using an NTSC-optical converter. The signals are then transferred through the wall of the shield room via an optical fiber cable. Inside the shield room, the signals received from the optical fiber cable are converted back to NTSC signals by an optical-NTSC converter and then displayed on an 8-inch LCD monitor. The displayed information is reflected in a mirror to allow it to be viewed by the patient. In the present study, after obtaining informed consent, 10 healthy volunteers were scanned using the following four methods and the results were compared.

1) Conventional WH MRCA during free breathing
2) WH MRCA during free breathing with VFB
3) Single-slab multi-breath-hold WH MRCA with and without VFB
4) Multi-slab multi-breath-hold WH MRCA with and without VFB

In method 2), WH MRCA was performed with VFB during free breathing. The subjects were instructed to observe the VFB monitor in the mirror and to adjust their breathing when the breathing level became low. In method 3), multi-breath-hold scanning with VFB was performed while confirming that each breath-hold position was within the RMC threshold. The number of slabs was 1, as in conventional WH MRCA. During the rest time between consecutive breath-holds, scanning was continued and the data was obtained with normal free-breathing WH MRCA. In method 4), the FOV for WH MRCA was divided into 2 to 6 slabs and data was acquired for each slab during a separate breath-hold using VFB and RMC. The RMC threshold was set for the first slab only, and for the remaining slabs, the subjects were instructed to adjust their breathing level so that the position of the diaphragm was within the threshold set for the first slab.

Results and Discussion

Comparing methods 1) and 2), data was acquired in a more stable manner and without prolongation of the scan time with method 2) in which VFB was used. The scan time was 14.1 ± 4.6 min for method 1) and 9.0 ± 3.0 min for method 2). The RMC success rate was 64.8% ± 11.0% for method 1) and 68.7% ± 5.2% for method 2). In method 1), the breathing level changed during scanning and the scan time was significantly prolonged (maximum of 24 min) in some subjects. In method 2), scanning could be performed in a stable manner, with a maximum scan time of 11 min. In addition, with VFB, data could be acquired successfully even without the use of an abdominal band.

Comparing methods 3) and 4) with VFB, the subjects were able hold their breath at almost the same position each time and imaging was performed successfully with both methods. The scan time was 7.6 ± 1.2 min for method 3) and 6.8 ± 3.0 min for method 4). The RMC success rate was 72.0% ± 11.1% for method 3) and 79.0% ± 7.8% for method 4). The scan time in method 4) was significantly shorter, but the rest time between consecutive slabs (approx. 1 min) was not included in the calculation, and the actual total scan time was approximately 10 min on average. On the contrary, in method 4), the scan time was not prolonged, because even during the rest time between consecutive breath-holds, scanning was continued with normal free-breathing WH MRCA. The RMC success rate was 100% during breath-holding, but time-average success rates were obtained including the rest time between breath-holds.

When VFB was not used in methods 3) and 4), misregistration occurred. This resulted in blurring and other types of degradation in image quality in method 3). In method 4), misregistration between slabs was more pronounced and the acquired data was not suitable for volume rendering. When VFB was used, the acquired multiple data sets were successfully used as a single volume data set for volume rendering in both methods. In method 4), however, low-sensitivity areas due to the slice characteristics of each slab were observed in some cases and few extra overlap slices were needed. These findings suggest that single-slab multi-breath-hold scanning with VFB provides images in the shortest practical time and with the highest image quality.

Conclusion

The VFB system permits patients to observe the changes in their breathing level during scanning and to adjust their breathing level accordingly. When this system is used, WH MRCA can be performed without difficulty or prolongation of the scan time, even in patients in whom an abdominal band cannot be used. In addition, the VFB system permits single-slab multi-breath-hold and multi-slab multi-breath-hold scanning to be performed in a shorter time. It is therefore concluded that the VFB system can be extremely helpful in WH MRCA studies.

References

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