Supplementary abbreviated supine breast MRI following a standard prone breast MRI with single contrast administration: is it effective in detecting the initial contrast-enhancing lesions?

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PURPOSE
We aimed to evaluate the detectability of contrast enhancing lesions, initially demonstrated in standard prone dynamic contrast-enhanced MRI (DCE-MRI), in a supplementary supine breast MRI examination performed following the standard prone DCE-MRI examination and to show the correlation of spatial displacement of the lesions with breast size and density.

METHODS
Forty-two patients with 45 lesions were prospectively evaluated. Supine breast MRI was acquired with a 6-channel body coil following a standard DCE-MRI in prone position after repositioning the patient. No additional contrast media was administered. Images were evaluated by two radiologists in consensus for the visibility of the lesions. Lesion localization relative to the sternal midline, chest wall and nipple was measured in both prone and supine positions. Correlations between lesion displacement and breast size or breast density were analyzed.

RESULTS
Of 45 lesions, 23 (52.3%) were masses, 22 (47.7%) were nonmass enhancements (NME). Forty-four lesions (97.8%) could be detected on supine images. One linear NME of 33 mm in length could not be seen on supine images. Twenty (46.5%) of the detected lesions in supine position were equal to or smaller than 10 mm (11 NME [55%] and 9 masses [45%]). Lesion displacement relative to the chest wall increased with increasing breast size (P < 0.001).

CONCLUSION
An abbreviated supine sequence following a standard prone DCE-MRI with single contrast media administration is an effective method for defining the lesion location in supine position.

Magnetic resonance imaging (MRI) of the breast is widely used and has a wide range of indications including the screening of high-risk patients. Dynamic contrast-enhanced MRI (DCE-MRI) has a higher sensitivity and specificity than conventional breast imaging in breast tumor detection (1–5). Prone positioning of the patient is the current practice for breast MRI. Dedicated breast coils are designed for prone imaging which enables the best image quality and definition (6). On the other hand, most of the procedures like ultrasonography (US), biopsy under US guidance, physical examination or breast surgery are performed while the patient is in supine position. This change in body position between procedures can cause large positional displacements of the lesions due to breast deformation and is one of the main challenges in determining the localization of the MRI-only detected lesions (7, 8). A novel technique, volume navigation US with real time co-registration of MRI data, is described in the literature for better localization of these lesions in supine position (9–11). This technique requires an additional supine MRI of the breast with a modified coil and scanning protocol (11). A supplementary supine MRI imaging protocol necessitates repetition of the contrast administration as these lesions are visible only after contrast enhancement. However, a short sequence of supine breast MRI could be added as a supplement following a standard DCE-MRI sequence. This would obviate any additional contrast administration. In this study, we aimed to evaluate the detectability of enhancing lesions, seen initially in prone MRI images, in a supplementary supine breast MRI examination per-
formed following a standard prone DCE-MRI examination and to show the correlation of spatial displacement of the lesions with breast size and density.

Methods

Patients

This study was approved by our institutional ethics committee (Approval number 09.2017.143). Patients were recruited from December 1, 2016 to January 1, 2017. All patients who had a DCE-MRI examination of the breast during this period were included in the study. Eighty-seven patients with different breast MRI indications were examined. The indications included screening, preoperative staging, and evaluation of difficult cases that were not solved by conventional imaging methods. Exclusion criteria were: (i) Patients refusing to enter the study (ii) patients who could not complete the routine prone breast MRI examination due to several reasons like claustrophobia or contrast reaction. One patient was excluded due to motion artifacts on both prone and supine MRI. Eighty-six patients were evaluated. The mean age was 47.61±10.82 years, ranging from 21 to 77 years. Forty-two of 86 patients had 45 contrast enhancing lesions. The remaining 44 patients did not show any enhancing lesion on the standard prone DCE-MRI; consequently, the supine examination of these patients was not evaluated. The mean age for the patients with lesions was 47.22±11.08 years (range, 21–77 years) and the mean age for the patients with lesions was 47.22±11.08 years (range, 21–77 years). The mean age for the patients with lesions was 47.22±11.08 years (range, 21–77 years).

Standard prone breast MRI examination

Standard clinical breast MRI protocol was acquired using a 3 Tesla scanner (Magnetom Verio, Siemens Healthcare) with the patient in prone position with a 16-channel phased-array dedicated breast coil (Siemens Healthcare). Examination protocol comprised following sequences: 1) Axial turbo spin-echo fat saturated T2-weighted sequence (TR/TE, 4100/70 ms; field of view, 30 cm; acquisition matrix, 440x380; slice thickness, 3 mm; and acquisition time, 3 min 43 s). 2) Diffusion-weighted imaging using echo-planar image (EPI) sequence with fat suppression (b values 50, 400 and 800 s/mm²; TR/TE, 9700/86 ms; FOV, 30 cm; in-plane resolution, 1.7×2 mm²; slice thickness, 3 mm; and acquisition time, 4 min 32 s). 3) 3D volumetric interpolated (VIBE) sequence (TR/TE, 5.01/1.77 ms; FOV, 30 cm; acquisition matrix, 512×460; slice thickness, 1 mm; in-plane resolution, 0.6×0.7×1.0 mm; and total acquisition time, 10 min with a temporal resolution of 82 s) for dynamic contrast-enhanced sequence. Contrast agent, Gadobutrol 0.1 mmol/kg (Bayer Schering Pharma AG), or Gadoterate Meglubine 0.1 mmol/kg (Guerbet) were administered intravenously via an antecubital vein at a rate of 2 mL/s using an automated injector system (Medrad Spectris Solaris EP; Bayer Medical Care) followed by a saline injection. Subtracted contrast-enhanced dynamic images were used as standard for lesion identification.

Supine breast imaging

After completion of the prone breast MRI the patient was taken out of the magnet. The dedicated breast coil was retrieved. Patient position was changed to supine with both arms extended over the head. A flexible 6-channel body coil (Body Matrix Coil, Siemens Healthcare) was centralized on the sternum and placed over both breasts and was fixed with a strap to prevent coil displacement and minimize artifacts due to respiratory motion. A single three-dimensional turbo field echo sequence was used for T1-weighted high resolution examination volume without fat suppression (TR/TE, 2030/12 ms; flip angle, 120 degrees; field of view, 320 mm; matrix, 322x480 mm; acquisition time, 82 s). The whole procedure time was 2 min 20 s. The mean time spent in between prone and supine MRI for the patient repositioning was 70 s (range, 60–85 s). The duration of the whole procedure with the patient repositioning and acquisition of pilot images was 3 min 10 s. The T1-weighted acquisition was started (on average) 12 min 20 s after the initial contrast administration.

Evaluation of the images

Prone and supine MRI were then compared using commercial PACS software (Infinitt Healthcare). Lesions were first located in standard prone MRI, and then sought for in supine MRI (Fig. 1). Subtracted images in the standard prone images were evaluated first, followed by original non-fat-saturated T1-weighted contrast-enhanced sequences. Two reviewers evaluated the images in consensus. Lesion size was measured as the longest diameter in any orthogonal plane. Lesion location was recorded in quadrants. The distances of the lesion from the sternum, the chest wall and the nipple were measured separately. The measurements were done as follows: For the measurements from the lesion to sternum, a horizontal line from the center of the lesion to the sternal midline was drawn; for the distance to the chest wall, a perpendicular line to the chest wall was drawn from the center of the lesion; for the distance to the nipple, a line was drawn from the center of the lesion to the nipple on a sagittal oblique reformatted image including both the lesion and the nipple. We measured the breast sizes on axial prone image passing through the nipple. A free-hand line was drawn around the breast to measure the breast area on the slice. The breast fibroglandular tissue composition was assessed according to ACR recommendations (12).

Statistical analysis

Data analysis was performed using SPSS Statistics v22 (IBM Corp.) statistical software. Kolmogorov-Smirnov test was used to analyze normality of data and nonparametric tests were used, in addition to descriptive statistics. Spearman's correlation test was used to look for correlations between breast area and lesion displacement and between lesion location and lesion displacement. Independent sample t-test was performed to look for association between breast density and lesion displacement. P < 0.05 was used as the cutoff to infer statistical significance.

Results

Forty-two of 86 patients had 45 lesions. Twenty-three (52.3%) of these lesions were masses and 22 (47.7%) had nonmass enhancement (NME). The mean lesion size was 14.47±11.11 mm (range, 3–59 mm). The mean size for masses was 14.29±7.88 mm (range, 6–34 mm) and 14.68±14.20 mm (range, 3–59 mm) for NMEs. Twenty (46.5%) of the detected lesions in supine position

Main points

- Prone breast MRI detected lesions can be challenging to relocate on supine body position due to significant displacement of these lesions and deformation of the breast tissue in supine position. This problem can be substantially overcome with a supplementary supine imaging obtained following a standard MRI.
- Almost all lesions can still be detected several minutes after contrast material injection on a supplemental supine MRI.
- Lesion displacement according to the chest wall was correlated with breast size.
were ≤10 mm (11 NME [55%] and 9 masses [45%]). Twenty-eight of 45 lesions showed benign histopathology (14 benign changes, 14 fibroadenoma) and remaining 17 were malignant (8 ductal carcinoma in situ and 9 invasive ductal cancer). The mean breast area was 10798±5590.79 mm², ranging from 1708 to 22351 mm².

We were not able to define one lesion in one patient in the supine images. The lesion was NME and the size of the lesion was 33 mm (Fig. 2). The remaining 44 lesions (97.8%) were detected in supine images.

Fibroglandular breast patterns of the breasts with those 44 lesions were type A in two (4.5%), type B in 16 (36.4%), type C in 16 (36.4%) and type D in 10 (22.7%) patients. Due to the small number of patients with type A fibroglandular breast composition, fibroglandular tissue composition was grouped as nondense (types A and B) and dense (types C and D).

Twenty-two lesions (50%) were located in the upper outer quadrant, 8 lesions (18.2%) were located in the upper inner quadrant, and 14 lesions (31.8%) were located in the lower outer quadrant.

Table 1 shows changes in distance from sternum, chest wall, and nipple when moving from prone to supine position. Lesions moved mostly away from the sternum and towards the chest wall due to the position change.

Lesion displacement relative to the chest wall and breast size were moderately correlated (r=0.527, P < 0.001) (Table 2). Displacement increased in larger breasts (Fig. 3). There was no correlation between lesion displacement relative to the chest wall and fibroglandular tissue composition (P = 0.34) (Table 3). There was no correlation between lesion displacement relative to the nipple and breast size (r=0.185, P = 0.23) or fibroglandular tissue composition (P = 0.16). There was also no correlation between lesion displacement from sternal midline and breast size (r=0.092, P = 0.55) or breast fibroglandular tissue composition (P = 0.91). There was no correlation between lesion location within the breast and the amount of lesion displacement relative to the chest wall, nipple, or sternal midline (Table 1).

Discussion

The present study showed that 97.8% of the lesions can be depicted on a supplementary abbreviated supine MRI examination following a standard diagnostic prone DCE-MRI with a single contrast administration. One lesion (2.2%) that was not detected on supine MRI was a 33 mm ductal carcinoma in situ presenting as NME. However, we were able to detect all lesions smaller than 10 mm (46.7%), which pose a bigger challenge in second-look US (13). The mean time spent for this supplementary method

| Table 1. Changes in distance from sternum, chest wall, and nipple when moving from prone to supine position (calculated as distance in prone position - distance in supine position) |
|-----------------|-----------------|-----------------|-----------------|
|                 | Range           | Minimum         | Maximum         | Mean            |
| Change in distance to sternum | -81             | 3               | -78             | -34.8           |
| Change in distance to chest wall  | 132             | -36             | 96              | 29              |
| Change in distance to nipple      | 109             | -47             | 62              | -14.7           |
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was 3 min 10 s including the patient reposi-
tioning and coil placement. This supple-
mentary sequence was performed approx-
imately 11 minutes after the initial contrast
injection.

To our knowledge there is not a similar
study in the literature. However, a previ-
ous study with prone imaging showed
97% overall sensitivity with a delayed con-
trast-enhanced sequence 6–9 min after
contrast injection (14). On the other hand,
value of supine imaging after a standard
prone protocol was not evaluated. In a pre-
vious study (15), 6 breast cancer patients

This study showed that a delayed se-
quence was effective in depicting the prone
MRI detected lesions (97.8% of the cases).
Thus, a delayed supine imaging after the
standard MRI protocol will enable ready su-
pine images. Showing the deformation and
placement of the lesion will be useful for
further clinical work, i.e., second-look US
examination, surgery planning. The success
rate of second-look US is variable (16). A re-
cent meta-analysis showed a markedly het-
erogeneous detection rate with second-look
US ranging between 23% and 81.2% (15).
This analysis showed that mass and malig-
nant lesions were more likely to be detected
on second-look US (66% and 79%, respec-
tively) compared to NMEs (29%). However,
they stated a 12.2% likelihood of malignan-
cy in cases where second-look US did not
detect any lesions (15). On the other hand,
the lesion that is detected on second-look
US may not be the real matching lesion
seen on prone MRI due to the deformation
and relocation of the lesions in supine po-
sition. A supine examination can be used
as a guiding tool for these incidents. A new
technique, i.e., volume navigation US imag-
ing with real-time co-registration of the MRI
data is used in different clinical settings for
second-look US or guidance for breast bi-
opsy (17, 18). This technique requires con-
trast-enhanced supine MRI of the breast
which necessitates an additional MRI exami-
nation and contrast administration (11). On
the other hand, in some centers supine MRI
is used as a guiding method for the preopera-
tive evaluation of breast cancer (15).

Our results were in line with the litera-
ture in terms of lesion dislocation despite
the different measurement method used in
our study (15). Lesions mostly moved lat-
erally and towards the chest wall when the
position is changed from prone to supine.
Additionally, we found a decrease in nipple
lesion distance in supine position. The dis-
placement towards the chest wall was cor-
related with breast size.

This study has some limitations. First, we
did not assess the interobserver variability
in defining the lesions on supine MRI se-
quences. Second, our study population was

<table>
<thead>
<tr>
<th>Breast pattern</th>
<th>Change in distance to sternum</th>
<th>Change in distance to nipple</th>
<th>Change in distance to chest wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nondense (n=18)</td>
<td>35.2±21.6</td>
<td>19.7±16.2</td>
<td>33.5±25.8</td>
</tr>
<tr>
<td>Dense (n=26)</td>
<td>34.6±15.1</td>
<td>11.3±21.1</td>
<td>25.9±25.6</td>
</tr>
<tr>
<td>P*</td>
<td>0.91</td>
<td>0.16</td>
<td>0.34</td>
</tr>
</tbody>
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SD, standard deviation.

*Independent sample t test.
was no correlation between breast size and correlated with breast size. However, there will not cause too much incremental time for the MRI schedules, if the patients will not benefit from this supplemental examination. We believe that further studies with a larger patient population evaluating the characteristics and the deformation of both masses and NMEs will be informative.

In conclusion, an abbreviated supine sequence following a standard diagnostic prone MRI examination with single contrast media administration is an effective method in defining the lesion location on supine body position and can be used for further procedures like second-look US, volume navigation US, or surgery. We believe that this abbreviated supplemental examination will not cause too much incremental time cost for the MRI schedules, if the patients who will get benefit from this supplemental sequence are chosen correctly. Lesion displacement according to the chest wall was correlated with breast size. However, there was no correlation between breast size and lesion displacement relative to the distance to sternum or nipple. The amount of fibroglandular tissue had no significant effect on lesion displacement within the breast.

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Conflict of interest disclosure
The authors declared no conflicts of interest.

References