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Compression Belt for Navigator-triggered trueFISP Whole-heart Coronary
Magnetic Resonance Angiography: Study in Healthy Volunteers

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Purpose: To evaluate in healthy volunteers the usefulness of an abdominal compression belt in reducing acquisition time by stabilizing respiratory motion during whole-heart coronary magnetic resonance angiography (WHCMRA) using conventional navigator triggering.

Methods: In 10 healthy volunteers, we performed free-breathing 3-dimensional segmented true fast imaging with steady-state precession (trueFISP) WHCMRA using conventional navigator triggering without motion-adapted gating. We acquired images with the abdominal compression belt rolled tightly around the upper abdomen and without the belt. We compared image acquisition time, navigator efficiency, and visible length of coronary arteries using paired t-test and subjective image quality on a 4-point scale (1, poor; 4, excellent) using Wilcoxon signed-rank test.

Results: There were no statistically significant differences for mean acquisition time (11.5 ± 5.0 vs. 9.3 ± 2.4 min, P = 0.150); navigator efficiency (38.7 ± 13.6 vs. 42.8 ± 11.0%, P = 0.336); mean overall visible length of the coronary arteries (99.7 ± 22.7 vs. 105.0 ± 16.5 mm, P = 0.530); or mean overall subjective image quality (2.5 vs. 2.7, P = 0.297) between results obtained with and without the abdominal compression belt.

Conclusion: In this small group of healthy volunteers, the use of an abdominal compression belt did not reduce image acquisition time or improve image quality in trueFISP WHCMRA using conventional navigator triggering; however, the technique’s feasibility requires additional consideration using other navigator-triggering methods for patients with irregular respiratory cycles.

Keywords: belt, coronary, heart, magnetic resonance angiography, magnetic resonance imaging

Introduction

Whole-heart coronary magnetic resonance angiography (WHCMRA) has recently been used to obtain relatively high-quality noninvasive images of the whole coronary arteries in a single acquisition.1-7 However, because images must be obtained under both cardiac and respiratory gating, long acquisition is a major drawback of this technique. A navigator echo is commonly used to monitor the movement of the diaphragm and gate respiratory motion during free breathing. Therefore, acquisition time, and probably image quality, can depend strongly on respiratory as well as cardiac motion.

Occasionally, an abdominal compression belt is used to reduce respiratory motion artifacts in the abdominal or pelvic region by suppressing the degree of respiratory motion.8-10 This technique has been attempted for WHCMRA to reduce acquisition time by stabilizing respiratory motion, but usefulness of the belt has not been reported for WHCMRA.

Therefore, in healthy volunteers, we evaluated the usefulness of an abdominal compression belt in improving acquisition time and image quality
of free-breathing 3-dimensional (3D) segmented true fast imaging with steady-state precession (trueFISP) WHCMRA using a conventional navigator-triggered method.

Materials and Methods

Study group

This prospective single-institution study was approved by the Institutional Review Board of this facility. Informed written consent was obtained from each volunteer.

We examined 10 healthy male volunteers (aged 24–40 years, median, 31.8 years) with no history of heart disease, and in sinus rhythm (mean heart rate, 68.6 ± 10.2 beats per minute [bpm]; range, 51–86 bpm). The mean body mass index was 22.7 (range, 19.2–26.1).

MR imaging examinations

We performed magnetic resonance (MR) imaging using a commercial 1.5T scanner (Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany) with a 6-element body phased-array coil as radiofrequency receiver.

All images were obtained during free breathing in the supine position. The abdominal compression belt was rolled tightly during deep inspiration, ensuring subject’s comfort. We performed an initial 2-dimensional transverse trueFISP sequence to localize the entire heart and include the coronary arteries. We defined subject-specific trigger delay time and the interval of minimal right coronary artery (RCA) motion in mid-diastole by visually inspecting RCA movement using a transverse view cine segmented trueFISP sequence with high temporal resolution (25 phases per RR interval). We obtained WHCMRA covering all coronary arteries in a transverse orientation using a 3D segmented trueFISP sequence: repetition time/echo time (TR/TE), 3.6/1.61 ms; flip angle, 90°; number of signals acquired per cardiac cycle, 31; bandwidth per pixel, 980 Hz; field of view (FOV), 300 × 225 × 120 mm; acquisition matrix, 256 × 229 × 128; reconstruction matrix, 512 × 459 × 128; and reconstructed voxel size, 0.6 × 0.6 × 1.5 mm. We used the fast acquisition parallel imaging technique of generalized autocalibrating partially parallel acquisitions (GRAPPA) with an acceleration factor of 2.

We prepared magnetization by applying a T1 preparation pulse (TR, 6.0 ms, TE, 1.8 ms; flip angle, 30°) with echo time 40 ms. A fat-saturation pulse was also applied. To compensate for respiratory motion, we used conventional prospective navigator gating. We produced spin-echo navigator signals by partially crossing 2 radiofrequency (RF) pulses, with flip angles of 90° and 180° and each slice thickness 10 mm, centering on the body axis and including the top of the right diaphragm. If the top of the right diaphragm was within the acceptance window of 5 mm at the end-expiratory phase during image acquisition, coronary artery data were acquired. We determined the base position of the navigator using a brief scout scan obtained previously with the same parameters. We did not use motion-adapted gating because we wanted to evaluate the pure effect of the abdominal compression belt; motion-adapted gating can automatically adjust the navigator’s base position according to the shift of the diaphragm’s base position from change in respiratory state during image acquisition.11–14 After initial WHCMRA acquisition, we released the abdominal compression belt to obtain WHCMRA without compression; we used the same parameters except for slice position and navigator location.

Data analysis

For each scan, we recorded the total number of respiratory (R-R) intervals and navigator efficiency, which was defined as the ratio of the number of R-R intervals that fell within the acceptance window to the total number of R-R intervals for the acquisition. The acquisition time was also recorded.

Curved multiplanar reformations of the coronary arteries, the left anterior descending (LAD) artery, left circumflex (LCx) artery, and RCA were performed on a commercially available workstation (Advantage Workstation 4.2; GE Healthcare, Milwaukee, WI, USA) by a radiologist (A) blinded to information regarding the abdominal compression belt. The curved length of each visualized artery was measured by tracing a path from its origin to the most distal portion visible in the reformatted image.

Two other radiologists (B and C), each with more than 5 years’ experience in evaluating MR images, assessed image quality by consensus. The reformatted coronary arteries of each volunteer were printed on film in random order in terms of subjects, arteries, and presence or absence of the abdominal compression belt, with the image window and level adjusted appropriately. The image quality was ranked using Kim’s previously reported scale (2): 1 = poor/uninterpretable (coronary artery visible with markedly blurred borders or edges); 2 = good (coronary artery visible with moderately blurred borders or edges); 3 = very good (coronary artery visible with mildly blurred borders or edges); and 4 = excellent (coronary artery visible with...
Table. Data obtained with and without abdominal compression belt

<table>
<thead>
<tr>
<th></th>
<th>With belt</th>
<th>Without belt</th>
<th>P-value</th>
</tr>
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<tbody>
<tr>
<td>Acquisition time (minutes)</td>
<td>11.5±5.0</td>
<td>9.3±2.4</td>
<td>0.166</td>
</tr>
<tr>
<td>Navigator efficiency (%)</td>
<td>38.7±13.6</td>
<td>42.8±11.0</td>
<td>0.336</td>
</tr>
<tr>
<td>Overall visible length (mm)</td>
<td>99.7±22.7</td>
<td>105.0±16.5</td>
<td>0.530</td>
</tr>
<tr>
<td>LAD visible length (mm)</td>
<td>111.6±24.7</td>
<td>116.9±23.6</td>
<td>0.515</td>
</tr>
<tr>
<td>LCx visible length (mm)</td>
<td>72.5±21.9</td>
<td>81.3±16.3</td>
<td>0.332</td>
</tr>
<tr>
<td>RCA visible length (mm)</td>
<td>115.0±37.6</td>
<td>116.9±35.0</td>
<td>0.889</td>
</tr>
<tr>
<td>Overall subjective image quality</td>
<td>2.5</td>
<td>2.7</td>
<td>0.297</td>
</tr>
<tr>
<td>LAD subjective image quality</td>
<td>2.4</td>
<td>2.7</td>
<td>0.345</td>
</tr>
<tr>
<td>LCx subjective image quality</td>
<td>2.1</td>
<td>2.4</td>
<td>0.345</td>
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<tr>
<td>RCA subjective image quality</td>
<td>2.9</td>
<td>2.9</td>
<td>0.999</td>
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Note: Data are mean ± standard deviation; LAD = left anterior descending artery; LCx = left circumflex artery; RCA = right coronary artery.
Fig. 1. Examples of curved multiplanar reformation images of the left anterior descending arteries (A, D), left circumflex arteries (B, E), and right coronary arteries (C, F) acquired with (A, B, C) and without (D, E, F) an abdominal compression belt in a healthy 37-year-old male volunteer. No significant difference in image quality was found. Changes of diaphragm position at the initial, middle, and final phases of image acquisition with (G) and without (H) the abdominal compression belt are shown. The y-axis shows the diaphragm position (cm), and the x-axis shows the number of respirations. The clear lines of each segment near the base position of the navigator (107 cm in G; 100 cm in H) mean the image data are acquired. In this case, movement of the diaphragm position with the abdominal compression belt (G) seems to be more regular than that without the belt (H). The navigator efficiency and acquisition time obtained with the belt's use are also better than those without it.
Looser rolling or rolling around the cardiac level might give different results.

Our study was limited by the small study population and exclusion of patients. We conducted all WHCMRA in healthy volunteers. In the clinical setting, image acquisition cannot be completed in some patients because of navigator insufficiency, partly because in patients, unlike healthy volunteers, the base position of the diaphragm would be more likely to shift during acquisition. In such case, the abdominal compression belt might be helpful by reducing excessive diaphragm shift.

Conclusion

In conclusion, in this small group of healthy volunteers, use of an abdominal compression belt did not reduce acquisition time or improve image quality in free-breathing trueFISP WHCMRA using a conventional navigator-triggered method; however, the feasibility of this technique requires additional consideration using other navigator-triggering methods and different rolling methods for patients whose respiratory cycles are irregular.

Acknowledgments

The authors wish to thank Kazuhiro Maruyama, Yugo Onodera, Kunihiro Watanabe, Norio Nishii, and Koji Torikai for image acquisition.

References